

Fire Retardation of Charcoal Board Added with Boron Oxide

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Charcoal board as for use a building interior material was newly developed by adhering charcoal powders with superfine natural fibers. The charcoal board adsorbs volatile organic compounds (VOCs). Since superfine natural fibers used as a binder of the charcoal board are combustible, boron oxide was smeared on the surface of the charcoal board, to impart fire retardation properties to the charcoal board. The fire combustion property of the charcoal board was evaluated by the simple screening method, which was developed by the authors. In the sample of boron oxide content over 150 g/m^2 , the fire retardation effect was observed. With a cone calorimeter method, which is in conformity to ISO/FDIS 5660-1, the heat release rate and the total heat released at 300 sec for the samples smeared with boron oxide, were estimated to be 40 kW/m^2 and 6 MJ/m^2 , respectively. The charcoal board was ranked as a fire-retardant material.

Key words: charcoal board, boron oxide, fire retardation, cone calorimetric method

1. INTRODUCTION

Charcoal board was newly developed by adhering charcoal powders with superfine natural fibers as a binder [1][2]. The charcoal board adsorbed volatile organic compounds (VOCs); for example, formaldehyde gas of 20 ppm in the small chamber was adsorbed to almost 0 ppm in two hours. And in room model of 21.6 m^3 , reduction of VOCs concentration was observed by adsorbing formaldehyde with the charcoal board set on the wall [3].

Since the charcoal board uses natural fibers as a binder, adsorbability of the charcoal was maintained, because superfine natural fibers do not cover micropores on the charcoal surface. Polymer binder, such as polyvinylacetate, covers the micropores decreasing the adsorbability of the charcoal. The natural fibers, however, are combustible, which is disadvantage from the practical viewpoint.

To impart fire retardation properties to the charcoal board, boron oxide (B_2O_3) was smeared on the surface of the charcoal board. Boron compounds were formerly recognized as fire retardant by J. L. Gay-Lussac who proposed the effect as a coating theory [4]. In 1960s it was interpreted that the fire retardation effect of boron compounds was due to inhibition effect of oxidation and vaporization of carbon accompanied with the dehydration-carbonization effect [5][6]. However, solubility of boron compounds in water was so poor that sufficient amount of boron compounds for the fire retardation could not be injected into woody substances. T. Taniguchi found the high solubility in methanol solution and

reported the fire retardation property of wood boron-compounds composite [7][8]. In this paper, the effect of B_2O_3 addition on the fire combustion property of the charcoal board was evaluated with both the simple screening method, which was developed by authors, and a cone calorimeter method.

2. EXPERIMENTAL

2.1 Sample Preparation

The charcoal board was made from carbon powder and cellulose and collagen fibers as a binder. The superfine natural fiber consisting of cellulose and collagen fibers were prepared from defiberized paper and leather scraps with a mortar-typed grinder (Super Grinder, Masuko Sangyo Co., Ltd.). The carbon powders and superfine natural fibers was mixed with superfine fibers, pressed and dried at $105 \text{ }^\circ\text{C}$ for 24 hours. The specific gravity of the board was about 0.3 depending on the forming pressure. The preparation process is pollution free one; it does not contain any chemical compounds.

The composition ratio of carbon/superfine fiber in the charcoal board was adjusted to 8/2, and the composition ratio of cellulose/collagen in the superfine fibers was 8/2.

B_2O_3 was smeared by applying saturated boron oxide methanol solution and then, dried at $105 \text{ }^\circ\text{C}$ for 12 hours. The B_2O_3 amount was adjusted to 0, 35, 110, 150 and 450 g/m^2 .

2.2 Simple Combustion Test Method

Sample size of the charcoal board was $100 \text{ mm} \times 50 \text{ mm}$, and 10 mm in thickness. Fig. 1 shows the

setup of the simple combustion test method. Using a gas burner of 49 mm in length and 1.5 mm in width, height of the flame was adjusted to 20 mm. Liquefied petroleum gas no. 5 (JISK2440) as a fuel was burned without air. Distance between the burner and the sample was adjusted to 30 mm in order to heat the sample surface to about 700°C. Heating time was 300 sec. Thermocouples were set on both the front surface and the back surface of the sample.

