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A Review of Durability of New and Old Concrete Joints

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Abstract

The purpose of this study is to explore the durability of the new and old concrete joints, including chloride ion erosion, freeze-thaw phenomena, and the influence of aggregates. Firstly, taking into account the difference in material properties between the old and new concrete, this study analyzes the chloride ion transport characteristics of the joints in detail, focusing on the key areas of the joints, that is, the areas where the old concrete may have been eroded by chloride ions. Secondly, this study explores the change in the properties of the joints under freeze-thaw conditions, and the influence of different interface treatment methods on the properties of the joints. Finally, this study examines the influence of the type and content of aggregates on the durability of the joints. Through the above research, this paper aims to provide some useful guidance and suggestions for the durability design of the old and new concrete structures.

Keywords

New-old Concrete; Chloride Erosion; Freeze and Thaw.

1. Introduction

The study and conclusions presented in this paper provide a comprehensive theoretical foundation for the design, maintenance, and repair of concrete structures, contributing to the extension of their service life. The research methodology and insights also offer valuable references and insights for the study of the durability of other types of concrete structures. This research is of significant guidance and practical value for engineers, architects, and professionals involved in concrete structures.Due to its advantages in safety, durability, economy, etc., concrete structures are the most widely used and fastest-growing structural systems in the construction field in the 20th century. However, in the process of its use, due to environmental effects and its own aging, the durability of concrete structures has become the main topic of research in related fields [1]. However, at present, the research on concrete durability mainly focuses on the integrally poured concrete [2,3], ignoring the impact of joints may lay unknown hidden dangers for new and old concrete structures in corrosive media environments.

The joint surface of new and old concrete widely exists in the reinforcement, repair and new construction of concrete structures. Such as the enlargement of beams, slabs, columns and other sections [4]; the seam and reinforcement of dams in water conservancy projects [5]; the construction joint of shear wall [6]; the post-cast belt of concrete and the assembled monolithic structure, etc.

Due to the difference in construction time, the hardening of old concrete, the volume shrinkage during the hardening process of new concrete, and various defects in the bonding surface of old concrete, the bonding surface of new and old concrete becomes a weak link in anti-crack, anti-slip and anti-seepage, which is related to the safety of the structure. The bonding surface performance of new and old concrete involves not only the safety of the bonding surface, but also the durability of the bonding surface.

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The impermeability of concrete refers to the ability of concrete to resist the intrusion of external media, and is one of the important indicators for evaluating the durability of concrete. Because most of the flowing water, solution and gas that are harmful to concrete enter the interior from the pores of concrete, resulting in concrete dissolution, structural looseness, compactness decline, and even structural damage. The quality of concrete impermeability directly affects the durability of concrete structures.

Some experimental research and theoretical analysis have been done on the bond performance of new and old concrete at home and abroad, but most of the research focuses on the mechanical properties of the bond surface, and the research on the permeability of the bond surface is less involved; secondly, the relationship between the permeability of the bond surface and the microstructure is less analyzed. Therefore, it is of great practical engineering significance and theoretical research value to carry out research on the permeability of the new and old concrete joint surface.

Regarding the durability of new and old concrete joints, relevant scholars mainly divide them into the following categories for research: 1. Research on whether stress is applied; 2. Research on the properties of new and old concrete bonding interfaces; 3. Research on concrete aggregates; 4. Research on concrete permeability.

2. Studies on Whether Stress is Applied

Li [7] et al. investigated the chloride ion permeation characteristics in the interface region of prefabricated and cast-in-place components under stress-free conditions. The results showed that the chloride content in the interface region is higher than that in other places. Based on the chloride ion measurement results, the interface zone effect (IZE) is mathematically described as a Gauss-Amp function.

Zhao [8] et al. analyzed the effect of constant compressive stress on the migration behavior of chloride ions in the interface region based on the definition of IZE. The results show that the chloride ion diffusion coefficient and the chloride ion concentration on the surface of the interface region are both related to distance and stress.

Shen [9] et al. investigated the effects of compressive stress and construction joints on the freeze-thaw durability of concrete through experiments. Accelerated freeze-thaw tests were carried out on the whole specimen and the specimen with different types of construction joints (i.e. normal wet joints, rough wet joints, epoxy joints and dry joints). The results show that compressive stress can improve the freeze-thaw durability of concrete, and the compressive stress not exceeding 0.5fck can improve the freeze-thaw durability of concrete, but the higher compressive stress of 0.5fck can improve the freeze-thaw durability of concrete, but the durability degradation caused by the higher compressive stress of 0.5fckis greater than that caused by the positive compressive stress of 0.3fck. The joint type of the segmental concrete specimen under the normal compressive stress of 0.3fckhas a greater impact on the freeze-thaw durability. And different types of construction joints also have a greater impact on the fro

Yang [10] et al. pointed out that concrete pavements in cold climate regions are often damaged by freeze-thaw cycles. Interfacial transition zone (ITZ) is the first area to deteriorate. Then an indoor-accelerated coupling test was carried out to study the changes of interface microstructure under the coupling action of fatigue load and freeze-thaw cycles. The results show that the coupling effect accelerates the deterioration rate of the material, increases the complexity of the microcrack structure, and increases the pores in the cracks and the crack nucleation. In addition, the coupling effect significantly reduces the impermeability. DOD (density) is the main factor that accelerates the decay rate of concrete penetration.

