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A Review of The Impact Resistance and Impact Tendency of Concrete Under Pressure Load

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Abstract

In this paper, the research on the impact resistance and impact tendency of concrete is reviewed, including domestic and foreign literature. The research on the impact resistance of concrete mainly focuses on the testing and evaluation of impact strength, impact fracture toughness and impact failure mode, and comprehensively evaluates the impact resistance of concrete through the application of different test methods. Foreign research pays more attention to the comparison and numerical simulation of the impact properties of different materials, and discusses in depth the various factors affecting the impact resistance of concrete. The impact tendency of concrete is an important index to evaluate whether the concrete structure is prone to failure when subjected to impact load, and the domestic research mainly focuses on the formulation of the tendency index and the improvement of the test method, and the response of concrete under different impact loads is studied through experiments, and the evaluation and discussion are carried out. Foreign studies have paid more attention to the comparison and numerical simulation of the impact tendency of different materials, which has further deepened the understanding of the impact tendency of concrete. The impact resistance and impact tendency of concrete are affected by a variety of factors, such as the composition of the material, the type and volume of the fibers, the strength and direction of the impact load, etc. In recent years, sustainability research has become one of the important directions of concrete research, and the use of waste or alternative materials to improve the impact resistance of concrete has become a research hotspot. Fiber plays a key role in improving the impact resistance of concrete, and reasonable selection and control of the type and volume of fiber can significantly improve the impact resistance of concrete. Based on the above research results, this paper comprehensively reviews the theoretical discussion and research progress of impact resistance and impact tendency of concrete, which provides an important theoretical basis and technical support for the safety design and engineering construction of concrete structures.

1. INTRODUCTION

With the rapid growth of the world economic development level, the shortage of mineral resources is becoming more and more obvious, the exploitation of surface resources in recent centuries, the mineral resources on the surface have basically been exhausted, so people will increase the exploitation of underground resources, however, the geological conditions and stress environment of the deep underground will also become complex with the increase of depth, and the geological disasters will gradually increase. Such natural disasters always cause serious casualties and operational difficulties. The impact load has a short time and large energy, and its action will cause great damage to the reinforced concrete structure, which will seriously affect the safety and durability of the concrete project. Therefore, in recent decades, researchers at home and abroad have begun to pay attention to the impact resistance and impact tendency of concrete. This study is based on a review of previous test standards and scientific research results, and analyzes the advantages and disadvantages of various testing schemes, aiming to

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provide ideas for the further research and development of impact resistance and impact tendency of borehole concrete

2. DOMESTIC RESEARCH ON THE IMPACT RESISTANCE AND IMPACT TENDENCY OF CONCRETE

2.1. Review of concrete impact performance test standards

Concrete is a commonly used building material, and it is common for it to withstand dynamic loads such as compressive loads in underground engineering. Therefore, evaluating the impact resistance of concrete is essential to ensure the safety and reliability of underground works. Some progress has been made in the research on the impact resistance of concrete in China, and a series of test standards have been formed, which provide a basis for the evaluation and design of impact resistance of concrete. This review will synthesize the research results on the impact performance test standards of concrete in relevant domestic literature, including test methods and performance evaluation indicators.

Impact testing is one of the common methods used to evaluate the impact resistance of concrete. According to the research results of Jiang Di et al. [1][6], they proposed a test system and method for the impact resistance of prestressed concrete containment. In this method, the prestressed concrete is tested by applying impact load to determine its response and failure characteristics under impact load, so as to evaluate the impact resistance of concrete.

Tensile testing is also a common method to study the impact resistance of concrete. Zhu Xuechao's research [2] explored the fracture toughness of concrete under impact loading by performing tensile tests in cement concrete. The results of the tensile test can reflect the fracture characteristics of concrete under impact load, and provide a reference for the impact design of concrete structures.

Compression tests are commonly used to evaluate the strength and stability of concrete. Compression tests are also widely used in the study of the impact resistance of concrete. For example, Guo et al. [5] investigated the performance of prestressed concrete beams under impact loads by performing compression tests on them. The compression test can evaluate the compressive capacity of concrete under impact load, and provide a basis for the design of concrete structures in underground engineering.

Impact strength is an important indicator to evaluate the ability of concrete to resist impact loads. This index reflects the failure resistance of concrete under impact loads, which can be determined by methods such as impact tests [7].

Impact fracture toughness refers to the ability of concrete to resist fracture and failure under impact loads. This index is usually evaluated by methods such as tensile tests to describe the ductility and toughness of concrete under impact loads.

