Experimental Study on Water-Resistant Performance of Emulsion Explosive under Condition of Coupled Deepwater Pressure and Soaking Time

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Abstract: The water-resistance of 3 common emulsion explosives with changing deepwater pressure and soaking time were studied through experiments. Major conclusions were drawn as follows: the detonation property of the three became slightly weakened with the increase of pressure and time and all of them presented superior water-resistance; besides, with the same emulsion matrix, the water-resistance of them was in the following order:glass microsphere sensitized explosive>chemical sensitized explosive>perlite sensitized explosive; lastly, in large-scale long-term construction of deepwater blasting, the water-resistance of emulsion explosive is not the major factor weakening its detonation performance.

Introduction

In China, the assessment on emulsion explosive and its water-resistance is mainly based on the attenuation of the detonation performance of explosive products after soaking in water, in which the dissolution loss rate is used as the aid. Methods of determining the water-resistance of emulsion explosive includes Laboratory Determination and Field Determination. The former consists of shallow-water determination and deepwater determination[1]. It is conventionally a must to test the water-resistance of emulsion explosive used in massive underwater blasting. For example, emulsion explosive is the major blasting cartridge in salvaging the sunken ship-"Changyu" by Shanghai Sea Rescue Center. Since the ship went down as deep as 46m, it took as long as 70h to distribute the explosive. That is why blasting experiments were conducted at the same depth after the explosive was soaked in water for 72 hours for a stable blasting[2]. The emulsion explosive used in the underwater in the 2nd-stage downstream cofferdam of Three Gorges was soaked in water for 9 hours, after which, its detonation velocity and explosive brisance attenuation was smaller than 6%[3]. While demolishing the cofferdam, the emulsion explosive used was soaked in the seawater for 120 hours at the depth of about 10m and its energy loss in casting crater was measured at about 10.71%[4].

In this paper, the water-resistance property of common emulsion explosive under deepwater was studied in a systemic way instead of a qualitative or qualitative-quantitative measurement with only one pressure spot or one soaking time, seeking for an in-depth understanding of the water-resistance.

Experimental method

Experiment principle

Laboratory deepwater determination was adopted in this paper. The total pressure on the underwater charge includes atmospheric pressure on the surface of still water and hydrostatic pressure. Underwater charge conditions were simulated in the experiments by changing the pressure on the

surface of still water. For instance, at the depth of 10m, 2 atmospheric pressure was exerted on the still water, which equals to the pressure of 30m water column on the underwater charge.

Experimental set-up

The set-up was designed based on previous designs to measure the water-resistance of emulsion explosive. As is shown in Fig 1, the set-up is composed by such parts as a drum, flanges, end sockets, sealing pads, a high-pressure needle valve and a pressure gage. Thanks to its small size, normal inflator or air compressor can be used to add pressure. Detonation velocity was measured through photoelectric detonation velocity tester with a range of 5-1500μs and a resolution ratio of 0.1μs, which is shown in Fig.2. The explosive brisance was measured through a lead cylinder, which is presented in Fig.3.

| Fig.1 Set-up for pressing | Fig.2 Denotation velocity tester | Fig.3 Brisance test |

Selection of explosive pattern

Three commonly-used emulsion explosives were selected, namely, chemically-sensitized one (No.:1#), perlite-sensitized one (No.:2#) and glass microspheres-sensitized one (No.:3#), all of which have the same emulsion matrix whose composition is a confidential trade secret. The basic composition of emulsion explosive is displayed in Tab.1.

Table 1 Information on Explosive Samples

Serial No.	Emulsifier		Sensitizer		Notes
	Type	Content	Type	Content	
1#	T155	2%	NaNO$_2$	0.15%	Prom a chemical plant
2#	T155	2%	Perlite	4.00%	Do the sensitization with the matrix from one chemical plant
3#	T155	2%	Glass microsphere	2.50%	Do the sensitization with the matrix from one chemical plant

Determination of experimental scheme

Experimental scheme: both of the ends of explosive sample were opened for a direct contact with the water; the soaking time was set as 72 hours; the pressure spots at 0.0MPa, 0.2 MPa and 0.4MPa were selected. For smaller error, the blasting velocity was measured 3 times at each pressure spot according to the requirements of GB/T13228-91 National Standard of Denotation Velocity Determination[5]. The brisance was measured 3 times at each spot as well, according to the requirements of GB12440—1990 Explosive—Determination of brisance[6].

Experiments

Data test

The measurement before and after soaking in water of the 3 samples are displayed in Tab.2 and Tab.3 respectively.

Table 2. Measurement results of denotation velocity

Serial No.	Pressing time	P/Mpa											
		0			0.2			0.4			0.6		
	(h)	D_1	D_2	D_3	D_1	D_2	D_3	D_1	D_2	D_3	D_1	D_2	D_3
1#	36	5000	4854	4951	4951	4808	4902	4773	4808	4630	4673	4584	4673
	72	5000	4854	4951	4808	4902	4773	4673	4630	4608	4584	4545	4467
2#	36	3876	3788	3704	3846	3597	3676	3623	3543	3521	3448	3448	3401
	72	3876	3788	3704	3641	3623	3579	3543	3497	3497	3386	3386	3347
3#	36	5495	5319	5376	5243	5376	5435	5185	5319	5185	5151	5051	5185
	72	5495	5319	5376	5243	5243	5185	5151	5185	5074	4985	4854	5051

[Note]: "0" refers to the detonation velocity before soaking; "0.2", "0.4" and "0.6" are the detonation velocity after soaking; "D_1", "D_2" and "D_3" are the parallel detonation velocity at the same spot.

