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CHARACTERISTICS OF HIGH-RISE MIXED-USE BUILDINGS RELATED TO FIRE PREVENTION ORGANIZATION IN VIETNAM

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Abstract

High-rise mixed-use buildings in Vietnam are increasingly being constructed and developed to meet the needs of society, especially in urban areas. This article focuses on presenting the research results of the characteristics of high-rise mixed-use buildings related to fire prevention organization, as well as proposing and orienting some solutions and measures to contribute to improving the effectiveness of fire prevention organization for high-rise mixed-use buildings in Vietnam in the future.

Keywords: *High-rise mixed-use buildings; fire prevention and control organization; fire prevention and fighting*

1. Introduction

In Vietnam today, especially in large cities, the trend of constructing high-rise mixed-use buildings is becoming a smart and inevitable solution, closely linked to the speed of urbanization, the development of science and technology, and the needs of modern living. High-rise mixed-use buildings are multi-functional buildings that integrate various functions such as housing, offices, hotels, shopping centers, and public services within a continuous architectural whole. This model not only solves the problem of limited land in large cities but also simultaneously meets many material and spiritual needs of people in the same living and working space. From an economic and social perspective, this type of building allows for the optimiza-

tion of land use value, promotes the growth of services and commerce, and creates an integrated, multi-utility living environment for urban residents. According to a report by the Fire Prevention, Fighting, and Rescue Police Department of the Ministry of Public Security of Vietnam, by the end of 2025, Vietnam will have 748 high-rise mixed-use buildings, a 26.4% increase compared to 2016, reflecting the rapid development of this type of building. In practice, when a fire occurs in a high-rise mixed-use building, firefighting and rescue efforts face numerous difficulties due to the multi-functional nature, complex structure, and large scale of the building. These difficulties not only hinder fire control but also result in loss of life, serious damage to property, infrastructure, business op-

erations, and even long-term impact on the morale of the local community. According to statistics, from 2016 to the end of 2025, the number of fires in high-rise mixed-use buildings in Vietnam was 176 (accounting for 0.87%), resulting in 16 deaths (accounting for 1.69%), 56 injuries (accounting for 1.28%), and estimated property damage of about 8,790.12 million VND (13). Given this situation, there are requirements to ensure fire safety and rescue for high-rise mixed-use buildings, including the urgent need to study the characteristics of high-rise mixed-use buildings in order to have solutions and measures to prevent fires and explosions in high-rise mixed-use buildings.

2. Research results

2.1. Architectural and Structural Characteristics of High-Rise Mixed-Use Buildings

— Architectural Characteristics of High-Rise Mixed-Use Buildings

The most fundamental architectural characteristic of high-rise mixed-use buildings is the vertical development of the structure. These are high-rise buildings that combine multiple functions within a single architectural whole, commonly including: a commercial and service base, office floors, hotels, and apartment blocks above. This leads to the concentration of a large number of people, assets, and activities in a limited horizontal space. Vertical development means that fire hazards (heat, smoke, toxic gases) affect multiple floors simultaneously, no longer confined to a small space as with low-rise buildings. This multi-functional integration creates a complex, interconnected vertical architectural space, making high-rise mixed-use buildings more fire-prone than single-function high-rise buildings.

In terms of architectural spatial organization, high-rise mixed-use buildings are typically divided into stacked functional blocks, each with different usage characteristics, fire load, and population density. Commercial and service blocks on the lower floors often concentrate a large number of people, use many flammable finishing materials, store diverse goods, and have high-power heat sources and electrical equipment. Meanwhile, office and hotel blocks have a more stable popula-

tion density but longer stays, while apartment blocks on the upper floors are for regular living and have a diverse user base, including the elderly and children. This difference leads to inconsistent evacuation, rescue, and fire safety requirements for each area, making it difficult to organize a comprehensive and safe architectural solution. Vertical movement via staircases prolongs evacuation time, especially when users have to move from upper floors to the ground. In conditions of smoke, limited visibility, and panic, the chances of safe evacuation are significantly reduced. This is a crucial architectural principle – a requirement that high-rise buildings must be equipped with protected escape solutions, such as smoke-free stairwells, buffer lobbies, refuge floors, or equivalent solutions.

Mixed-use high-rise buildings are typically organized with a concentrated traffic and technical core, including stairwells, elevators, electrical and water shafts, and ventilation shafts. Architecturally, this core optimizes usable space and ensures a rational floor plan. However, from a fire safety perspective, the core is the most sensitive area, posing a potential risk of becoming a “smoke and fire conduit” if not properly protected. If stairwells are not properly positioned, separated by fire-resistant structures, and lack smoke control solutions, they will quickly be infiltrated by smoke, rendering them unusable as escape routes. This is especially dangerous for high-rise buildings, where stairwells are almost the only escape route...

— Structural Characteristics of High-Rise Mixed-Use Buildings

High-rise mixed-use buildings must withstand large and diverse loads, with wind and earthquake loads increasing significantly with height. Therefore, the structural system is usually a monolithic reinforced concrete structure, a composite structure, or a steel structure, with solutions such as frame-core, frame-wall, or central load-bearing core.

