Developments of Granular Emulsion Explosives

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Abstract

Highly improved drilling machines and mucking machines have been used for the underground construction. To have rapid construction, the roles of blasting operation have been growing more important. At the most tunneling of present, cartridged emulsion explosives have been used for a blasting in Japan. Under this circumstance, a blasting system of ANFO explosives using loading machine has been used recently for a tunnel blasting. However, ANFO has some problems, such as a useless explosives in wet boreholes, bad blasting fumes and the ammonia gas due to the decomposition of ammonium nitrate in contact with the sprayed concrete in tunnel.

A blasting system using bulk emulsion explosives with loading machine has been used practically. However, it is difficult to introduce this system to Japanese tunneling because of the Japanese Explosives Control Law. Also, bulk emulsion explosives need complicated loading machine for chemical gassing.

Therefore, Granular Emulsion Explosives is developed with the development concept, which has detonation performance of emulsion explosives and handle ability of ANFO, which can be used by the simple machine. And the field blasting tests were carried out to confirm actual operations and blasting effects in some tunnels. As a result of the field tests, safety was improved at the face, because the loading time can be reduced. The cycle time is less than that of cartridged explosive products, and blasting fumes are better than that of ANFO.

Introduction

In recent years, the mechanization of explosives loading is requested in the quarry and tunnel construction in Japan. The examination of the long hole blasting have been carried out to extend the length of advance in the tunnel. The blasting system of the ANFO using a loading machine by compressed air has been used as the examination of long hole blasting. However, ANFO is poor in waterproof and blasting fumes are bad for environment of tunnel[1)]. Therefore, the use of ANFO sometimes receives restriction.

The pumping chemically sensitized bulk emulsions have been used for the underground constructions of the world [2]. However, loading machine with this system is complexity, and it is difficult to introduce this system for small underground construction, because this system requires the technical services by explosive company.

Therefore, Granular Emulsion Explosives was developed with the development concept, which has detonation performance of emulsion explosives and handle ability of ANFO, which can be used by the simple machine.

Granular Emulsion Explosives

Granular emulsion explosives consists of oxidizer salts, water, fuels, emulsifiers and glass micro-balloons (GMB). The formulation is shown in Table 1. Granular emulsion explosives is made a small cylinder of diameter 4mm and length 4mm by extrusion. The emulsion explosives have a viscous property generally and tend to stick together. Therefore, the special wax and resin as fuels were chosen to harden granular emulsion explosives. Granular emulsion explosives can be loaded into borehole with loading machine using compressed air.

Table 1 Formulation of granular emulsion explosives

Composition	Ammonium nitrate	Sodium nitrate	Water	Fuels	Emulsifiers	GMB
Mass(%)	70- 80	5- 10	10- 12	3- 5	1- 2	3- 5

Figure 1 Granular emulsion explosives (Diameter: 4mm, Length: 4mm)

The performances of granular emulsion explosives, ANFO and cartridged emulsion explosives are shown in Table 2. During loading, granular emulsion explosives are brown out through the hose by compressed air so that they stick together into a continuous column in the boreholes. Figure 2 shows granular emulsion explosives, which was loaded to pipe.

Figure 2 Granular emulsion explosives loaded to pipe
(Loading density: 0.75 g/cm^3)

Table 2 Performances of granular emulsion explosives

Explosives	Granular emulsion explosives	Cartridged emulsion explosives	ANFO
Density (g/cm^3)	(Bulk density) 0.6~ 0.7 (Loading density) 0.7~ 0.9	1.15~ 1.23	0.8~ 0.9
Waterproof performance	Good	Excellent	None
Cap sensitivity	None	Yes	None
VOD (m/s)	3500~ 4500	5800~ 6000	2500~ 3000
Ballistic pendulum (mm)	72~ 78	78~ 84	62~ 68

Velocity of Detonation (VOD of granular emulsion explosives)

The measurements of velocity of detonation (VOD) were conducted in the steel pipes having an inside diameter of 42mm, a length of 1000mm, using 50g primer (cartridged emulsion explosives). The optical fiber method was used VOD measurement at an interval of 100mm. The loading density of 0.65 g/cm^3 was poured to a steel pipe. The loading densities of 0.7 to 0.9 g/cm^3 were loaded to a steel pipe with the charge machine. The relation between VOD and loading density is shown in figure 3.

The loading density of granular emulsion explosives can be specified from 0.7 to 0.9 g/cm^3 by varying the air pressure of loading machine. The VOD changes to the range of 3500-4500 m/s depending on the loading density.

