Fungus resistance of vermiculite board and comparison to calcium silicate board and gypsum wall board

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Vermiculite is a member of clay minerals, produced by the decomposition of mica and occurs as quite large crystals of mica-like appearance. Fired, exfoliated, vermiculite is a low-density material and is utilized as a constituent of lightweight concrete, and plaster, a filler for plastics, paints, and fertilizers, and a soil enhancer. [1]. We reported the development of a new building material, made from unfired vermiculite, $Ca(OH)_2$, SiO_2 and pulp, by autoclaving at 187 °C at a pressure of 1.08 MPa [2, 3]. It was made by a process of usual calcium silicate boards with minor alterations. The material exhibited the vermiculite crystals dispersed uniformly in a definite direction among the matrix of calcium silicate. The board showed marked plastic deformation caused by interlayer sliding of vermiculite crystals and had mechanical properties like artificial wood, superior moisture control, and formaldehyde adsorption capacity, to improve the living environment [3]. This paper describes fungus resistance of the vermiculite board, and comparison to calcium silicate board, and gypsum wall board.

Fungus resistance of the board was first tested according to JIS Z 2911 [4]. Although the test method for general industrial products prescribed the use of a mixture of spore suspensions prepared from five kinds of fungi, *Cladosporium cladosporioides* de Vries (IFO 6348) was used alone in the present study, which is a variety of black molds frequently found on concrete and building products. The fungus was cultured with potato sucrose agar medium in an 18 mm diameter glass test-tube at 28 °C. The spores were harvested from a 9-day-culture with the aid of a plastic inoculation loop, suspended in 10 cm^3 of 50 μg cm^{-3} dioctyl sodium sulfosuccinate solution, and filtered with a 70 μm nylon cell strainer (Falcon, New Jersey, USA). Test samples of 30 × 30 × 6 mm were cut from the vermiculite boards, sterilized with 70% ethanol for 1 min, and dried on a clean bench. Commercial calcium silicate boards (30 × 30 × 6 mm) and gypsum boards (30 × 30 × 9.5 mm), served as controls. The surface papers of the three gypsum boards out of six were mechanically removed and the surfaces were polished with 400 grit SiC paper. The number of specimens for each group was three. The plates were centrally placed in 90 mm plastic dishes, inoculated with 0.5 cm^3 spore suspensions, cultured at 28 °C at 95% relative humidity for 8 weeks, and mold growth on each plate was visually examined.

At 4 weeks, mycelium was not visually observed on the surfaces of the vermiculite boards, but observed under a microscope. A very small number of mycelia were seen on the calcium silicate boards. A number of mycelia grew on both gypsum boards and the areas of mold growth were ∼1/3 of the surfaces. The mold growth was dominant near the edges of the as-cut gypsum boards.

At 8 weeks, a small number of mycelia appeared on the vermiculite boards. It is difficult to distinguish between mycelia and vermiculite crystals (Fig. 1a), because most of vermiculites have a metallic luster which are seen as dark particles under an electronic flash light. Several distinct colonies were observed on the calcium silicate boards (Fig. 1b). In the as-cut gypsum boards (Fig. 1c) the mycelia grew extensively and covered all surfaces. In surface paper removed gypsum boards (Fig. 1d) the areas of mold growth were ∼1/2 of the surfaces. Mold density of the surface paper removed gypsum boards was higher than that of the as-cut ones. Thus, the vermiculite board showed higher fungus resistance in comparison to the other building products.

Fungus resistance of the board was retested according to the ISO 846 test method for plastics [5]. *Cladosporium cladosporioides* was cultured with the potato sucrose agar medium in a glass test-tube at 28 °C for 9 days. The culture was rinsed with 5 cm^{-3} of 50 μg cm^{-3} dioctyl sodium sulfosuccinate in an inorganic salt solution [5] three times. The resultant suspensions were filtered with the cell strainer, centrifuged at 170 g for 5 min, and the residual spores were again suspended with 50 cm^{-3} of the solution. Test samples of the four groups were prepared by the above-mentioned methods. The plates were centrally placed on inorganic salt agar plates [5] in 90 mm plastic dishes, inoculated with

