Article

Development and field-blasting tests of water-resistant granular explosive

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Abstract

An ammonium nitrate and fuel oil explosive (referred to as ANFO hereinafter) is the most useful industrial explosive in Japan as well as other countries in the world because it is safe and easy to handle, and relatively inexpensive. On the other hand, ANFO easily dissolves in water. Therefore, A packaged explosive such as a dynamite, an emulsion explosive, or ANFO previously charged in a polymer tube cartridge is used when groundwater or rainwater permeates into a bore hole. We developed a granular explosive that has water resistance and the advantage of ANFO such as excellent handle ability, for example, fluidity and usability in a bulk form.

We have evaluated the sufficient explosion performance and the water resistance of the granular explosive in various experiments. Then, we have carried out the field-blasting tests of Water-resistance granular explosive (referred to as WRGE hereinafter). WRGE could be charged directly into bore holes without removal of water contained in bore holes and gave the same fragmentation as in the case of the blasting with ANFO in a dry condition.

Keywords: Water-resistant, Granular explosive, ANFO

1. Introduction

ANFO is the most widely used blasting agent in Japan as well as other countries in the world. It has many benefits such as cost efficiency, safe and ease of handling. Another advantage of ANFO is its flexibility. Recently, ANFO has become diversified in Japan also. ANFO mixed with different additives have produced to comply with the demands of the users. Adding for example inert low density material produces light type ANFO for the reduction of blast vibration or the production of armour stone blocks[1].

The drawback of ANFO has been its poor water resistance, and hence it has been difficult to use ANFO in wet boreholes. Water-resistant ANFO containing the additive which form a waterproof gel has been used in wet conditions[2), 3)]. It has good resistance to returning borehole water only when it is placed in a borehole from which the water has been removed. Therefore, it requires dewatering before loading. Many consumers have required the ANFO type explosive that can be directly loaded into wet boreholes without dewatering.

We have developed a granular explosive of which each prill coated with the polymer film has good water resistance. Then, we have carried out the field-blasting tests of WRGE.

2. Properties

The Composition of WRGE is shown in Table 1[4)]. WRGE is composed of porous prilled ammonium nitrate as an oxidizer, dinitro compound as a fuel and a sensitizer, and polyurea as a coating material. After ammonium nitrate and dinitro compound are mixed, polyurea is added to make waterproof polymer film on the surface of the mixture prills. The true density and the loading density of WRGE are respectively 1.25 $g \cdot cm^{-3}$ and 0.75 $g \cdot cm^{-3}$.

WRGE and regular ANFO were poured into the measuring cylinders of equal amounts of water, and they were left for 3 and 6 hours. If the coating film of WRGE is broken, ammonium nitrate is dissolved and the coating material is floated on the water surface. Water resistance was evaluated by measuring the weight of coating material floated.

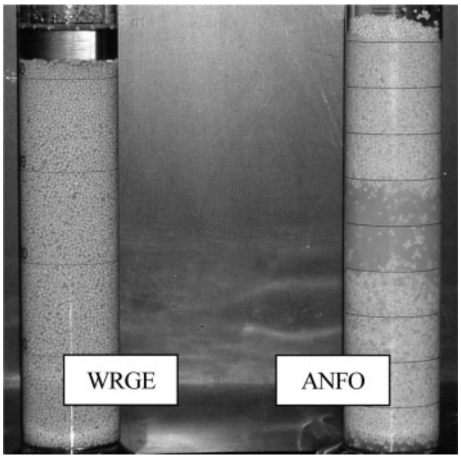

Fig. 1 Soon after pouring.

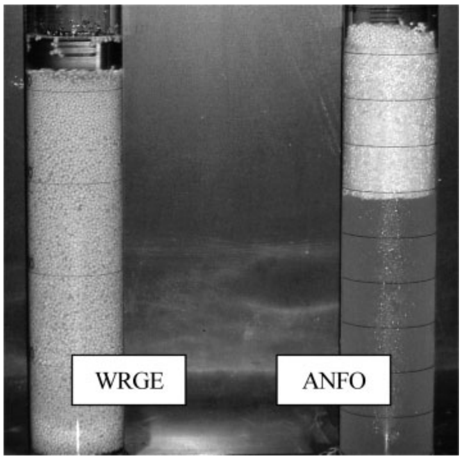

Fig. 2 6 hours after pouring.

