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Development of the inorganic water-stop agent for water leakage of concrete infrastructures

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In this research, inorganic water-stop agents were suggested in order to prevent water leakage of architectural concrete structures. This study was focused on the development of a high-performance inorganic water-stop agent based on the low-pressure injection method. Results from mock-up tests through water-stop constructions on reinforced concrete structures with and without cracks showed that the developed agent has swelling effects on cold joints, water leakage cracks and wet cracks around through cracks. It was confirmed that it could be possible to manufacture a new type of inorganic crack repair material that could fill cracked areas in structures.

Key words: Inorganic water-stop agent, Crack, Water leakage, Repair materials.

Introduction

Generally, water leakage cracks develop in joint placements during concrete deposition like cold joints, or by deterioration by the external environment, faulty waterproofing design or material, or lack of construction abilities. In the case of outdoor leakage crack, deterioration is intensified by solar heat and dryness, acidic rain and concentration of carbon dioxide and sulphurous acid gas in the atmosphere, salt stress, and freezing and thawing, and the width and depth of the crack changes with environmental conditions [1-4]. Because intensified water leakage cracks gradually lead to rebar corrosion and the scaling and spalling of the parent concrete, they cause fatal defects in the structure in the long term. Therefore, cracks due to humidity or water leakage, which undermine concrete durability, must be repaired immediately, and even if their width is under the allowable crack width, the structure's lifespan can only be increased by repairing them after consultation with a professional.

Currently, materials used to repair water leakage sites include water-swelling rubber, bentonite, PVA/vinyl chloride, urethane, accelerating agents, and inorganic chemical materials, and repair method types include taping and injecting [4-5]. However, the types of water-stop material differ depending on the environment of the water leakage, use of the material, and the surface area of application, and are chosen by subjective judgement. In addition, the materials used are organic materials different from the parent concrete, and often require additional construction on the leakage after repair or cause another leakage. Repeated leakage and repair can cause scaling and spalling on the concreteness. Therefore, this study strives to supplement the shortcomings of existing waterstop agents, and seek economic feasibility and durability, to develop and evaluate the performance of advanced inorganic waterstop agents based on low-pressure injection, which could be used in a structure's water leakage, using only inorganic particulate material.

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Experimental Methods

In this research, it was examined that compared the performances of a commercial organic water-stop agent (water repellent urethane) made in Japan, which is widely being used abroad, and the inorganic agent is developed in domestic. From previous research [6, 7], one of developed various inorganic water-stop agents was selected for this research.

Materials

The viscometer was used to measure the gel time, and the fluidity was measured with a P-type funnel tester. Also, the anti-washout property and fluidity were evaluated, In case of gel time of water-stop agents, it was observed that the gel time of 30 seconds to 1 minute for the Japanese organic water-stop agent (water repellent urethane) used in this study, which has a property of swelling by the reaction to water. On the other hand, for the developed inorganic agent, the gel time was measured using the mini cup test shown in Fig. 1, after mixing water and binder at 1 : 1 ratio for

Table 1. Gel time measurement of water-stop agents.

Types	Plastic viscosity (Pa · s)	Yield stress (Pa)	Gel time (second)
Organic water-stop agent	0.1	0.2	30
Inorganic water-stop agent	0.39	1.22	30

Fig. 1. Gel time change of inorganic water-stop agent.

Table 2. Material fluidity evaluation.

Types	Measures	Standard
organic water-stop agent	15.68	less than 45 seconds
inorganic water-stop agent	14.98	less than 45 seconds

three minutes, It was also observed that the inorganic agent maintained its fluidity for up to 1 minute and 30 seconds, and depending on the mix proportion, it lasted for a maximum of 5 minutes. The experimental results of each material are shown in Table 1.

Fluidity evaluation between organic and inorganic water-stop agent were conducted as shown in Table. 2. It was found that the flow values of both water-stop agents were around 1/3 of the JHS references, and had high fluidity.

