

## FIRE-RESISTANT BUILDING MATERIALS AND THEIR SAFETY STANDARDS

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**Abstract:** This article analyzes the physical, chemical and structural properties of fire-resistant building materials and evaluates their role in ensuring the fire safety of modern buildings. It discusses traditional materials such as brick and concrete, as well as advanced materials such as basalt fiber composites, mineral wool, gypsum board and intumescent coatings. International fire safety standards (ISO, EN, UL, NFPA) and their implementation in Uzbekistan are also examined. The article concludes with an overview of emerging technologies, including nanomaterials and smart fire-protective systems.

**Keywords:** fire-resistant materials, fire safety, basalt wool, mineral insulation, intumescent coating, fire standards, thermal stability, building safety.

Fire safety has become one of the most essential priorities in modern construction, especially in densely populated urban environments where the number of high-rise buildings, industrial facilities and energy-intensive infrastructure is steadily increasing. The rapid spread of fire, the high temperature it generates and the toxic gases released during combustion can lead to catastrophic consequences for both human life and property. Therefore, the development and use of fire-resistant building materials as well as the improvement of fire safety standards have become fundamental components of contemporary architectural and engineering practices.

Fire-resistant building materials are defined as materials that maintain their structural integrity when exposed to high temperatures, do not sustain combustion, do not release toxic fumes and prevent or significantly slow down the spread of fire. The fire resistance of a material depends on its chemical composition, density, thermal stability, heat absorption capacity and behavior under prolonged heating. In contrast to conventional materials, fire-resistant ones are specifically engineered to withstand thermal shock, ensure the stability of load-bearing structures and protect buildings long enough for evacuation and fire-control measures.

Among the oldest and most widely used fire-resistant materials are **brick and concrete**. Ceramic brick, fired at extremely high temperatures, is inherently non-combustible and possesses excellent thermal inertia. This makes brick walls natural barriers against flame penetration. Many historical buildings have survived for centuries precisely because brickwork demonstrates exceptional resistance to fire.

Concrete also exhibits strong fire-resistant properties: the moisture trapped inside its matrix evaporates under heat, absorbing a significant amount of energy and delaying the rise of internal temperature. As a result, concrete structures resist deformation for long periods, allowing them to maintain load-bearing capacity even under severe fire exposure.

Advances in materials science have paved the way for new types of fire-resistant composites, especially those based on **basalt fibers**. Basalt, a natural volcanic rock, is melted at temperatures around 1400–1500°C and then extruded into continuous fibers. These fibers do not burn, do not melt under extreme heat and do not emit toxic gases. When combined with polymer binders, basalt-fiber composites become highly stable insulating materials capable of withstanding temperatures of up to 1000°C. As a result, basalt wool, basalt panels and basalt-reinforced composites have become widely used in both civil and industrial construction, particularly in façade systems, thermal insulation layers, roofs, and flooring structures.

Another essential fire-resistant category is **mineral wool insulation**, produced from basalt, dolomite or recycled glass. Mineral wool does not ignite and can withstand prolonged exposure to flames. Its low thermal conductivity contributes not only to fire protection but also to energy efficiency and acoustic comfort. Similarly, **gypsum board**, commonly used in interior walls and ceilings, demonstrates natural fire-resistant characteristics due to the chemically bound water in its crystalline structure. When exposed to fire, this water transitions into steam, absorbing heat and slowing down the spread of flames.

One of the greatest dangers during a fire is the release of **toxic smoke and gases**, which can pose lethal risks even before flames reach occupants. Therefore, modern fire safety regulations emphasize the use of **low-smoke and low-toxicity materials**. Many contemporary polymers and composite materials undergo special treatments with flame retardants—substances that delay ignition and inhibit the chemical reactions necessary for combustion. Among the most sophisticated technologies are **intumescent coatings**, which expand under heat, forming a thick char layer that protects structural steel and wood from reaching critical temperatures. Such coatings can increase the fire-resistance rating of metal structures from mere minutes to over two hours, significantly enhancing overall safety.

Globally, fire-resistant materials are regulated by stringent **international standards**. The ISO 834 standard outlines test methods for determining the fire resistance of building elements under a standardized thermal curve. In Europe, the EN fire classification system categorizes materials from fully non-combustible to easily flammable based on their contribution to fire. The United States relies on UL (Underwriters Laboratories) and NFPA (National Fire Protection Association)

guidelines, which define strict criteria for heat release, smoke development, structural integrity and toxicity of emitted gases.

In Central Asia, including Uzbekistan, fire safety regulations have been significantly strengthened in recent years. National building codes now require fire-resistant certification for materials used in high-rise buildings, public spaces, industrial facilities and transportation infrastructure. Basalt insulation, mineral wool boards, fire-resistant paints, gypsum-fiber boards and flame retardant treatments for wooden structures are now mandatory components of many modern projects. The growth of local manufacturers producing fire-resistant insulation materials has contributed to both improved safety and the development of domestic construction technologies.

Fire-resistant building materials continue to evolve thanks to innovative research in the fields of nanotechnology, chemistry and materials science. Recent developments include **nanoceramic coatings**, which offer exceptional thermal stability, **aerogel-based insulating panels**, known for their ultra-low thermal conductivity, and **smart materials** capable of modifying their behavior under heat. Some of these advanced materials can automatically release fire-suppressing compounds when heated, while others can expand or contract to prevent structural collapse. Future architectural concepts envision buildings equipped with self-extinguishing façades, intelligent thermal barriers and fully non-toxic, high-performance composites.

In conclusion, fire-resistant building materials represent a cornerstone of modern structural safety. Their effective use not only prevents the spread of flames and delays structural failure, but also saves countless lives by ensuring sufficient evacuation time. As building technologies advance and urban environments expand, the role of fire-resistant materials will only continue to grow. For countries like Uzbekistan, where construction activity is rapidly increasing, integrating advanced fire safety solutions is essential for sustainable and secure urban development. The combination of stringent safety standards, innovative materials and modern engineering approaches forms the basis for creating buildings that are not only functional and aesthetically pleasing but also resilient, reliable and safe under extreme conditions.

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