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Study of the Combustion Performance of Three Kinds of Organic Heat Insulation Materials

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Abstract

In this research, the combustion performances and the smoke toxic of three kinds of thermal insulation materials: Expanded Polystyrene (XPS) insulation boards, polyurethane and rube-plastic sponge were studied by single burning item test (SBI), limiting oxygen index (LOI), oxygen bomb combustion heat and smoke toxicity test. Results showed that fireproof safety performance of the polyurethane is worst.

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Keywords: Single burning item test (SBI), Smoke toxicity, combustion performances;

Introduce

Fire, especially indoor fire is one of the most significant dangers which endanger the lives and property of the people. The organic heat insulation material which is widely used in building products usually make the fire develop and spread quickly. The organic heat insulation materials not only provide the fire load but also increase the toxicity smoke which will add the dangers of the fire. So the correct assessment is very important. XPS insulation boards, polyurethane and rube-plastic sponge are popular thermal insulation materials, and have attracted great attention of scientists. In this paper, the combustion performance and smoke toxicity of the XPS insulation boards, polyurethane and rube-plastic sponge were studied by single burning Item test (SBI), Limiting oxygen index (LOI), Oxygen bomb combustion heat and smoke toxicity hazard test.

1. Experimental

1.1. Analysis Methods
1.1.1 Single burning item test (SBI)

Calorimeter (Fire Testing Technology Limited, England) was used to perform SBI testing. SBI testing simulates the single specimen burning in the corner of the room. The instrument shown in Fig.1. The test refered to EN

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Reaction to fire tests for building products - Building products excluding floorings exposed to the thermal attack by a single burning item. The specimen is fixed in the corner of the wall. The dimension of burning room is 3m×3m×2.4m and the specimen dimensions is 1.0m×1.5m×0.04m and 0.5m×1.5m×0.04m.

1.1.2 Limiting oxygen index (LOI)

LOI test measures the minimum concentration of oxygen in a flowing mixture of oxygen and nitrogen that will just support flaming combustion. The HC-2 oxygen index meter (Nanjing Jiangning Analysis Instrument Company, China) was used for testing. LOI was measured according to ISO 4589-2:1996.

1.1.3 Oxygen Bomb Combustion Heat

Oxygen bomb instrument (Changsha Bente Instrument Factory, China) was used to perform the oxygen bomb combustion heat testing according to ISO 1716:2002. In this test, a specified mass of the test specimen is burned under standardized conditions. The heat of combustion under these conditions is calculated on the basis of the observed temperature rise, taking account of heat loss and the latent heat of vaporization of water.

1.1.4 Smoke Toxicity

Smoke Toxicity testing Instrument (Shenzhen Vizna Precision Instrument Co., Ltd., China) was used to perform the smoke toxicity testing according to GB/T 20285. In this method, the small white mice are made to exposure to toxic smoke for 30min, and then observed for 3 days. The results express by the mass of the smoke material in unit area (MSMU), the higher the value, the less the smoke toxicity of material.

2 Results and discussion

2.1 LOI and oxygen bomb combustion heat testing

The LOI is widely used to evaluate flame retardancy of polymers. The flammability behavior of the various composite materials in terms of LOI and oxygen bomb combustion heat testing are summarized in Table 1. The oxygen index of rube-plastic sponge, XPS insulation boards and polyurethane is 33.8%, 26.4% and 22.6% respectively. The rube-plastic sponge has the highest LOI indicating the flame retardant of rube-plastic sponge is best. The XPS insulation boards has the highest value of combustion heat of 3.91MJ/kg, the rube-plastic sponge has the lowest value of combustion heat of 1.66 MJ/kg indicating the fire fatalness of XPS insulation boards is the biggest and the rube-plastic sponge is the safest.

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<th>XPS insulation boards</th>
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Table 1. Result of combustion performance
Maintain the carrier gas velocity, diluent gas velocity and pyrolysis temperature and other parameters invariant, change the mass of the generating smoke material in unit area (MSMU) to decide the max MSMU of irritation eligible and narcotic eligible. The less the mass number, the more the toxicity of the material is. The smoke toxicity results of the three organic heat insulation materials shown in table 2, table 3 and table 4. The irritation eligible and narcotic eligible of max mass of MSMU of XPS insulation boards is 23.5mg/L, which is the highest of the three materials, while that of the rube-plastic sponge and polyurethane is 14.5mg/L and 3.5mg/L respectively. Conclude from the data in table 2, table 3 and table 4, the smoke toxicity of the polyurethane is heaviest, outclass that of the XPS insulation boards and rube-plastic sponge. So in the using of the building products, the flammability behavior and smoke toxicity of the materials should be considered in the same time.