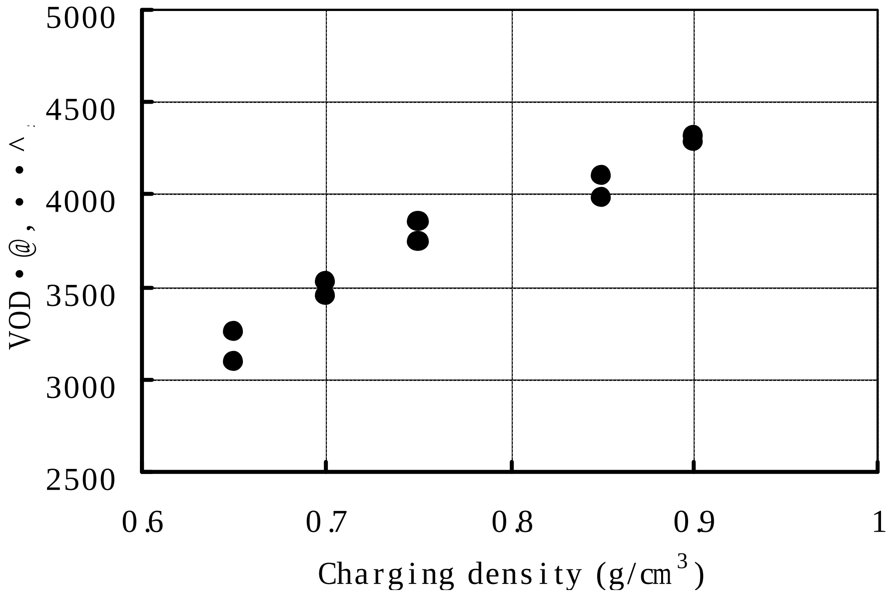

Figure 3　Relation between loading density and VOD

After fumes of granular emulsion explosives

The test procedure for after fumes can be described as follows. It is based on the method described in the Bureau of Mines Bulletin 346 and has been somewhat modified by Nippon Kayaku. Each explosives of 300g were back-primed with 30g primer (cartridged emulsion explosives) and were loaded without tamping material into borehole (diameter: 45mm, length: 1m) of steel cannon.

The cannon is placed in a steel gallery of 35m^3 volume. The door of gallery is closed and a blower circulates the gas in the gallery immediately after the explosives is fired. Carbon monoxide (CO) and nitrogen oxide (NO_x) were measured using the gas detector (Drager Safety AG &Co.KgaA). Test equipment is shown in figure 4. Gaseous products obtained from explosion of granular emulsion explosives, cartriged emulsion explosives and ANFO is shown in Table 3. Each component of gaseous products is represented by dimension (L/kg), which used the following equation.

$$(L/kg) = \frac{35000 \times 10^{-6}}{0.300} \qquad (ppm)$$

Granular emulsion explosives have less generating of NO_x and CO than ANFO and cartriged emulsion explosives. Granular emulsion explosives is good explosive for work environment of underground constructions.

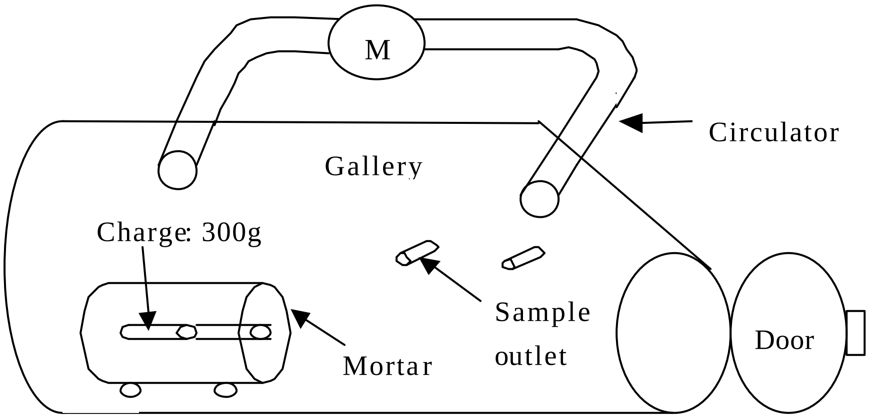

Figure 4 Equipment for measuring gaseous products of explosion

Table 3 Components of after fume

Explosives	Granular emulsion explosives	Cartridged emulsion explosives	ANFO
Component (L/kg)			
NO_X	1	2	6
CO	2	4	23
CO_2	87	120	115

Loading machine of granular emulsion explosives

The loading machine of granular emulsion explosives was developed for underground construction with concept of simple mechanism. The loading machine is shown in figure 5. Granular emulsion explosives are blown through the loading hose of 30m to bore holes by compressed air. The pressure of compressed air can be changed easily to vary the loading density of granular emulsion explosives. The loading machine and compressor are placed on the deck of a truck.