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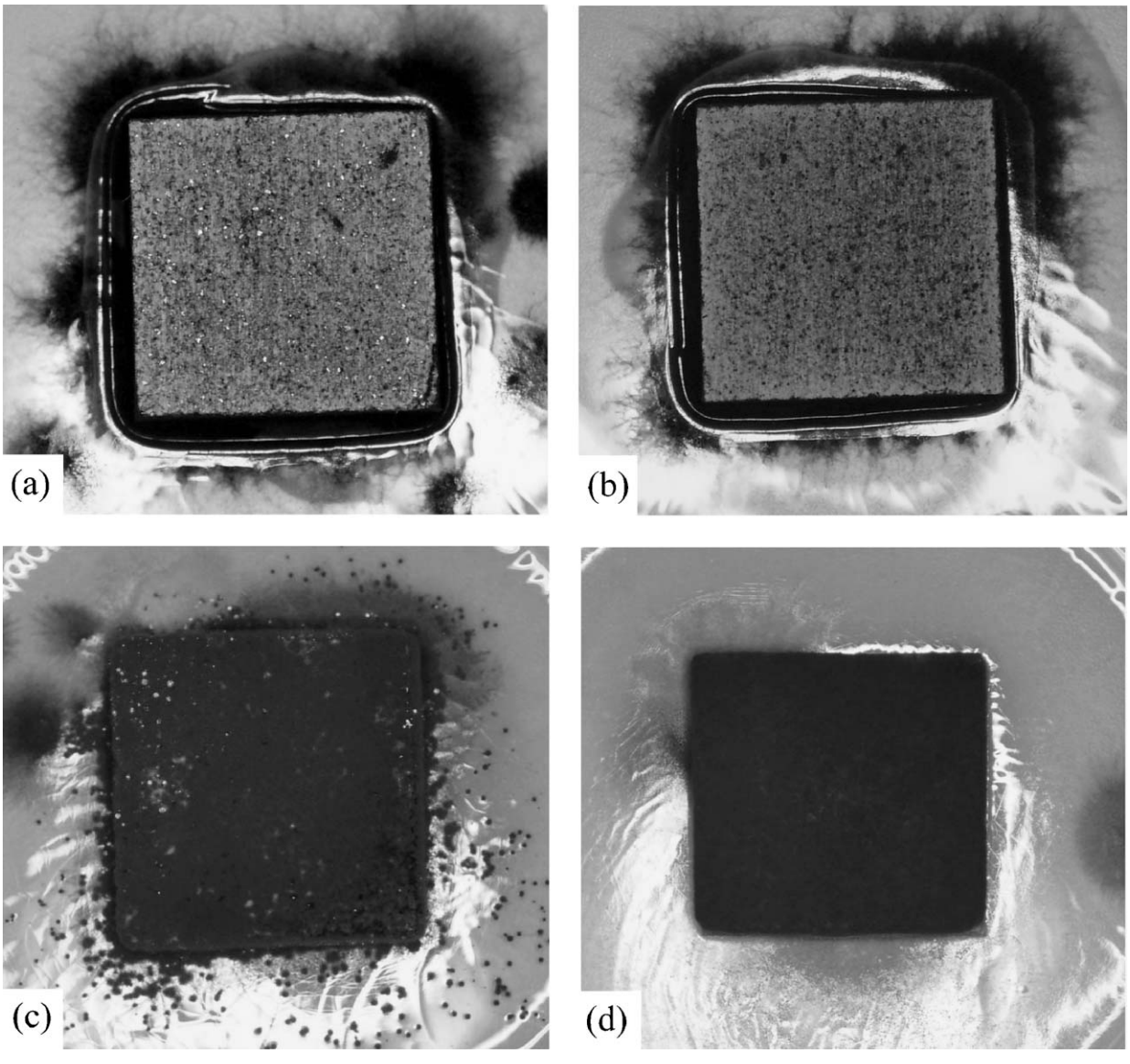

Figure 1 Photographs of fungus resistance test results at 8 weeks for (a) vermiculite board, (b) calcium silicate board, (c) as-cut gypsum board, and (d) surface paper removed gypsum board, based on JIS Z 2911 for general industrial products.

0.5 cm^3 spore suspensions, and cultured at 28 °C at 95% relative humidity for 4 weeks.

At 1 week, a small number of mycelia appeared on the vermiculite boards and the calcium silicate boards, and the areas were less than 25% of the surfaces. A number of mycelia are seen on both gypsum boards, and the areas were more than 25% of the surfaces. Distinct colonies were formed near the edges of the as-cut gypsum boards. At 2 weeks, thin molds spread on the entire surfaces of the vermiculite boards and the calcium silicate boards, whereas dense molds completely covered the surfaces of both gypsum boards. At 4 weeks (Fig. 2), mold density of each specimen became higher, but there were no mycelium on vermiculite crystals existing on the surfaces of the vermiculite boards. Vermiculite crystals are seen as clear zones in Fig. 2a. Outgrowth of mycelia was observed on some specimens. The mold density was in the order: vermiculite board < calcium silicate board << gypsum board with surface paper < gypsum board without surface paper. In general, mold growth in the ISO tests was faster than in the JIS tests, and mold density in the ISO tests was much higher than that in the JIS tests, since the inorganic salt agar plates in the ISO tests supplied sufficient water required for mold growth.