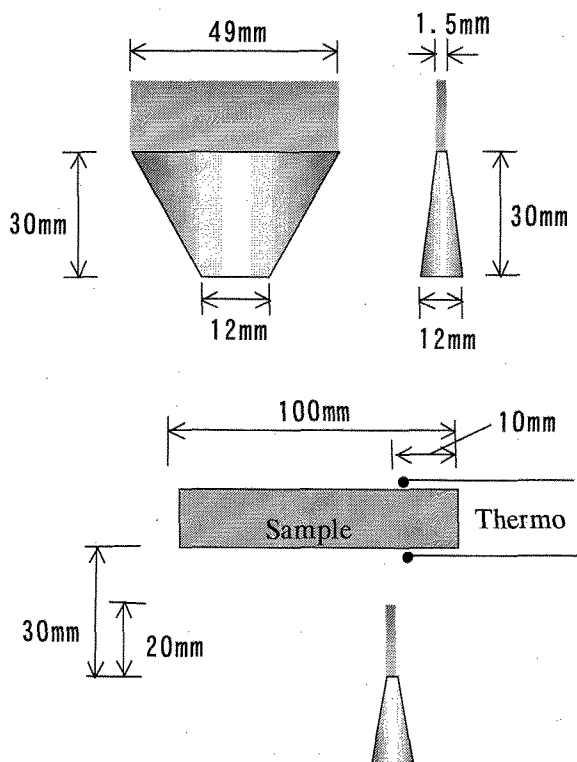


Fig. 1 Setup of the simple combustion test method.

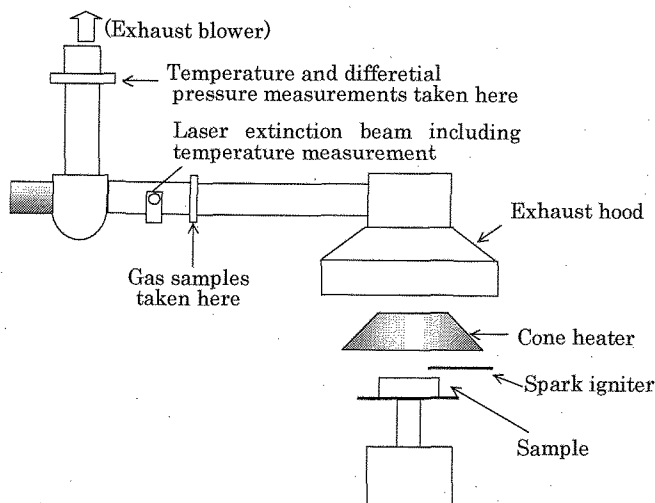


Fig. 2 Schematic view of a cone calorimeter.

2.3 Cone calorimeter method

The sample used was 100 mm X 100 mm, and 10 mm in thickness. Fig. 2 shows schematic view of a cone calorimeter, which is in conformity to ISO/FDIS 5660-1 [9]. The sample in the test was burned in ambient air conditions, while being predetermined external irradiance of 50 kW/m² and measurements were made of oxygen concentrations and exhaust gas flow rates. Finally heat release rate and total heat release for the samples were estimated.

3. RESULTS AND DISCUSSION

3.1 Simple combustion test

Photographs of the as-prepared sample and burned sample with the simple combustion test are shown in Figs. 3 (a) and (b). In the right-hand side sample of Fig. 3 (a), the heated edge is burned-out in the sample without B₂O₃, while the shape is maintained in the sample added with 450 g/m² of B₂O₃ in Fig. 3 (b).

Fig. 4 shows the temperature change of the heated surface and the back surface of the charcoal board without B₂O₃ during the simple combustion test. The heated surface temperature of ca. 650 °C during 300 sec comes from heating with the flame from the burner. After 300 sec the temperature decreases to 200 °C. The temperature of the back surface increases gradually to 200 °C from 300 sec to 900 sec. The temperature drops on both sides of the surface around 900 sec, because the end of the sample burned-out.

