ISSN: 2414-1895 DOI: 10.6919/ICJE.202308_9(8).0024

Review on Impact Resistance of Steel Reinforced Concrete Columns

Shulin Mao

School of Yangtze University, Jingzhou, Hubei 434023, China

*1061094894@qq.com

Abstract

The resistance of steel-concrete columns to impact is crucial for ensuring structural safety. This article aims to introduce research methods for studying impact issues, present current research findings on the impact resistance of steel-concrete columns, and explore future research directions.

Keywords

Steel Reinforced Concrete; Impact Load; Finite Element.

1. Introduction

Steel-concrete composite structures refer to structures in which steel reinforcement and steel sections are embedded in concrete. Due to their excellent corrosion resistance, fire resistance, and seismic performance, they are widely used in important supporting components such as high-rise buildings, super high-rise buildings, bridges, and train stations. However, in practical engineering, building structures often experience dynamic impacts caused by human or natural factors. The sudden loads resulting from these accidental collisions act on the columns in a short period of time, leading to severe damage or even collapse of the entire structure. Research [1] has shown that the failure of critical components can significantly affect the structural safety. Therefore, it is necessary to study the dynamic response and reliability of steel-concrete columns under impact loads. This research holds significant importance in enhancing the safety and anti-collapse capacity of structures, achieving a harmonious development of seismic and impact resistance capabilities, and exploring the field of disaster prevention, mitigation, and protective engineering for such structures under impact loads.

2. Research and Development Status

2.1 Research Methods of Impact Loads

An impact problem refers to the short-term response of a structure caused by a sudden change in external forces during collisions. In previous research, the analysis methods for impact problems can be broadly categorized into empirical formula approach and dynamic analysis approach.

The empirical formula approach obtains concise empirical formulas through experimentation, statistics, and analysis, making it convenient and practical for practical engineering design. However, this method does not account for time effects and energy loss factors, leading to approximate calculation results. Furthermore, this method neglects the influence of impact duration and friction, which weakens its theoretical robustness

The dynamic analysis approach transforms the structural system into a model consisting of mass, spring, and damping systems. By establishing equations of motion based on the principles of dynamics, this approach enables calculation of excitation and response. The method offers significant improvements in theoretical rigor and accuracy, allowing for the computation of dynamic parameters.

However, incorrect model assumptions can introduce errors and overlook critical weak points. For structures with multiple degrees of freedom, the errors may be more pronounced, and the computational complexity can pose challenges.

The latest method for impact analysis utilizes the finite element method, which significantly enhances accuracy compared to traditional approaches. Since the 1970s, a series of dynamic nonlinear finite element analysis programs, such as LS-DYNA, have been developed and refined. The finite element analysis method employs various finite element software and utilizes mathematical approximation concepts to simulate real physical systems. Although the results obtained from finite element analysis are approximate solutions, they exhibit high precision and can simulate objects with complex shapes under various complex working conditions. Due to its efficiency and practicality, the finite element analysis method has rapidly become a widely applied numerical analysis technique. In the analysis of structural impact dynamics, it plays an irreplaceable role and has achieved a series of research accomplishments.

2.2 Research Status of Impact Resistance of Steel Reinforced Concrete Column

Currently, scholars both domestically and internationally are primarily focused on researching the axial mechanics, bond-slip behavior, seismic performance, fire resistance, and durability of composite steel-concrete members. Through experimentation and numerical analysis, significant progress has been made in developing improved testing methods, computational theories, and engineering design guidelines. However, due to factors such as high testing costs, low safety factors, time-consuming procedures, and challenges in assessing the bond-slip behavior between steel and concrete, there is a limited number of research reports on the impact resistance of steel-concrete composites.

Jiang Jing et al. [2][3]conducted a study on the lateral impact resistance of composite steel-concrete members with embedded T-shaped steel core using numerical modeling in Abaqus. In their simulation, they focused on analyzing the effects of variables such as axial compression ratio, boundary conditions, impact location, and steel content on the dynamic response of the structure by employing the parameter transformation method. The results demonstrated that the composite steel-concrete members with embedded T-shaped steel core exhibited high impact resistance stability and excellent impact performance. All the parameters had an influence on the impact resistance capacity, although to varying degrees.

Zhang Nan et al. [4] conducted horizontal impact tests on steel-concrete bridge piers to analyze their failure modes and influencing factors. They also developed a calculation formula for predicting the dynamic shear strength of steel-concrete bridge piers under impact. The research findings demonstrated that the embedded steel core significantly improved the resistance to impact cracking and enhanced the impact resistance capacity of the structure. Additionally, the reinforcement in the foundation also played a crucial role in the impact resistance capacity of the concrete bridge piers.