The impact failure mode describes the failure mode of concrete when it is subjected to impact loads. This index reflects the mechanical characteristics of concrete under impact load, which is of great significance for the stability and safety of concrete structures [8].

The domestic research on the test methods and performance evaluation indicators of concrete impact resistance needs to be further deepened. At present, researchers mainly focus on basic test methods such as impact test, tensile test and compression test, but the testing and evaluation of impact resistance of concrete under complex conditions still need further research. In addition, factors such as the type and mix ratio of concrete materials may also have an impact on its impact resistance, which also requires more theoretical discussion and experimental verification [9].

Some progress has been made in the research on the impact resistance of concrete in China, and the relevant test standards and performance evaluation indicators provide a basis for the

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evaluation of the impact resistance of concrete. However, there are still many issues that need further research, including more complete and detailed test methods, the influence of concrete materials and mix ratios on their impact resistance, etc. Future research can continue to deepen the theoretical discussion and experimental research on the impact resistance of concrete, so as to improve the safety and reliability of concrete structures in underground engineering.

2.2. Review of concrete impact tendency test standards

Concrete impact tendency is an important index to evaluate whether concrete structures are prone to failure when subjected to impact loads. For concrete structures in underground engineering, the study of their impact tendency is very important to ensure the safe operation of the project. This review will synthesize the research results on the test standards of concrete impact tendency in relevant domestic literature, including the formulation of propensity indicators and the improvement of test methods.

Liu Juanhong and Wu Ruidong conducted an experimental study on the impact tendency of concrete under complex stress conditions in deep ground [10]. By simulating the actual working environment of underground engineering, they explored the response of concrete to impact loads under complex stress states. This study provides an important basis for the safety assessment of concrete when it is subjected to impact load in actual underground engineering.

Xue Yang et al. conducted a study on the relationship between the impact tendency of RPC concrete based on deep mining [11]. They studied the impact loads that concrete structures could experience during deep mining and analyzed the impact tendencies of RPC concrete under such conditions. The study provides guidance for the design and construction of concrete structures in the process of deep mining.

Zhou Yucheng et al. conducted an experimental study on the impact tendency of fiber-reinforced concrete wellbore under temperature-composite salt coupling conditions [12]. They investigated the impact tendency of fiber reinforced concrete in a specific environment by conducting experimental studies under the coupling effect of temperature and composite salts. This study provides a reference for the evaluation of the impact tendency of concrete under different environmental conditions.

The domestic concrete impact tendency test standards mainly focus on the response and failure characteristics of concrete under different conditions. However, due to the complexity and variability of the underground engineering environment, the response of concrete when subjected to impact loads can be affected by a variety of factors. Therefore, future studies can further explore the variation law of concrete impact tendency under different environmental conditions, as well as the influence of concrete material type and mix ratio on its impact tendency [13][14].

Some progress has been made in the research on the test standards for concrete impact tendency in China, and the relevant experimental research and the formulation of tendency indicators provide a reference for the design and construction of concrete structures in underground engineering. However, there are still many issues that need to be further studied, including the variation law of concrete impact tendency under different environmental conditions and the influence of concrete materials. Future research can continue to explore the test methods and evaluation criteria for the impact tendency of concrete to improve the impact resistance and safety of concrete structures in underground engineering.

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3. FOREIGN RESEARCH ON THE IMPACT RESISTANCE AND IMPACT TENDENCY OF CONCRETE

3.1. Overview of concrete impact performance test standards

Salman Siddique et al. [15] determined the impact resistance of concrete containing 40% fine bone china ceramic aggregate by drop weight test and rebound test. The test results show that the addition of fine bone china ceramic aggregate increases the number of blows of concrete failure and initial cracking, and improves the energy absorption capacity of concrete. The addition of fine bone china ceramic aggregates changes the failure mode from a single large crack to a set of cracks.

Al-Tayeb, Mustafa Maher [16] et al. replaced fine aggregate (FA) with plastic waste (PW) and used 0%, 20%, 30% and 40% fly ash as a substitute for fine aggregate, and studied the mechanical properties of concrete under impact load through drop weight tests. The results show that a proportional increase of 20% PW can improve the bending load, impact load and inertial load of concrete.

Younis, Khaleel H. [17] et al. studied the impact resistance of steel fiber reinforced concrete (SFRC) by adding 0%, 0.5%, 1%, 1.25% and 1.5% steel fibers to concrete, respectively. The results show that steel fiber reinforced concrete has better impact resistance. Increasing the amount of fiber can improve the impact resistance of concrete, but the amount of fiber can improve the impact resistance of concrete within a certain range. When the steel fiber content is 1.25% of the concrete volume, the increase is maximum.

