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Antifungal effects of cement mortars with two types of organic antifungal agents

Jeongyun Do[a,*], Hun Song[a], Hyoungseok So[b], Yangseob Soh[a]

[a]Architectural Engineering, College of Engineering, Chonbuk National University, Chonju 561-756, South Korea
[b]Department of Architecture, College of Engineering, Seonam University, Namwon 590-170, South Korea

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Abstract

This study is concerned with investigating the antifungal effects of cement mortar with an organic antifungal agent on the *Aspergilus niger* which might be easily discovered in the interiors and exteriors of buildings. Two types of organic antifungal agents: isothiazoline/cabamate and nitrofuran, were used in this study for the purpose of investigating the antifungal effect of cement mortar with antifungal agent on the *A. niger* of various fungus which can be easily discovered in the interiors and exteriors of building. In addition to the investigation of the antifungal effect, the experiment of basic physical properties, such as compressive and flexural strengths, and flow test was carried out. Cement mortar with the antifungal agent of isothiazoline/cabamate exhibited the outstanding antifungal effects but the antifungal agent of nitrofuran did not give the antifungal effects to cement mortar. Although there is a very slight decrease in the strength, it is almost equal to that of cement mortar without antifungal agents.

Keywords: Antifungal effect; Mortar; Admixture

1. Introduction

1.1. Background and literature survey

Cement has been studied by numerous researchers and mortar and concrete made with portland cement have been broadly used construction materials with the structural and functional demand because they offer flexibility in application and are also capable of forming structural concrete element into a variety of shapes and sizes, and have the high natural performance such as the good compressive strength, the excellent resistance to water, and easy availability of material on site in spite of the disadvantages, such as low tensile strength, drying shrinkage or low resistance to sulfur, and the heterogeneous distribution of many solid components. Hence, a variety of the investigation and study on the physical and chemical properties and durability has been continuously carried out until now. High-performance concrete, such as ultra high strength concrete, high-fluidity concrete, and high-durability concrete, was developed and even the performance and serviceability of concrete have been excessively advanced. Nevertheless, the academic and scientific study on the influence of organisms, such as bacteria, fungus, microbial, insect, etc. on the concrete, except sulfation bacteria—aerobic bacteria oxidizing sulfuretted hydrogen (H_2S) into sulfuric acid (H_2SO_4)—has hardly been progressed in spite of the well-known fact that such organisms can adversely affect concrete [2]. According to Ramachandran, even durable concrete can, under certain conditions, suffer severe degradation by bacteria, fungi, and insects. It is pointed out that although the alkaline hydrates neutralize the initially formed acid, the fermentation or other bacterial metabolic activity, itself, continues as long as nutrients, bacteria, and moisture prevail. Prolonged exposure to such conditions results in the erosion of the surface of concrete [1].

Furthermore, fungus does harm to human in the sense that it could cause the outbreak of diseases, such as a respiratory disease, considering the resident's quality of living because various fungi are lively inhabiting in the inside and the outside of the building [2]. Only a few investigations about the antifungal effect in cement mortar or concrete exist. Method of addition and effects on the

* Corresponding author. Tel.: +82-63-270-2258; fax: +82-63-270-2285.
E-mail address: arkido@cricmail.net (J. Do).

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fresh and hardened properties of concrete and mortar was briefly introduced in the *Concrete Admixture Handbook* of Ramachandran [1], which informs the subject of bacterial, fungicidal, and insecticidal admixtures.

Nevile, through his book, *Properties of Concrete*, informed that some organisms, such as bacteria, fungi, or insects, can adversely affect concrete and it is necessary to incorporate in the mix some special admixtures which are toxic to the attacking organisms [3]. Some effective admixtures are listed in ACI 212.3R-91, which gives the addition rate ranging from 0.1–10% by weight of cement [4].

A survey of the literature showed that few investigators had been interested in the subject of the use of chemical admixtures to inhibit fungal attack. Accordingly, this paper is concerned with investigating the antifungal activities of cement mortar with organic antifungal agent and to present it as a scientific basic data.

