Research progress on fire resistance in steel structure building

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Abstract. Due to its high strength, light weight, good shock resistance, low cost of land, small occupation, high degree of industrialization, beautiful appearance and can be reused, the steel structure has been widely applied in high-rise buildings. The steel structure, however, is poor fire resistance, thus, the steel structure for fire protection is of great significance. This paper firstly summarizes the development and advantages of steel structure. Secondly, since the fire protection of steel structure is of great significance, the method of it is introduced in detail in this paper, including cut-off method and grooming method. Among which the cut-off method includes Spraying method,Coating method, Shield method, Water spray method. Various protection methods have their own excellent, shortcomings, people need to choose the most appropriate and the most economical protection method according to the actual situation.

1. Introduction

Steel has gradually become a considerable ecological building materials because of the high strength, good durability and good recycling efficiency. Compared with the traditional structure, the steel structure is characterized by its light weight, beautiful appearance, fast construction speed, good economic efficiency, small environmental pollution, good seismic performance and easy industrialization. In all kinds of single or multi-storey industrial buildings, large public buildings, high-rise civil buildings and bridges, it shows more obvious advantages and widely get used. In foreign countries, beginning from the American nine-storey steel structure-Second Rand Menally building in 1889 [1], so far its development history has been more than 100 years. In China, with the rapid development of China's economy, steel production increased rapidly, steel structure has also been widely used, especially in recent years the government introduced a series of policies to encourage the construction industry to actively promote the use of steel structure, which makes steel residential system has become one of the development trend of China's current housing construction system.

This article first introduces the development and advantages of steel structure. And then introduces the fire protection of steel structure which has great significance, a detailed summary of the fire protection of steel structure of the various methods is explained with the hope that people can choose the most appropriate and most effective method in the future onthe steel structure fire protection issue.

2. The Development of Steel Structure

The steel structure system has the advantages of high strength, light weight, stable performance, good toughness, easy installation, short construction period, good seismic performance, quick investment recovery, less environmental pollution and suitable for mass production. Compared with reinforced concrete structure, it has unique advantages in the "high, big, light" aspects, making the steel has become the best structural materials for the building [2].

From the history of steel structure, as early as the 19th century, the application of steel structure

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in the building hadreached a very high achievement. With the combination of structural mechanics theory and the establishment of systems of statics from experiments and the popularity of rolling wrought iron and steel, steel construction has opened a new era. From the 1880s onwards, the building structure began to use rolled steel. At this time a large number of railway stations, warehouses and exhibition halls and other steel structures emerged, until today these buildings are still fully playing their respective functions. One of the most prominent results is in 1889, the construction of the three-hinged arch mechanical museum and the Eiffel Tower in Paris, France. Eiffel Tower is 312.27m high and 7300t heavy, with the use of 18038 wrought iron components, and 25,000 rivets fixed,. The Eiffel Tower had been hampered by the construction at the time, but after its completion it became a symbolic building in Paris.

Since twentieth Century, the steel structure construction in theory and practice has a new development, representatives such as the completion in 1977 of the Le centre Georges Pompidou, the 1986 London Lloyds Building. By the end of the twentieth Century, the scale and function of the steel structure were no longer the most important elements. All buildings needed a perfect combination of design and construction techniques.

3. The Advantages of Steel Structure

3.1 Steel structure has light weight, the steel tensile, compression and shear strength is relatively high.Although the proportion of steel is large, due to its good mechanical properties, it can withstand a larger load, therefore, the same structural section will have smaller size. When the span and load are the same, the weight of the steel roof truss shall not exceed the 1/4 or 1/3 of the reinforced concrete roof truss. The steel structure is small in weight and easy to be transported.

3.2 The material is uniform, which is consistent with the assumptions of mechanical calculation. And the internal steel structure is relatively uniform, near the isotropic body, which is almost completely elastic in a certain range of stress. The steel structure has good ductility and seismic performance.Especially in high intensity earthquake areas, the use of steel structures is more advantageous. In the high intensity earthquake area,there are high-rise buildings with seismic requirements, if the weight is reduced by half, it will reduce the seismic fortification intensity for one degree [3].

