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Non-combustibility of Charcoal Board Covered with Low Softening Point Glass

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We newly developed charcoal board by adhering charcoal powders with superfine natural fibers as binder. The charcoal board adsorbs volatile organic compounds (VOCs). We examined the effect of covering with low softening point glass (softening point: 671°C) on the fire-retardant property of the board. The Cone Calorimeter method, which is in conformity to ISO-5660, was adopted as the measurement of the fire retardant property. The heat release rate and the total heat release were estimated. In the sample covered with the glass of 500 g/m^2 or more, the total heat release at 600 seconds decreased under 8.0 MJ/m^2. And with applying composite fire retardant of the glass of 1000 g/m^2 and B_2O_3 of 10 g/m^2 on the surface of the board, the total heat release at 1200 seconds was 7.7 MJ/m^2. These results suggest that the charcoal board are ranked as the semi-non-combustible material with the low softening point glass and the non-combustible material of the composite with the glass and B_2O_3.
Key words: charcoal board, low softening point glass, 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 untill almost 0 ppm in two hours. And in room model with the charcoal board set on the wall of 21.6 m^3, reduction of VOCs concentration was observed by adsorbing formaldehyde [3].

Since the charcoal board is prepared using superfine natural fibers as a binder and the natural fibers do not cover micropores on the charcoal surface, adsorbability of the charcoal is maintained. Polymer binder, such as polvinylacetate, covers the micropores resulting in decreases of the adsorbability for the charcoal.

It is one of problems that the natural fiber adhesives bunrs easily. Therefore, using the charcoal board inside a building is restricted from a legal viewpoint. In the previous paper, addition of boron oxide (B_2O_3) to the surface of the charcoal board was effective for decreasing combustibility of the board [4]. We found that the B_2O_3 coating on the surface of the board is effective to inhibiting the emission of combustive gas from the board and blocking air into the board. It is known that B_2O_3 has fire retardation property at a coating theory and char formation [5]-[8].

In this study, we adopted low softening point glass instead of B_2O_3 as fire retardant for the charcoal board. Glass which is on the market as low malting point glass has been used as fire retardant for polymer materials [9]~[11]. The main component of this glass is not silica (SiO_2) but phosphorus oxide (P_2O_5), which is caustic and expensive. We studied the effect of low softening point glass with silica, which is lower cost, as main component on the combustibility of the charcoal board. Fire retardant composite with low softening point glass and B_2O_3 was also investigated. The combustion property of the charcoal board with fire retardant was evaluated with the Cone Calorimeter method.

2. EXPERIMENTAL

2.1 Sample Preparation

The charcoal board was made from carbon powder and superfine natural fibers as a binder. The superfine natural fiber consisting of cellulose and collagen fibers were prepared from defiberized paper and leather scraps using a mortar-typed grinder (Super Grinder, Masuko Sangyo Co., Ltd.). The carbon powders was mixed with superfine fibers, pressed and dried at 105°C for 24 hours. The specific gravity of the board was dependent on the forming pressure, which was adjusted to 0.4. The preparation process is pollution free ; it does not contain any chemical compounds. The gravimetric composition ratio of carbon/superfine fiber in the charcoal board was adjusted to 8/2, and the ratio of cellulose/collagen in the superfine fibers was 8/2.

The surface of a charcoal board covered with glass powder for fire retardation. The glass used in this report is used generally for arts and crafts. The glass ingredients are SiO_2 69.0 %, Na_2O 12.0 %, K_2O 7.0 %, B_2O_3 1.0 %, CaO 3.0 % and Al_2O_3 2.0 %, and the softening point is 671°C. Glass was treated by a ball mill for 1 hour, and was made into powder. Particle size of glass which was measured by laser diffraction particle size analyzer, distributes 5 to 100 μm and average particle size is 11 μm.

Starch paste was used for adhesives. The gravimetric composition ratio of glass powder/adhesives in fire retardant was adjusted to 40/3, and 70~90 % water of glass weight was added to it. The paste was coated on the board surface by a spatula. Composite fire retardant was made from B_2O_3 and the glass. The gravimetric composition ratio of glass powder/B_2O_3/adhesives in composite fire retardant was adjusted to 40/4/3, and 80~100 % water of glass weight was added to the mixture. The paste was coated on the board surface by the spatula. The amount of glass on the board was adjusted to 400, 600, 800 and 1000 g/m^2. In order to check the effect of adhesives, the board on which glass was scattered without adhesives was prepared.