Zhao [11] et al. carried out long-term low-frequency experiments with fatigue stress and exposure time as the main variables. The chloride ion migration behavior in the interface area of the new and old concrete joints of prefabricated prestressed bridges under the combined action of fatigue load and chloride ion infiltration was studied. The results showed that the chloride ion content in the interface area was higher than that in other areas, showing the interface area effect (IZE). By introducing the IZE index, the influence law of fatigue stress range and exposure time on IZE was revealed, that is, with the increase of fatigue stress range, IZE increased first and then decreased; with the increase of exposure time, IZE continued to decrease. The influence mechanism of fatigue stress range and exposure time on the distribution and evolution of chloride ion concentration in the interface area was analyzed. The chloride ion diffusion coefficient model was established considering the heterogeneity of meso-component distribution and internal defects (pores) in the interface region of new and old concrete. Based on the relationship between volume strain and porosity, strain and specific crack area, a modified model for the effective chloride ion diffusion coefficient in the interface region under fatigue stress was proposed.

3. Research on New and Old Concrete Joints

The existing studies on the durability of concrete bridges proposed by Issa [12] et al. mainly focus on the monolithic concrete members, while the influence of wet joints is often ignored. Wet joints (cast-in-place concrete) are usually used as connections for prefabricated prestressed concrete bridges. Therefore, due to the connection between two adjacent members, the joints have an interface area of old and new concrete, which is a weak area for mechanical properties and durability.

Huang [13] et al. studied the effect of two kinds of construction joints (direct wet joints and rough wet joints) on chloride ion corrosion of four kinds of steel bars (mild steel, ferritic stainless steel, austenitic-ferritic stainless steel and epoxy-coated steel bars) in concrete by designing two environmental conditions of salt solution immersion and dry-wet circulation. The results show that, except for epoxy-coated steel bars, the most severely corroded parts of the tested steel bars in concrete samples are at the nodes, and the corrosion at non-nodes is relatively uniform and less, especially in the alternating dry and wet environment, even in stainless steel bars.

Li [14] et al. investigated the effect of segmental joint type and load conditions on the resistance to chloride ions of segmental joints by performing salt solution immersion tests on samples of direct wet joints, rough wet joints, and epoxy joints. According to the chloride ion content at different depths after immersion, the following conclusions were drawn: For samples with a certain compressive strain level or no strain, the monolithic concrete exhibited the best chloride ion resistance, which was superior to direct wet joints and rough wet joints. However, the diffusion coefficient of epoxy joints is fluctuating.

Li [15] et al. in order to prove the durability of concrete joints, four types of joints commonly used in segmented bridge concrete structures, such as direct wet joints, chiseled wet joints, dry joints and epoxy glue joints, were carried out for chloride ion intrusion, Carbonization, freeze-thaw and corrosion of steel bars at joints. The results clearly show that although the durability of different types of joints is different, they are all weak parts of concrete's environmental resistance. Among them, the measures to improve the bonding of old and new concrete by mechanical chiseling may cause damage to the joint interface and damage the durability of the structure; the durability indicators of dry joints are significantly worse than other types of joints, and should not be used in areas with poor environment; epoxy rubber joints do not show significantly better durability than other types of joints, and further relevant research is still needed; the steel bars at the joints, including stainless steel bars, reflect more serious corrosion conditions. The joint is the most critical part of the durability of concrete, and factors such as the cement mortar matrix or construction damage on the connection interface are the main

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factors that reduce its anti-environmental performance. Therefore, the durability study of concrete should pay more attention to its joints, and corresponding measures should be taken in design, construction and maintenance.

Qiao [16] et al. studied the frost resistance of new and old concrete bonded specimens under the action of cement paste interface agent and new modified epoxy interface agent respectively, and analyzed the influence of different interface agents on the frost resistance. The results show that the frost resistance of new and old concrete bonded specimens coated with new modified epoxy interface agent is better than that of new and old concrete bonded specimens using cement paste interface agent.

Guo et al. [17] found that the split tensile strength of low-roughness and high-roughness specimens decreased to 44.2% and 74.5%, respectively, after 100 F-T cycles.

