Exploring the application of intelligent concrete in highway engineering

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Abstract. All leaps in civil engineering are inseparable from the change of materials, and with the development and progress of construction technology at this stage, the status of new materials with intelligent functions is rising. Taking highway engineering as an example, the use of intelligent materials can break through the bottlenecks faced in the traditional highway industry and become an important way to solve its own problems. This background to explore the types of intelligent concrete and the application of ways to provide a certain reference basis for relevant design research.

Keywords: Intelligent concrete;highway engineering;self-repair;engineering applications.

1. Introduction

Since the invention of concrete is known as a great technological revolution in the engineering world, with its economic cost, compressive capacity, corrosion resistance and durability capacity and other better advantages, as the most widely used materials in infrastructure construction, with the emergence of reinforced concrete, prestressed concrete, etc., better make up for the poor tensile capacity of concrete defects, but once the concrete components cracked, its continued load-bearing capacity will rapidly decline, in There are more major engineering accidents caused by cracking of concrete members in highway projects. Such as anti-slip piles were sheared off, moments landslide around the village and highwa; highway roadbed all kinds of retaining walls cracking damage, so that the roadbed slide; in bridge engineering, bridge pier cracking fracture led to the collapse of the bridge;in tunnel engineering, tunnel lining and other cracking damage, shed cave support cracking damage, etc. thus using Certain technical measures to treat concrete components to ensure the mechanical properties of concrete components after cracking, you can ensure the continued load-bearing capacity of concrete components, so the self-healing intelligent concrete came into being.

2. Intelligent concrete classification

Self-healing intelligent concrete belongs to one of the categories of intelligent concrete. intelligent concrete is concrete with self-aware, self-adaptive and self-healing functions, which are mainly divided into the following categories.

2.1 Self-aware concrete

Concrete material itself can not have self-sensing function, but in the concrete base material composite part of the conductive phase can make concrete with self-sensing function. Commonly used conductive components are polymers, carbon and metals, of which the most commonly used are carbon and metals. Carbon conductive components include: graphite, carbon fiber and carbon black, metal materials are metal micro powder, metal fiber, metal sheet, metal mesh, etc.

2.2 Self-diagnostic concrete

Self-diagnostic concrete is achieved by adding materials such as carbon fiber or fiber optics to concrete, which can reflect changes in internal stress, deformation and temperature through the above added materials when they occur.

2.3 Structural self-regulating concrete

In addition to the normal loading of a concrete structure, one would expect it to be able to adjust its load-bearing capacity and mitigate structural vibration during natural disasters such as typhoons and earthquakes. Concrete itself is an inert material, and to achieve self-regulation, it must conform to component materials with drive functions. The basic approach is to embed shape memory alloys in the concrete. Using the shape memory alloy's sensitivity to temperature and the function of recovering the corresponding shape at different temperatures, the concrete structure is disturbed by abnormal loads, and the internal stresses are redistributed and a certain amount of pre-stress is generated through the change in the shape of the memory alloy, thus increasing the load-bearing capacity of the concrete structure.

2.4 Moisture self-regulating concrete

Some buildings have strict requirements for their indoor humidity, and current control measures are limited to the use of humidifiers and dehumidifiers, which not only consume a lot of electrical energy, but also have a limited scope of action, poor application benefits, and high costs and usage maintenance. Zeolite powder is the key component that brings the function of automatic environmental humidity regulation to concrete materials. Depending on the ambient temperature, zeolite powder has good moisture absorption/exhaustion properties, so its addition to concrete can achieve moisture regulation.

2.5 Temperature self-regulating concrete

Carbon fibers are highly temperature sensitive and are also good conductors of electricity. Studies have found that temperature affects the concentration and transport properties of carriers in carbon fibers, where the carrier concentration increases with temperature, which is reflected in the resistivity of carbon fibers. By adding carbon fibers to concrete and using corresponding technical measures to monitor the resistivity of carbon fibers in real time, the temperature of concrete structures can be monitored in real time. The electrical conductivity of the carbon fiber material can also be utilized, i.e., when the temperature gradient of the concrete structure is large by using the electric field to excite it, it will produce a thermal effect, thus achieving the temperature regulation of the concrete structure.