Regular ANFO began to dissolve in water as soon as pouring, resulting in the loss of all explosive value (Fig. 1). Ammonium nitrate was dissolved completely, and the fuel oil or the solid content except for ammonium nitrate floated on the water 6 hours after pouring (Fig. 2). Compared with regular ANFO, WRGE hardly showed any change 6 hours later (Fig. 2). 97 - 100 wt. % of WRGE was not dissolved 3 hours later and 90 - 95 wt.% of it survived 6 hours later (Table 2). This result shows that it retains the detonation characteristics 6 hours after pouring into water.

According to the Japan Explosives Society standard ES - 32 (2), the initiation sensitivity test was conducted on WRGE and regular ANFO as a reference explosive. It consisted of placing each explosive sample in a 60 mm outside diameter and 1 mm thickness by 130 mm long polyvinyl-chloride pipe. Initiation was made by emulsion explosive (Ultex: Nippon Kayaku) as a booster with a No. 6 detonator because of not cap sensitive. The sensitivity was evaluated with the amount of emulsion explosive required for complete explosion of the explosive sample. Table 3 shows the initiation sensitivity of each explosive. ANFO was sensitive to a booster of 5 g initiated by a detonator and required a 10 g booster for the complete explosion three times out of three. The sensitivity of WRGE was much lower than ANFO. It needed a 25 g booster to be initiated three times out of three. It would appear that the coating film decreases the sensitivity of WRGE. This result shows that it may be handled more safely than ANFO although it contains the dinitro compound.

The detonation velocity test in dry condition was conducted in a steel pipe having an inside diameter of 35 mm, a length of 300 mm and a thickness of 3.5 mm based on the Japan Explosives Society standard ES - 41 (3). It was initiated by 30 g emulsion explosive with a No. 6 detonator. The detonation velocity was measured at an interval of 100 mm by using fiber optic velocity meter (Explomet-fo: Kontinitro). The detonation velocity in a steel pipe having an inside diameter of 53 mm, a length of 500 mm and a thickness of 3.8 mm, was measured also. 50 g of emulsion explosive was used as primer. The interval measured was same as above. The detonation velocity measurements in steel pipes with diameters of 35 - 53 mm has shown almost equal values for WRGE compared to regular ANFO (Table 4).

WRGE was loaded into the water filled steel pipe with an inside diameter of 53 mm, a length of 500 mm and a thickness of 3.8 mm. It was initiated by 50 g of emulsion explosive with a detonator under wet conditions 2 - 6 hours after

Table 1 Composition of WRGE.

Ingredient	Weight percentage
Ammonium nitrate	80
Dinitro compound	5 - 15
Polyurea	5 - 15

Table 2 Water resistance.

Immersion time (hr)	Survival (wt.%)	
	WRGE	ANFO
3	97 - 100	0
6	90 - 95	0

Table 3 Results of initiation sensitivity test.

Booster charge (g)	WRGE	ANFO
5		×○○
10		○○○
20	××○	
25	○○○	

○ : Complete explosion
× : Non-explosion

Table 4 Detonation velocity measurements.

Conditions		VOD (m·s^{-1})	
		WRGE	ANFO
Dry	ϕ35 mm	2950	3000
	ϕ53 mm	3300	3450
Wet	2 hours later	3150	-
	4 hours later	3100	-
	6 hours later	3150	-

loading. The detonation velocity was measured in the same way as dry conditions. WRGE has detonated at 3100 m · s^{-1} after leaving underwater for 2 - 6 hours (Table 4). The detonation velocity measurements under wet conditions have shown slightly lower values than the dry condition. However, it has been unaffected by time of leaving in water.

3. Field test condition

The field-blasting tests of WRGE have been carried out at some quarries to evaluate the practical use of it with attention to the following points.

