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Research and application of anti buckling braces in energy dissipation and seismic reduction

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Abstract

By improving the disadvantage of ordinary supports being prone to buckling under compression, anti buckling supports have become a new type of energy absorbing and seismic reducing component, which exhibits good extensibility during earthquakes and improves the stability of the overall structure. With the cooperation of the framework, it has a relatively complete dual anti lateral force system, and the overall stability of the components is excellent. It has been increasingly widely used in Japan and the United States, and some projects in China are gradually being applied, with considerable development prospects. Based on the current research status of anti buckling, explore the existing problems and related solutions, analyze the stress principle and application prospects of anti buckling supports.

Keywords

Anti buckling support; shock absorption; application prospect.

1. Background of the proposal of anti buckling support

Seismic support structures are designed to address lateral stiffness issues, and the commonly used supports often suffer from compression buckling, resulting in significant differences in hysteresis response. Under the action of a large earthquake, the support itself and connecting nodes are damaged, and the buckling of the support also leads to a decrease in hysteresis energy and a reduction in seismic resistance. Anti buckling braces have been improved based on ordinary braces to address the issue of easy buckling. By setting constraint elements on the periphery to reduce compressive buckling, a fuller load displacement hysteresis curve can be obtained to enhance the ductility of the support system.

2. Composition and design requirements of anti buckling support

Buckling resistant braces have dual structural functions through their own characteristics, enhancing the overall lateral stiffness and reducing the seismic response generated during earthquakes. The system mainly consists of two parts, including the core unit and the peripheral constraint. The relevant cross-section is shown in Figure 1, and a gap is used to separate the two, so that the peripheral constraint unit will not bear internal axial loads. During the process of re compression, the buckling of internal elements is hindered, and the force borne by the entire support under axial tension and compression is the same. The mechanical behavior reflected is only related to the material characteristics and cross-sectional area of the core element. There are various shapes during the construction process to meet the requirements of different stiffness and energy dissipation; The peripheral constraint units provide more bending stiffness to match the necessary constraints of the core units, mostly made of mortar or concrete, and some are composed of steel pipes[1].

Most of the anti buckling supports in the frame are of the monoclinic, positive V, and inverted V types, connected to the frame beams and columns through splice plates and hinges at the nodes, using a transition form. In most cases, a set of bolts are installed separately at the support and nodes, and connected using splice plates.

There are various shapes of anti buckling support core units, but most of them are composed of a single cross-section. By strengthening the extension of the core unit and the cross-section of the node plate, and utilizing connecting plates and symmetrically arranged bolt holes, the strength of the connection and the stability of the unconstrained areas at both ends are enhanced. Traditional supports suffer from the phenomenon of excessive length and short effective constraint area, as well as excessive bolts and splice plates directly affecting the construction progress. In response to the above shortcomings, a double steel tube sleeve anti buckling support has been developed. By inserting a core plate inside, the inserted core plate is used as a component, and the two components are combined together through on-site installation. The outer end of the double T extension at the end is connected to the node plate, which can significantly reduce the amount of splice plates and bolts used. This support will improve construction efficiency, but the additional auxiliary components between the sleeve and the components do not reflect better economic effects.

The key point of anti buckling support is to use peripheral constraints to provide necessary anti buckling for the core unit, which is used to limit the longitudinal and lateral expansion of the structure. The anti buckling support is achieved through the interaction between the core unit and the peripheral constraints. When the core unit is compressed and deformed, local sliding occurs between the core unit and the peripheral constraints. To adjust for similar situations, apply an adhesive free layer to the constrained area of the kernel unit to minimize friction. Meanwhile, the Poisson effect caused by the kernel unit cannot be ignored. The gap should be set appropriately. If it is too small, it cannot resist the expansion deformation of the constrained internal unit caused by compression. Due to the hoop effect, the core unit will produce yield hysteresis, which affects energy consumption and ultimately leads to the failure of the constrained unit. If it is too large, it will directly affect the constraint effect of peripheral constraint units on kernel units.