Sreekumaran, Sreenath et al. [18] studied the synergistic effect of GGBFS and RHA on the impact resistance of non-fiber and fiber-active powder concrete RPC by replacing cement with two fillers, GGBFS (GGBFS) and quartz powder (QP) and rice husk ash (RHA), respectively. The results show that sustainable RPC mixtures with good impact resistance can be developed using GGBFS as a supplemental cementitious material (SCM) and RHA as an active filler (as well as an internal curing agent).

G Ong et al. [19] performed a low-velocity projectile impact experiment on concrete slabs by controlling the type and volume of fibers incorporated into the concrete to assess impact resistance. The experimental results show that when the fiber volume fraction is 0.5%, 1% and 2%, the fracture energy values of the steel fiber reinforced concrete slab are about 40%, 100% and 136% higher than that of the polyolefin fiber reinforced concrete slab, respectively, and about 19%, 53% and 80% higher than that of the polyvinyl alcohol fiber reinforced concrete slab. The results show that the steel fiber reinforced concrete slab exhibits excellent performance in terms of cracking characteristics, shear plug formation, energy absorption and impact integrity.

Abdulkader Ismail Al-Hadithi et al. [20] investigated the behavior of self-compacting concrete (SCC) slabs containing PET fibers with an aspect ratio of 28 under impact loads through impact tests. Experiments show that the addition of PET fiber improves the ability of the slab to resist impact load and absorb energy, and also enhances the ability of SCC to absorb energy under low-speed impact.

R.Yu et al. [21] used an improved Andersen model for the design of the concrete matrix, and studied the impact resistance of sustainable ultra-high performance fiber-reinforced concrete (UHPFRC) by using two pendulum impact devices, the "Charpy impact device" and the "improved pendulum impact device". The two experimental methods showed that a higher proportion of short fibers (SSF) would reduce the energy absorption capacity of the concrete target when the amount of steel fiber was constant at 2% volume. Fiber length plays a leading role in improving the energy dissipation capacity of sustainable UHPFRC; In the concrete phase,

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hybrid steel fibers (HF + LSF) are more effective than single size fibers (HF) in improving the energy dissipation capacity of sustainable UHPFRC under pendulum impact.

Ravi Ranade et al. [22] investigated the behavior of high-strength-high-ductility concrete (HSHDC) sheets under multiple moderate velocity impacts using drop weight impact tests. The impact load resistance of the HSHDC plate was determined. The experimental results show that the HSHDC plate still retains its impact bearing capacity and structural integrity under up to 20 impact drop weight impacts, indicating that the HSHDC plate has good impact resistance.

Banthia et al. [23] used a newly designed drop weight impactor to control the ambient temperature at 22 °C and -50 °C, respectively, to measure the impact resistance of large deformed fibers of steel with a fiber volume fraction of 2% and fine fibers of steel and carbon to reinforced concrete, and also studied hybrid composites with a combination of coarse and microfibers. The results show that the coarse fiber of steel can improve the toughness of concrete more than microfiber, and the impact resistance of fiber reinforced composites is slightly higher at higher hammer speed, but the impact energy absorbed is reduced at lower than normal temperatures. However, contrary to popular belief, no particular reduction in stress rate sensitivity was observed at lower-than-normal temperatures.

Arathi Krishna [24] studied the impact resistance of synthetic and natural fibers (including monofilaments and mixed fibres) at different temperatures (27, 200, 400 and 800°C) through drop weight experiments and compared them with conventional concrete. The results show that the incorporation of fibers can help to improve the impact resistance of concrete at room temperature and high temperature. In monofilament mixtures, the performance of microsteel fibers is higher than that of other fibers; in mixed fibers A mixture of 0.5% microsteel and 0.5% sisal fibre performed better.

3.2. Review of concrete impact tendency test standards

Concrete impact propensity is a key engineering performance indicator used to assess whether a concrete structure is susceptible to failure when subjected to impact loads. In foreign countries, the research on the impact tendency of concrete covers many aspects, including comparative studies of different materials, numerical simulations and experimental studies. These research results provide important technical support for the construction and design of underground engineering, aiming to ensure that the engineering structure has sufficient stability and durability in the complex impact environment.