Fig. 2 shows the anti-washout property on the inorganic agent. To evaluate the inorganic agent's performance, water was added to the mixture 3 minutes later and the mixture's concentration was observed, but not much change in viscosity was found. There was no major washout phenomenon, either.

In case of construction assessment, the injection performance was evaluated by attaching a low-pressure injection plug to the acrylic panel, which was designed for a 0.2 mm leakage crack, as shown in Fig. 3. Finally, it was evaluated that the bonding strength of the inorganic waterstop agent to the parent concrete, and examined the chemical resistance using SEM-EDS (Scanning Electron Microscopy-Energy Dispersive Spectroscopy). The evaluated the constructability via a mock-up test by applying the recently developed inorganic water-stop agent to reinforced concrete samples with and without water leakage cracks.

Results and Discussion

Fig. 4 represents the injection performance evaluation on the developed inorganic agent in the material's crack area. A crack with a width of 0.2 mm

Fig. 2. The anti-washout property of inorganic water-stop agents.

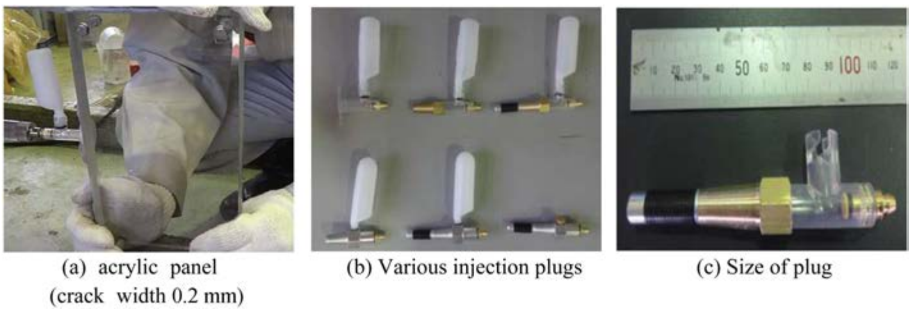

Fig. 3. Injection test tools for inorganic water-stop agents.

