Letter

Attenuation of blast wave using sand around a spherical pentolite

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Abstract

Attenuation effect of sand on blast wave was studied. Two spherical PMMA containers of 100 mm and 200 mm, respectively, were prepared and each filled with sand. Spherical pentolite (100 g) was ignited at the center of the each container. Three pressure transducers were placed around the container and the blast pressure was measured. The scaled distance from the charge, to each of the three transducers, were 3, 4, and 5 $m \cdot kg^{-1/3}$, respectively. The 200 mm-diameter container was the more effective for decreasing the peak pressure and the impulse. The peak pressure and the impulse decreased to 21-27 % and 37-40 %, respectively, in comparison to that without the sand. The attenuation effect of sand was larger than that of water gel and/or foam polystyrene for same volume.

Keywords: Blast wave, Attenuation, Sand.

1. Introduction

Attenuation of blast wave using water gel and/or foam polystyrene was reported in our previous study [1]. The charge was surrounded by barrier materials, which were water gel and/or foam polystyrene. The paper concluded that the attenuation effect depended on not only the amount of barrier materials, but also the density of the barrier materials.

Sand is often used as a barrier material for attenuating blast waves, and some papers [2)-4)] have been presented previously. Sand is denser than water gel, making its weight is larger for the same volume. Sand is solid, making it is easy to treat as a barrier material.

In this short report, attenuation effect of sand on blast wave is presented. Pentolite surrounded by a sand layer is ignited, blast wave profiles obtained, and the attenuation effect of sand layer on blast pressure and impulse discussed.

2. Experimental procedure

Experimental procedure in this work was same as that in our previous work [1]. Experimental conditions in this work are summarized in Table 1.

Spherically shaped pentolite of 100 g (Chugokukayaku CO., LTD) was adopted as an explosive. Its diameter was 49.2 mm. An electric detonator "Risi RP-501" was used. "Soma sand" was used as a barrier material. "Soma sand" is the name of a particular kind of natural silica sand that contains more than 95 % SiO_2. The density of the sand is 1.52 $g \cdot cm^{-3}$. The representative particle size distribution of "Soma sand" is shown in Table 2. Two PMMA hemispherical domes (thickness of about 2 mm, injection molding) are joined with adhesive and used as a container. The outer diameters of the containers are 100 mm or 200 mm (Hereinafter, the containers are called the ϕ100 container, and the ϕ200 container, respectively). The thickness of the sand layer was about 25 mm in case of the ϕ100 container and about 75 mm in case of the ϕ200 container, respectively. Compared with the radius of the pentolite, the thickness of the sand layer was almost similar to the radius of the pentolite, which was about 25 mm, in case of the ϕ100 container and about three times as thick as the radius of the charge in case of the ϕ200 container, respectively. The pentolite was fastened at the center of sand filled containers. The sectional view of the container is shown in Fig. 1.

The experiments were carried out in an indoor pit, of which inner diameter was 5 m. The height of the charge from the floor was 1 m. With the floor comprising of wire netting the reflection of blast wave at the floor was negligible. By this arrangement the work can be assumed to be free-air.

Table 1 Experimental conditions.

Container diameter (mm)	Container weight (g)	Barrier materials	Barrier materials density ($g \cdot cm^{-3}$)	Pentolite weight (g)	Gross weight (g)
100*	×	None	0	100.60	×
100*	×	None	0	100.55	×
100	66.79	Soma sand	1.52	100.75	793
200*	402.8	None	0	101.17	512.9
200	402.4	Soma sand	1.52	99.14	6520.6

*These asterisked experiments are "standard" experiments, and are reported in previous paper [1].
"×" means that the value is not measured. The representative weight of the ϕ100 container is 66 g.
The "standard" experiment of the ϕ100 container was carried out twice.

Table 2 The representative particle size distribution of "Soma sand".

Mesh size (mm)	1.7	1.18	0.85	0.6	0.425
Weight percent (%)	0-5	15-25	55-72	10-15	0-3

