Research paper

Characteristics of ANFO explosive after blasting detonating cord

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Abstract

We are suggesting the low-emission blasting technique that focused on the reduction of scrapped materials after blasting. In the blasting method, when the time lags between the detonation of the detonating cord and the ANFO explosive are long, the detonation velocity of the compressed ANFO explosive by the detonation of the detonating cord is higher than the normal ANFO explosive. This result shows that the improvement of the effect of rock blasting might be possible, if we can examine and provide the most suitable blasting condition that fit each the blasting fields.

Keywords : compressed ANFO explosive, low-emission blasting ; detonating cord ; short lead

1. Introducton

One of the main bench blasting method used in Japan features a combination of a NONEL detonator and a NONEL-SL detonator to detonate the booster. But this problem with using this method is that there is a large amount of residue remaining in the NONEL tube (not involved the explosive) after the blasting, which takes a long time to recover and isn't safety to recover. So in our design, we have replaced the NONEL detonator with a detonating cord and combined this with the NONEL-SL for the blasting method. (Fig.1) We call this the "low-emission blasting technique", which minimizes the amount of residue remaining in the NONEL tube after the blasting[1].

In this method, the detonating cord which leads through into the ANFO explosive in the blasting hole is initiated from the top by the detonator. After the detonating cord propagates detonation through into the ANFO explosive, the booster charge is initiated by the detonator with the fuse pipe at the bottom of the ANFO explosive. One of the problem of this "low-emission blasting technique" is the shock wave and gases generated by the detonation of the detonating cord subjecting the ANFO explosive with high pressures. The resulting compression leads to the different performance levels of the ANFO explosive under varying conditions[2-4].

In this paper, we investigated the effects on the performance of the ANFO explosive after it has been compressed by the detonation of the detonating cord. Our experiments focused on how the performance levels of the ANFO explosive is affected with different density of the ANFO explosive and detonating cord.

2. The performance of the compressed and recoverd ANFO explosive

2.1 Method of this experiment

A 250 mm long 40A (diameter : 41.6mm) carbon steel

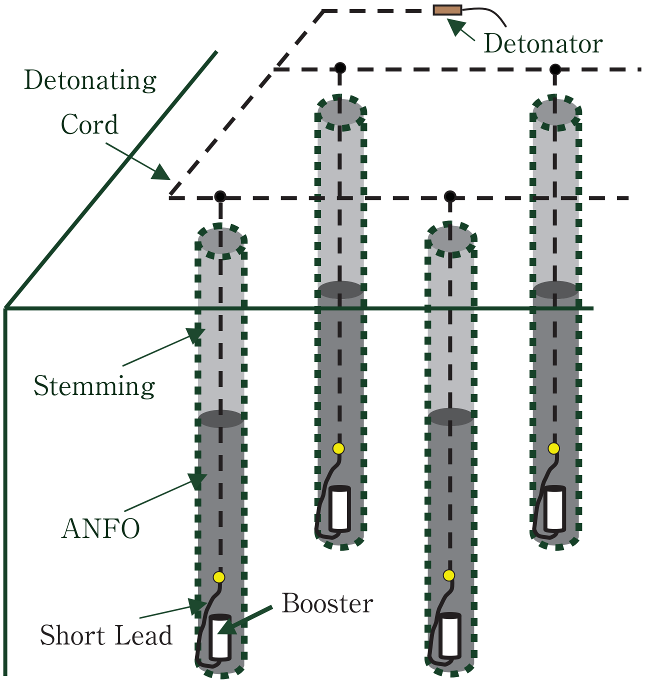

Fig. 1 Low−emission blasting technique.

