Research on Design and Selection of Large-Span Steel Structure Based on Performance Environment and Its System Optimization

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Abstract: Large-span steel structures can be attributed to the large deformation instability from system to component to node. The safety control indicators include two aspects of bearing capacity and deformation capacity. Current domestic steel structures and related design codes for large-span steel structures the system and node performance and safety control indicators lack system regulations. Starting from the practice of large-span steel structure engineering design and combining experimental research, through calculation and analysis considering geometric nonlinearity and material nonlinearity, the full process curves of load-stress, load-strain, and load-displacement of systems, components, and nodes are obtained Based on the analysis of the ductile bearing capacity and deformation capacity, the elastic, elastoplastic bearing capacity, deformation capacity control indicators of large-span steel structure systems and nodes are proposed, and the performance-based design method of large-span steel structures is proposed.

1. Introduction

In recent years, with the development of the national economy and the continuous improvement of science and technology, more and more types of steel structure buildings have appeared, especially the types and forms of large-span steel structure buildings, from various sports, exhibition venues to various It can be seen everywhere in industrial buildings and large-span steel structures. The design trend of large-span buildings at home and abroad is that the span is getting larger, the appearance is more and more novel, and the internal structure is becoming more and more complicated. With the continuous development of these features, more and more regulations and limits are exceeded, and the requirements of engineering design can no longer be met according to ordinary routines. On the other hand, natural conditions are constantly deteriorating, the level of strong winds is increasing, and the impact on buildings is increasing. Therefore, how to choose a reasonable structural solution and select reasonable design parameters in the design, so that the safety and economics of engineering design are reasonably balanced, it is increasingly important. In this paper, the calculation and analysis of a large-span steel structure project, the analysis and selection of several structural design schemes, and the use of professional calculation software to optimize the structure, provide a useful theoretical basis and practical significance for this type of building structural design.

2. Performance-Based Design Overview of Steel Structures

Due to the application of high-strength materials and new technologies, steel structure buildings are becoming lighter and longer in span. The structure deforms greatly before reaching the yield load, and exhibits a considerable degree of geometric nonlinearity. Traditional analysis methods based on plane and linear assumptions are no longer applicable, and geometric nonlinearities must be considered for carrying capacity analysis. In many cases, when the structure is gradually approaching the ultimate load it can bear, the steel structure enters the yield stage, and the properties of the material gradually change from linear elasticity to plasticity, showing the material nonlinearity. Therefore, the design should consider the dual nonlinearity of geometric nonlinearity and material

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nonlinearity, and use the finite element method to analyze the entire process of large displacement elastoplasticity of the structure to determine the working state of the structure under the limit load. At present, general finite element calculation software such as ANSYS has been widely used at home and abroad, providing engineering designers with a practical method and method for full-process calculation and analysis based on structural geometry and material nonlinearity.

Ductility is usually defined as the deformation capacity of a structure, member, or a section of a member that reaches its ultimate load from yield or after the load has not decreased significantly after reaching the ultimate load. Structures or components with good ductility have large deformation capacity at the later stage, and can still absorb a certain amount of loading energy after reaching the limit state of yield or bearing capacity, so that there is obvious deformation or other omen (ie, ductile failure) before its failure. Controlling ductility is the basic principle of steel structure design. According to the definition of ductility, the basic idea of ductility performance design of large-span steel structures can be clearly identified: (1) Key performance parameters of ductility design include yield load, failure load, yield deformation (Dy) and damage deformation (Du). Among them, the yield load is the load when the structure or component load-structure response curve turns; the failure load is the maximum load in the structure or component load-structure response curve. Because the strengthening and necking stages after buckling of material strength are generally not considered in structural design, the load-structure response full process curve calculated by structural design stops at the highest point of the load, so the maximum load is the failure load. Yield deformation is the deformation of the structure or component corresponding to the yield load; failure deformation is the deformation of the structure or component corresponding to the damage load. (2) The key to ductility design is first how to calculate the above-mentioned ductility performance parameters, and analyze and determine the reasonable yield load value and yield deformation value index to ensure the safe use of the structure under the normal design load. (3) The second key to ductile design is to analyze and determine a reasonable bearing capacity ratio coefficient (for materials, it is a strong yield ratio, for a component, it is a stress ratio; for a system, it is a stable bearing capacity coefficient, and for a node, it is the design bearing capacity.) To ensure that there is a certain bearing capacity reserve before the structure is destroyed under the super normal design load.