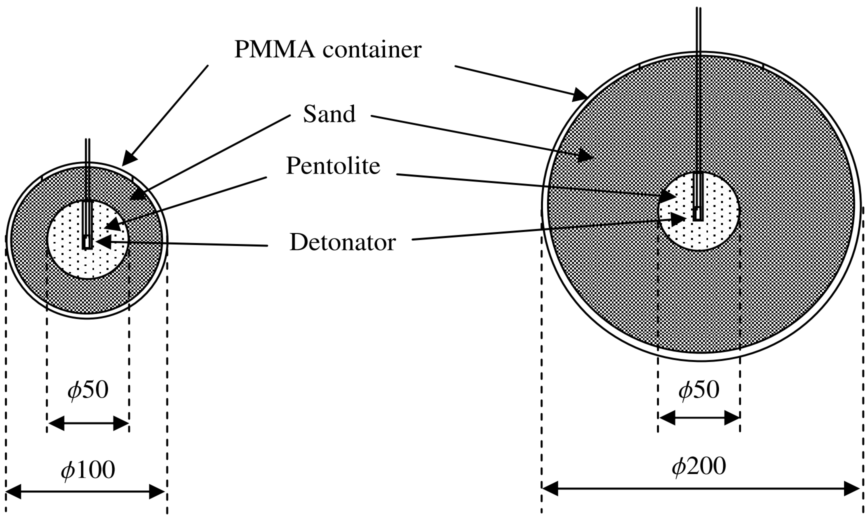

Fig. 1 Sectional view of the spherical containers, filled with the pentolite and the sand.

Piezoelectric pressure transducers (PCB 102A12 and 102A07) were used to measure the blast pressure. The transducers were set with a flush-diaphragm parallel to the floor. The height of the transducer was identical to the charge. The scaled distance R_s $m \cdot kg^{-1/3}$ (the unit will be omitted hereinafter) from the charge was 3, 4, and 5, respectively. The transducers were not placed in line, for suppressing the mutual influence.

The measurement system used in this study was identical to that of the previous study [1]. The validity of the system was examined in the previous study [1]. The experiments only with PMMA containers (without barrier materials) were carried out for comparison and reported in the previous paper [1]. These experiments are referred to as the "standard experiment" for each container size. The peak pressure and the impulse of these standard experiments are referred to as the "standard pressure" and the "standard impulse", respectively. The data obtained in this study is compared with that of the standard experiment.

3. Results and discussion

The obtained blast wave profiles were clear enough to analyze, although some of the profile contained some turbulence due to fragments that originated from the container. These data were fitted using a spline function. The peak pressure and the positive impulse (just referred to as "impulse", hereinafter) were determined from the fitted curve.

Figure 2 (a) and (b) show the peak pressure obtained in this study, combined with the standard peak pressure. Figure 2 (a) shows the relation between the peak pressure and the scaled distance from the charge. In Fig. 2 (b), the obtained peak pressure was divided by the standard peak pressure. Although the mass of the pentolite and the distance from the charge differed slightly for each experiment, the difference of calculated scaled distance was less than 1 % and determined negligible. The standard experiment using the ϕ100 container was carried out twice. The calculated mean of these two data was used as the standard peak pressure. In case of the ϕ100 container experiment,

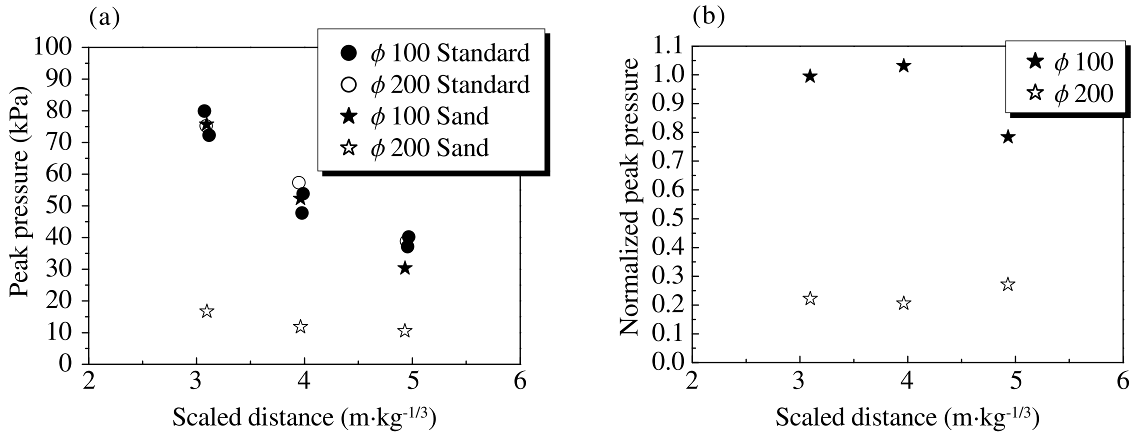

Fig. 2 (a) Relation between the peak pressure and the scaled distance from the charge.
(b) Relation between the peak pressure divided by the standard peak pressure and the scaled distance. The ϕ100 standard experiment was carried out twice (See Table 2).

