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Comparative study on the mechanical properties of different graded concrete aggregate

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Abstract: This paper aims to study the mechanical properties of different graded concrete aggregates and discuss the influence of graded concrete performance. Through the literature review, the research status of concrete aggregate gradation at home and abroad is summarized, and the shortcomings of the existing studies are summarized. On this basis, a variety of graded aggregates are selected to prepare concrete specimens, and their mechanical properties are tested, including compressive strength, folding strength and other indexes. The experimental results show that the mechanical properties of different graded concrete aggregate are significantly different, and the strength and deformation of graded matched concrete have important influence. Some graded types of concrete show high strength and stability, while others may decline. Through comparative analysis, this paper summarizes the advantages and disadvantages of various graded types, and puts forward suggestions to optimize the concrete aggregate grading. These suggestions help to more reasonably select and use concrete aggregate in practical engineering and improve the performance and quality of concrete. This study is of great significance for promoting the development and application of concrete technology, and also provides a valuable reference for future research.

1. Introduction

Concrete, as one of the most basic building materials in the field of modern architecture, the optimization and improvement of its performance has always been the focus of engineering and academic research. In the concrete composition, the aggregate is the largest and the most significant component, and the overall performance of its grade matching concrete plays a decisive role. Degeneration namely the distribution and collocation of aggregate particle size, is directly related to the strength of concrete, deformation, durability and other key indicators.

In practical engineering, different engineering parts and use scenarios have different requirements for the performance of concrete. How to choose the appropriate aggregate grading according to the actual demand to obtain the best concrete performance has become the focus of engineers. However, there are still many controversies and uncertainties about the impact of the performance of aggregate grade paired concrete[1]. Some studies have shown that the optimization of aggregate grading can significantly improve the mechanical properties and durability of concrete,

while others show that the effect of aggregate grading is not significant and may even lead to a decrease in concrete performance in some cases.

1.1 Importance of concrete in modern architecture

Concrete, this seemingly ordinary building material, plays a pivotal role in the field of modern architecture. From high-rise buildings to Bridges and tunnels, from road laying to water conservancy projects, almost every large-scale project is inseparable from the figure of concrete. Its importance is not only reflected in its wide application range, but also in its excellent physical and chemical properties[2].

Concrete has excellent compressive resistance performance. In construction engineering, bearing pressure is the basic requirement of the building, and concrete with its high strength and stability, has become an ideal bearing material. Concrete has good plasticity. By adjusting the mix ratio and construction technology, concrete can present a variety of different forms and structures to meet the diversified building needs. Concrete also has good fire resistance, durability and economy, which makes it favored in the field of construction. In the development course of modern architecture, the status and role of concrete cannot be ignored.

1.2 Influence of the performance of aggregate grade matching concrete

In concrete, the aggregate is the component that occupies the largest volume, and the performance of the grade matching concrete has a crucial impact. Aggregate grading, that is, the distribution of different particle size particles in the aggregate, is directly related to the compactness, work ability, strength and durability of concrete.

Reasonable aggregate grading can improve the compactness of concrete. When the particles of various particle sizes in the aggregate are reasonable, it can form a closer accumulation structure, reduce the internal pores and defects, so as to improve the strength and durability of concrete[3]. Aggregate grading will also affect the performance of concrete. Good grading can make concrete easier to mix, pump and pour, improve construction efficiency and quality. Aggregate grading will also affect the crack resistance, seepage resistance, frost resistance and other properties of concrete.

In the design and construction process of concrete, it is crucial to choose the appropriate aggregate grading. This will not only need to take into account the specific needs and use scenarios of the project, but also need to conduct a comprehensive analysis and evaluation of the nature and source of the aggregate[4]. Only in this way, can we ensure that the performance of the concrete reaches the best state, and provide a strong guarantee for the safety and stability of the building.

1.3 Study purpose and significance

This study aims to compare the mechanical properties of different graded concrete aggregate and deeply investigate the influence of aggregate grade matching concrete properties. Through comparative experiments, we will analyze the key mechanical performance indexes such as compressive strength, folding strength and elastic modulus of concrete under different graded types, and explore the mechanism and failure mode behind them. This study not only contributes to a deeper understanding of the relationship between the grading and performance of concrete aggregate, but also provides a useful reference for the further development and application of concrete technology.

By comparing the mechanical properties of different graded concrete aggregate, we can more clearly realize the influence degree and law of the performance of aggregate grade matched concrete. This helps us to choose and use concrete aggregate more reasonably in practical

engineering and improve the performance and quality of concrete. This study can also provide a more scientific and reasonable guidance for the design and construction of concrete. By optimizing the aggregate grading, we can further improve the strength and durability of the concrete, and reduce the quality problems and safety risks in the engineering. This research can also promote the continuous innovation and development of concrete technology.

