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Research on Fire Protection Design of Steel Structures

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Abstract: Steel structures themselves have the characteristics of light weight, high strength, easy construction, and recycling, and are widely used in the construction field. However, in the context of the rapid development of the construction industry, there are more and more safety hazards in buildings, and steel structure fire protection design is particularly important. Fire, as an important factor affecting the safety of buildings and people's lives and property, needs to be taken seriously in the design process of building steel structures. Steel itself does not burn, but as a metal, it has good thermal conductivity. In the event of a fire, it only takes more than ten minutes to reach the critical temperature of the steel itself. The steel's load-bearing capacity sharply weakens, causing building collapse, causing casualties and economic losses. Therefore, it is necessary to carry out fire prevention treatment for steel structure buildings, and currently there are many fire prevention methods applicable to steel structure buildings. How to reasonably select the fire prevention methods suitable for prefabricated steel structure buildings is also a problem faced by designers. Based on this, this article analyzes the hazards of steel structure buildings themselves, understands the problems in fire protection of steel structure buildings, and proposes countermeasures to strengthen fire protection of steel structure buildings, aiming to improve the fire performance of steel structure buildings.

1. Introduction

Steel structure buildings account for a certain proportion of existing buildings in China, especially large frame transportation buildings, industrial buildings, high-rise buildings, sports halls, exhibition halls, etc. [1]. Compared to traditional concrete buildings, steel structure buildings use steel plates or steel sections to replace reinforced concrete, which improves the overall strength and seismic resistance of the building. Steel structure buildings are conducive to construction and installation, greatly reducing the construction period. The steel itself can also be recycled, reducing construction waste, and making it more environmentally friendly. It is known as the "green building" of the 21st century and is the development direction of future architecture [2].

Currently, with the increasing scale of high-rise building construction, steel structures have become the most widely used structural form in high-rise buildings [3]. Steel structure buildings have been widely used in recent years due to their lightweight, good seismic performance, high degree of assembly, and fast construction progress [4]. There are two main quality control difficulties in steel structure buildings: high construction accuracy of standardized steel components and poor fire and corrosion resistance of steel structures. Due to the numerous vertical stairwells, elevator shafts,

pipeline shafts, cable shafts, exhaust ducts, and other types of loosely sealed vertical pipe shafts inside high-rise buildings, if improper fire separation or fire prevention measures are taken, the chimney effect of the vertical pipe shaft during a fire can lead to the rapid spread of smoke and fire inside the building. This leads to panic among the crowd and chaos, making safe evacuation very difficult. Steel belongs to non combustible materials, but under fire conditions, the critical temperature of steel is usually only 550 ℃, and the fire resistance limit of unprotected steel structures is about 15 minutes. During a fire, the steel structure will undergo significant deformation and lose its load-bearing capacity. According to relevant research statistics, the average annual number of fires in many countries around the world is over 100000, and the harm and losses caused by fires are becoming increasingly serious. Therefore, the fire protection design of steel structures is particularly important. Steel structure fire protection requires long-term maintenance of good physical and chemical properties in order to play a protective role in fires. In order to comprehensively improve the safety and stability of building steel structure applications, it is necessary to carry out fire prevention design work in accordance with relevant specifications and requirements during the design process of building steel structures, further optimize and improve the fire prevention performance of building steel structures, and provide effective guarantees for the safe use of later buildings [5].

Daily inspection and tracking services for steel structure fire protection have found that many engineering designs are designed with steel structure fire protection coatings. In the early stages of coating, the appearance and physical and chemical properties of the coatings are good, but over time, cracks, peeling, and other phenomena occur, seriously affecting the fire resistance limit of steel structures. Some engineering projects have coatings that occur within six months, and even completely lose the basic function of fire protection [6]. The existing protective coatings for steel structures have a single function and exhibit coating separation due to poor compatibility between fire and anti-corrosion coatings. At the same time, the organic solvents contained in the coating are prone to volatilization during the film-forming process and cause environmental pollution. In practical engineering, due to the many existing fire prevention methods for steel structure buildings, it is particularly important to choose suitable fire prevention methods when designing steel structure buildings [7].