3.3 A high degree of mechanization of steel structure manufacturing and installation.Copper structure has the features of technology intensive, while the steel structure is made of single material, and is a finishedproduct, hence the process is simple with high degree of mechanization and rapid construction, makes it easy to ensure the quality and suitable for mass production. From the production to installation, its industrialization degree is much higher than that of the cast-in-place reinforced concrete structure with labor intensive nature [4].

3.4 High flexibility of steel structure in the layout.The steel structure construction is easy to be transformed in the process of using, such as reinforcement, heighten, expansion of the floor and so on, so it is easy and flexible to change. In the information age of today,the requirements for interior, plane, space and interior facilities are more stringent. The original layout and equipment may soon become inadequate or totally out of the question, but the steel structure may provide greater possibilities for plane re-layout, thereby prolonging the service life of the building.

3.5 The raw materials can be recycled, which contributes to environmental protection and sustainable development.Steel is a high-strength and high-performance material, with a high recycling value, its scrap is also valuable, hence no need to re-mold construction. In the structural space of the steel structure, there are many holes and cavities, and the web of the steel girder is also allowed to pass through less than a certain diameter of the pipeline, so that the layout of the pipeline is more convenient, but also can increase the height of the building, and replacement and repair ismore convenient.

4. The Significance of Fire Protection of Steel Structure

The objective of the steel structure fire protection design is to make the actual refractory time of

the structural greater than or equal to the specified refractory limit. Although the steel is non-burning material, but is not fire-resistant. At high temperatures, structural steel strength and stiffness will be rapidly reduced, so no fire protection of steel components in the fire is easy to damage. Therefore, the general requirement for fire resistance design of steel structures is that how to determine the fire protection measures quantitatively so that the refractory time of the steel structure components is greater than or equal to the specified fire resistance limit [5,6].Figure 1. Is the comparison of the steel structure under the condition of fire protection and no protection for the fire resistance test

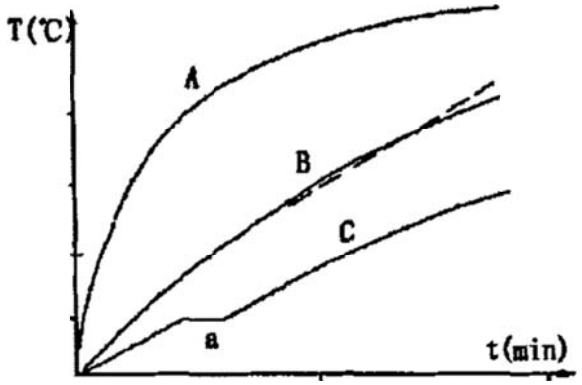

Fig. 1 In the experiment, a comparison of heating steel structure fire protection and protection conditions (A is the standard temperature curve, B is not protected by the steel structure temperature curve, C is the protected steel structure temperature curve, a said warming pause time period)

Fire prevention design of steel structure has the following meanings:

(1)Reduce the damage of steel structure in fire, avoid the steel structure collapsed in the local fire, which facilitates the fire fightingand evacuation.The aim of fire protection of steel structure is to extend the steel structure to the critical temperature as soon as possible, so as to save time and extinguish fire.

(2)To avoid the overall collapse of the steel structure in the fire and reduce casualties

(3)Reduce the cost of repairing steel structures after fire, shorten the recovery period of post-disaster structural functions, and reduce indirect economic losses.

5. Fire Protection Method of Steel Structure

Due to poor fire resistance of steel structure, which is soon collapsed under the effect of high temperature, its fire resistance is only 15 minutes. If the measures are taken to protect the steel structure so that the temperature does not exceed the critical temperature during the fire, the steel structure can maintain stability in the fire. The protective measures taken for the steel structure are, in principle, two kinds of methods: cut-off method and grooming method [7-9].

5.1 Cut-off method

5.1.1 Spraying method

Spraying method is to use a spraying machine to spray the fire retardant coating directly on the surface of the component to form a protective layer. Steel structure fire retardant coating can be divided into organic fire retardant coating and inorganic fire retardantaccording to its different uses, and be divided into two types of thin coating and thick coating according to the thickness of the coating, thin coating steel coating thickness is generally 2 ~ 7mm, there is a certain decorative effect, the coating expands and thickens while the temperature is high, which has the fire-resistant insulation, fire resistance can be up to 0.5 to 1.5 hours, this coating is also known as steel structure expansion fire retardant coating. Thick coating type steel structure fire retardant coating has a thickness of generally 8 ~ 20mm, it has granular surface, small density, low thermal conductivity, as well as a fire resistance up to 0.5 ~ 3.0 hours, which is also known as steel structure fire insulation coating.