In fire conditions, high temperatures rapidly reduce the load-bearing strength of concrete and steel, especially for components not protected against fire. If the structure does not meet the required fire resistance limit, the risk of local instability and conductive collapse is very high, directly threatening the safety of evacuees and firefighters.

High-rise building structures have a high degree of continuity, with columns, walls, and load-bearing cores extending throughout the entire height of the building. When a fire occurs on one floor, the reduction in the load-bearing capacity of that floor's structure can have a chain reaction affecting the floors above and below, compromising the overall safety of the building. Therefore, the structure of high-rise buildings must not only meet normal load-bearing requirements but also maintain stability during a fire, sufficient to ensure the safe evacuation of occupants and the deployment of firefighting forces.

In high-rise buildings, structural elements such as floors, walls, partitions, and rigid cores simultaneously act as fire-resistant partitions to divide the building into fire compartments horizontally and vertically. Especially for mixed-use high-rise buildings, fire compartmentation vertically is a mandatory requirement to limit the scale and spread of the fire. If the fire-resistant structure does not meet the fire resistance limit, or is penetrated by pipes or technical cables without proper treatment, the effectiveness of fire compartmentation will be rendered ineffective...

2.2. Functional Layout Characteristics of Mixed-Use High-Rise Buildings

Mixed-use high-rise buildings are a type of high-rise structure that integrates various functions such as residential, office, hotel, shopping center, and public services within a single, interconnected architectural complex. Although these functions coexist within a single building, each functional area has different fire hazard characteristics. The basic characteristics of this type of building are its large construction scale, high population density, and large volume of flammable materials, goods, and substances, significantly increasing the risk of fire and explosions and the complexity of fire prevention and firefighting.

Commercial and service areas typically attract large crowds during the day, contain many flammable goods and materials, and the main fire risk is related to the electrical system. Fires often occur at night when the building is closed; however, due to their location on lower floors, these areas have the advantage of easy access to the outside space and convenient evacuation routes. Office spaces are typically located on intermediate

floors, featuring open workspaces and escape routes centered around the building's core. Apartment buildings, on the other hand, are usually situated on higher floors with high population density and a diverse population including the elderly, children, and those with mobility impairments, making evacuation and rescue efforts in the event of a fire more challenging.

Furthermore, high-rise mixed-use buildings often have multiple basements and podiums housing fire-hazardous functions such as parking garages, substations, warehouses, and garbage disposal areas. In the event of a fire in a basement, the flames spread rapidly, producing a large amount of toxic smoke and spreading to upper floors through stairwells, ventilation shafts, and technical systems, posing a serious threat to the entire building.

2.3. Characteristics of the Technical Systems of High-Rise Mixed-Use Buildings

High-rise mixed-use buildings are equipped with many complex technical systems such as electrical systems, substations, generators, central gas systems, ventilation and air conditioning systems, and automatic fire alarm and extinguishing systems. A malfunction or improper operation of any one of these systems can lead to serious fire and explosion risks.

Most high-rise mixed-use buildings must be equipped with automatic fire alarm systems, automatic fire extinguishing systems, smoke protection systems, indoor and outdoor fire water supply systems, emergency lighting systems, escape route signage, and fire-fighting elevators in accordance with current regulations and standards.

In modern buildings, the Building Management System (BMS) plays a central role in monitoring, controlling, and interconnecting technical systems, especially the fire protection system. When a fire occurs, the BMS receives signals from the fire alarm system and automatically activates emergency scenarios such as cutting off power to the fire area, controlling elevators to a safe floor, activating the pressurization and smoke extraction system, controlling fire doors and fire extinguishing systems, contributing to reducing response time and improving the efficiency of evacuation and firefighting.

2.4. Characteristics of Flammable Materials, Heat Sources, and Fire Spread Potential in High-Rise Mixed-Use Buildings

The flammable materials present in high-rise mixed-use buildings are diverse, varied, and highly fire-hazardous. Many different types of flammable materials are always present in high-rise mixed-use buildings, depending on the nature and function of the building. The main flammable materials are paper and paper products; wood and wood products; fabrics and cotton and fiber materials; gasoline, oil, and gas; rubber and rubber products; synthetic resins and polymer derivatives... This further increases the risk of fire and explosion and complicates fire-fighting and rescue operations in high-rise mixed-use buildings.

The heat sources that can cause fires in high-rise mixed-use buildings are very diverse. The main sources of heat causing fires in high-rise mixed-use buildings originate from electrical systems, open flames in daily life, production and business activities, metal welding and cutting, and violations of fire safety regulations. In many cases, improper use of the electrical system, contrary to its original design, leads to overloading, short circuits, and fires.

The spread of fire and smoke and toxic gases in mixed-use high-rise buildings is very rapid. Fires can spread through inter-floor technical systems such as elevator shafts, ventilation ducts, cable trays, technical pipes, and structural openings. When a fire occurs, toxic smoke can spread into stairwells within minutes, rendering escape impossible if effective smoke protection measures are not in place.

