Letter

Attenuation of blast wave using biodegradable foam material around a spherical charge of composition C−4

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Abstract

The attenuation effect on a blast wave resulting from completely covering an explosive charge with biodegradable foam material (BFM) was studied. As the BFM does not have an electrostatic charge, it is considered to be safer than foam polystyrene small spheres (FPS), which were verified to be an effective barrier material in our previous study. A cylindrical polyetyrene bag made of thin polyetyrene film was filled with BFM. A spherical charge of composition C−4, weighing 50 g or 100 g, was detonated at the center of the bag. The diameter and height of the bag were identical, measuring 200 mm, 300 mm, or 400 mm. The blast pressure was measured at a scaled distance of 2m・$kg^{-1/3}$to 6.5 m・$kg^{-1/3}$. The attenuation effect of the BFM was slightly smaller than that of the FPS for the same barrier−material thickness, while the density of the BFM was half that of the FPS. The attenuation effect of the BFM on the explosive charges of 50 g and 100 g was described consistently using the scaled barrier−material thickness ; i.e., the thickness divided by the cubic root of the explosive weight.

Keywords : blast wave, attenuation, biodegradable foam material.

1. Introduction

Attenuation of a blast wave using such barrier materials as water gel, foam polystyrene, and sand was reported in our previous studies[1−4]. The explosive charge was completely surrounded by these barrier materials. One of these studies[3] concluded that the use of foam polystyrene small spheres (FPS) minimized the weight of barrier material required for attenuation. The diameter of the FPS used in our previous study was approximately1mm and the density was 30 kg・m^{-3}. However, the electrostatic charge of FPS can cause accidents. In addition, the significant amount of smoke originating from FPS after an explosion is not eco−friendly. In this study, the attenuation effect of commercially available biodegradable foam material (BMF) on blast waves was examined to avoid these problems.

2. Experimental Procedure

"Okapack F bara L" (The Sailor Pen Co., Ltd.) was employed as a barrier material in this study. Okapack is a commercially available BFM made from wheat bran. It consists of a type of packing "peanuts" for filling voids in shipments. The advantages of Okapack are that it has no electrostatic charge and does not generate toxic gas when incinerated. Okapack pieces are cylindrical, with a diameter of approximately 25 mm and a length of approximately 70 mm.

Composition C−4 (Nippon Koki Co., Ltd.) was employed as a high explosive. Its density is approximately 1.4 x 10^3 kg・m^{-3}. The explosive charges were shaped into spheres by hand. The weight of the charges was 50 g or 100 g, and the diameter was approximately 41 mm or 52 mm, respectively. An exploding−bridgewire (EBW) detonator (RP−501, Teledyne RISI, Inc.) was set at the center of the explosive charge to detonate it.

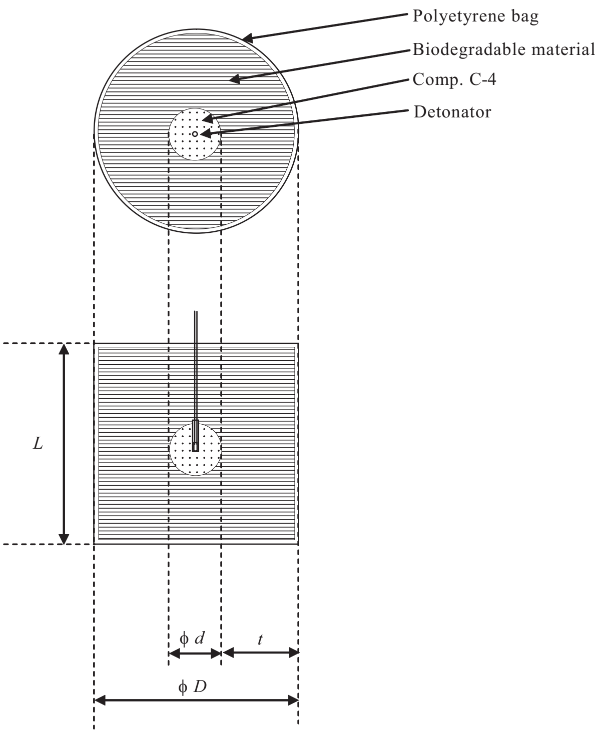

Fig. 1 Cross−sectional view of the cylindrical bag, filled with the composition C − 4 and biodegradable foam material. The diameter and height of the bag were identical. L and D were 200, 300, and 400 mm ; d was approximately 41 mm (50 g) and 52 mm (100 g) ; and t is the thickness of the barrier material.