2.2 Smoke toxicity

Total heat release (THR) and heat release rate (HRR) are also important factors for assessing performance of materials fireproof safety performance which determine the flashover probability and the flame spread velocity in the fire. In this paper, wall corner fire was simulated by the SBI test. HRR curve of the three specimens shown in Fig.2. As shown in Figure 2, HRR curve for rube-plastic sponge show a lowest peak value, which implies that rube-plastic sponge has the best flame retardant.
The time when of the peak value of HRR appeared is also very important to evaluate the fireproof safety performance of the material. The peak value appeared early will make against person escape. From the Fig.2, the time when the peak value of the HRR appeared of polyurethane is about 150s and XPS insulation boards is about 550s.

The values of the THR of the three specimens are shown in Table 1. As observed in the Table 1, the rube-plastic sponge has the lowest value of THR of 1.68KJ, much higher than that of polyurethane and XPS insulation boards which is 9.27KJ and 7.92KJ respectively. The higher value of THR and HRR, the higher probability of flashover of the material has. From the above analysis, the probability of flashover of polyurethane is highest in the fire, and the rube-plastic sponge is lowest. This is different from the result of LOI and smoke toxicity testing, so we should take different factors into consideration in the practice.

The smoke is solid granules, fluid drops and gas-phase substance produced by combustion or decomposing of the materials. According to the statistic, 70%~75% people die from inhaling the toxicity smoke in the fire. So smoke release rate (SRR) is other important parameter for assessing performance of materials fireproof safety performance. The SRR curves shown in Fig.3.

In Fig.3, the peak values of SRR of rube-plastic sponge is the biggest and the XPS insulation boards is the lowest. The result is different from the smoke toxicity result which showed that polyurethane is the most toxic, and XPS insulation board is the least toxic. This is because the smoke toxicity not only relate with the value of SRR but also mostly effect by the toxicity gas content. The atmosphere will harm the health of person when the CO content of the atmosphere is beyond $5 \times 10^{-5}$. The increasing of CO$_2$ content in the atmosphere will increase the breath of people and much more toxicity gas will be inhaled. So the CO and CO$_2$ content is an important parameter to assessment materials fireproof safety performance.

Fig.4 and Fig.5 show CO and CO$_2$ content variation curves of the three specimens, Fig.6 shows the CO and CO$_2$ gross content of the three specimens. In the Fig.4 and Fig.5, the peak value of CO and CO$_2$ content in the smoke and gas of polyurethane is 0.081% and 0.76% respectively, which is outclass those of rube-plastic sponge and XPS insulation boards. The increasing contents of CO and CO$_2$ increases the toxicity of the smoke. This result is the same with the result of smoke toxicity testing. In Fig.6, the CO$_2$ gross content of rube-plastic sponge and XPS insulation boards is nearly equality. The CO gross content of rube-plastic sponge is slight bigger than XPS insulation boards. Take the CO and CO$_2$ content into account, the fireproof safety performance of rube-plastic sponge and XPS insulation boards is similar. But smoke toxicity test shows that the max. MSMU of rube-plastic sponge is 15.5mg/L which is much less than XPS insulation boards of 23.5mg/L. The main reason is that
combustion is a complex process, toxic gas in smoke contain HCN, NO, HCl and SO\textsubscript{2} except for CO and CO\textsubscript{2}, different gas can also react with each other which increase the toxicity of smoke.

![Graph of CO content variation curves in the test](image1)

![Graph of CO\textsubscript{2} content variation curves in the test](image2)

![Graph of Curves of CO and CO\textsubscript{2} gross content](image3)

3. Conclusion

(1) The LOI of rube-plastic sponge is the highest and that of polyurethane is the lowest. The flame retardant of rube-plastic sponge is the best and the polyurethane is the worst.

(2) The max MSMU of polyurethane is only 3.5 mg/L indicated that the smoke toxicity of the polyurethane is heaviest, outclass that of the XPS insulation boards and rube-plastic sponge. The CO and CO\textsubscript{2} content in combustion smoke and gas of polyurethane is also much higher than that of XPS insulation boards and rube-plastic sponge. So the smoke toxicity of polyurethane is the biggest, the fire danger is the highest.

(3) The value of HRR and THR of XPS insulation boards are bigger than the rube-plastic sponge, so the potential flashover fatalness of XPS insulation boards is higher. But the fatalness of combustion smoke of XPS
insulation boards is less than rube-plastic sponge. So in the using of the building products, different parameter of the materials should be considered in the same time.

References