Four kinds of loading weight can be inputted into control panel, and a choice of loading weight is operated by wireless remote controller at face. Since loading weight can be set per 200g, it is possible to charge with the optimum loading weight. The loading machine have two loading hoses of independent control, and the loading rate is 25kg/minute.

Figure 5 Loading machine of granular emulsion explosives

Field test No.1

The field test No.1 of granular emulsion explosives was carried out in a highway tunnel. Cartridged emulsion explosives have been used exclusively in this tunnel. The performances and handle ability of granular emulsion explosives were inspected in this field test as compared to cartridged emulsion explosives. Granular emulsion explosives were loaded at a loading density of 0.75 g/cm^3.

The face area was 60m^2, and the rock type was a granodiorite. The boreholes were 45mm in diameter and drilled to a depth of 1.2 m. The test blasting used granular emulsion explosive was carried out 6 times, and the blasting used cartriged emulsion explosives was carried out 6 times. The results of field tests No.1 are shown in Table 4. The average of 6 times is shown in results.

Table 4 Results of field test No.1

Explosives type	Granular emulsion explosives	Cartriged emulsion explosives
Number of boreholes	97 (89%)	109 (100%)
Total charge of explosives (kg)	53 (113%)	47 (100%)
Loading time of explosives (min)	24 (65%)	37 (100%)

The number of boreholes per face was reduced about 10%, and the loading quantity was increased about 10% as compared to cartridged emulsion explosives. If a depth of boreholes becomes long, the number of boreholes will be able to be reduced further.

Although 2 workers loaded for granular emulsion explosives and 5 workers loaded for cartriged emulsion explosives, the loading time of granular emulsion explosives was reduced about 35%. So the safety of workers was improved for faces.

Field test No.2

The field test No.2 of granular emulsion explosives was carried out in a tunnel for underground construction. ANFO have been used exclusively in this tunnel, and small quantity of cartriged emulsion explosives have been used for toe holes in which water exists. The performances and blasting fumes of granular emulsion explosives were inspected in this field test as compared to ANFO. Granular emulsion explosives were loaded at a loading density of 0.75 g/cm^3.

The 59.4m^2 faces were drilled out with 128 boreholes, and the rock type was granite. The boreholes were 45mm in diameter and drilled to a depth of 4.0m. The test blasting used granular emulsion explosive was carried out 3 times, and the blasting used ANFO was carried out 3times.

Carbon monoxide (CO) and nitrogen oxide (NO_x) were measured using the gas detector (Drager Safety AG &Co.KgaA) at 85m point from a face shortly after blasting. The results of field tests No.2 are shown in Table 5. The average of 3 times is shown in results.

Table 5 Results of Field test No.2

Explosives type		Granular emulsion explosives	ANFO
Total loading weight of explosives (kg)		409 (88%)	463 (100%)
Blasting fumes	NO_x (ppm)	10 (25%)	40 (100%)
	CO (ppm)	120 (48%)	250 (100%)

The loading weight of granular emulsion explosives was reduced about 12% as compared to ANFO. Since the loading density of granular emulsion explosives was smaller than that of ANFO, the loading weight was reduced in the case where it is set as the same length of explosive column. Although the loading weight of granular emulsion explosives were reduced, similar fragmentation were obtained as compared to ANFO. Granular emulsion explosives were loaded to toe holes in which water exists, and the fragmentations of toe were good.

As a result of blasting fumes measurement, there was less poisonous gas than ANFO. It was confirmed that the blasting fumes of granular emulsion explosives were excellent and it is good for work environment.

Conclusion

Granular emulsion explosives developed have high performance of detonation property, waterproof and good blasting fumes. Granular emulsion explosives can be loaded by simple loading machine using compressed air. The loading density of granular emulsion explosives can be specified from 0.7 to 0.9 g/cm3 by varying the air pressure, and the VOD can be changed to the range of 3500-4500 m/s depending on the loading density.

As a result of field tests, the number of boreholes per face and explosives loading time were reduced as compared to cartridged emulsion explosives. Therefore, cycle time was shortened and the safety of face was also improved. The specific charge was reduced and the blasting fumes (NO_x, CO) were excellent as compared to ANFO.

Reference

1) Berit B, et al. “Effects of blasting fumes on exposure and short-term lung function changes in tunnel construction workers”, Scand J Work Environ Health 2001, vol27, pp250-257
2) “Blasters Hand book 17th Edition”, pp547- 560, International Society of Explosives Engineers