2.5. Characteristics of the Electrical System in High-Rise Mixed-Use Buildings

Complex Load Classification: Due to the presence of various business and residential activities within the same building, the electrical system must be clearly separated, specifically as follows: **Service/Commercial Electricity:** shopping malls, supermarkets (high power, concentrated). **Office Electricity:** lighting systems, power outlets for office design. **Apartment Electricity:** personal living systems. **Public Electricity:** elevators, water pumps, corridor lighting.

Extremely High Reliability and Safety: **Backup Power:** always has a backup generator (capacity usually meets 100% of priority loads such as elevators, fire pumps, emergency lighting). **ATS System:** automatically switches power between the grid and the generator in case of a fault. **Fire Safety:** uses fire-resistant (FR) or flame-retardant (LSZH) cables for emergency systems.

Vertical structure (Busway): Instead of traditional cabling, high-rise buildings often use a Busway system (electrical conductors) running along the technical axis. Busways save space, handle heavy loads, and allow easy connection (L-off) at each floor.

Building Management System (BMS): The electrical system is often integrated with the BMS for remote monitoring: tracking electricity consumption, controlling smart lighting to save energy, and automatically shutting off power to non-priority areas in case of fire.

Grounding and lightning protection system: Due to the high height, buildings are required to have extremely strict direct lightning protection and surge protection (SPD) systems to protect sensitive electronic equipment inside.

Transformer substation (TBA): Usually located in the basement or technical floor. For high-rise buildings, TBAs are often dry-type transformers to minimize the risk of fire and explosion compared to oil-filled transformers.

2.6. Characteristics of Traffic and Water Sources

High-rise mixed-use buildings (combining apartments, offices, shopping centers, services, etc.) are large-scale and have a high population density. Therefore, traffic conditions and water sources for firefighting have unique characteristics that directly impact the effectiveness of firefighting and rescue operations. Specifically: high-rise mixed-use buildings are often constructed in urban centers and densely populated residential areas, which can easily lead to: traffic congestion during peak hours; encroachment on roads and sidewalks for business and parking; limited turning space; and the need for access roads for fire trucks: ensuring sufficient width, turning radius, and road load capacity to accommodate specialized fire trucks

(ladder trucks, pump trucks, rescue vehicles). Access to multiple sides of the building is required: for high-rise mixed-use buildings, access roads for fire trucks are needed on at least one or more sides (prioritizing the side with stairwells, main entrances, and technical areas).

For mixed-use high-rise buildings, the water tank must contain enough water to supply the entire fire hydrant system, automatic sprinkler system, and outdoor fire extinguishing system for at least 3 hours. Firefighting water can be shared with domestic water, but technical measures (partitions, suction pipe elevation) must be in place to ensure that domestic water never contaminates the firefighting water reserve. In addition to underground tanks, mixed-use high-rise buildings often have rooftop water tanks to create initial hydrostatic pressure and support immediate fire suppression in the first few minutes before the pumps reach maximum capacity. The building must have water inlet points located on the street so that professional fire trucks can directly pump water from outside into the building's piping system when the internal water reserve runs out.

3. Some directions for further research to contribute to improving the effectiveness of fire prevention work for high-rise mixed-use buildings

Through research, the following directions are drawn:

1) Proactively advise, propose, and improve legal regulations on fire prevention, firefighting, and rescue, and develop programs and plans for organizing fire prevention work for high-rise mixed-use buildings;

2) Strengthen leadership and guidance in organizing fire prevention work for high-rise mixed-use buildings;

3) Organize the development of plans, programs, and content for disseminating and educating knowledge and laws on fire prevention, firefighting, and rescue, and build a movement for all citizens to participate in fire prevention and firefighting activities for high-rise mixed-use buildings;

4) Strictly implement the process of organizing design appraisal and inspection of fire prevention and firefighting acceptance work for high-rise mixed-use buildings;

5) Improve the quality of organizing inspection and handling of administrative violations related to fire prevention and fighting for high-rise mixed-use buildings;

6) Organize and build a fire prevention, fighting and rescue force at the grassroots level and provide training and professional development in fire prevention, fighting, rescue and relief for high-rise mixed-use buildings;

7) Consolidate the organizational model, build a team of officers and equip the Fire Prevention, Fighting and Rescue Police force with means to serve the organization of fire prevention work for high-rise mixed-use buildings;

8) Promote preliminary and final reviews, research, application of science and technology, digital transformation and coordination to serve the organization of fire prevention work for high-rise mixed-use buildings.

4. Conclusion

The study of the characteristics of high-rise mixed-use buildings is of significant importance, contributing to ensuring fire safety and rescue in high-rise mixed-use buildings in Vietnam today. Given the current situation regarding the construction, development, and operation of high-rise mixed-use buildings, as well as the current fire and explosion situation, the Fire and Rescue Police force of the Ministry of Public Security of Vietnam, under the direction of various levels and sectors, has performed well in this area, contributing to minimizing fire incidents. However, this work still has limitations that need to be overcome. Furthermore, although there have been studies on this topic, there is a lack of systematic and in-depth research specifically on high-rise mixed-use buildings. Therefore, choosing this issue for research is necessary. This preliminary study proposes a system of guidelines to improve the effectiveness of fire prevention and control in high-rise mixed-use buildings in Vietnam.

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