Over the past few decades, many scholars have conducted extensive research on the impact tendency of concrete. In their 1981 study, A. Kidybiński et al. experimentally measured the impact tendency index in coal mines, which provided an important reference for coal mining [25]. In a 2014 study, Su C et al. studied the effect of saturation period on the impact tendency index of coal mines, and the results showed that the increase of saturation period can improve the impact resistance of concrete [26]. In a 2015 study, Zhaoyang S et al. discussed the evaluation method of coal-rock impact tendency, which provided technical support for the design and construction of coal mine engineering [27]. In a 2020 study, Gbadamosi AR et al. analyzed the spontaneous combustion tendency index and coal recording standards, which provided an important reference for coal mine production safety [28]. In their 2022 study, Liu et al. conducted an experimental study on the impact tendency of coal considering creep predamage, which is helpful for gaining insight into the mechanical properties of coal under complex working conditions [29].

In addition to coal mines, other types of concrete have also received a lot of attention. Younis KH et al. added steel fiber content in the experiment and studied the impact tendency of steel fiber reinforced concrete. The experimental results show that the steel fiber content has a significant effect on the impact resistance of concrete [30]. Sreekumaran et al. investigated the

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impact resistance of non-fibrous and fiber-reinforced concrete by incorporating fillers such as ground slag and rice husk ash into their research, which contributed to the development of sustainable concrete materials with good impact resistance.

There are many new techniques that have been applied in the study of the impact tendency of concrete structures. K.C.G Ong et al. compared the effects of different types of fibers on the impact resistance of concrete through low-velocity projectile impact experiments. The results of the study show that the steel fiber reinforced concrete exhibits excellent performance in terms of energy absorption and impact integrity. Abdulkader Ismail Al-Hadithi et al. studied the effect of heat treatment on the impact properties of concrete and found that the addition of PET fibers could improve the impact load resistance and energy absorption capacity of concrete. R.Yu et al. used an improved model for concrete matrix design to study the impact resistance of sustainable UHPFRC, which provides useful information for the development of new concrete materials. Arathi Krishna et al. studied the effects of different types of fibers on the impact resistance of concrete at different temperatures, and the experimental results showed that the incorporation of fibers could significantly improve the impact resistance of concrete.

4. DISCUSSION ON RESEARCH THEORIES AT HOME AND ABROAD

The domestic research on the impact resistance and impact tendency of concrete has formed a certain system, in which the test standard is the basis of the research. Domestic researchers usually use impact test, tensile test, compression test and other methods to evaluate the impact resistance of concrete. For example, Jiang Di et al. developed a test system and method for the impact resistance of prestressed concrete containment, and measured the impact resistance of prestressed concrete through experiments. In his master's thesis, Zhu Xuechao studied the method for measuring the impact resistance of cement concrete, which provided a new way for the test of impact resistance of concrete. Liu Zhiyong deeply discussed the relationship between the impact resistance of concrete and prestress through the static load test of damaged prestressed concrete T-beams and the study of effective prestress detection methods. These experimental studies provide a basis for the evaluation of the impact resistance of concrete in China.

Significant progress has also been made in the research on the impact resistance and impact tendency of concrete. Researchers mainly focus on the comparative study of the impact tendency of different materials and the numerical simulation of the impact tendency. Through experiments and simulations of the impact behavior of concrete under different conditions, researchers have a deeper understanding of the impact tendency of concrete. For example, Salman Siddique et al. determined the impact resistance of concrete containing 40% fine bone china ceramic aggregate by drop weight test and rebound test. The test results show that the addition of fine bone china ceramic aggregate increases the number of blows of concrete failure and initial cracking, and improves the energy absorption capacity of concrete. The addition of fine bone china ceramic aggregates changes the failure mode from a single large crack to a set of cracks. Al-Tayeb et al. used plastic waste (PW) instead of fine aggregate (FA) and used different proportions of fly ash as a substitute for fine aggregate, and studied the mechanical properties of concrete under impact load through drop weight test. The results show that a proportional increase of 20% PW can improve the bending load, impact load and inertial load of concrete. Younis et al. incorporated 0%, 0.5%, 1%, 1.25% and 1.5% steel fibers into concrete to study the impact resistance of steel fiber reinforced concrete (SFRC) through drop weight tests. The results show that steel fiber reinforced concrete has better impact resistance. Increasing the amount of fiber can improve the impact resistance of concrete, but the amount of fiber can improve the impact resistance of concrete within a certain range. Sreekumaran et al.In this study, the synergistic effect of GGBFS and RHA on the impact resistance of non-fiber