Hossain [18] et al. pointed out that cracks caused by drying and curing of the coating may promote the entry of water and aggressive ions, thus jeopardizing the long-term durability of the repair. Therefore, before the repair of the overlay is prescribed, it must be screened and mechanical and physical tests must be performed to avoid accidental cracking of the joint concrete, especially for some ECC and UHPC compositions with high early shrinkage and autogenous shrinkage.

4. Research Related to Concrete Aggregates

Yang [19] et al. used ACMT to study the properties of the interface region and the effect of the interface region on the chloride ion diffusion coefficient of five different volume fraction fine aggregates, w/c = 0.35 mortar samples, and used the double inclusion method and Mori-Tanaka theory to predict the chloride ion diffusion coefficient of three-phase composite mortars.

Wang [20] et al. used laboratory physical test methods to study the influence of natural coarse aggregate on chloride ion concentration distribution and diffusion behavior of concrete specimens under artificial dry and wet cyclic exposure conditions. The relationship between chloride ion distribution and exposure time, coarse aggregate volume fraction and maximum particle size was discussed. Based on the experimental data, a time-varying model of chloride ion concentration on concrete surface and a multi-factor model of chloride ion diffusion coefficient were established, including exposure time, volume fraction and maximum particle size of coarse aggregate. In addition, an empirical prediction model of chloride ion diffusion coefficient in the interface transition zone considering the influence of coarse aggregate was established. Finally, a meso-finite element numerical simulation method of chloride ion diffusion into concrete was used to verify the accuracy and rationality of the chloride ion diffusion coefficient model for concrete and interface considering the influence of coarse aggregate.

5. Regarding the Study of Concrete Permeability

Long [21] et al. studied the effects of water binder ratio (w/b) and mineral admixtures on water absorption and permeability of old and new concrete composite systems through a number of experiments, and further understood the transport performance and degradation mechanism of old and new concrete repair systems. The results show that reasonable selection of new concrete w/b is of great significance for obtaining old and new concrete composites with low water absorption. Adding ultrafine powders such as silica powder as one of the components of repair materials will effectively reduce the water absorption and permeability of old and new concrete repair systems.

Li [22] et al. have shown that the permeability of the new and old concrete bonding surfaces is significantly higher than that of the concrete itself, and its permeability coefficient is usually an order of magnitude different. Improperly treated new and old concrete bonding surfaces may become a weakness, greatly increasing the water permeability. Experiments have found that the equivalent hydraulic gap width of the bonding surface is 0.11-0.27μm, while the permeability coefficient is mostly 1.1×10^(-10) to 4.8×10^ (-9) cm/s, and in very rare cases it can reach 1.8 × 10 ^ (-4) to 2.5 × 10 ^(-4) cm/s. The application of interface agents can improve the impermeability of the bonding surface, but the anti-permeability effect of rough treatment is limited, and excessive roughness may reverse the permeability. Therefore, it is recommended to use brushes and cement slurry to treat the adhesive surface in engineering to enhance the impermeability.

6. Conclusion

(1) This paper synthesizes the research results of old and new concrete under different stress states, and analyzes the effect of constant compressive stress on the migration of chloride ions in the interface region. Both the chloride ion diffusion coefficient and surface concentration are related to distance and stress level. It is worth noting that under stress-free conditions, prefabricated concrete and cast-in-place concrete exhibit higher chloride ion content in the interface region. The chloride ion measurement results lead to the mathematical characterization of the interface region effect (IZE) using Gaussian amperometric function.

(2) This paper explores the relationship between chloride ion distribution and exposure time, coarse aggregate properties and concrete surface properties. The time-varying model of chloride ion concentration and the multi-factor model of diffusion coefficient are analyzed. In addition, the meso-finite element numerical simulation method of chloride ion diffusion is summarized, and the accuracy of the diffusion coefficient model considering the influence of coarse aggregate is verified.

(3) The paper summarizes the new and old concrete under freezing and thawing conditions, deeply analyzes the changes of the interface performance of old and new concrete under cold climate conditions, and puts forward improvement suggestions to enhance the freezing and thawing resistance of concrete structures and prolong their service life. By considering structural weaknesses and cracks, a series of feasible improvement suggestions are summarized to enhance the freezing and thawing resistance of concrete structures.

To sum up, this paper expounds the impact of chloride ion erosion and freeze-thaw conditions on the performance of concrete structures at the interface between old and new concrete from a comprehensive and summary perspective. The summary provides valuable lessons for the development of concrete technology in the future, and provides theoretical support for design and maintenance. Looking to the future, more in-depth empirical research can provide more accurate and reliable guidance for the design and maintenance of concrete structures, thus promoting the continuous advancement of sustainable construction.

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