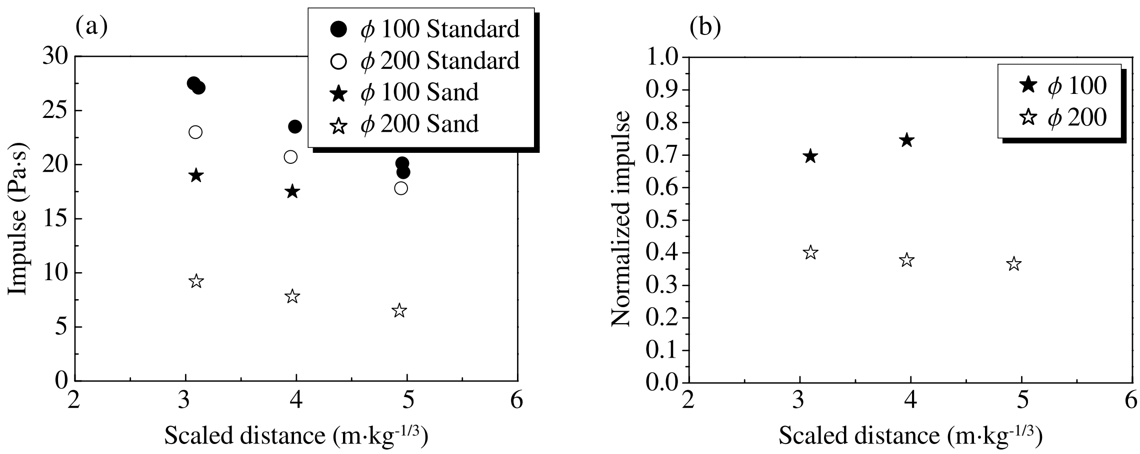

Fig. 3 (a) Relation between the positive impulse and the scaled distance from the charge.
(b) Relation between the positive impulse divided by standard impulse and the scaled distance. The obtained blast wave profile of the ϕ100 container experiment at 5 m·kg$^{-1/3}$ was not clear enough to determine its impulse.

the peak pressure was from 78 % to almost 100 % of the standard peak pressure. The attenuation effect was relatively small. To the contrary, in case of the ϕ200 container experiment, the peak pressure decreased to 21-27 % of the standard peak pressure. The dependence of the attenuation effect on the distance from the charge is not apparent.

Figure 3 (a) and (b) show the impulse obtained in this study, combined with the standard impulse. In case of the ϕ100 container experiment, the impulse decreased to 70-75 % of the standard impulse. In case of the ϕ200 container experiment, the impulse decreased to 37-40 % of the standard impulse. The dependence of the attenuation effect on the distance from the charge is not apparent, either.

As shown in Figs. 2 and 3, the peak pressure and the impulse decreased the most in the ϕ200 container. The thickness of the sand must be more than three times as thick as the radius of the charge for obvious attenuation. This result agrees with the previous result [1].

The attenuation effect of sand is much larger than that of water gel and foam polystyrene mixture for the same volume. As the density of the sand is larger than that of water gel mixture, the more energy of explosion converted to the kinetic energy of the barrier materials. However, as described in previous paper [1], the appropriate density of the water gel and foam polystyrene mixture maximized the attenuation effect for the same volume. The mass of the barrier material is not the only factor for attenuation effect. The appropriate content of air bubble increases the compressibility and promotes the conversion of explosion energy to heat. The sand also contains openings between the grains. Here, energy can be converted to heat by compressing the openings and/or the friction between the grains. Moreover, the floor of the pit was covered with fine powder after the experiment; this powder originated from fragmented sand. The blast energy was also dissipated by the destruction of the sand grain.

4. Conclusion

In this work, the attenuation effect of sand on blast wave was studied.

1. The thickness of the surrounded sand layer was set to 25 mm or 75 mm, while the radius of the charge was 25 mm. The attenuation effect increased with the thickness of the sand. The thickness of more than three times as thick as the radius of the charge gave obvious attenuation.
2. Such a thick sand layer decreases the peak pressure and the impulse to 21-27 % and 37-40 % of that without the sand layer, respectively. The attenuation effect of sand is much larger than that of water gel and polystyrene foam mixture for the same volume.
3. The dependence of the attenuation effect on the distance from the charge is not apparent.

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砂による爆風圧低減効果

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爆薬を砂（相馬砂特４号）で覆った状態で点火し，周囲における爆風圧力の時間履歴を計測することにより，砂が爆風圧を低減する効果の評価を行った。外径 100 mm，200 mm の２種類の大きさのアクリル製球形容器を用意し，砂を満たした。100 g の球形ペントライトを容器中心に設置し，点火した。換算距離 3, 4, 5 $m{\cdot}kg^{-1/3}$ の３点で爆風圧の計測を行った。200 mm 容器の時に低減効果が大きく，ピーク圧力は，緩衝材がない場合の 21-27 % であった。また，正相のインパルスは，緩衝材がない場合の 37-40 % であった。緩衝材として同体積のゲル化水・発泡スチロール混合物を用いた場合に比べて，爆風圧低減効果は大きかった。

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