Fungus resistance of vermiculite single crystal was further tested according to AATCC test method 90 [6], the so-called halo-test. Vermiculite single crystals used were from Shawa, Zimbabwe. Plates 15 × 15 × 2 mm were cut from the crystals and sterilized with 70% ethanol. The plates were centrally placed on potato sucrose agar plates in 90 mm plastic dishes, inoculated with 0.5 cm^3 of the latter spore suspensions, and cultured at 28 °C at 95% relative humidity for 1 week. As shown in Fig. 3, mold growth was inhibited around the vermiculite single crystals.

Spores of fungi germinate at appropriate temperature and humidity, but the growth of mycelia requires organic nutrients. The vermiculite board and the calcium silicate board contain pulp as organic components. Succharides and polysuccharides are added to the gypsum boards to control setting time and to form

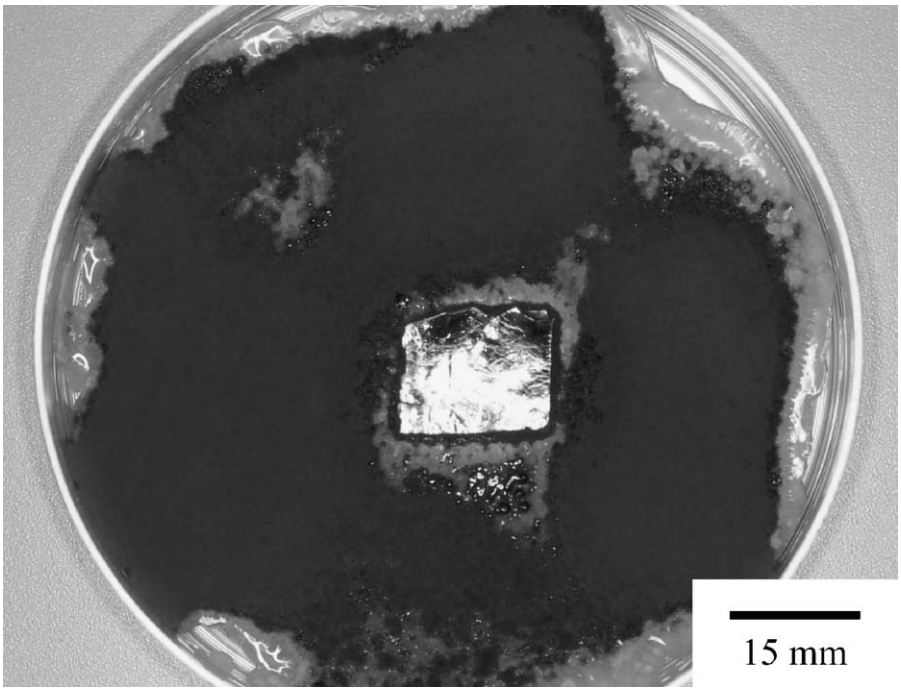

Figure 2 Fungus resistance test results at 4 weeks for (a) vermiculite board, (b) calcium silicate board, (c) as-cut gypsum board, and (d) surface paper removed gypsum board, based on ISO 846 for plastics.