2. Problems in Fire Protection of Steel Structure Buildings

2.1 Inadequate Design of Fire Protection

Steel is the main raw material for steel structure buildings. For reinforced concrete and brick concrete structures, due to its good thermal conductivity and poor thermal insulation, fire protection must be done well during the construction process [8]. When designing steel structure buildings, some special fire protection designs are usually utilized, but the design of fire protection for some steel structure buildings is not appropriate enough. In the process of designing fireproof coatings, the main focus is on the value and advantages of coating materials. Due to aesthetic and construction requirements, 100% of the steel beams in some buildings are specified in the design specifications to use expansion type steel structure fireproof coatings. The thickness of this type of coating is generally less than 5mm, and it forms a dense carbon layer with a thickness of more than 5 times the original thickness after expansion in case of fire, which protects the steel structure. However, there are counterfeit and inferior products in the current steel structure building fire retardant coating market. If these coated steel components are used, the fire retardant protective coating of the steel structure building is likely to fail after it is put into use for a period of time.

According to "Steel Structure Fireproof Coatings", expandable steel structure fireproof coatings can be divided into two categories: the first category is water-based steel structure fireproof coatings; The second type is solvent based fireproof coatings for steel structures [9]. Due to weather conditions,

water-based fireproof coatings often peel off within two days of construction, as shown in Figure 1. If solvent based steel structure coatings are chosen to protect steel components when designing steel structure buildings, the quality of harmful substances contained generally does not meet the limit standards required by relevant regulations. Designating such coatings for protection during design not only makes it difficult to meet the requirements of the above standards, but also poses significant risks to the fire safety of steel structure buildings for long-term use.

Figure 1: Coating detachment

2.2 Inadequate Acceptance Work

Some steel structure building fire protection testing personnel lack awareness of the importance of testing work, are not responsible enough for their work, and there are cases of fraud with construction personnel and supervision units. Steel structure fire protection testing personnel do not need professional qualifications for steel structures, and cannot clearly grasp the type and fire resistance limit requirements of steel structure components. During the construction phase of steel structure construction projects, it is not uncommon for construction units to entrust inspection agencies to carry out engineering quality testing in the field of construction engineering in China. Many subcontracting construction units are entrusted to third-party testing institutions for testing. Construction units often entrust lower qualified and inferior testing units to enter the construction site at a relatively low price, resulting in poor testing quality and inability to timely detect problems and loopholes in steel structure fire protection construction. In order to obtain more benefits, the testing agency ignores the situation where the thickness of non expansive coatings does not meet the standards or the expansion of expansive coatings fails, and still issues qualified testing reports for subcontracting construction units. This is clearly a violation of relevant regulations, which will lead to difficulty in ensuring the safety of steel structure buildings after being put into use [10].

Some steel structures in construction projects have experienced quality problems in just a few years. The main reason for this phenomenon is the lack of a maintenance and management responsibility system for steel structure fire protection engineering in the later stage, resulting in a lack of effective maintenance after the building is put into use and a large area of coating detachment. At present, although many regions in China have included the acceptance of steel structure fire protection quality in the acceptance of steel structure buildings, and have also included it in the fire acceptance, with clear acceptance processes and standards established, some regions have not yet fully inspected the fire protection of steel structure buildings.

3. Countermeasures for Strengthening Fire Protection of Steel Structure Buildings

3.1 Scientific and reasonable selection of fire protection design methods for building steel structures

In the process of fire prevention design for building steel structures, designers need to make scientific and reasonable choices in design methods, accurately analyze and calculate the fire resistance limit of steel structures based on the specific situation of the fire, and maximize the quality of fire prevention design for building steel structures. Designers should recommend durable fire protection measures. The design service life of steel structure engineering is generally over 50 years, and hidden steel structure fire protection measures are ineffective and difficult to repair; In addition, during the maintenance of steel structure buildings during use, equipment shutdown and personnel evacuation are generally required, resulting in significant losses. The design unit must, in strict compliance with the Technical Specifications, reasonably set up multiple protective measures and fully consider how to improve the durability of protective measures in the context of long-term use, in order to reduce the risk of later protection failure and the cost of resetting protective protection. According to the current national standard "Code for Fire Protection Design of Buildings", the fire resistance limits and combustion performance of high-rise building components with different fire resistance levels are shown in Table 1.