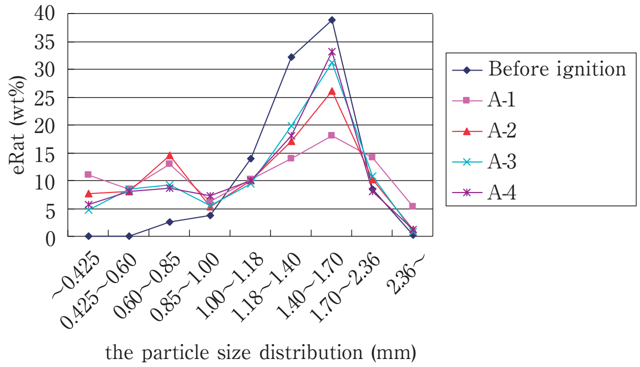

Fig. 2 Distribution of the particle size

tube was fully packed with the ANFO explosive and a detonating cord passed through the center. A type6detonator was attached to the detonating cord to trigger the detonation. After the detonation of only the detonating cord, the compressed ANFO explosive is recovered and a 500 mm long 40A carbon steel tube was fully packed with the compressed ANFO explosive to measure the detonation velocity. And the particle size distribution of recovered ANFO explosive was measured.

2.2 The ANFO explosives and detonating cords used in this experiment

The four type samples with deferent densities of the ANFO explosive were used. Bulk density of Sample A−1 is 0.63~0.65, A−2 is 0.70~0.72, A−3 is 0.78~0.80, A−4 is 0.86 ~0.88. While the 7.5G (1.5g/m) and the 25G (5g/m) detonating cords were used.

2.3 The detonation velocity of the compressed and recoverd ANFO explosive

Table.1shows the detonation velocity's result of the compressed ANFO explosive after the detonation by the detonating cord and recovered, and velocity's result of the normal ANFO explosive. (not the compressed ANFO explosive) The detonation velocity of the compressed ANFO explosive increases regardless of the density of the ANFO explosive and the detonating cord. It is thought that the normal porous ammonium nitrate increase the specific surface area when the particles are ground down by the detonation of the detonating cord, which in turn is thought to increase the reactivity.

So we investigated the particle size distribution of the compressed ANFO explosive after the detonation when using 7.5G detonating cord.

2.4 The particle size distribution of the compressed ANFO explosive

Figure2 shows that the particle size distribution of the compressed ANFO explosive after the detonation when using 7.5G detonating cord. The experiment is carried out with the particle size distribution made uniform before detonation so there is only one type listed in the image. The measurement results show that the particle size distribution of 1.40 to 1.70 mm is lower than before ignition. (not compressed ANFO explosive) And the particle size distribution of less than 1.00mm is more than before ignition. (not compressed ANFO explosive)

By this result, it is thought that the detonation velocity of recovered and compressed ANFO explosive is higher than the normal ANFO explosive.

2.5 Consideration of this experiment

By the way when this low−emission blasting technique (using the detonating cord) is used in bench blasting fields, the ANFO explosive is compressed as the detonating cord detonates first. Until now, it had been thought that if the booster is detonated before the pressure by the detonation

Table 1 Velocity of ANFO explosive.

Sample	Compressed ANFO (7.5G)		Compressed ANFO (25G)		ANFO (normal)	
	Loading Density	Density (m/s)	Loading Density	Density (m/s)	Loading Density	Density (m/s)
A − 1	0.878	3900	0.905	4100	0.689	3450
A − 2	0.937	4000	0.954	4100	0.773	3400
A − 3	0.994	4050	1.018	4050	0.841	3150
A − 4	0.984	3500	1.002	3700	0.886	2700