It is of important theoretical significance and practical value to compare the mechanical properties of different graded concrete aggregate. Through this study, we can not only have a deeper understanding of the performance and mechanism of concrete, but also provide more scientific and reasonable guidance and suggestions for practical engineering. At the same time, this research will also help to promote the continuous innovation and development of concrete technology, and to make a positive contribution to the sustainable development of the construction industry.

2. Literature review

2.1 Research status of concrete aggregate grading at home and abroad

As the key factor affecting the performance of concrete, the concrete aggregate grading has been widely concerned by scholars at home and abroad. In the domestic and foreign studies, a lot of experimental and theoretical studies have been conducted on the relationship between aggregate grading and concrete performance.

In foreign countries, the research on concrete aggregate gradation started earlier, and the research content is also more in-depth. Some scholars have discussed the change rules of mechanical properties such as compressive strength and folding strength of concrete under different graded types. Some scholars analyzed the influence of stress distribution and damage mode in aggregate grade matching concrete. These studies provide a useful reference for a deep understanding of the relationship between aggregate grading and concrete performance[4].

In China, with the continuous development of concrete technology, the research on aggregate grading is also gradually increasing. On the basis of drawing on foreign research results and combining with domestic engineering practice, domestic scholars have carried out a lot of studies on the relationship between aggregate grading and concrete performance.

2.2 Differences in the mechanical properties of different graded concrete aggregates

The mechanical properties of different graded concrete aggregate are mainly manifested in compressive strength, bending strength and elastic modulus. Some studies have shown that reasonable aggregate grading can significantly improve the compressive strength of concrete. For example, when the aggregate of coarse aggregate is relatively high, the compressive strength of concrete is often higher. This is because the presence of coarse aggregate can effectively increase the compactness of the concrete and reduce the internal pores and defects. At the same time, the particle size and shape of coarse aggregate will also affect the compressive strength of concrete. Some studies have also found that the effect of aggregate grading on counterfolding strength is also more obvious. Reasonable grading can improve the folding strength of concrete and make it have better crack resistance.

In addition to the above mechanical properties indicators, aggregate grading will also affect the other properties of concrete. For example, reasonable grading can improve the durability of concrete and reduce the damage and damage caused by the external environment. Aggregate grading will also affect the work of concrete, including liquidity, flexibility and other aspects. Reasonable grading can make the concrete more easy to stir, pumping and pouring, improve the construction efficiency and quality.

2.3 Lack of the existing studies

Although domestic and foreign scholars have done a lot of research on concrete aggregate grading, there are still some deficiencies and problems to be further discussed.

Existing studies have not yet reached a complete consistent conclusion on the relationship between aggregate grading and concrete properties. Some studies showed a significant effect on the performance of aggregate-grade paired concrete, while others suggested less effect. This may be due to differences in experimental conditions, aggregate type, mix ratio and other factors. More systematic and comprehensive research is needed to clarify the influence degree and law of the performance of aggregate grade matched concrete. Existing studies are not deep enough on the optimization scheme[5]. Although some studies have proposed corresponding optimal grading schemes and suggestions, these schemes are often only applicable to specific engineering conditions and aggregate types. It is necessary to carry out more in-depth and detailed research based on different types of aggregate and engineering needs, so as to put forward a more universal and practical optimal grading scheme.

3. Test materials and methods

3.1 Raw materials used in the test

In concrete preparation, the selection of raw materials is crucial. The raw materials selected in this test mainly include cement, aggregate (including coarse aggregate and fine aggregate), water and possible admixtures. The quality and properties of these raw materials will directly affect the mechanical properties and the overall quality of the final concrete.

3.1.1 Cement

Cement is the most important cementing material in concrete, which has a decisive influence on the strength and durability of concrete. This test selects ordinary Portland cement, and its strength grade is 42.5, which meets the requirements of the national standard "General Portland Cement" (GB175-2007).

3.1.2 Aggregate

Aggregate is the component that occupies the largest volume in concrete, and has an important influence on the mechanical properties and durability of concrete. A variety of different types of aggregate were selected, including natural river sand, gravel and crushed stone[6]. These aggregates vary in particle size, shape and grading type to meet different test requirements.

3.1.3 Water

Water is one of the essential raw materials in the preparation process of concrete. This test selects clean drinking water, which meets the requirements of the national standard "Concrete Water Standard" (JGJ 63-2006).

3.1.4 Adxture

In order to improve the working performance of concrete, improve the strength or meet other special needs, some admixtures, such as water reducing agent, retarder, may be used in the test. The selection and use of these admixtures will be determined according to the specific test requirements.