2.2 Cone calorimeter method

The Cone Calorimeter (Fire Testing Technology) in conformity to ISO/FDIS 5660-1 has been used for standard measurement of fire retardation property for various building materials. In the Japanese Building Standard Law, the fire retardation property is determined by the heat release rate of the sample and the total heat release from the sample. The heat release rate less than 200 kW/m^2 should be required basically 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 glades, the fire-retardant material, the semi-non-combustible material and the non-combustible material, which are classified according to the heating time reaching up to 8 MJ/m^2 of the total heat release. For the heating time within 300 seconds, 600 seconds and 1200 seconds, the fire-retardant material, the semi-non-combustible material and the non-combustible material are specified, respectively.

The sample was used 100 mm x 100 mm, and 10 mm in thickness. The sample using the test was bathed in external irradiance of 50 kW/m^2 in air. Oxygen concentration in the exhaust gas and the exhaust gas flow rates were measured, and finally heat release rate and total heat release were estimated. The heat release rate was determined from the heat of combustion estimated based on the oxygen consumption derived from CO_2, CO, and O_2 concentration in the exhaust gas.

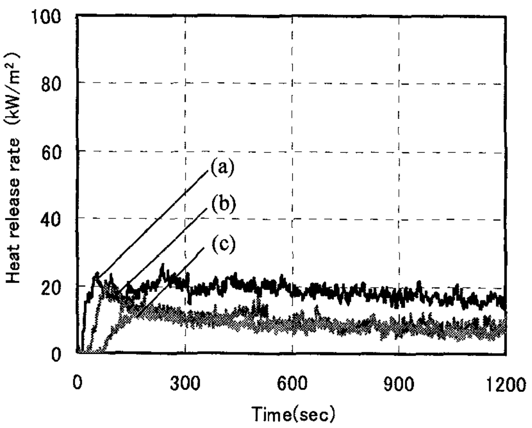

Fig. 1 Heat release rate of charcoal board of fire retardant treatment. (a); without glass, (b); glass of 600 g/m^2, (c); composite fire retardant with glass of 600 g/m^2.

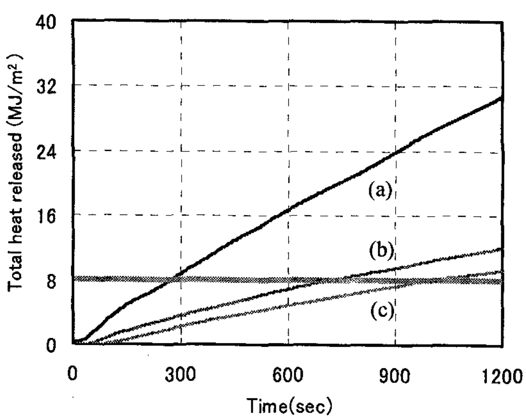

Fig. 2 Total heat release of charcoal board of fire retardant treatment. (a); without glass, (b); glass of 600 g/m^2, (c); composite fire retardant with glass of 600 g/m^2.

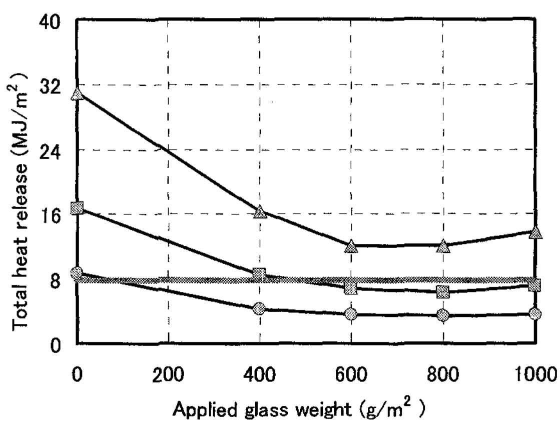

Fig. 3 The relation between applied glass weight and the total heat release at 300 seconds, 600 seconds and 1200 seconds. O; 300 seconds, □; 600 seconds, △; 1200 seconds.

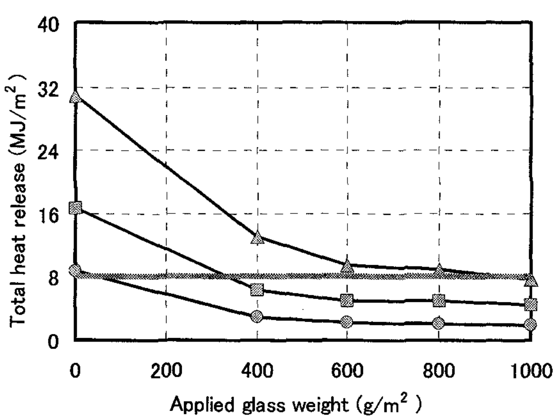

Fig. 4 The relation between applied glass weight in composite fire retardant and the total heat release at 300 seconds, 600 seconds and 1200 seconds. O; 300 seconds, □; 600 seconds, △; 1200 seconds.