5.1.2 Coating method

The coating method is to make fire-resistant protection layer on the surface of steel structure:

(1)The cast-in-place concrete is used as refractory protection layer. Materials used include concrete, lightweight concrete and aerated concrete. These materials have both flame resistance and large thermal capacity. They are used as fire protection layers to slow down the heating of components. As the surface of concrete is easy to flake off at high temperature, steel mesh can be applied to the surface of steel to further improve its fire resistance.

(2) Use mortar or ash cement as refractory protection layer. The materials used are mortar, lightweight magma, perlite mortar or ash mortar, vermiculite mortar or lime mortar, etc.. All of the above materials have good fire resistance, and the construction method is to apply the above-mentioned materials on the metal net.

(3) The usage of mineral fiber. Its materials are asbestos, rock wool and slag cotton. The concrete construction method is mixed with cement and mineral fiber, then utilized the special spray gun and water spray coating to spray on the steel structure at the same time to form a layer of spongy, and smooth it or let it be of its concave convex. The above method can be sprayed directly on the steel structure, and can also be sprayed to the metal mesh, and the latter is better.

(4)Lightweight prefabricated panels are used as protective coatings. The materials used include lightweight concrete slabs, foam concrete slabs, calcium silicate forming panels and asbestos forming panels, etc. the practice is to use the prefabricated panels to cover the components, and the connections between the panels can be nailed and bonded. This construction method is easy to construct and shorter in duration, and is beneficial to industrialization. At the same time, the function of the bearing (steel structure) and the fireproof (prefabricated plate) are clearly defined, and the repair after fire is convenient and does not affect the function of the main structure, so it has good resilience.

5.1.3 Shield method

Shield Method is to hide the steel structure in the wall or ceiling of the refractory material and to used as steel beam and steel roof. When the fire occurs, the temperature rise of the steel beam and the steel roof can be greatly delayed, and the fire resistance of the steel structure can be greatly improved,which can also increase the interior of the beautiful, but should pay attention to the ceiling joints, holes should be tight, to prevent channeling fire.

5.1.4 Water spray method

The water spray method is to equip a spray water supply network at the top of the structure. When the fire starts, it starts automatically (or manually) and forms a continuous flow of water film on the surface of the component so as to protect the structure.

From what can be seen above, the common feature of these methods is to minimize the heat flow to the component, which is called the closure method.

5.2 Grooming method

Unlike the cut-off method, the grooming method allows heat to be transferred to the component, and then the heat is taken away or consumed, and the temperature of the component can not be raised to the critical temperature, thus the steel structure is protected.

The method of dredging is mainly the method of water filling and cooling protection. This method is to fill water in the hollow columns, and during the fire, the heat of fire can be absorbed and be transferred to water.Depending on the evaporation of water, the heat is transferred or the heat is recycled through the loop, and the temperature of the component can be kept at about 100 degrees.

The above introduced several methods of fire protection of steel structure, each method has its advantages and disadvantages, we should consider the following factors when choosing the method of fire protection of steel structure: The structure of the steel structure, the nature of the components to be protected; the steel structure to take protective measures after the structure of the increased

weight and space occupied, construction difficulty and economy, etc.

6. Conclusion

Building fire is a common fire, it is the most closely related with people, which is the greatest impact on people's lives and property. Thus, it has been the the focus of fire prevention and control from all of the countries. In recent years, with the development of market economy and the increasingly prosperity of construction market, the steel structure system has been widely used. The purpose of the fire prevention of steel structures is to improve the fire protection design of steel structures and thus to reduce the casualties and the loss of property. This paper introduces the development and advantages of steel structure. And then introduces the fire protection of steel structure has great significance, summarizes the various methods of fire protection of steel structure in detail. Fire protection coating and other steel structure fire method has a greater advantage. With the development of science and technology, a variety of new technologies have gradually applied to the fire retardant coating, the thickness is getting thinner with better fire protection effect, and the application is more and more extensive.

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