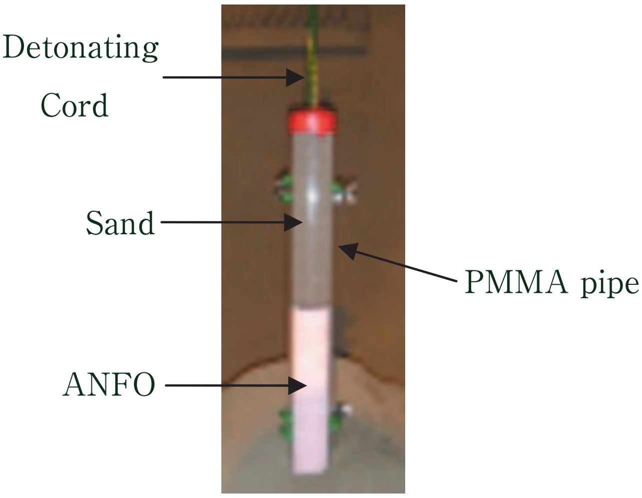

Fig. 3 the image of the pre−experimental setup

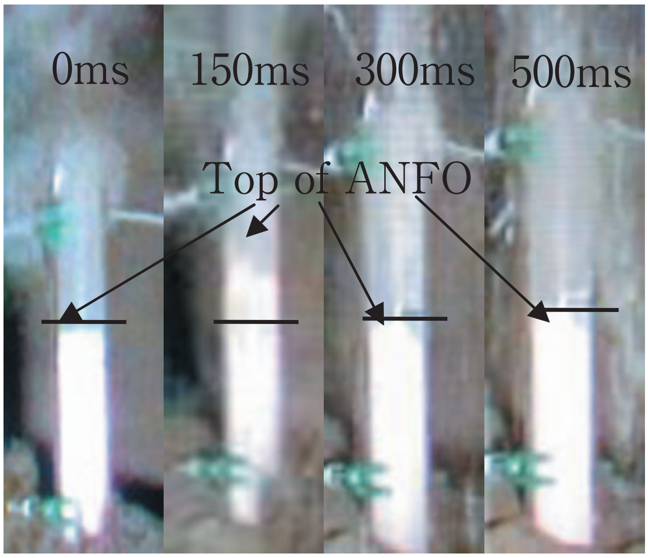

Fig. 4 the image of movement of ANFO

of the detonating cord is released, the detonation velocity of the ANFO explosive is low or even interrupted altogether because the ANFO explosive isn't fully packed tight by the pressure of the detonating cord's detonation.

On the other hand, if the booster is detonated after the pressure by the detonation of the detonating cord is released, the detonation velocity of the ANFO explosive is higher than the normal ANFO explosive because the ANFO explosive is packed tight and the particles become ground down increasing the reactivity.

So we investigated the detonation velocity of the ANFO explosive with changing the time lags of detonation between the detonating cord and the ANFO explosive.

3. The detonation velocities of the ANFO explosive with changing the time lags

3.1 Method of this pre−experiment (Observation of particle's movement to set the detonation delay between the detonating cord and the ANFO explosive)

A preparatory experiment was observation of particle's movement after only the detnation of detonating cord to set the detonation delay. Figure3 shows the image of the pre−experimental setup. ANFO explosive and sand was packed into an acrylic tube with an internal diameter of 50 mm, external diameter of 60 mm and length of 510mm. A 7.5G detonating cord was passed through the center. The length of the ANFO explosive and the sand were same. (255mm)

The A−2 from the table.1of the research was used. The pipe was set in a lengthwise direction to simulate the actual bench blasting. The movement of the ANFO particles was recorded with a video camera when the detonating cord was only detonated. The detonation delay was set based on the movement of the particles. The video camera was capable of recording 30 frames per second.

3.2 Result of this pre−experiment (Observation of particle's movement)

Figure4 shows the image that is recorded with the video camera. From the first left, the image is 0ms after detonation of detonating cord. (Just after that detonation of detonating cord) From the second left, the image is 150 ms. From the third left, the image is 300ms. From the first right, the image is 500ms. This line represents the end of the ANFO explosive before detonation.

After the detonating cord is detonated, the particles start to move with the pressure generated. (move the top of ANFO) The particles then start to settle as the pressure is released. The results indicate that the particles begin to settle approximately 300 to 500 ms after the detonating cord is detonated, with no further changes apparent after that time. From the results, the experiment was carried out with the detonation delay for the detonating cord and booster was set to less than 500 ms.

3.3 Method of this experiment

Figure5 shows the method of this experiment. A 800 mm 40A carbon steel pipe was packed with the ANFO explosive. The length of the ANFO explosive was set to 500 mm. A 7.5G detonating cord was passed through the center and a detonator1 attached on the detonating cord. On the other end of the tube, an emulsion explosive was attached as a booster and a detonator2 attached to the booster. A MS delay detonator was used for the detonator 2. This experiment had the pipe set in a lengthwise direction to simulate the actual bench blasting.

In this ignition method, after the detonating cord propagates detonation through into the ANFO explosive, the booster charge is initiated by the detonator2 at the bottom of the ANFO explosive.

In details, after the detonator1 was detonated on the detonating cord side, the detonator2 was used with a certain delay to measure the detonation velocity of the ANFO explosive when the booster was detonated. These kinds of delay time are 0.1, 25, 100, 300, 500MS by the results of the pre−experiment. The four types of the ANFO explosive with varying specific densities shown in 2.1 was used.