1.2. Scope and limitations

This study is limited to the experimental examination of the addition effect of two types of antifungal agent to cement mortar on the fungus. The fungus used in this study is *Aspergilus niger*, which is frequently used in examinations about the antifungal effect of cloth, paints, fiber, plastic, etc. and might be easily detected in the interior of building in damp environments [5,6]. Cement mortar with antifungal agents for testing physical properties was cured in water until corresponding testing, but those for antifungal effect was cured with the polythene enveloped because the problem of redissolution of agent within water, and also the moisture existent in the surface of, or inside, the specimen which cured in water probably prohibited the more correct measurement of antifungal zone. After all cement mortars with antifungal agents for testing antifungal effect were stored with polythene enveloped for 28 days, it was perfectly neutralized, i.e., preprocessed, in a 10% CO_2, 20 °C, RH 65% chamber due probably to the hindrance of strong alkaline of cement mortar. With the above research scope and limitation, this study would rather be planned with the purpose to present the basic data and the index of research scope than to develop the application of the cement mortars with two types of organic antifungal agents. Plate 1 shows the procedure of this study.

2. Experimental program

2.1. Mix constituents

For the purpose of this study, ordinary portland cement as specified in KS 5201 (Specification for Portland Cements)

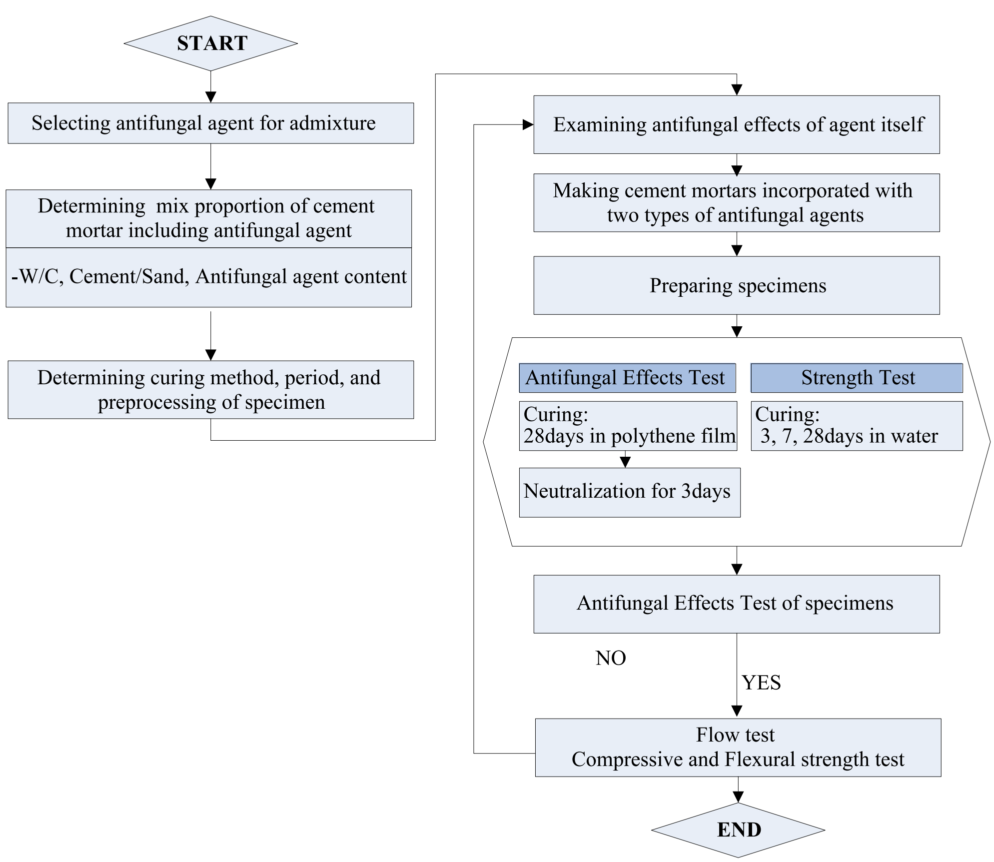

Plate 1. Study procedure.

Table 1
Chemical composition of ordinary portland cement

CaO	SiO_2	Al_2O_3	Fe_2O_3	MgO	SO_3	Insol.	Ig. loss	Total (%)
65.3	22.2	5.1	3.2	1.3	1.9	0.3	0.6	99.9

was used in the manufacture of all mixes. The chemical compositions and physical properties of the cement are listed in Tables 1 and 2, respectively. Standard sand, predominantly graded to pass No. 30 (600 μm) and be retained on No. 50 (300 μm) was used as the fine aggregate. Two types of organic antifungal agents, as described in Table 3, lively used in various fields, were used in this paper in order that cement mortar might be forced to exhibit the antifungal effect on the fungus. *A. niger*, which can broadly inhabit interiors and exteriors of buildings in the existence of humidity and nutrition, was used for the purpose of investigating the antifungal effect of cement mortar with antifungal agents activated by the antifungal agent.