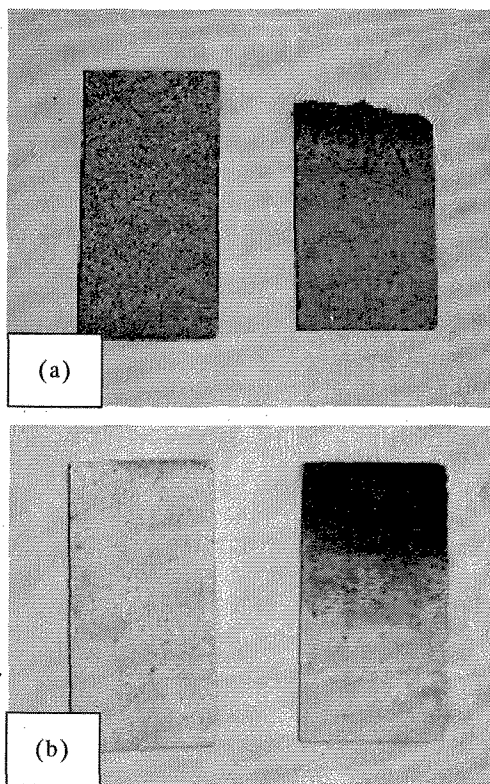


Fig. 3 Photographs of as-prepared sample and burned sample. (a) without B₂O₃, and (b) 450 g/m² of B₂O₃.

By studying the temperature change on the back surface of the sample, the combustion behavior was estimated. Fig. 5 shows comparison of the back surface temperature changes of the samples with different amount of B_2O_3 with the simple combustion test. The samples without and with 35 g/m^2 B_2O_3 burned-out around 900 sec. In the sample with 110 g/m^2 of B_2O_3 , the temperature of $200 \text{ }^\circ\text{C}$ was maintained even after 1,200 sec, meaning that the inside of the sample continues burning. After 300 sec heating the samples with 150 and 450 g/m^2 B_2O_3 , the temperatures decrease to the room temperature. It is mentioned that these temperature decreases are attributed to fire retardation effect of B_2O_3 .

Increase rate of the back surface temperature in the initial heating period and the back surface temperature at 1,200 sec vs. amount of added B_2O_3 are compared with those of the plaster board of 9.5 mm in thickness in Fig. 6. The increase rate decreases to $0.4 \text{ }^\circ\text{C/sec}$ with increasing B_2O_3 amount, which is nearly doubled for that of the insulation board. The back surface temperature in the sample over 150 g/m^2 of B_2O_3 is the same as that of the plaster board.

3.2 Cone calorimeter

A cone calorimeter is used for normalization of fire retardation property of various building materials. The fire retardation property is determined by the heat release rate and the total heat released from the sample. The heat release rate less than 200 kW/m^2 is required during the test running. This value was determined by the threshold one which occurs a flash-over phenomena in the real fire. The fire retardation property of building materials is divided into three grades, fire-retardant material, semi-non-combustible material and non-combustible material, which is defined by the heating time reaching up to 8 MJ/m^2 of the total heat released. In this case of the heating time within 5 minutes, 10 minutes and 20 minutes, fire-retardant material, semi-non-combustible material and non-combustible material are specified, respectively. The sample added with 380 g/m^2 of B_2O_3 was prepared, base on the result of the simple combustion test. The fire retardation property was estimated by the cone calorimeter. The heat release rate was determined by the combustion heat estimated by measuring CO_2 , CO and O_2 concentration in the combustion gas. Fig. 7 shows the heat release rate of the charcoal board without. A heat release rate of 40 kW/m^2 or lower was maintained during the test. In the combustion process no large flame was observed.

Total heat released was integrated with the heat release rate in Fig.7 and the result is shown in Fig.8. Figs. 8 (a) and (b) show the total heat release from the charcoal board without B_2O_3 and with B_2O_3 of 380 g/m^2 , respectively. Though the total heat release increase gradually with the testing time, it does not exceed 8 MJ/m^2 at 300 sec.