Setting gaps does not cause arbitrary sliding between the core unit and the peripheral unit. Limit cards should be added to the internal unit board to connect the peripheral units and prevent deformation and sliding of the peripheral units, in order to maintain reasonable constraints on the core unit.

Buckling resistant braces are different from general steel structural products and require high manufacturing accuracy. Some companies in Japan and the United States have mature production processes. Specialized merchants produce the overall construction with strict production and verification standards, which can achieve ideal processing scenarios

Based on the above content, anti buckling support is mainly supported by the core element to bear axial forces, while external constraints mainly provide bending limitations for internal elements to avoid buckling during compression; In general, the surface of the kernel unit will have an adhesive free layer and fixed gaps, mainly to ensure that external constraints can provide support and also have a constraining effect on internal units [2].

The anti buckling support solves the problem of compression buckling of ordinary supports, making there no difference in tensile and compressive forces. In terms of design, the anti buckling support frame system has stricter requirements: 1) to withstand wind loads and small seismic effects, to ensure the elastic state of the overall structure, and to have sufficient lateral stiffness to ensure the stress requirements of the entire structure; 2) After experiencing a major earthquake, the main frame should still maintain its elastic state and neutralize the input structural energy consumed by the earthquake through plastic deformation. The rigid connection is the main way of connecting frame beams and columns, which can have strong resetting ability during earthquakes.

There are differences in the structural analysis methods for each stage. In the elastic stage, two methods can be used for random vibration analysis: the formation decomposition response spectrum method and the power spectral density method. The superposition principle can no longer be used in the plastic stage of the structure, and it is more advantageous to use the time history analysis method for simplification. The calculation at this stage is mainly to control the allocation of total seismic input energy, prevent the overall structure from entering a non elastic state, and ensure the stability of the overall structure.

3. Research and application status of buckling restrained braces at home and abroad

The advantages of stable performance and obvious shock absorption effect of anti buckling braces have become widely recognized, and now they have become the most researched and widely used energy absorbing components [3]. China started relatively late in the research of buckling restrained braces, but the research speed is very impressive, and significant achievements have been made in theoretical development; And the application of anti buckling support has begun to be emphasized, and there are already buildings with anti buckling support components involved.

Buckling resistant support is mainly used to ensure that the component does not yield under compression, and can be composed of both transverse and longitudinal yielding. The horizontal composition mainly depends on three parts: rigid core constraints, peripheral constraints, and non stick materials. Although there are various forms of shapes, their working principle still relies on the interaction between external constraints and core elements to prevent buckling caused by pressure.

Due to the frequent hazards of earthquakes and the protection of their own people, Japan and the United States were among the early countries to study buckling restrained braces. Japan was the first to provide the most complete anti buckling support component, which was named as a non viscous support based on its characteristics. After that, India also conducted relevant research and still has its own name, and the issue of name uniformity is still ongoing.

The anti buckling support structure has been widely used in most buildings in Japan, improving their country's seismic fortification level. The following figure shows a high-rise building in Osaka, Japan, which uses anti buckling braces as part of its earthquake resistance.

In response to this, Japan has developed specific requirements for the use of steel for anti buckling braces. After years of research, it has been found that steel has better plastic deformation ability when it is at a low yield point, which can absorb and dissipate more energy during large earthquakes to reduce overall seismic response.

After the Beiling earthquake, the United States also began to increase the application of buckling restrained braces in engineering, and today's buckling restrained braces are also translated from BRB [4]. The research in the United States does not have an advantage in terms of time, but its development speed and technological level are far ahead, which has led many regions in the United States to accelerate the application of anti buckling structures, such as Utah, Oregon, and California.

Multiple anti buckling support buildings have been constructed in Taiwan, and a large number of buildings have improved their seismic resistance, maintaining a stable level of overall economic expenditure. On the one hand, this ensures the safety of the people, and on the other hand, reduces economic expenditure. The use of anti buckling support is a major trend that will gradually be applied to people's lives.