2.2. Preparation and curing of cement mortars with antifungal agents

The experimental cement mortar with antifungal agents were manufactured by means of 2.45:1 of the ratio of fine aggregate to cement; W/C of the cement mortar with antifungal agents were fixed at 0.55 in order to observe the effect on the fluidity during addition of antifungal agent. Antifungal agents were directly added into the cement mortar, which were measured as six levels of 0%, 0.3%, 0.5%, 1%, 2%, and 5% by mass to cement. Details of the mixes used in the test program are given in Table 4. The size of cement mortar with antifungal agents for testing flexural strength was 40 × 40 × 160 mm. Portions of beams remaining from flexural test were used for the determination of compressive strength; that of antifungal effect was 40 mm (diameter) × 5 (height) mm. Cement mortar was manufactured in accordance with ASTM C 305 (Standard Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency). The cement mortar in the mold was covered with a polythene sheet and left for 24 h in the laboratory at 20 ± 2 °C. After 24 h, the cement mortars with antifungal agents for testing strength were removed from the molds and placed in water until measurement dates. On the other hand, the cement mortars with antifungal agents for testing antifungal effect were wrapped and sealed in polythene sheets until antifungal effects in the cement mortar with antifungal agents were measured because the moisture of cement mortar with antifungal agents placed in the water

Table 2
Physical properties of ordinary portland cement

Density (g/cm^3)	Fineness (cm^2/g)	Setting time (h–min)		Compressive strength (MPa)		
		Initial set	Final set	3 days	7 days	28 days
3.14	3300	2–18	3–12	15.0	25.5	43.3

Table 3
Properties of antifungal agents

Composition	Isothiazoline/cabamate	Nitrofuran
pH (20 °C)	5.0	–
Density (g/cm^3, 20 °C)	1.10	–
Appearance	White aqueous solution	Transparent aqueous solution

tended to disturb the correct measurement of antifungal effect. In addition, the cement mortars with antifungal agents for testing antifungal effect were neutralized for 3 days in the chamber set to maintain a 10% carbon dioxide concentration at 20 °C and relative humidity of 65%.

2.3. Testing procedure

(1) The flow tests of each specimen were performed by using flow table conforming to ASTM C 230 (Standard Specification for Flow Table for Used in Tests of Hydraulic Cement) in order to comprehend the change of consistency in accordance with addition of antifungal agent.

(2) Compressive and flexural strength.

Measurement of flexural strength for activated cement mortar produced in this study is carried out, conforming to ASTM C 328 (Standard Test Method for Flexural Strength of Hydraulic Cement Mortars). Both portions from each prism broken in flexure were used for compression testing in accordance with ASTM C 349 (Standard Test Method for Compressive Strength of Hydraulic Cement Mortars—Using Portions of Prisms Broken in Flexure).

(3) Measurement of antifungal effect.

(1) Cultivation of fungus and preparation of cement mortar with antifungal agents for antifungal effect.

After disk-typed cement mortar with antifungal agents made on the basis of mix proportions were neutralized in the given condition, the liquid state of culture medium was made by admixing distilled water, 5% nutrient (by mass to water), and 3% agar (by mass to water) in the flask. Disk-typed cement mortar with antifungal agents and culture medium were autoclaved and sterilized for about 15 min at 125 °C because both culture medium and disk-typed cement mortar can probably possess the invisible fungus or spore.

The constant content of the above-declared spore of A. niger was equally sprayed on the culture medium after the liquid culture medium poured into the flask became colloid.