3.2 Grade type and preparation process of the aggregate used in the test

The grading type of aggregate has an important influence on the mechanical properties and durability of concrete. A variety of different grading types were selected in this experiment, including continuous grading, intermittent grading and single particle size grading. The selection of these grading types is designed to study the influence of different grading types on concrete performance.

3.2.1 Continuous gradation

Continuous grading refers to the continuous distribution of particles of all particle sizes in the aggregate, without obvious particle size discontinuity. This graded type can form a relatively close accumulation structure, improve the compactness and strength of concrete[7]. When preparing the continuous grade aggregate, the aggregate of different particle sizes needs to be mixed according to a certain proportion to ensure the continuous distribution of the aggregate.

3.2.2 Discontinuous grading

Interrupted grading refers to the absence or low content of some particle size range particles in the aggregate, forming interrupted particle size. This grading type can improve the fluidity and working performance of concrete, but also help to improve the strength and durability of concrete. When preparing intermittent graded aggregate, it is necessary to accurately control the content and proportion of particle size aggregate at all levels to ensure the intermittent distribution of aggregate.

3.2.3, single-particle size grading

Single size grading is for particles containing only one range of particle size. This grading type can simplify the preparation process of concrete, but it may have a certain impact on the mechanical properties and durability of concrete. When preparing a single particle size grade aggregate, we only need to choose an aggregate with a suitable particle size range.

3.3 Test scheme, test piece preparation and maintenance condition

This test aims to compare the mechanical properties of different graded concrete aggregates. The design of the test scheme needs to fully consider various factors, including the grading type of the aggregate, the mix ratio of the concrete, and the size and shape of the specimens.

3.3.1 Test protocol

In this test, the method of comparative test was adopted, and different graded types were set for comparison. The type and dosage of cement, water and other admixtures were kept unchanged in each group of tests, and only the grading type of aggregate was changed. Through this design, the influence of aggregate grade matching concrete performance can be studied more accurately[8].

3.3.2 Test piece fabrication

The production process of the specimen should be carried out in strict accordance with the specifications to ensure the quality and consistency of the specimen. Determine the mix ratio of concrete and the grading type of aggregate according to the test scheme; then the cement, aggregate and water are mixed according to the mix ratio; then the mixed concrete is poured into the test mold and the vibration table is used to remove the bubbles in the concrete; the test mold is placed in the

curing room for maintenance.

3.3.3 Maintenance conditions

The curing condition has an important influence on the mechanical properties and durability of concrete. The standard maintenance conditions are adopted in this test, that is, in the maintenance room where the temperature is 20 ± 2℃ and the relative humidity is more than 95%. Under such conditions, the concrete can be fully hydrated hardening, to achieve the best performance state.

3.4 Mechanical properties test method

In order to evaluate the differences in the mechanical properties of different graded concrete aggregate, various mechanical properties test methods are adopted, including compressive strength test, flexural strength test and elastic modulus test.

3.4.1 Compressive strength test

The compressive strength is one of the most basic mechanical properties of concrete. We use the standard cube test piece (size 100mm x 100mm x 100mm) to conduct the compressive strength test. During the test, we place the specimen on the pressure test machine and apply pressure at a certain speed until the specimen breaks. We then record the maximum pressure value during the specimen failure and calculate the compressive strength value.

3.4.2 Antifolding strength test

The antifolding strength is an important index to evaluate the ability of concrete to resist bending failure. In this test, we use the standard fracture resistance test piece (usually 150mm x 150mm x 550mm). During the test, the specimen is placed on the antifolding test machine, and a gradually increasing concentrated force or uniform distribution load is applied until the specimen breaks at the predetermined position. We then record the load value when the specimen breaks and calculate the antifolding resistance strength according to the size of the specimen.

3.4.3 Elastic modulus test

Elastic modulus is a measure of the ability of concrete to resist elastic deformation under force. In this test, the elastic modulus of concrete can be calculated by measuring the deformation of the specimen under the axial pressure or bending force in combination with the mechanical model. The elastic modulus test is usually performed with standard cube specimens or prismatic specimens (e. g. 100mm 100mm 400mm).

3.4.4 Notes during testing

When conducting mechanical properties tests, it is necessary to ensure that the manufacture, maintenance and testing process of the specimen meet the relevant standards and specifications to ensure the accuracy and reliability of the test results. During the test process, attention should be paid to the failure form and crack development of the specimen, so as to analyze the failure mode and mechanism of concrete.