The measurement of detonation velocity is ion gap's method. We inserted the ion gaps 250 and 350mm from the end of the tube (the detonator2 side − in Fig.5) and we did-

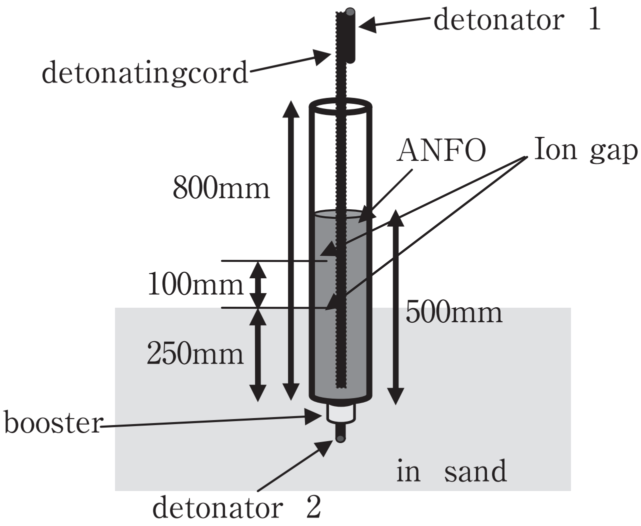

Fig. 5 Method of experiment.

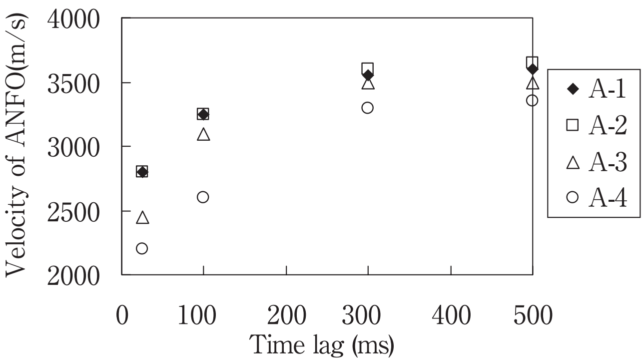

Fig. 6 Detonation velocity by time lags.

n't make the ion gaps touch the detonating cord. The sampling time is 100(MS/sec).

3.4 Results of this experiment

Figure6 shows the detonation velocity of the ANFO explosive at different detonation delays between the detonating cord and the ANFO explosive. With a short delay of 25 ms, the velocities were low regardless of the density. A delay of 0.1 ms resulted in interruption of detonation. The reason is thought that the ANFO explosive isn't fully packed tight by the high pressure of the detonating cord's detonation. But as the delay becomes larger, the detonation velocities increase regardless of the density, with any delay greater than 300 ms showing the detonation velocities higher than the normal ANFO explosive (not the compressed ANFO explosive). The reason is thought that the ANFO explosive is packed tight and the particles become ground down by the pressure of the detonating cord's detonation, increasing the reactivity.

4. Conclusion

We investigated the effects on the performance of the ANFO explosive after it has been compressed by the detonation of the detonating cord. When the time lags between the detonating cord and the ANFO explosive are short, the interruption of detonation or the low velocities detonation are occurred. But on the other hand when the time lags are long, the detonation velocities are higher than the normal ANFO explosive. These results show that the improvement of the effect of rock blasting might be possible, if we can examine and provide the most suitable blasting condition that fit each the blasting fields.

We will investigated the influence of diameter of the explosive and the detonating cord, difference of static effect and the causes for the high detonation velocities of the ANFO explosive. We will want to suggest the "low−emission blasting technique" on site in Japan with the results of these experiments.

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導爆線発破後のANFO爆薬の特性

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発破後の火工品由来の残存物を削減できる発破工法「環境低負荷発破工法」を提案している。本工法については穿孔内の導爆線が起爆前のANFO爆薬を通過し雷管を起爆する。このため導爆線の伝爆により周囲のANFOが圧縮される。本研究において導爆線とANFO爆薬の起爆の秒時差を長くすると，加圧されたANFO爆薬は高爆速化することがわかり，発破現場に適した条件を検討することで，起砕効果向上の可能性が得られた。

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