Table 4
Mix proportions

C:S (by mass)	W/C (%)	Antifungal agent content (%, by mass to cement)
1:2.45	55.0	0.0
		0.3
		0.5
		1.0
		2.0
		5.0

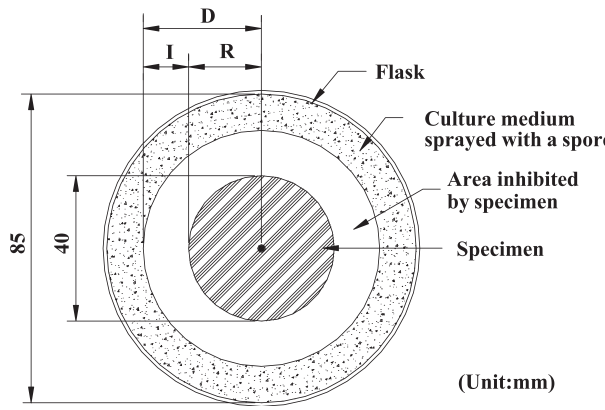

Fig. 1. Measurement of antifungal zone.

Then, the disk-typed cement mortar with antifungal agents, which was placed in the middle of the spore-sprayed flask with the same method as above, was sealed and cultivated in the incubator in order to prevent the invasion of another fungus or bacterium. A more detailed and sequential procedure of measurement is shown in Fig. 1.

(2) Estimation of antifungal effect.

The estimation criteria of the antifungal zone, as shown in Fig. 1 and Eq. (1), was presented as the length given by subtracting the radius of disk-typed specimen from the distance between the end of antifungal zone and the center of disk-typed specimen in order to quantify antifungal effects of cement mortar with antifungal agents. The detailed size of the antifungal zone is calculated from Eq. (1) as follows.

The major axis: $I_1=(D_1-R_1)$

The minor axis: $I_s=(D_s-R_s)$

$$I=(I_1+I_s)/2 \quad (1)$$

where I indicates antifungal zone (mm), D is the distance from the center of cement mortars with antifungal agent to the survival area of fungus (mm), and R is the radius of disk-typed cement mortars with antifungal agent (mm).

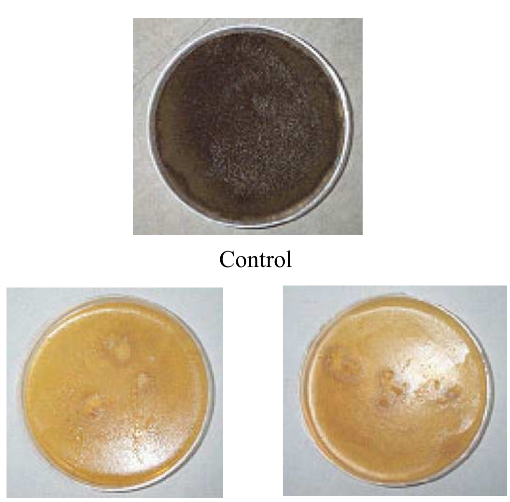

Fig. 2. Photograph of the antifungal effect of the different antifungal agents in just 1 day.

3. Results and discussion

3.1. Antifungal effect

(1) Natural antifungal effect of antifungal agent.

Fig. 2 illustrates the natural antifungal effect exhibited in just 1 day by dropping the antifungal agent on the culture medium containing the spore of A. niger. It was observed that both two types of the antifungal agents used in this study exhibited the excellent antifungal effect on A. niger. It was experimentally confirmed that the antifungal effect of antifungal agent existed by nature.

(2) Antifungal effects of cement mortars with antifungal agents.

Figs. 3 and 4 illustrate antifungal effects of cement mortars with two types of antifungal agents. The cement mortars with antifungal agent of nitrofuran do not exhibit the antifungal effect in spite of the condition that antifungal agent of nitrofuran is added up to 5% to cement while the antifungal effect of cement mortar with the antifungal agent of isothiazoline/cabamate, as shown in Fig. 4, increases with an increase in antifungal agent content.

Fig. 5 illustrates the antifungal zones of the cement mortar with the isothiazoline/cabamate on A. niger at the

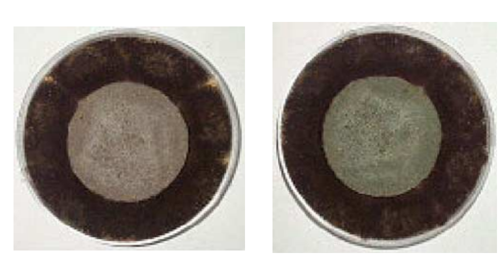

Fig. 3. Photograph of the antifungal effect of cement mortars with antifungal agent of nitrofuran at an exposure period of 14 days.