2.6 Highly damped concrete

The modern seismic pathway is to apply control devices to the structure, which are used to coordinate and mitigate the seismic response of the structure by bearing the seismic action together with the structure. However, the cost of the control system and the use of maintenance are higher. Highly damped concrete, on the other hand, is considered from the concrete material itself, and the addition of latex micro-materials, silica powder, and methyl cellulose in ordinary concrete can increase the damping ratio of the concrete material itself to a greater extent, which can avoid the problem of using and maintaining the applied devices, and can likewise improve the seismic capacity of the structure.

2.7 Self-repairing concrete

Self-repairing concrete is a new composite material that imitates the bone tissue structure of animals and the mechanism of regeneration and recovery after being traumatized, and uses the

method of bonding materials and substrate composite, which has self-healing and regenerative functions for material damage damage, and restores or even improves material performance.
2.7.1 natural self-healing concrete
Concrete crack width is the key to the occurrence of self-healing concrete. When the crack width is less than 200 μ m, preferably less than 50 μ m, the conventional concrete cracks in the unhydrated or insufficiently hydrated cementitious materials, under the action of the water medium, further reaction to generate new reaction products, micro-cracks can be naturally self-healing. Calcium carbonate crystalline precipitation is its main self-healing mechanism. The reaction process continuously generates calcium carbonate crystals, which gradually carry out natural self-healing of microcracks by continuously gathering and growing in the cracks with bonding between adjacent crystals and chemical bonding with cement paste and aggregate surface.
2.7.2 Electrolytic self-healing concrete
Using electrochemical effect, the electrolytic reaction of various minerals in water or seawater as an electrolyte solution generates insoluble substances that accumulate on the concrete surface or in the cracks to achieve the purpose of self-repair of micro-cracks. At the same time, a new protective layer is formed on the concrete surface, which effectively reduces the flow of fluid medium inside the concrete and further reduces the permeability of the concrete.
2.7.3 Bionic self-healing concrete
Mimic biological tissue to the injured part from rupture-bleeding-condensation-healing process. The repair microcapsules or repair microfibers containing the repair agent are evenly dispersed in the concrete matrix material, and the microcapsules or microfibers also rupture when the concrete is injured and cracked, and the repair agent that flows out, penetrates into the matrix cracks, cures and repairs the cracks in the matrix material, forming a bionic self-healing network system.
2.7.4 Intelligent self-healing concrete
The core of intelligent self-healing concrete is a shape memory alloy. In the crack-prone zone of concrete matrix material, liquid core optical fiber and shape memory alloy are pre-buried. When the concrete is cracked, the optical fiber picks up the signal and sends a command to the microprocessing system, the microfiber breaks and the repair agent flows out to repair the crack. At the same time, the shape memory alloy produces a shape recovery effect and applies pressure to the crack, which closes the crack and restores the concrete deflection and deformation.

3. Intelligent concrete in highway engineering application outlook

Intelligent concrete types of multi-functional wide, most of the concrete components in highway engineering face with crack work, self-healing concrete has more application occasions, representative of the application of microencapsulated self-healing concrete in the following ways:

3.1 roadbed support blocking project

For the support structure in the process of use of cracking and corrosion and other phenomena, the use of self-healing concrete can ensure its bearing capacity and durability. Self-repairing concrete retaining wall, for example, under the action of external forces such as rainstorm, earthquake, etc., at the beginning of the small cracks in the retaining wall, the microcapsules reach their tensile limit strength and rupture, releasing the internal liquid so that the concrete condenses and regains the common stress state. Effectively avoid the crack expansion and the damage caused by the external liquid invasion.

For the submerged retaining wall in corrosive waters, the steel produces sharp corrosion after the retaining wall cracks, which greatly reduces the service life of the retaining wall. And once the problem occurs, maintenance is difficult and costly. The use of microencapsulated self-healing retaining walls can play a self-healing role when a small crack occurs, blocking corrosive liquids from invading the structure, avoiding corrosion of reinforcement, ensuring its applicability and safety, and greatly reducing the cost of post-maintenance.