Based on a large amount of theoretical analysis and experimental results, a relatively systematic provision for buckling restrained braces has been provided, which was included in

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the seismic regulations by the Federal Emergency Management Agency in 2003. Regarding anti buckling braces, they are being used in countries such as Canada, New Zealand, and Taiwan in China. Currently, most basic research is conducted through experimental methods.

4. Application and development of anti buckling braces in China

The research on anti buckling braces in China is still in the development stage. The seismic code has added content on shock absorption and isolation, and detailed regulations have been made based on design characteristics. Some design points and methods for determining the effective damping ratio of components are still principle clauses, and there are no specific relevant regulations and provisions for the anti buckling brace frame system. With the emergence of a large number of high-rise buildings in China and the gradual improvement of seismic resistance concepts, China has begun to develop anti buckling support engineering. Although the theory has adapted to relevant requirements, it is still necessary to improve the relevant regulations to meet engineering needs.

To apply the new type of anti buckling support to practical engineering, the following aspects should be explored in detail: 1) Theoretical basis: Conduct reasonable research on anti buckling frame support through mechanical analysis, and provide more reasonable practical theories; 2) Pilot project: Conduct pilot research on experimental engineering through simple theoretical analysis, and summarize design methods suitable for buckling restrained braces; 3) Product development and formulation: Through theoretical foundation and experimental research, develop anti buckling support products with independent intellectual property rights, meet usage standards and relevant regulatory standards, improve relevant performance indicators, and achieve shock absorption effects.

Along with the progress of anti buckling braces, there are also many problems: due to the randomness of loads and errors, the position of anti buckling braces during the yielding process is random, resulting in a large number of problems in the design process and posing numerous challenges in analysis and practical applications [5]. In terms of material design, it is necessary to use steel with a lower yield point for welding, which results in significant processing difficulties and material waste; The use of non adhesive materials leads to a wide variety of supporting component materials, making the analysis process more difficult and even affecting the overall seismic performance. At present, self researched researchers have kept their research content confidential after applying for patents. Although it is beneficial for the protection of intellectual property rights, it limits the promotion and development of this technology, and there is currently no detailed report. China has conducted more research on anti buckling braces and has gradually achieved results, which can also be referenced and borrowed from international experience. In order to promote anti buckling brace components in China, the country's development must break through material types, detailed specifications, standard drawings, daily maintenance, specialized production enterprises, pilot engineering construction, and other aspects.

There are many advantages to the application of anti buckling braces, among which, compared with anti bending steel frames, anti buckling braces can easily meet the deformation requirements of the specifications under small deformations, and can achieve stable support under tension and compression. Compared with ordinary braces, anti buckling braces are more stable and have stronger and more stable energy dissipation capacity in earthquakes. The overall welding technology is more convenient, using bolts and hinges to connect to the node plate, which is more economical and convenient. More convenient to replace, in case of support damage during large earthquakes, it can be replaced more easily, and the anti buckling support is more convenient. The design system is more flexible and easy to adjust, which can better simulate hysteresis performance in non elastic analysis.

5. Conclusion

During the research process, the anti buckling support frame needs to meet the requirements of lateral stiffness, while also improving the defect of ordinary support under buckling, providing better hysteresis energy dissipation capacity. The use of anti buckling braces in new projects can improve the seismic resistance of buildings. Adding anti buckling braces to existing buildings can reinforce existing seismic structures, providing more new solutions for future research and application of seismic isolation and shock absorption.

The key issue of the anti buckling support structure system is to determine the section position, which can be determined by the buckling analysis in theoretical analysis, and the layout can be determined by the structural system analysis. Due to the lack of sample projects, a large number of projects were unable to proceed according to normal procedures, resulting in significant delays but unable to complete the project.

China already has comprehensive material conditions for research in this area, and there is a large demand in the domestic market. Technical issues need to be addressed. Regarding intellectual property issues, many products lack their own intellectual property rights, and the cost of use is gradually increasing. This requires China to make efforts to research and apply its own products.

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