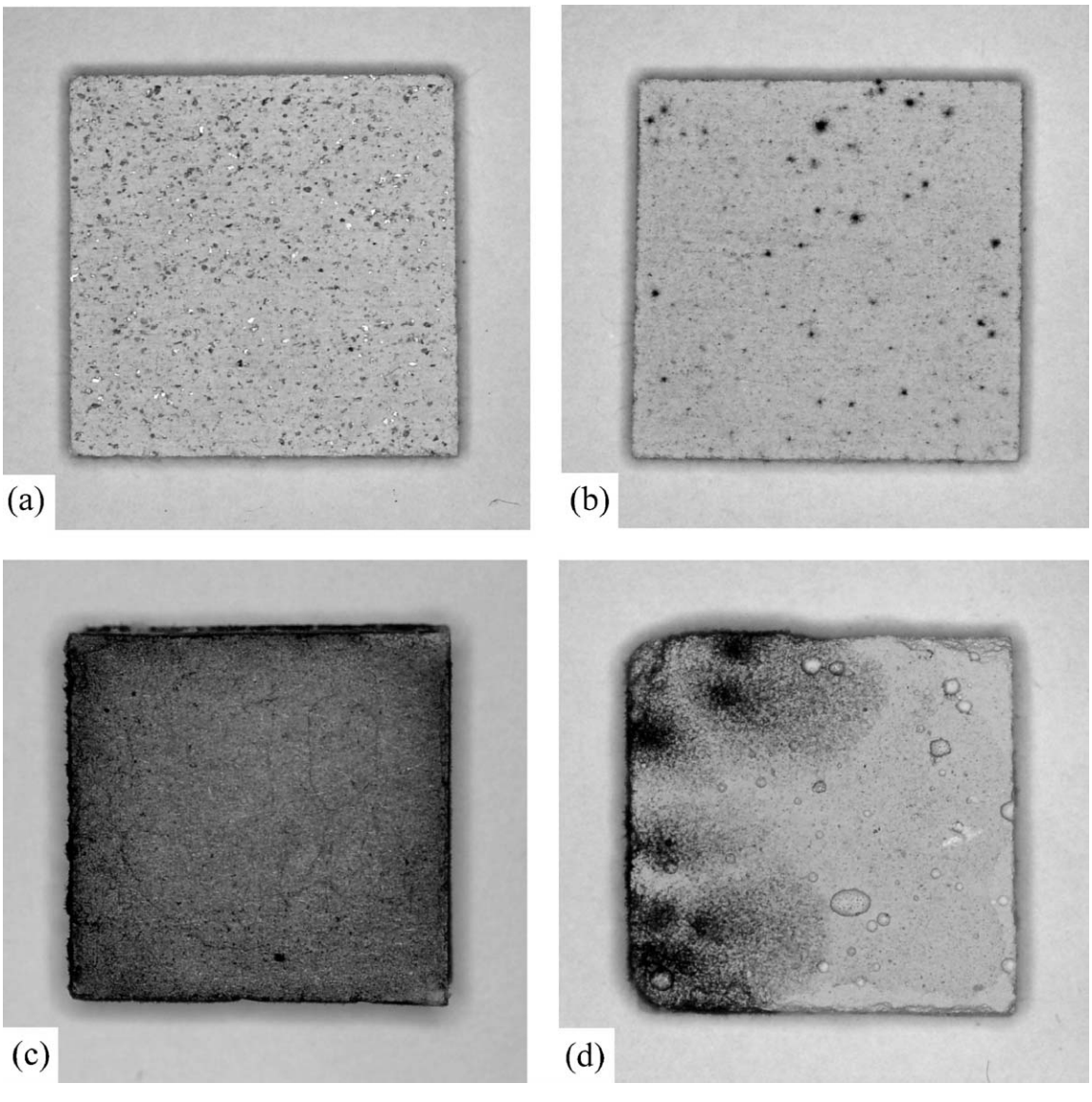

Figure 3 Halo-test result for vermiculite single crystal at 1 week, showing inhibition of mold growth around vermiculite.

a porous body. The nutrients of molds were partially dissolved by the sterilization with 70% ethanol before testing. For example, molds mainly grew on the left side of the gypsum board without surface paper (Fig. 1d), and the nutrients seemed to be dissolved on the right side.

There was no mycelium on the vermiculite crystals existing on the surface of the vermiculite board. As a result of the halo-test, the vermiculite single crystals demonstrated inhibition of mold growth. This fact indicates bacteriostasis of vermiculite. The bacteriostasis existance is owing to vermiculite, which adsorbs water molecules necessary for mold growth. In general, molds actively grow in slightly acidic conditions, and pH of the culture media is adjusted to be ∼5.6. Suspending fine vermiculite crystals in distilled water, pH ranged from 8.8 to 9.6. The calcium silicate matrix seems to be fungus resistant, since pH of the matrix was ranged from 10 to 11. Consequently, the vermiculite board revealed a high fungus resistance.

Acknowledgment

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References

1. W. A. DEER, R. A. HOWIE and J. ZUSSMAN, "Rock-Forming Minerals, Sheet Silicates," 2nd ed. (Longmans, London, 1963) Vol. 3, p. 246.
2. F. YAHAGI, H. SHIOCHI, Y. FUKUDA and M. OHOKUBO, PCT Patent no. JP01, 09847 (2001).
3. M. AKAO, A. YAMAZAKI and Y. FUKUDA, *J. Mater. Sci. L.* **22** (2003) 1483.
4. JIS Z 2911, Methods of tests for fungus resistance (2000).
5. ISO 846, Plastics—Determination of behaviour under the action of fungi and bacteria (1978).
6. AATCC test method 90, Detection of antibacterial activity of fabrics: Agar plate method (1982).

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