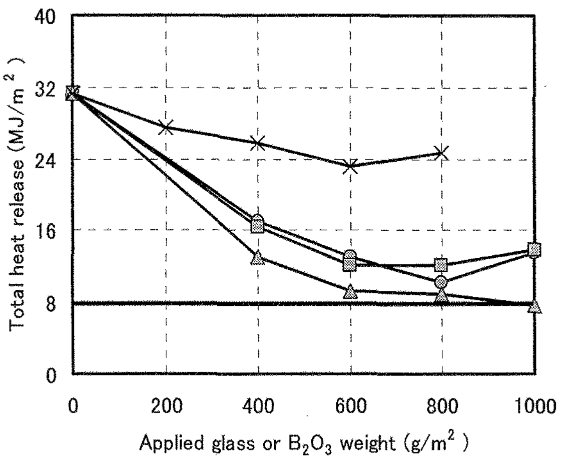

Fig. 5 The relation between applied glass weight and total heat release at 1200 seconds. O; glass, △; composite fire retardant, □; scattered glass, ×; B_2O_3.

3. RESULTS

Fig. 1 shows the heat release rate from the charcoal boards without glass, with glass at 600 g/m^2 and with composite fire retardant in which glass of 600 g/m^2 contained. It is thought that the charcoal board is flammable because it consists of natural fiber and charcoal. Heat release rate of 30 kW/m^2 or lower was maintained during the test for the charcoal board without glass. It is confirmed that the heat release rate during 1200 seconds is not over the standard value of 200 kW/m^2. And during the combustion test, no flame was observed. The average heat release rate and the maximum of heat release rate is 18.2 kW/m^2 and 13.6 kW/m^2 for the charcoal board with composite fire retardant, respectively. The average heat release rate of the board with glass and composite fire retardant is about half of that for the board without glass. Rising of heat release rate is delayed by addition of fire retardant for 30 seconds and 75 seconds for the samples with glass and composite fire retardant, respectively.

Total heat release was estimated by integrating of heat release rate in Fig. 1. Fig. 2 shows the total heat release for the charcoal boards without glass, with the glass of 600 g/m^2 and with the composite fire retardant in which the glass of 600 g/m^2 is contained. The total heat release at 1200 seconds of the board without glass, with the glass and with the composite fire retardant was 30.9 MJ/m^2, 12.1 MJ/m^2 and 9.3 MJ/m^2, respectively.

The total heat release at 300 seconds, 600 seconds and 1200 seconds decreases with increasing applied glass weight of the charcoal board, as shown in Fig. 3. As covered with 400 g/m^2 glass, the total heat release at 1200 seconds is about 2/3 times of the board without glass. For the sample of the glass content over 600 g/m^2, the total heat release at 1200 seconds was almost constant. For the sample covered with the glass of 400 g/m^2 or more, the total heat release at 300 seconds does not exceed 8 MJ/m^2, ranking the board as the fire-retardant material due to the Japanese Building Standard Law. The total heat release at 600 seconds does

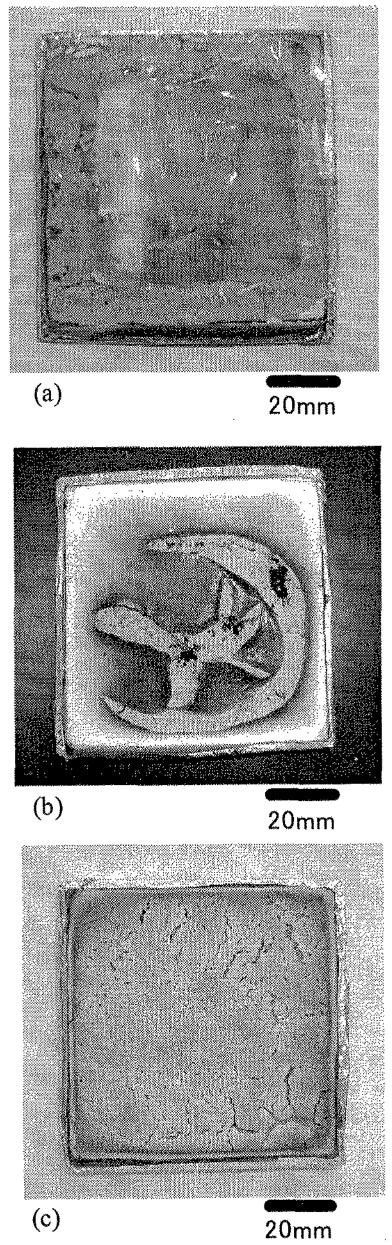

Fig. 6 Photographs of burned sample. (a); scattered glass 600 g/m^2, (b); glass 600 g/m^2, (c); composite fire retardant 600 g/m^2.

not exceed 8 MJ/m^2 for the sample with the glass of 600 g/m^2 or more, which is ranked as the semi-non-combustible material.