This shows that the charcoal board is ranked as

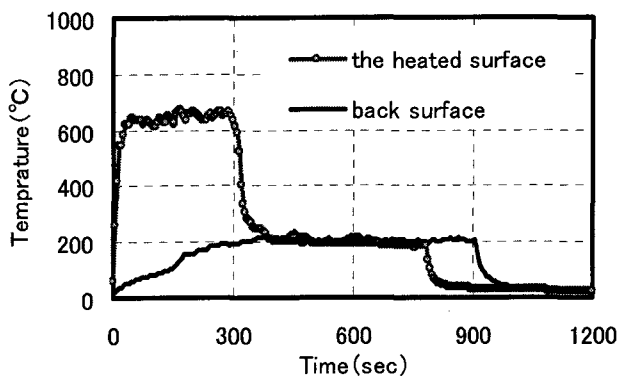


Fig. 4 Temperature change of the heated surface and the back surface of the charcoal board without B_2O_3 during the combustion test.

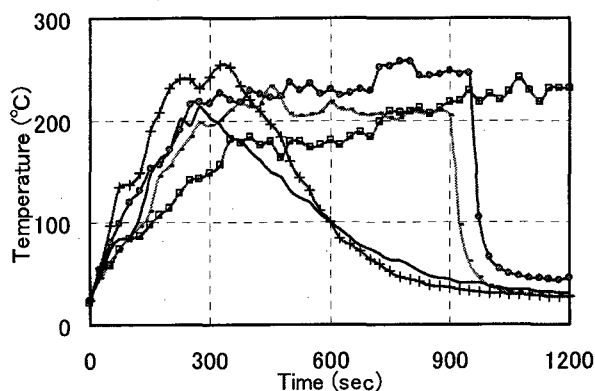


Fig. 5 Comparison of temperature changes on the back surface of the sample added with different amount of B_2O_3 during the combustion test. — ; 0 g/m^2 , ○ ; 35 g/m^2 , □ ; 110 g/m^2 , + ; 150 g/m^2 and - - ; 450 g/m^2 .

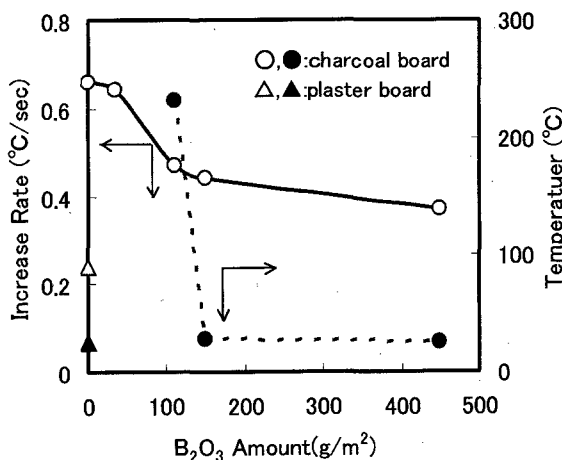


Fig. 6 B_2O_3 amount dependence of the increase rate of the back surface temperature in the initial heating period and the back surface temperature at 1,200 sec of the charcoal board. The data are compared with those of the plaster board. Open and filled symbols represent the increase rate and the backside temperature, respectively.

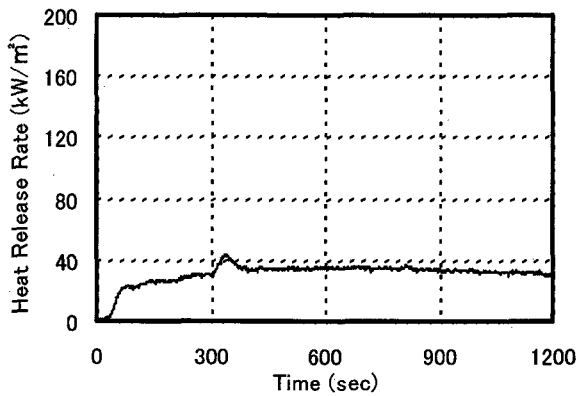


Fig. 7 Heat release rate of the charcoal board without B_2O_3 .