· Propagation of detonation in wet boreholes.
· Loading properties in wet boreholes.
· Blasting effect compared with ANFO.

One of the field-blasting tests at a quarry of Kasama Saiseki Co., Ltd. in Kanto area of Japan is presented in this paper[5].

The type of rock in the field test site is mainly sandstone and contains many joints with faults of clay. Water-resistant ANFO is normally used by loading into tough plastic tube in borehole after removal of water at this quarry. Three boreholes were prepared for the field test. Two of them contained standing water around 5 - 6 m deep that was seeped from saturated cracks and seams in the subsurface material.

Table 5 Field test conditions.

	WRGE	ANFO
Type of rock	Sandstone	
Bench height (m)	11.0	
Hole diameter (mm)	75	
Hole depth (m)	12.5	
Hole inclination (°)	75	
Burden (m)	3.7	
Spacing (m)	3.8	
Primer charge (kg)	1	1
Column charge (kg)	30	32
Charge length (m)	8.9	7.9
Stemming (m)	3.6	4.6
Specific charge (kg·m^3)	0.20	0.21
Water level (m)	5 - 6	Dry
Flood time (hrs.)	3	-

Fig. 3 Loading operation in a wet borehole.

The drilling, charging and other blasting conditions are shown in Table 5. WRGE was loaded in two wet holes and regular AFNO was loaded in another dry hole to compare the blasting effect. The loading of WRGE replaced the standing water with it, resulted in the water level rising to the surface. The column charge and the stemming were smaller figures for WRGE compared to ANFO because of lower density. 1 kg of emulsion explosive was used as primer. It was placed in the topside of the column charge. The shot was fired 3 hours after loading WRGE. The detonation velocities of WRGE and ANFO were measured at three intervals of 0.5 m from the primer by using a fiber optic velocity meter.

4. Test result

Figure 3 shows a scene of loading WRGE into a wet borehole with the water level of 5 - 6 m. WRGE could be directly loaded into wet boreholes without dewatering. But it took longer time to load it than ANFO because the settling in water required time and it was loaded in small quantity to prevent it from creating a bridged area.

The blasting with WRGE resulted in good rock fragmentation and good forward displacement of the blasted rock as well as the blasting with ANFO. No stumps in the bottom part was also confirmed by the excavation with the shovel after the blasting.

The detonation velocity measurements are shown in Table 6. The detonation velocity measurement showed equal valued for WRGE compared to ANFO, which suggested that it detonated completely in the wet borehole as well as ANFO.

Table 6 VOD in the field test.

Distance from primer (m)	VOD (m·s^{-1})	
	WRGE	ANFO
0.5	3390	3770
1.0	3420	3260
1.5	3250	3220

5. Conclusion

Water-resistant granular explosive developed has shown sufficient explosion performance and good water resistance in a series of experiments. The results of the field-blasting tests have shown that it could be put to practical use. Its main characteristics ascertained in this study are as follows:

· It has almost the same detonation properties and handle ability as regular ANFO.
· It can be directly poured into water and maintain good water resistance for 6 hours.
· It completely detonates with the detonation velocity of 3300 $m \cdot s^{-1}$ in wet boreholes having 75 mm diameter by 12.5 m deep.

More effective loading method has to be considered to reduce the time of loading operation. The further field tests will be necessary in the practical application.

Acknowledgement

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耐水性粒状爆薬の開発及び実用試験

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硝安油剤爆薬（ANFOと略す）は，取り扱い性に優れ，比較的安全で安価であることから，産業用爆薬として広く使用されている。しかしながら，水に対する著しい溶解性から，水孔ではポリチューブで包装されたカートリッジタイプのANFO，あるいはダイナマイト，エマルション爆薬等，耐水性の良好な爆薬が使用されている。本研究において，バルク装填が可能である等，ANFO同様の取り扱い性を有し，耐水性を付与した粒状タイプの爆薬（耐水性粒状爆薬と略す）の爆発特性及び耐水性について評価し，実用試験において耐水性粒状爆薬の取り扱い性，発破効果について評価を行ったので報告する。

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