Fig. 4 shows the change of the total heat release at 300 seconds, 600 seconds and 1200 seconds of the charcoal board applied with the composite fire retardant. Total heat release of 8 MJ/m^2 at 600 seconds is attained by applying glass of 400 g/m^2. For the sample covered with the composite fire retardant of 1000 g/m^2 glass the total heat release at 1200 seconds is lower than 8 MJ/m^2. These results suggest that the charcoal board with the composite fire retardant of the 400 g/m^2 glass or more and of 1000 g/m^2 or more are ranked as the semi-non-combustible material and the non-combustible material, respectively.

The purpose of our study is to fabricate the charcoal board to be non-combustible. Therefore, it is necessary to discuss total heat release at 1200 seconds of the boards applied with various fire retardants. The relation between applied glass weight and total heat release at 1200 seconds is shown in Fig. 5, where the total heat release applied with B_2O_3 [4] is shown as comparison. The amount of applied B_2O_3 was limited to 800 g/m^2, because the further B_2O_3 was peeled off from the surface of the board. The difference of the total heat releases between with the glass and with the scattered glass is scarcely observed. This means that there is no influence of starch as adhesives on the combustibility of the board. The composite fire retardant is more effective than the glass on non-combustibility of the board. By applying B_2O_3 on the surface of the board, small decrease of the total heat release is obtained. However, addition of 10 wt% B_2O_3 into glass decrease the total heat release.

4. DISCUSSION

In order to discuss the fire retardation mechanism by applying low softening point glass to the charcoal board, photographs of burned samples after the cone calorimeter test are shown in Figs. 6 (a), (b) and (c). Figure 6 (a) shows the surface of the charcoal board on which glass powder was scattered. In Fig. 6 (a), glass sheet of several hundreds μm thick forms in the central region of the sample. Just after beginning of the test, the glass powder was melted momentarily and the melted glass was drawn to the central region. As shown in Fig. 6 (b) for the board coated with the 600 g/m^2 glass, the glass sheet with large cracks forms all over the sample surface. In this sample it was observed that the small cracks occurred at about 60 seconds after the test started, and then the cracks grow largely. Although starch as adhesive prevents the gathering of melted glass into the central region of the sample, the large cracks in the glass sheet are resultantly occurred. Many small cracks are observed in the glass sheet on the heated board with the composite fire retardant in Fig. 6 (c), because that B_2O_3 in the composite fire retardant decreases surface tension of the glass [12], and therefore, the cracks does not grow largely.

In the samples of Figs. 6 (a) and (b), although the region uncovered with the glass sheet burns to ashes, the black color of the char is maintained under the glass sheet. The black color of the char is also maintained all over the sample with the composite fire retardant, irrespective of many small cracks formed in the glass sheet on the surface of the board in Fig. 6 (c). These results mean that the glass sheet on the board inhibits emission of combustive gas from the board and blocks oxidation of the board surface.

5. CONCLUSIONS

As fire retardation for the charcoal board, low softening point glass was covered on the surface of the charcoal board. The total heat release decreased with increasing the glass amount. With 400 g/m^2 of the glass, the board was ranked as the fire-retardant material, because the total heat release at 300 seconds decreased under 8 MJ/m^2. The total heat release at 600 seconds does not exceed 8 MJ/m^2 for the sample with the glass of 500 g/m^2 or more. And with the composite fire retardant in which the glass of 1000 g/m^2, the total heat release at 1200 seconds was 7.7 MJ/m^2. These results suggest that the charcoal boards are ranked as the semi-non-combustible material with the low softening point glass and the non-combustible material with the composite fire retardant. When the charcoal board is covered with the low softening point glass with B_2O_3, the surface tension of the glass was lowered and the melted glass sheet spread over the whole surface of the board. Finally, the board with the composite fire retardant can be ranked as non-combustibility, because the glass sheet on the board inhibits emission of combustive gas from the board and blocks oxidation of the board surface.

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