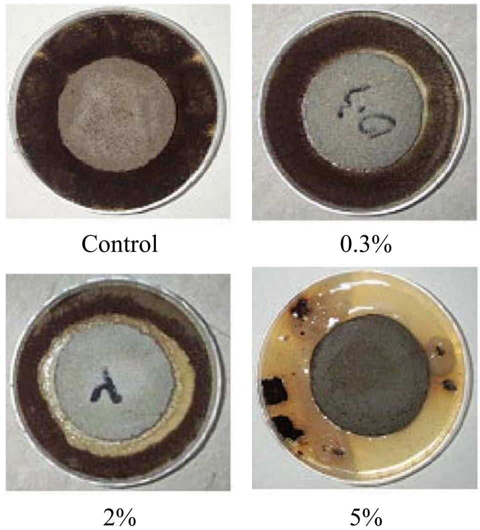

Fig. 4. Photograph of the antifungal effect of cement mortars with antifungal agents of isothiazoline/cabamate at an exposure period of 14 days.

exposure periods of 2 and 14 days to the fungus-active environment, respectively. In the case of adding the antifungal agent of isothiazoline/cabamate to cement mortar, antifungal effect is enhanced almost linearly according to the increase in the antifungal agent of isothiazoline/cabamate. On the contrary, the antifungal effect in the case of doing the antifungal agent of nitrofuran does not appear. The antifungal zones at the exposure period of 14 days are almost equal to those at the exposure period of 2 days.

3.2. Physical properties of cement mortars with antifungal agent

Physical properties were performed only on the cement mortar with the antifungal agent of isothiazoline/cabamate-based mortar and not on the cement mortar containing the antifungal agent of nitrofuran. The reason is that it

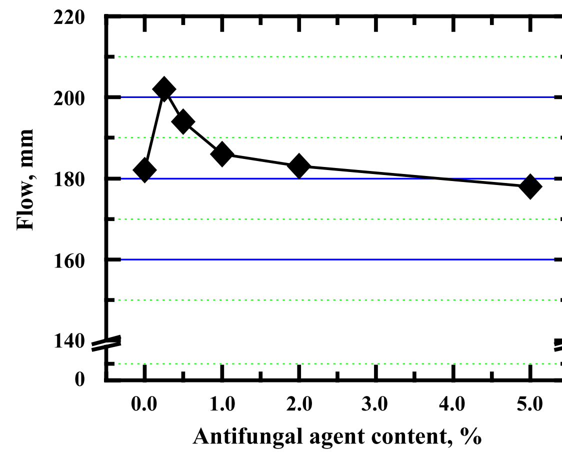

Fig. 6. Antifungal agent content vs. flow of cement mortar with antifungal agent.

exhibited very little antifungal effect when added in the cement mortar and no meaning of physical property test exists.

(1) Effect of antifungal agent content on consistency of activated cement mortar.

Fig. 6 illustrates the flow of cement mortar with the antifungal agent of isothiazoline/cabamate according to the increase in the content of antifungal agent to cement. It is revealed that the flow of cement mortar with antifungal agent reaches the maximum when antifungal agent is added into cement mortar up to 0.25% probably because of the effectiveness of a little surfactant included in the antifungal agent. The flow of cement mortar with the antifungal agent of isothiazoline/cabamate was relatively excellent in comparison with the cement mortar not containing the antifungal agent. From this experimental result of the specimen flow, it is possible that even the excessive usage of antifungal agent for an admixture of cement mortar may not cause much loss in the consistency of the cement mortar and can turn out not to act adversely significant

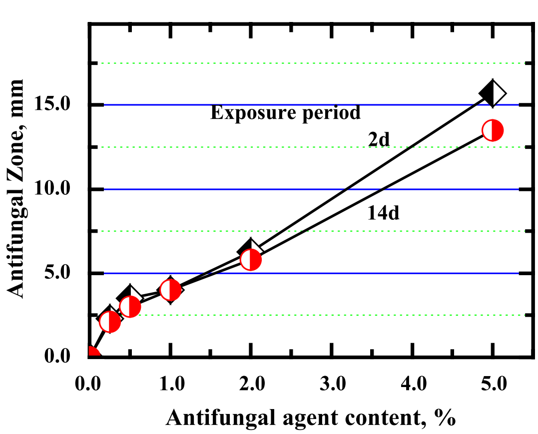

Fig. 5. Antifungal agent content vs. antifungal zone at exposure periods of 2 and 14 days.