3. Performance Design of Steel Members

China's current code GB 50017-2003 provides the following provisions for the elastic deformation performance of components: ① In order not to affect the normal use and look and feel of the structure or component, the corresponding deformation (deflection or side shift) of the structure or component should be specified in the design. Limit. In general, the allowable values of structural or component deformation are specified in Appendix A of this code. When you have practical experience or have special requirements, you can make appropriate adjustments to the provisions of Appendix A based on the principle that does not affect normal use and look and feel. ② When calculating the deformation of the structure or component, the cross-section weakening caused by the bolt (or rivet) hole may not be considered. ③ In order to improve the appearance and use conditions, the laterally-stressed members can be arched in advance. The arching size should be determined according to actual needs. Generally, the deflection value is the sum of the standard value of constant load and the standard value of 1/2 live load. At the same time, the deformation limit under live load is specified. Although it seems to be very specific, the engineering design still faces the following difficulties: (1) In actual engineering, the control value of the elastic displacement of large-span steel structures is within the range of L / 250 to L / 400. Due to the large value range, Designers are often at a loss. (2) The pre-arching of the structure is performed before the building roof load, decoration load, and live load. Therefore, the pre-arching cannot reduce the absolute deformation value of the structure under the above loads. The normal use performance of the building structure is often controlled by the absolute deformation value generated by the above loads. Therefore, the pre-arching is used to reduce the deformation value of the component relative to the initial geometric shape to solve the normal use performance requirements (anti-crack, waterproof, etc.). Scientific basis. (3) The code allows pre-arching of the structure to solve the problem of deformation limit. The arching amplitude can reach 1. 0 static load + 0.5 live deformation. Pre-arching according to this range, almost all structures with insufficient stiffness can achieve pre-arching to achieve the elastic deformation control index. So when the strength of the component is safely met, why should the elastic displacement of the structure under normal use load be controlled? Is it necessary to generate reverse arches for pre-stress measures to solve the displacement control index? (4) The current steel structure and related design codes (processes) The design of the deformation performance of steel members is limited to the elastic small deformation stage, and there is no Regulations. Under the condition of achieving the design goal of small elastic deformation capacity, can it ensure the safety under the situation of large-span structural system elastoplastic large deformation?