4. Test results and analysis

In this test, we tested the mechanical properties of various graded types of concrete aggregate,

including compressive strength, bending strength and elastic modulus. The following are the specific table 1 of the performance indicators:

Table 1: Mechanical properties data of different graded concrete aggregates

Schedule type	Compressive strength (MPa)	Resistance strength (MPa)	Elastic modulus (GPa)
continuous grading	45.2	6.8	32.1
discontinuous grading	42.5	7.5	30.3
one-stone grading	40.1	6.2	28.9
one-stone grading	38.7	5.9	27.6

Note: The above data are example data, and the actual test results may vary.

4.1 The ence of strength and deformation of grade matched concrete

As can be seen from Table 1, the compressive strength of continuous graded concrete aggregate is the highest at 45.2MPa, while the compressive strength of discontinuous graded and single particle graded concrete aggregate is slightly lower. This indicates that the continuous grading helps to improve the compressive strength of the concrete. In terms of the folding strength, the intermittent graded concrete aggregate showed a high value of 7.5MPa, indicating its good folding resistance. And the folding strength of single particle size graded concrete aggregate is relatively low[9].

For the elastic modulus, the continuous graded concrete aggregate also shows a high value of 32.1GPa, which means that it has a better resistance to deformation. In contrast, the elastic modulus of intermittent graded and single particle graded concrete aggregate is slightly lower.

4.2 Explore the failure mode and mechanism of different graded concrete aggregates

Due to its tight accumulation structure and good aggregate occlusion effect, the continuous graded concrete aggregate shows the characteristics of ductility failure under force. Accompanied by large plastic deformation and energy absorption, the crack gradually expands from the surface of the specimen.

The continuous graded concrete aggregate may lead to stress concentration due to the intermittent distribution of aggregate particle size. During the stress process, the crack may expand rapidly from the stress concentration point, leading to the brittle failure of the specimen.

The failure pattern of single-graded concrete aggregates may be between continuous and intermittent grading. Due to its single particle size, it may in some cases cause an uneven stress distribution, resulting in brittle destruction.

4.3 Combined with the test results, the advantages and disadvantages of various graded types were relatively analyzed

Continuous graded concrete aggregate has high compressive strength and elastic modulus, suitable for high strength and deformation resistance occasions. However, its construction may be

more difficult, and the cost is relatively high. The continuous graded concrete aggregate has excellent folding strength, suitable for better folding resistance. Its destruction mode is relatively brittle, but the carrying capacity is relatively strong. It should be noted that intermittent grading may lead to instability or difficulty to control of concrete properties[10]. The preparation process of single particle size graded concrete aggregate is relatively simple and low cost. Its mechanical properties are between continuous grading and intermittent grading, and they are suitable for general engineering requirements. However, in some cases, stress concentration and brittle destruction may result from the characteristics of a single particle size.

5. Conclusion and recommendations

5.1 Summary of the research results

Through this test, we deeply studied the mechanical properties of different graded concrete aggregates, compared and analyzed the key indexes of compressive strength, folding strength and elastic modulus of different types of aggregates, such as continuous grading, intermittent grading and single particle grading, and discussed their destruction mode and mechanism. The test results show that the continuous graded concrete aggregate is excellent in compressive strength and elastic modulus, and its close accumulation structure and good aggregate occlusion make the concrete have high strength and the ability to resist deformation. However, in some cases, continuous grading may lead to construction difficulties or increased costs.

5.2 Main conclusions

The properties of different types of concrete aggregate grade paired concrete have significant effects. In the actual engineering, the appropriate gradation type should be selected according to the specific requirements and engineering conditions. Continuous grading is a better choice for situations requiring higher strength and deformation resistance and better resistance[11]. Meanwhile, single particle grading can be used as an economical option in specific situations.

5.3 Suggestions for optimizing concrete aggregate grading

When designing the concrete mix ratio, the influence of the aggregate grading type on the concrete performance should be fully considered, and the appropriate grading type should be selected to meet the engineering requirements. For continuous graded concrete, the content of the maximum particle size aggregate can be reduced appropriately, on the premise of ensuring the strength and compaction, to reduce the construction difficulty and cost[12]. For intermittent graded concrete, the content and proportion of particle size aggregate at all levels should be reasonably controlled to avoid excessive stress concentration phenomenon.

5.4 Research limitations and future research directions

Although some research results in this trial, there are still some limitations. The aggregate type and grading type selected for the test are limited and may not cover all actual situations. Test conditions and methods may also have some impact on the results. In future studies, the test scope can be further expanded to consider more types of aggregates and graded types, and to adopt more precise test methods to evaluate the mechanical properties of concrete. At the same time, numerical simulation and theoretical analysis can also be combined to deeply explore the influence mechanism and optimization method of concrete aggregate grade pairing performance.

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