Table 1: Combustion performance and fire resistance limit of building components (h)

Name	Fire resistance rating	
Member	Level 1	Level 2
Firewall	Non-combustible component 3	Non-combustible component 3
Load bearing walls, stairwell walls, etc	Non-combustible component 2	Non-combustible component 2
Evacuation walk	Non-combustible component 1	Non-combustible component 1
Column	Non-combustible component 3	Non-combustible component 2.5
Beam	Non-combustible component 2	Non-combustible component 1.5
Floors and stairs	Non-combustible component 1.5	Non-combustible component 1
Suspended ceiling	Non-combustible component 0.25	Non-combustible component 0.25

Choose coatings for fire protection. It is recommended to choose high-quality non expansive steel structure fire resistant coatings with good durability and water-based fire resistant coatings indoors; For outdoor and petrochemical fields with harsh environments, it is recommended to use epoxy type fire-resistant coatings for expansion type steel structures. At present, some high-quality fireproof coatings from abroad have been applied in steel structure construction projects for more than 20 years, and they have been kept intact, playing an important role in fire protection.

3.2 Improve Detection Methods

In response to the issue of fire protection materials and construction not meeting standard requirements during the construction stage of steel structure buildings, which reduces the fire protection performance of steel structures, the building construction unit, as the primary responsible party, should develop comprehensive building construction supervision measures. To ensure the construction quality of building projects, it is necessary to comprehensively supervise the entire construction process using comprehensive requirements, standards, and relevant laws and regulations during the actual construction process. For steel structure buildings, it is particularly necessary to strengthen the detection of fire protection during the construction stage of steel structure buildings. During the acceptance inspection and on-site supervision of steel structure engineering, the fire resistance limit test report and factory qualification report of the steel structure fire protection

materials should be verified. Combined with the design documents, the fire protection method of the steel structure components should be confirmed, including the type and thickness of the coating, and the construction method of the support and fixing components such as the fire protection board keel and screws. The problem of management and maintenance in engineering use can be solved through the formulation of relevant standards, making fire protection identification and maintenance rule-based. In response to the lack of a responsibility system, local construction management departments should analyze past cases to determine the specific responsibility attribution for steel structure fire protection construction and post maintenance, and clarify the specific measures, processes, and principles for fire protection engineering repair and maintenance.

4. Conclusions

At present, many industrial buildings, public buildings, and other structures in China use steel structures. Due to the good thermal conductivity, fast heating rate, and poor fire resistance of steel materials, in the event of a fire, the shape of the building is likely to change, and even collapse, causing incalculable losses. In order to prevent and reduce the fire hazards of building steel structures, it is necessary to carry out scientific fire resistance design on steel structures, and adopt safe, reliable, and economically reasonable fire protection measures. During the process of carrying out the protection design of building steel structures, designers strictly implement relevant standards, accurately grasp the key points of building steel structure fire protection design, and continuously optimize and improve the fire protection design based on the actual situation, ensuring the scientific and rational nature of building steel structure fire protection design. The fire protection of steel structure buildings requires units such as construction, design, construction, testing, acceptance, and use to fulfill their respective responsibilities, master the key issues and technical points of steel structure fire protection engineering, improve the quality of fire protection, meet fire safety needs, avoid the waste of social resources caused by the use of unqualified materials, eliminate the confusion of responsibility shifting after accidents, and improve the safety level of buildings. In order to ensure the effectiveness of fire protection in steel structure buildings, it is necessary to develop comprehensive strategies for the use and maintenance of steel structure buildings, in order to maximize the lifespan of fire protection.

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