4. Performance Design of Steel Structure System

The performance-based design method was first applied in the seismic design of high-rise building structures. The design goal of the seismic ductility of high-rise building structures is that the structure moves at a certain seismic ground motion (such as 63%, 10%, and 2 probability of surpassing within a given period of time). % ~ 3% of small earthquakes, moderate earthquakes and large earthquakes). The level of deformability of a building includes various combinations of performance levels of structure, non-structure and building ancillary facilities. At present, the design technology of ductility performance of “exceeding limits” high-rise building structures has been widely mastered by designers, so this article will not repeat them. Regarding the large-span steel structure system's small elastic deformation capacity, the relevant design codes (processes) in China are basically the same as those of steel members, and the actual engineering design also faces the same difficulties (see section 3.2 of this article). For the design of the elastoplastic phase of the large-span steel structure system, only relevant JGJ 7-2010 in China's relevant design codes (processes) have provisions for the stable bearing capacity of the space lattice structure. Regarding the design of large-span steel structures with elastoplastic large deformation performance, China's relevant design codes (Cheng) have not proposed any regulations or requirements. In order to ensure the safety of large-span steel structures, the engineering design community urgently needs to conduct in-depth systematic research on elastoplastic stable bearing capacity and large deformation performance, and put forward clear design control indicators of stable bearing capacity and large deformation capacity. At the same time, combining a large number of engineering practices and analytical studies, the following conclusions were reached: ① For large-span steel structures with small stiffness, after the strength of the components meets the requirements, the existing measures can be achieved through pre-arching and pre-stressing of the structure. The requirements of the structural elasticity small deformation performance requirements specified in the code. ② Pre-arching has a certain effect on the stable bearing capacity of the structural system, and the degree of influence of different structural systems varies. However, the reduction of elastoplastic large deformation values of prestressed arches to different large-span steel structure systems is small, and pre-arching cannot improve the elastoplastic large deformation capacity of large-span steel structures. In engineering design, the pre-arch method is used to solve the requirement of small elastic deformation capacity according to the current code method, but the elastoplastic deformation capacity of the structural system cannot be guaranteed. ③ The prestressing force greatly improves the stable bearing capacity of long-span steel structure systems other than the large cantilever structure system. At the same time, it can greatly reduce the elastoplastic large deformation value of large-span steel structure systems. Prestressing is an effective and reliable measure to simultaneously improve the elastic and elastoplastic deformation capabilities of large-span steel structure systems. When the large-span steel structure system adopts prestressing, the damage deformation value of the structural system decreases greatly. When the prestressing degree is too large, the load-displacement process curve sometimes shows “brittleness” failure characteristics without obvious yield steps, so the design response the overall arrangement of the prestressed cable system and the degree of prestressing should be optimized. At the same time, the safety factor of the prestressed members should be appropriately increased to ensure that the prestressed members are still in the elastic stage under the large deformation of the structural system to avoid the occurrence of brittle failure. ④ Large-span steel structures with relatively small stiffness can only meet the limit of stable bearing capacity, and the elastoplastic limit deformation value of the structural system is too large, and the maximum elastoplastic deformation value of some engineering structure systems is greater than L / 30, or even L / 15. At this time, the structural system is actually in a state of large deformation and collapse. Therefore, the large-span steel structure system must meet the requirements of both the stable bearing capacity and the large deformation capacity.

The calculation and analysis curve and the experimental measured curve of the joint's load-strain process show that, before the material strain in most regions reaches the yield strain, the non-linear growth occurs, indicating that the joint is under low stress of the steel tube member The local area of the node will enter the plastic redistribution state; on the other hand, from the local occurrence of plasticity at the node to the full development of the plastic area, the load can increase by more than double. Therefore, the bearing capacity of steel structure joints should not use the material's yield stress as its safety control index, and the design bearing capacity of the joints is too conservative to take its elastic limit load. Therefore, in this paper, the joint yield load is defined as the corresponding load value when the inflection point of the load-strain (displacement) whole process curve appears after the plastic zone of the node is fully developed, rather than the load when the joint is locally plastic. The joint strain and displacement corresponding to the joint yield load are taken as the joint yield strain and yield displacement. The joint yield load can be used as the joint design bearing capacity, but the joint from the elastic limit state to the yield state is a plastic development process with a large flow plasticity. It is difficult to determine the yield point and the corresponding yield load value. However, the node failure load corresponding to the node failure limit state is close to a fixed value. Therefore, a feasible method for designing the bearing capacity of a node is based on the node failure load, leaving an appropriate safety factor to determine the node design bearing capacity.

5. Conclusion

Long-span steel structures should be performance-based in terms of systems, components, and nodes. Firstly, through the analysis of geometric nonlinearity and material nonlinearity, the full process curves of load-stress, load-strain, and load-displacement of systems, components and nodes are obtained, and then key ductile performance parameters are obtained, and corresponding performance control indicators are determined. , Node, system security for comprehensive performance design. The majority of scientific researchers and engineering and technical personnel should work together to reflect the ideas and methods of performance-based design into China's current steel structure code (process) system to ensure the safety of steel structure engineering and further promote the scientific and technological innovation of China's steel structure industry. And development.

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