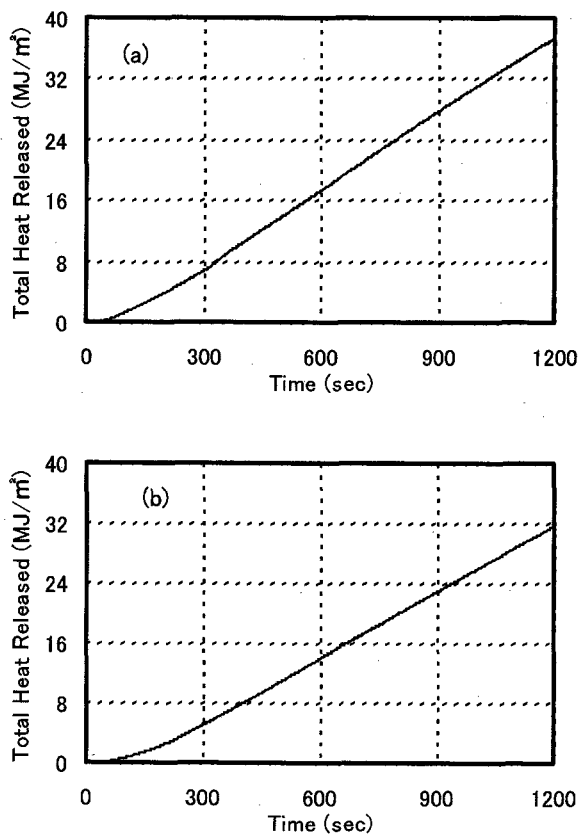


Fig. 8 Total heat release from the charcoal board, (a) without B_2O_3 and (b) with B_2O_3 of 380 g/m^2 .

a fire-retardant material. In the sample added with B_2O_3 , the time in the initial increase of the heat release is elongated, which is due to the fire retardation effect of B_2O_3 . And the total heat release of 8 MJ/m^2 is observed at 400 sec. Addition of B_2O_3 to the charcoal board is effective in delaying the ignition time and depressing the heat release from the charcoal board.

4. CONCLUSIONS

As fire retardation for the charcoal board, boron oxide was smeared on the surface of the charcoal board. In the sample of boron oxide content over 150 g/m^2 , fire retardation effect was observed by the simple combustion test method. With a cone calorimeter method, which is in conformity to ISO/FDIS 5660-1, the heat release rate and the total heat release for the samples were estimated under 40 kW/m^2 and 6 MJ/m^2 , respectively, when boron oxide was doped. Finally, the charcoal board was ranked as a fire-retardant material.

5. ACKNOWLEDGEMENT

The authors would like to thank Dr. T. Murayama, the former researcher of the Ministry of Agriculture, Forestry and Fisheries, for his helpful supporting their research and development.

6. REFERENCES

- [1] K. Shibano, S. Yoshizawa, Y. Ogawa, Proc. 2nd Inter. Sympo. on Environmentally Conscious Design and Inverse Manufacturing (EcoDesign 2001), IEEE Computer Society, 2001, pp.1110-1113.
- [2] K. Shibano, S. Yoshizawa, S. Goto, Y. Ogawa, Tanso, no.204, 166-170 (2002).
- [3] K. Shibano, S. Yoshizawa, S. Goto, Y. Ogawa, Proc. 9th Inter. Conf. on Indoor Air Quality and Climate (Indoor Air 2002), Monterey, CA, 2002, pp. 694-699.
- [4] J. L. Gay-Lussac, Ann. Chim. Phys., C6, 18 (1823).
- [5] R. J. Brotherton, H. Steinberg, Eds., Progress in Boron Chemistry, Pergamon Press, Elmsford, N. Y., 1970.
- [6] J. G. Rakszawski, W. E. Parker, Carbon, 2, 53 (1964).
- [7] T. Taniguchi, Abstracts of 45th Annual Meeting of Jpn. Wood Res. Soc., Tokyo, Aug., 1995, p.277.
- [8] K. Kashiwakura, Y. Tamura, N. Hori, T. Taniguchi, Jpn. Construction Soc. Meeting, Kyushu, Sept., 1998, p.217.
- [9] ISO/FDIS 5660-1, Fire test-Reaction to fire-Heat release, smoke production and mass loss rate: Part 1: Heat release (cone calorimeter method).

(Received December 20, 2002; Accepted October 11, 2003)