Spherical polymethyl methacrylate (PMMA) containers were employed to fasten the explosive charge and the barrier materials in our previous studies[1−4]. Although this method can assure a spherically symmetrical setup of the explosive and the barrier materials, it was found that the PMMA fragments contaminated the obtained pressure profile ; for example, the oscillation noise. In this study, a cylindrical bag, made of thin polyetyrene sheet with a thickness of 0.03 mm was selected to avoid the effect of the fragments. The ratio of the diameter to the length was 1 : 1.The explosive was fastened at the center of this bag and filled with BFM. The diameter and length of the bag were 200 mm, 300 mm, or 400 mm. These bags are referred to hereafter as the D200 bag, D300 bag, and D400 bag, respectively. The measured density of the BFM in the bag was from 14 kg·m^{-3} to 16 kg·m^{-3}. Figure 1 shows a cross−sectional view of the cylindrical bag.

The experiments were carried out in an indoor pit with an inside diameter of 5m. The bag was suspended from a beam using a rope as the height of the charge from the floor, which consisted of wire netting, was 1 m. Free−air explosion experiments were also carried out for each size of explosive charge as standard experiments to evaluate the attenuation effect.

Four piezoelectric pressure transducers (HM102A15 and 102M256, PCB Piezotronics, Inc.) were used to measure the blast pressure. The transducers were set in a pancake−like streamlined housing parallel to the floor. The height of the transducer was identical to that of the charge. The distances from the explosive to the transducers were 0.9 m, 1.4 m, 1.9 m, and 2.3 m. The corresponding scaled distances, namely, the K factor, were from 2 m·kg$^{-1/3}$ to 6.5 m·kg$^{-1/3}$. The transducers were not placed in line, in order to avoid the mutual influence. The output signal was recorded using a transient recorder (LTT184/8, Labortechnik Tasler GmbH ; sampling rate 5.00 MHz and resolution 15 bits in this study) through an amplifier system (30510 and 30622, H−Tech Laboratories, Inc.).

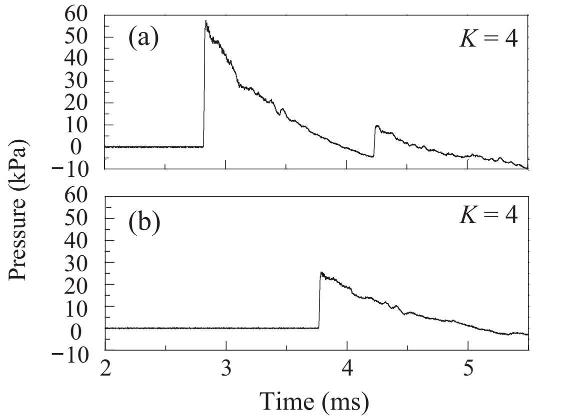

Fig. 2 Typical pressure profiles obtained. Time 0 corresponds to the detonation of the charge. (a) Bare composition C − 4 , weight 100 g. (b) Composition C − 4 , weight 100 g, surrounded by the biodegradable foam material. The bag was a D400 bag in both cases. The scaled distance was approximately 4 m·kg$^{-1/3}$.

3. Results and Discussion

Although the bag attracted FPS due to the electrostatic charge, it did not attract BFM. No electrostatic charge was sensed during our use of the BFM.

Typical pressure profiles obtained in this study are shown in Fig. 2. As described above, the avoidance of PMMA−fragment generation suppressed oscillation noise in the pressure profile. It can be seen in the figure that the barrier material decreases the peak pressure and delays the arrival time. Furthermore, it hinders the secondary shock wave caused by the successive implosion of rarefaction waves from the contact surface between the explosion products and air[5].

