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Review on research progress and application of seismic reinforcement technology at home and abroad

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Abstract

In the face of frequent earthquake disasters, improving the seismic resistance of existing buildings has become a key issue in the global engineering community. This paper systematically reviews the research progress and application status of seismic reinforcement technology at home and abroad, and focuses on the principle, applicability and innovative achievements of traditional reinforcement methods (increased cross-section, outer steel, etc.), fiber reinforced composite materials (FRP) reinforcement, energy-dissipating shock absorption technology and seismic isolation technology. The differences in technical standards, material research and development, and engineering applications of various countries were compared. The results show that FRP leads the material innovation with its light weight, high strength and convenient construction. Smart materials (e.g., SMA) and structural control technologies provide a new direction for adaptive reinforcement; Seismic isolation reinforcement is effective in important buildings, but the cost is high. Future research needs to focus on green and low-carbon reinforcement materials, intelligent design and construction systems, and life-cycle performance evaluation, so as to promote seismic reinforcement in the direction of efficiency, intelligence, and sustainability.

Keywords

Seismic reinforcement; FRP composites; energy consumption and shock absorption; foundation seismic isolation; smart materials.

1. Introduction

As a highly destructive natural disaster, the earthquake poses a major threat to the safety of people 's lives and property. A large number of existing buildings in global earthquake-prone areas (such as the Pacific Rim, Eurasian seismic zone) are seriously insufficient in seismic capacity due to lagging or aging design standards. As one of the countries with the most serious earthquake disasters, about 60 % of urban residential buildings in China were built before the promulgation of the current seismic code, and the seismic performance is generally weak. Enhancing its seismic capacity through efficient reinforcement has become a strategic focus in the field of disaster prevention and mitigation at home and abroad, which has more economic and environmental benefits than demolition and reconstruction. The purpose of this paper is to systematically review the research trends and engineering practices of seismic strengthening technology at home and abroad, and to provide reference for technology optimization and promotion.

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2. Progress and application of traditional seismic reinforcement technology

2.1. Domestic research and application

Technical development : The enlarged section method and the steel-encased reinforcement method are mature, and are listed as the basic methods by the ' Technical Specification for Seismic Reinforcement of Buildings ' (JGJ 116-2009). High performance ferrocement laminate (HPFL) technology has developed rapidly, which solves the problem of easy cracking of traditional mortar.

Material innovation : High strength grouting material and high performance composite mortar greatly improve the bond strength and durability of the reinforcement layer.

Engineering practice : widely used in primary and secondary school buildings (' school security project '), hospitals, residential and other masonry and concrete structure reinforcement. For example, after the Wenchuan earthquake, a large number of damaged frame structures were strengthened by the steel-encased method in Sichuan Province.

2.2. Research and Applications Abroad

Technical optimization : European and American countries pay attention to fine design theory (such as considering the influence of secondary force) and standardized construction process. Japan has developed steel plate lightweight technology and efficient anchorage system.

Specification system : FEMA 547 of the United States and Japan 's " Guidelines for Seismic Retrofit of Existing Reinforced Concrete Buildings " provide detailed design methods and structural requirements.

Application scenarios : mostly used for the protection of historical buildings (such as the reinforcement of Italian churches) and infrastructure reinforcement (the reinforcement of bridge piers in the United States).

Summary : The traditional technology is mature and reliable, and has a wide range of applications. However, there are some shortcomings, such as large amount of wet work, large space occupation, and large damage to the original structure.

3. Research progress of new materials and advanced reinforcement technology

3.1. Research and Applications Abroad

International frontier : The United States, Japan and Europe have achieved fruitful results in FRP-concrete interface bonding mechanism, long-term performance, high temperature / fatigue resistance and design theory. Prestressed FRP technology significantly improves the utilization efficiency (the NSM method in the United States is mature).

Domestic innovation : Breakthroughs have been made in FRP-confined concrete constitutive models, hybrid FRP applications (such as CFRP / GFRP combinations), and rapid construction techniques (such as prefabricated FRP slabs). A weather-resistant FRP suitable for humid and hot environments was developed.

Typical application : a large number of piers in Japan after the Kobe earthquake are strengthened by CFRP wrapping ; during China 's " 13th Five-Year Plan " period, FRP reinforcement technology has been applied to more than one million square meters in highway bridges and stadiums.

3.2. Energy dissipation (damper) reinforcement technology

The core technology is to absorb seismic energy by adding viscous dampers, metal yield dampers (such as BRB), friction dampers and so on.