Zhu Xiang et al. [5] conducted lateral impact tests on steel-concrete composite members with an embedded cross-sectional steel frame using a super-heavy drop hammer testing machine. They analyzed the characteristics of the entire failure process, impact force, displacement, and axial force-time curves of the members. They compared the effects of different impact velocities, impact energies, axial compressive loads, and boundary conditions on the dynamic response of the steel-concrete composite members. The results revealed that under the impact of the drop hammer, the outer concrete of the members with an embedded cross-sectional steel frame suffered severe damage, and the higher the impact energy, the more prone the outer concrete was to shear failure. However, the damage to the internal steel bars and steel frame was relatively low.

In 2017, Chen Zhijun [6]conducted drop hammer impact tests to investigate the lateral impact resistance of lattice-shaped steel columns. Subsequently, the residual bearing capacity of the steel columns, reinforced with external steel bars and concrete, was determined through static load tests. The residual bearing capacity was used as an indicator to analyze the influence of initial impact damage on the overall load-bearing performance of the components. Finite element software

ISSN: 2414-1895 DOI: 10.6919/ICJE.202308_9(8).0024

ABAQUS was employed to establish models of undamaged and initially damaged components, and the numerical analysis results showed good agreement with the experimental reinforcement outcomes.

In 2019, Quanquan Guo[7] conducted impact tests on steel-concrete walls using a drop hammer method to study their impact resistance. Based on the principle of energy conservation, a method for calculating the maximum deformation of steel-concrete walls was proposed. Design requirements for this structure were established based on local failure characteristics, maximum deformation, and failure modes. Analysis of several factors revealed that increasing the thickness of the embedded steel plate effectively enhances the impact resistance of this structure.

In general, there are significant research gaps in the study of impact resistance of steel-reinforced concrete columns. However, scholars have made important achievements in the field of impact resistance of steel-reinforced concrete through various experimental and numerical analysis methods, providing valuable references for further improvement of impact analysis methods and design codes.

3. Summary

At present, the research on the response of structural components under impact loads mainly focuses on single impact conditions, without fully considering the possibility of secondary or multiple impact damages that may occur in actual engineering accidents. This leads to a lack of effective experimental and theoretical descriptions of the extent of damage and dynamic behavior of components after multiple impacts.

Existing research focuses more on the dynamic response and damage modes of structures or components under impact loads, with less reporting on the residual mechanical performance of the components after impact damage. However, the bearing capacity is a key indicator for ensuring structural reliability and provides important guarantees for the rational design and protective measures of structures under impact loads. Therefore, it is necessary to study the residual mechanical performance of components as well.

Furthermore, the impact loads in real-life situations are characterized by randomness, and single deterministic tests and simulations cannot comprehensively summarize the reliability of components. The reliability of structures is an important indicator for assessing structural safety, thus it is necessary to increase research on structural reliability.

References

[1] Wang, T.; Chen, Q.; Zhao, H.; Zhang, L. Experimental study on progressive collapse performance of frame with specially shaped columns subjected to middle column removal. Shock Vib. 2016, 2016, 7956189.

[2] Jiang, J., Xu, Y. Analysis of the lateral impact performance of T-shaped steel-concrete composite columns based on slenderness ratio. In: Proceedings of the 10th Shenyang Annual Scientific Conference (Volume of Information Science and Engineering Technology) (in Chinese). Shenyang Association for Science and Technology, 2013.

[3] Jiang, J. Study on the lateral impact resistance performance of irregular-shaped steel-concrete columns [D]: [Master's thesis]. Shenyang: Shenyang Jianzhu University, 2015.

[4] Zhang, N., Wang, H., Chen, X., Chen, J., Sha, X. (2017). Experimental Study on Impact Resistance Performance of Steel-Reinforced Concrete Bridge Piers. China Journal of Highway and Transport, 30(11), 99-107.

[5] Zhu, X., Liu, H., Lu, X., Wang, R. (2019). Experimental Study on Impact Resistance Performance of Steel-Reinforced Concrete Components. Explosion and Impact, 39(11), 98-108.

[6] Chen Zhijun. Study on the Axial Compressive Performance of Grid-Structural Steel Columns Reinforced with External Reinforced Concrete after Lateral Impact [D]. Shanxi: Taiyuan University of Technology, 2017.

[7] Guo Q Q, Zhao W Y. Design of steel-concrete composite walls subjected to low-velocity impact [J]. Journal of Constructional Steel Research,2019,154:190-196.