The profiles were fitted using a spline function. The peak pressure and the positive impulse (referred to hereafter as “impulse”) were determined based on the fitted curve. The relations between the peak pressure or the impulse and the scaled distance are shown in Fig. 3. To compare these dispersive data with each other, liner fittings for each data set were applied on a log−log plot. The normalized peak pressure and impulse, comprising the peak pressure or impulse with the barrier material divided by the data for the free−air condition, at a scaled distance of 4 m·kg$^{-1/3}$, were calculated based on the fitting results. The relations between the normalized peak pressure and impulse and the scaled thickness of the barrier material are shown in Fig. 4. Although the diameter of the bag was identical, the relative barrier−material thickness depended on the diameter of the explosive charge. The thickness of the barrier material is expressed using scaled thickness in Fig. 4 for comparison. The scaled thickness is

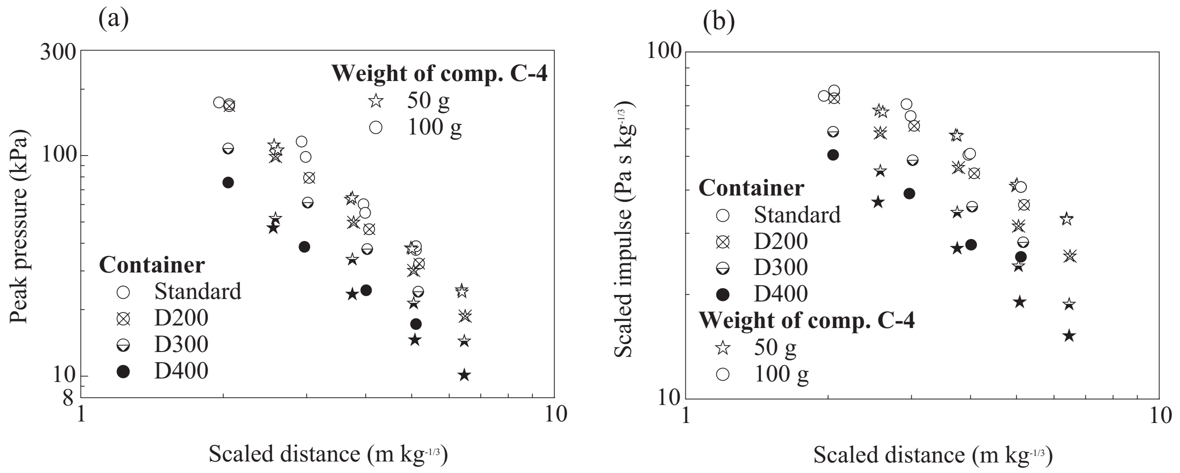

Fig. 3 Relations between (a) the normalized peak pressure and scaled distance, and (b) the normalized scaled impulse and scaled distance.

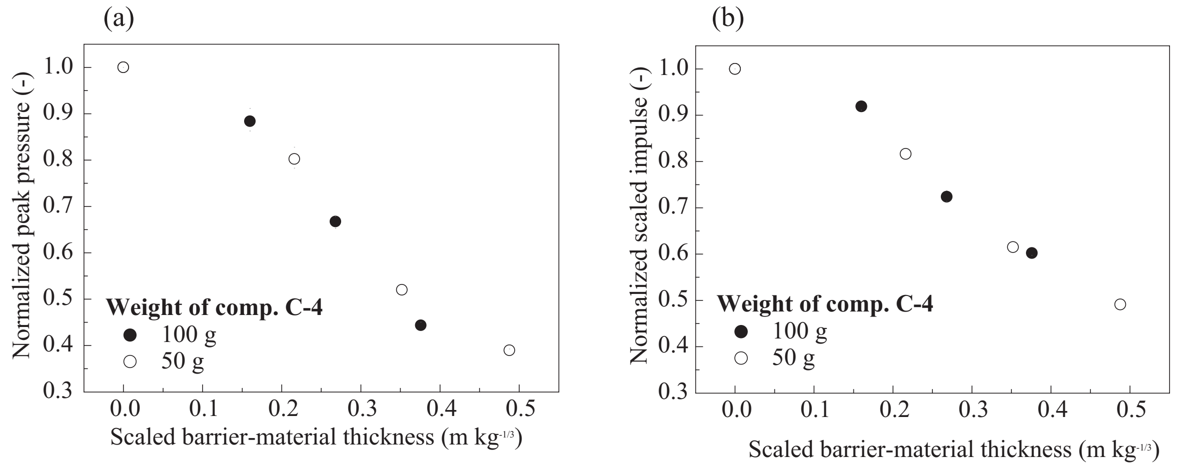

Fig. 4 Relations between (a) the normalized peak pressure and scaled barrier−material thickness, and (b) the normalized scaled impulse and scaled barrier−material thickness. The scaled distance was 4 m·kg$^{-1/3}$.