International trends : The United States has developed a self-centering damper (combined with SMA), and Japan is leading in miniaturization and high-performance oil dampers.

Domestic application : BRB technology is relatively mature (national standard atlas), a large number of schools, hospitals for reinforcement (such as Xinjiang primary and secondary school building reinforcement project). The viscous damper has a significant effect in the reinforcement of super high-rise buildings in high-intensity areas.

Advantages : The effect is significant and has little effect on the building function, especially for buildings with limited space or need to maintain the use function.

3.3. Seismic enforcement

Principle : isolation bearings (rubber bearings, friction pendulum bearings, etc.) are installed on the foundation or between layers to block the transmission of seismic energy to the superstructure.

International benchmark : New Zealand, Japan, the United States widely used, the most mature technology. Japan has successfully used seismic isolation technology for the protection of ancient buildings (such as the departure of Akasaka in Tokyo).

Domestic progress : from important historical buildings (Xi 'an bell tower, part of the Forbidden City) to hospitals, data centers and other lifeline projects. Lead rubber bearing (LRB) and friction pendulum bearing (FPS) are widely used. The challenge lies in the high cost and the need for overall lifting construction.

3.4. Seismic enforcement

Shape memory alloy (SMA) : Using its superelasticity and self-centering characteristics, it is applied to self-centering dampers or prestressed tendons to significantly reduce residual deformation (active research in Chinese and American laboratories).

Intelligent monitoring and BIM : embedded sensors in reinforced structures, combined with BIM technology to achieve health monitoring and performance evaluation (European ' H2020 ' project focus).

Machine learning : used to optimize reinforcement scheme selection and parameter design (international research hotspot).

Summary : FRP is lightweight and efficient, the energy dissipation and shock absorption effect is outstanding and the interference is small. The isolation technology has superior performance, but the cost is high and the construction is complex. Intelligent materials and digital technology are the core of future development.

4. Development differences and challenges at home and abroad

Specifications and standards : Europe, the United States and Japan standard system is more perfect (especially for new technologies such as FRP, damper), update more timely. Chinese specifications are rapidly following up, but there is still room for improvement in detail construction and durability requirements.

Materials and products : High-end FRP fibers (such as carbon fibers above T700), high-performance damper core components (special steel, viscous fluid) are still partially dependent on imports. Domestication rate and cost control are the key points.

Design concept : International more emphasis on ' performance-based design ' and ' toughness improvement ', the pursuit of rapid recovery after the earthquake function. China is changing from ' collapse prevention ' to ' functional recovery '.

Cost and cognition : The cost of new technology (especially isolation) is still high, and the owner 's acceptance is insufficient. It is necessary to strengthen publicity and policy guidance (such as subsidies, expansion of the scope of compulsory reinforcement).

Special structure : the applicability of high-efficiency reinforcement technology for brick-concrete structure, earth-rock structure and historical style building still needs to be tackled (common challenges at home and abroad).

5. Conclusion

The seismic strengthening technology is developing rapidly from the traditional ' passive enhancement ' to ' active energy dissipation ' and ' intelligent adaptation '. The current technology development presents multiple characteristics : the traditional technology is mature and reliable, which is the main force of large-scale buildings, but the wet operation and space occupation need to be improved ; fRP technology leads the material innovation with its light weight, high strength and convenient construction. Its interface performance and long-term durability are the focus of continuous research. The energy dissipation technology has excellent effect and little interference to the building function. It is the key technology to improve the structural toughness and has great potential for promotion. Seismic isolation technology provides the highest level of protection and is suitable for important buildings. The key to its popularization lies in reducing costs and simplifying construction. In the future, intelligence (such as smart materials SMA, structural health monitoring, AI / BIM integration applications) and low carbonization (such as the development of low-carbon materials such as recycled FRP, geopolymer mortar) are the core development directions. Looking forward to the future.Research and practice should focus on : deepening the research and development of new materials with high performance, multi-function and low environmental impact ; establish a structure life cycle performance monitoring and evaluation system that integrates intelligent sensing, big data and AI ; development of fine design theory based on performance / toughness ; promote standardization, industrialization and rapid construction technology to reduce cost and construction period ; policy guidance and economic incentives should be strengthened to promote the large-scale application of advanced technologies (especially energy dissipation and seismic isolation) in new construction and reconstruction projects. Only through continuous innovation of technology, improvement of standards and optimization of policies can we build a safer and more resilient building environment and effectively cope with the challenges of earthquake disasters.

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