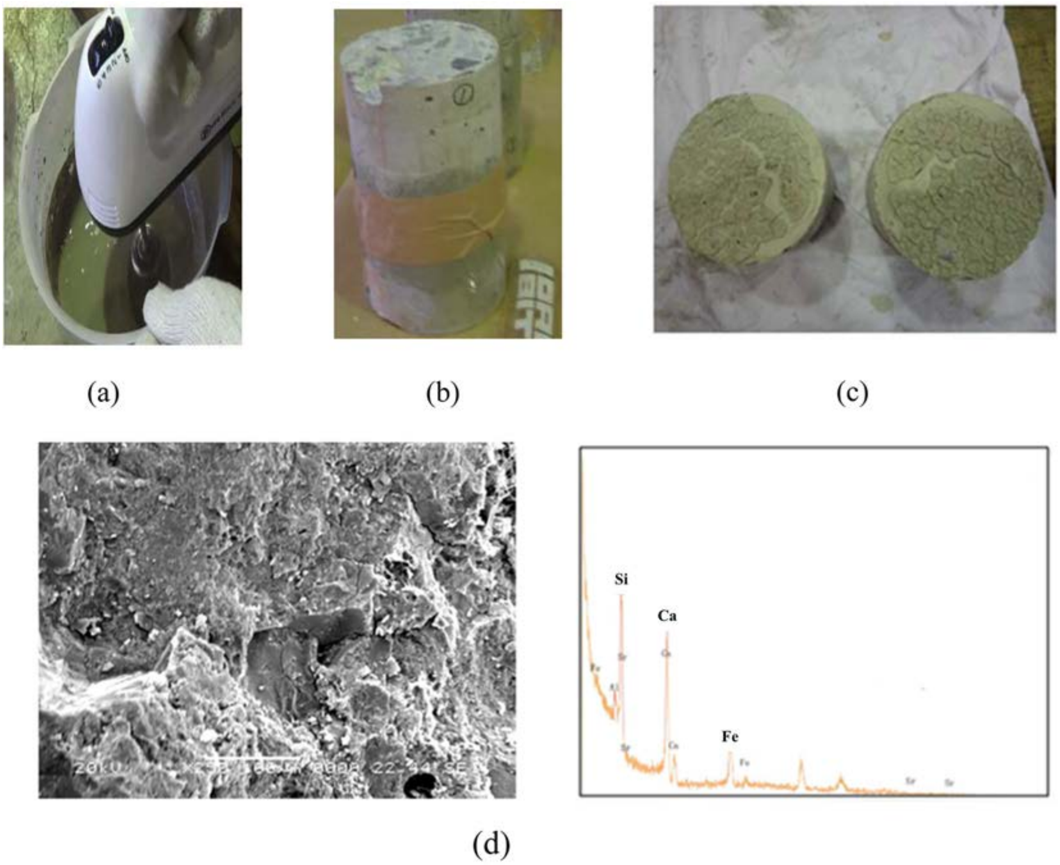

Fig. 4. Formation of calcium silicate hydrates from inorganic water-stop agents.

Fig. 5. Crack induction of reinforced concrete.

was applied to an acrylic panel and cracked concrete. The inorganic water-stop agent was simply mixed with water by the hand mixer as shown in Fig. 4(a), before being injected with an injector. To examine the bonding strength of the developed inorganic water-stop agent to the parent concrete, the impregnating agent was injected to cracked concretes as shown in Fig. 4(b). The hydrate solidified after being injected, and it was observed SEM-EDS after splitting specimens in order to evaluate the material's chemical resistance as shown in Fig. 4(c) and (d). The hydration products were mostly formed stable cementitious materials based on the calcium silicate hydrates as shown in Fig. 4(d). These results indicated that it could be possible to manufacture an inorganic agent with chemical resistance.

In order to apply the developed inorganic water-stop

Fig. 6. Drilling of reinforced concrete cracks.

Fig. 7. Surface finishing for the plug installation and injection of inorganic water-stop agent.

Fig. 8. Injection situation of inorganic water-stop agent.

(a) water leakage

(b) plug installation

(c) injection

(d) finishing

Fig. 9. Effects of water stop by injection of inorganic water-stop agents.

agent to cracked reinforced concrete, the following experiment was done. As shown in Fig. 5, the inorganic agent was applied to the RC beam with a plug and accelerating agent. The hole was drilled into the crack to allow for the installation of the plug as shown in Fig. 6. In this experiment, a total of 8 cracks were used to evaluate the performance of the inorganic waterstop agent.

Fig. 7 shows that quick-setting cement was used to seal the surface after the plug was installed for the injection of waterstop agent, to ensure smooth injection. After the plug installation was complete, the inorganic impregnating agent was injected. It was confirmed that the impregnating agent was being injected smoothly as shown in Fig. 8. After the injection was complete, the sample was left to cure for 28 days.

In case of water-stop agents, in order evaluate the water-stop performance of the developed product under water leakage situation, an artificial crack with a width of 0.3 mm or greater was added to artificial water-retaining structures. After the water leakage situation was set up, the inorganic impregnating material was injected, immediately initiating the waterstop operation. It was confirmed that the material was capable of stopping the leakage from a concrete wall with a thickness of 10 cm as shown in Fig. 9.

Conclusions

In this research, the new method based on inorganic water-stop agent to repair cracks in reinforced concrete structures was suggested. Especially, it was focused on the development of a high-performance inorganic waterstop agent based on the low-pressure injection method. Evaluation on its fluidity showed that both the organic and inorganic agents had high fluidities. In case of the washout phenomenon, it was not observed from the inorganic water-stop agent, and construction assessment on injection performance through cracks showed good performance compared other inorganic agents. From these results, it was found that it is possible to develop a new kind of inorganic water-stop agent under various water leakage conditions.

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