expressed as

$$t_s = \frac{\frac{1}{2}(D-d)}{W^{1/3}}, \qquad (1)$$

where t_s is the scaled barrier−material thickness, D is the diameter of the bag, d is the diameter of the explosive charge, and W is the weight of the explosive charge. These parameters are illustrated in Fig. 1. The lower plots in Fig. 4 indicate a low peak pressure and low impulse, and thus a large attenuation effect. The larger amount of BFM in the larger bag enhanced the attenuation effect. As the data for both 50 g and 100 g are found to be on a smooth curve, the scaling law on the thickness of the barrier materials should hold in this region.

The blast attenuation effect of BFM was compared with that of FPS[3], although the precise experimental conditions, such as the shape and material of the bags and the type of explosive were different. The spherical PMMA containers and spherical charges of pentolite were used in our previous study[3]. The closed triangles in Fig. 5 indicate the normalized peak pressure attenuated by the FPS. The normalized peak pressure attenuated by the BFM is higher than that attenuated by the FPS for the same scaled thickness. This must be due to the fact that the density of the BFM is half that of the FPS. If the density were identical, the volume would be double. The corresponding scaled thickness is shown as open triangles in Fig. 5. The

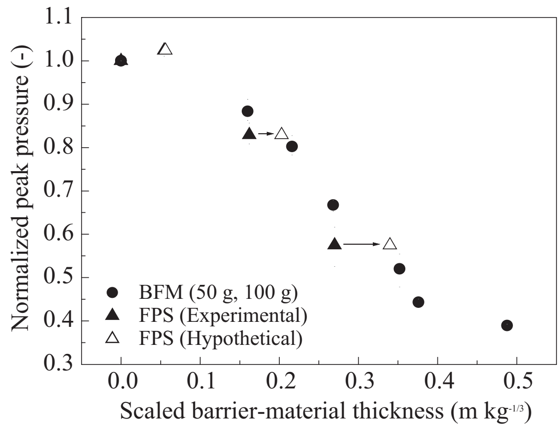

Fig. 5 Comparison of attenuation effect on blast waves. The closed circles and closed triangles represent the experimental results for the biodegradable foam material and foam polystyrene spheres, respectively. Hypothetical plots, assuming that the density of the foam polystyrene was equal to that of the biodegradable foam material, are also indicated in the figure as open triangles.

blast attenuation effect is similar in this hypothetical comparison.

In conclusion, BFM showed a blast attenuation effect comparable to that of FPS, and the absence of an electrostatic charge in the case of BFM assures safer use as a barrier material.

Acknowledgement

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生分解性緩衝材による爆風圧低減効果

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爆薬を生分解性緩衝材で囲んで点火した場合の爆風圧低減効果を評価した。生分解性緩衝材は，帯電性がないため，以前の研究で効果が高かった発泡スチロール微小球よりも安全性が高いことから評価対象とした。コンポジションC－４爆薬50 gまたは100 gを直径，高さともに200 mm，300 mm，400 mmのポリエチレンシート製円筒容器中に固定し，この容器の残りの部分を生分解性緩衝材で満たした。換算距離２m $kg^{-1/3}$から6.5 m $kg^{-1/3}$で爆風圧を計測した。爆風圧低減効果は，同じ緩衝材の厚さで比較すると，発泡スチロール微小球よりも若干低かった。ただし，かさ密度は発泡スチロール微小球のほぼ半分であった。また，爆薬50 g，100 gの爆風圧低減効果は，緩衝材の厚さを換算距離で現した値で統一的に整理できた。

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