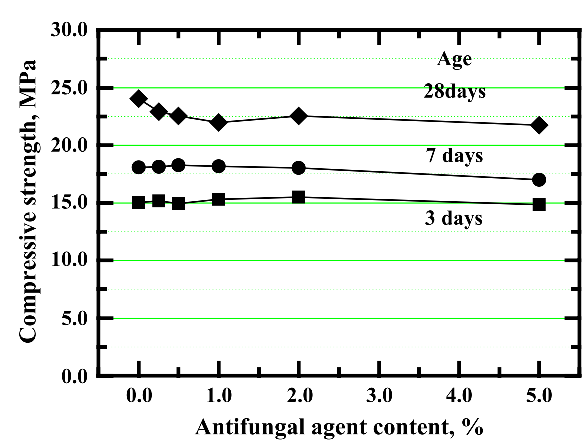

Fig. 7. Antifungal agent content vs. compressive strength of cement mortars with antifungal agent of isothiazoline/cabamate.

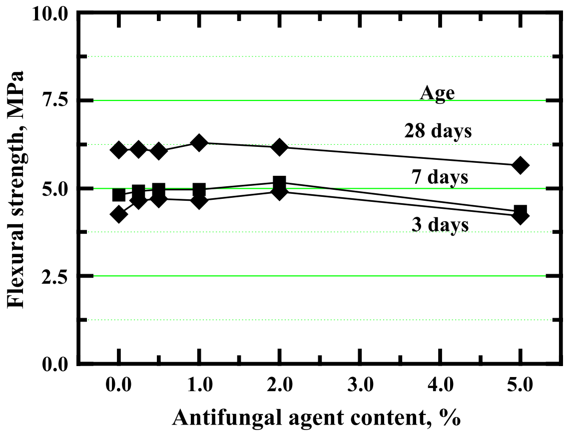

Fig. 8. Antifungal agent content vs. flexural strength of cement mortars with antifungal agent of isothiazoline/cabamate.

from the standpoint of the consistency of the cement mortar.

(2) Effect of antifungal agent on strength of activated cement mortar.

Figs. 7 and 8 illustrate the compressive and flexural strengths of cement mortars with antifungal agents according to the increase in antifungal agent content. As shown in Fig. 7, the compressive strength of cement mortar containing the antifungal agents exhibit about 22–23 MPa at 28 curing ages with change in the content of antifungal agent and are almost equal to that of nonadded cement mortar, although there is a slight decrease of about 1–3 MPa at 28 curing ages. The flexural strength of cement mortar containing the antifungal agents amounts approximately to 6 MPa at 28 curing ages in the case of antifungal agent content of 2%, and also was almost similar to that of nonadded cement mortar. Hence, it turned out that there is a very little adverse effect of the antifungal agent of isothiazoline/cabamate on the strength of cement mortar with the antifungal agent.

4. Conclusions

Based on the results obtained from the basic investigation on the antifungal effects and physical properties of cement mortars with two types of antifungal agents, the following conclusions were reached.

(1) Although the natural antifungal effect of nitrofuran and the antifungal agent of isothiazoline/cabamate exhibited excellently, the cement mortar with the antifungal agent of nitrofuran never exhibited the antifungal effect on the A. niger.

(2) Even a small quantity of the antifungal agent of isothiazoline/cabamate shows a very good antifungal effect of the cement mortar that its antifungal zone may amount to about 15 mm in the case of the content of 5% to cement.

(3) The antifungal effect corresponding to an antifungal zone of cement mortar with the antifungal agent of isothiazoline/cabamate tends to linearly increase with an antifungal agent content irrespective of exposure periods of 2 and 14 days to the fungus-active environment.

(4) The flow of cement mortars with antifungal agent was dependent on the content of the antifungal agent, and reached a maximum at an antifungal agent content of 0.3%. The flow of cement mortar with antifungal agent was better than the noncement mortar with antifungal agent.

(5) The effect of antifungal agent on strength, such as compressive and flexural strengths of cement mortar, was negligibly insignificant; it proved to be about equal to that of noncement mortar with antifungal agent.

(6) From this study, which focused on antifungal effects, the application possibility of antifungal agent to cement is thought to be shown. But further investigations about assessing the precise effect of other antifungal types and comprehending the action principle are likely to be required in order to present a scientific data on the antifungal effects of cement mortar in application.

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