The application of self-healing concrete in the support structure of the roadbed can effectively avoid various problems caused by the cracking of structural elements, to ensure the normal service of the project. But by the self-healing concrete cost, construction difficulty and controllability constraints, the application of large volume in the roadbed support structure is not economic, can be used in some more complex and important degree of place.

3.2 landslide support project

Highway route corridor belt is a comprehensive consideration of many factors in the selection, the route is inevitable through the landslide and other adverse geological areas. For small-scale landslides, it takes to remove and then build, for larger and more complex landslides, in order to ensure the stability of the overall project, anti-slip piles are usually used to resist the larger sliding force. The anti-slip pile is composed of the embedded section below the sliding surface and the cantilevered end above the sliding surface, relying on its own large bending stiffness and shear strength to resist the sliding force of the slide, thus ensuring the stability of the slide.

If the cracks continue to develop and are affected by the atmosphere and water, the anti-slip pile resistance will be sharply reduced and excessive displacement or even fracture will occur. The use of microencapsulated self-healing cement material can play its repair role to achieve re-bonding with the surrounding concrete, thus ensuring its continued load-bearing capacity.

The anti-slip pile is located in the part of the slip surface, often due to the larger force is more likely to crack, and the location is located in the soil, once the crack, not easy to repair, so the anti-slip pile into the cracked working state, the future of the continued load is not conducive. The use of microencapsulated self-healing concrete can be repaired when a small crack appears in the structure, to avoid the further expansion of cracks later and affect the continued bearing.

3.3 Bridge and tunnel project

For mountain highways, due to its complex topography, highway bridges and tunnels are relatively high, the use of high pier large span bridges and long, extra-long tunnels are very common.

Such as bridge projects, often located in steep ravines, these parts are often not convenient for post-maintenance. In the post-construction operation stage, under the vehicle load and earthquake and other factors, once a small crack appears, the crack continues to expand, which will lead to a significant decline in the bridge bearing performance, the safety and durability of the structure has a greater impact, and even cause safety accidents.

In tunneling projects, the arch ring concrete bears the pressure of surrounding rock or soil, and also faces the corrosion of reinforced concrete by corrosive groundwater or surface water. As a result, once the tunnel lining is cracked, it will affect the operational safety of the tunnel.

Based on this, microencapsulated self-healing concrete structures are used in the crack-prone parts of bridges and tunnels to achieve self-healing under minor cracks, which can ensure safety and durability while reducing operational maintenance difficulties and costs.

3.4 Crack repair

Microencapsulated self-repairing concrete can be used as a repair agent for cracked members, which can play the role of traditional repair agents in a short period of time, and can release the repair agent after later cracking again, improving repair efficiency and durability.

Highway engineering professional categories, covering a wide range of areas, with the further development of intelligent concrete, will have self-monitoring, self-diagnosis, self-feedback, self-adaptive, self-healing function of intelligent concrete applied in the key components of highway engineering, to achieve the intelligence of the structural components, greatly reduce the maintenance and operation costs, increase structural safety and durability, which will become the future trend of development and research direction.

4. Summary

In summary, based on the current development trend of highway engineering, it is inevitable to develop in the direction of more efficient, smarter and greener. The application of intelligent concrete to build highway engineering structural components, while maintaining the convenience of construction, according to the needs of the structure itself, the flexible use of different functions of intelligent concrete, while improving the durability of the structure, potentially improving its safety, reduce management and operating costs, making the structure more modern, technological, intelligent, and lay the foundation for highway engineering to usher in another big change.

Fund Projects

National Key Research and Development Program-emergency rescue monitoring and rescue technology and intelligent operation components for sudden geological and meteorological disasters in the access road to Tibet（2022YFC3002603 ）;Research on the whole-life risk assessment and disaster warning technology of mountain disposal sites(cstc2020jscx-msxmX0101)

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