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and fiber-active powder concrete RPC was studied. The results show that sustainable RPC mixtures with good impact resistance can be developed using GGBFS as a supplemental cementitious material (SCM) and RHA as an active filler (as well as an internal curing agent). K.C.G Ong et al. performed a low-velocity projectile impact experiment on concrete slabs by controlling the type and volume of fibers incorporated into the concrete to evaluate impact resistance. The experimental results show that when the fiber volume fraction is 0.5%, 1% and 2%, the fracture energy values of the steel fiber reinforced concrete slab are about 40%, 100% and 136% higher than that of the polyolefin fiber reinforced concrete slab, respectively, and about 19%, 53% and 80% higher than that of the polyvinyl alcohol fiber reinforced concrete slab. The results show that the steel fiber reinforced concrete slab exhibits excellent performance in terms of cracking characteristics, shear plug formation, energy absorption and impact integrity. Abdulkader Ismail Al-Hadithi et al. investigated the behavior of self-compacting concrete (SCC) slabs containing PET fibers with an aspect ratio of 28 under impact loads through impact tests. Experiments show that the addition of PET fiber improves the ability of the slab to resist impact load and absorb energy, and also enhances the ability of SCC to absorb energy under low-speed impact. R.Yu et al. used an improved Andersen model for the design of the concrete matrix, and investigated the impact resistance of sustainable ultra-high performance fiber-reinforced concrete (UHPFRC) using two pendulum impact devices, the "Charpy impact device" and the "improved pendulum impact device". The two experimental methods showed that a higher proportion of short fibers (SSF) would reduce the energy absorption capacity of the concrete target when the amount of steel fiber was constant at 2% volume. Fiber length plays a leading role in improving the energy dissipation capacity of sustainable UHPFRC; In the concrete phase, hybrid steel fibers (HF + LSF) are more effective than single size fibers (HF) in improving the energy dissipation capacity of sustainable UHPFRC under pendulum impact.

Significant progress has been made in the study of impact resistance and impact tendency of concrete at home and abroad. Domestic research focuses on the formulation of test standards and the improvement of impact performance test methods, which provides important technical support for domestic engineering construction. Foreign studies pay more attention to the comparative study and numerical simulation of different materials, and deeply discuss the various influencing factors of concrete impact tendency. However, there are still many issues that need further research, such as the impact properties of concrete under extreme temperature conditions, the influence of different types of fibers on the impact properties of concrete, the impact properties of composite materials, etc. Therefore, the research on impact resistance and impact tendency of concrete still has a broad space for development, and will continue to attract the attention and input of more scientists and engineers. These research results will provide more reliable theoretical basis and technical support for the safety design and engineering construction of concrete structures.

5. CONCLUSION

In this review, we review and summarize the research on the impact resistance and impact tendency of concrete, covering the research results at home and abroad. Through the analysis of a large number of literatures, we can draw the following conclusions:

Research on impact resistance of concrete: The research on impact resistance of concrete in China mainly focuses on the testing and evaluation of impact strength, impact fracture toughness and impact failure mode. Different test methods, such as impact tests, tensile tests, and compression tests, are widely used to study the impact resistance of concrete. At the same time, foreign research also pays more attention to the comparison and numerical simulation of

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the impact performance of different materials, and deeply discusses various factors affecting the impact performance of concrete.

Research on impact tendency of concrete: impact tendency is an important index to evaluate whether concrete structures are prone to failure when subjected to impact loads. Domestic research mainly focuses on the formulation of propensity indicators and the improvement of test methods, and evaluates and discusses the response of concrete under different impact loads through experiments. Foreign studies have paid more attention to the comparison and numerical simulation of the impact tendency of different materials, which has further deepened the understanding of the impact tendency of concrete.

Factors influencing the impact resistance and impact tendency of concrete: Studies have shown that the impact resistance and impact tendency of concrete are affected by a variety of factors, such as the composition of the material, the type and volume of the fibers, the strength and direction of the impact load, etc. Especially under complex stress conditions, the impact resistance of concrete shows more characteristics.

Sustainability research: In recent years, sustainability has become one of the important directions of concrete research. The use of waste or alternative materials to improve the impact resistance of concrete has become a hot topic of research at home and abroad. For example, researchers have improved the impact resistance of concrete by adding waste such as ground slag, rice husk ash, or alternative materials to prepare sustainable RPC mixtures.

Application of fibers in concrete: Fibers play a key role in improving the impact resistance of concrete. Different types of fibers, such as steel fibers, polyolefin fibers, polyvinyl alcohol fibers, etc., all have different effects on the impact properties of concrete. Reasonable selection and control of the type and volume of fibers can significantly improve the impact resistance of concrete.

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