Table 3. Measurement results of Brisance

Serial No.	Pressing time	P/Mpa											
		0			0.2			0.4			0.6		
	(h)	H_1	H_2	H_3	H_1	H_2	H_3	H_1	H_2	H_3	H_1	H_2	H_3
1#	36	19.52	19.23	18.44	18.27	18.55	17.94	17.64	17.18	17.83	16.32	16.74	15.76
	72	19.52	19.23	18.44	18.12	17.46	17.69	17.08	16.73	16.47	15.74	15.46	15.17
2#	36	14.93	14.47	13.59	13.68	13.17	12.64	12.74	12.46	12.89	12.28	12.34	11.74
	72	14.93	14.47	13.59	13.27	12.56	12.75	12.44	12.28	12.19	11.32	11.64	11.56
3#	36	19.27	19.58	20.16	19.35	18.86	19.14	18.75	18.33	17.84	17.37	17.62	16.79
	72	19.27	19.58	20.16	18.74	18.34	19.23	18.31	17.45	17.68	16.47	16.26	16.87

[Note]: unit of the brisance: mm. "0" refers to the brisance before soaking; "0.2", "0.4" and "0.6" are the brisance after soaking; "H_1", "H_2" and "H_3" are the parallel brisance at the same spot.

Data processing

The following formula containing denotation velocity was used to measure how much the brisance had been weakened after soaking:

$$\eta = (D_0 - D)/D_0 \tag{1}$$

In this formulaD0 is the denotation velocity before soaking and D is the velocity after soaking $\eta_0 = (D_0 - D_0)/D_0 = 0$; $\eta_1 = (D_0 - D_{misfire})/D_0 = (D_0 - 0)/D_0 = 1$

η refers to how much the denotation performance of emulsion explosive had been weakened before and after soaking, ranging from 0 to 1. Clearly, higher value of η means greater weakening. η_0 is the weakening before soaking, when it is the smallest—0 while η_1 is the weakening in misfire denotation, when it reaches the greatest—1.

And the following formula containing brisance was used to measure how much the denotation performance had been weakened after soaking:

$$\theta=(H_0-H)/ H_0 \tag{2}$$

In this formula, H_0 refers to the brisance before soaking while H is the brisance after soaking
$\theta_0=(H_0 - H_0)/ H_0 =0$; $\theta_1=(H_0 - H_{misfire})/ H_0 =(H_0 – 0)/ H_0=1$

θ was used to show the detonation performance reduction before and after soaking, ranging from 0 to 1. Similarly to the above, higher value of θ means greater reduction. θ_0 is the performance reduction before soaking, when it is the smallest—0. θ_1 is the performance reduction after soaking, when it is the highest—1.

The above Formula (1) and Formula (2) were used to process the experimental data in Tab.1 and Tab.2. The processing results are presented in Diagram 4~11 as follows:
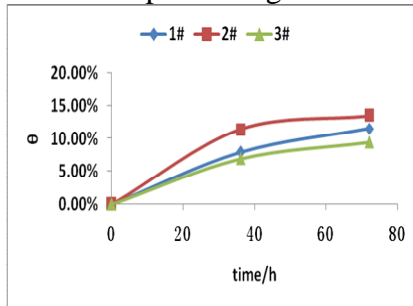

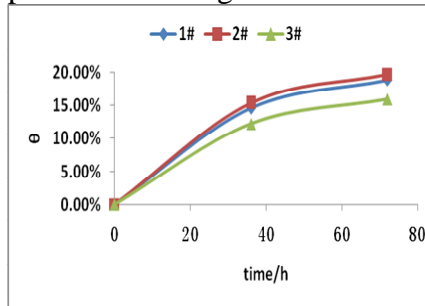Fig.4 P=0.4MPa, relationship between θ and soaking time

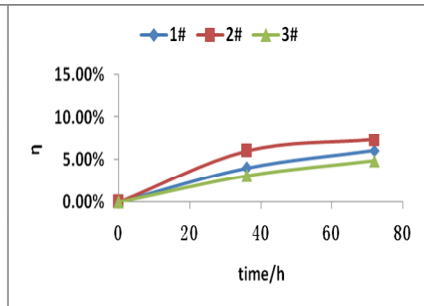Fig.5 P=0.6MPa, relationship between θ and soaking time

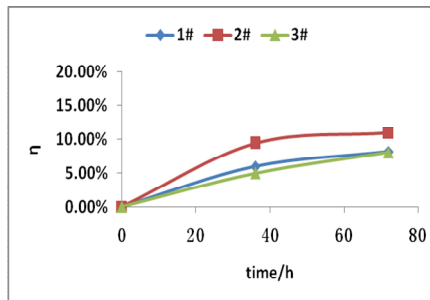Fig.6 P=0.4MPa, relationship between η and soaking time

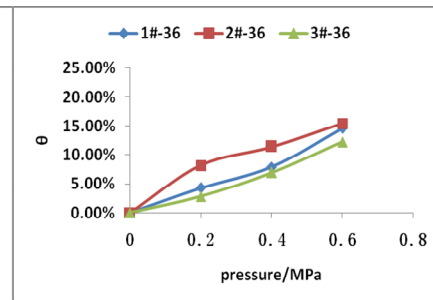Fig.7 P=0.6MPa, relationship between η and soaking time

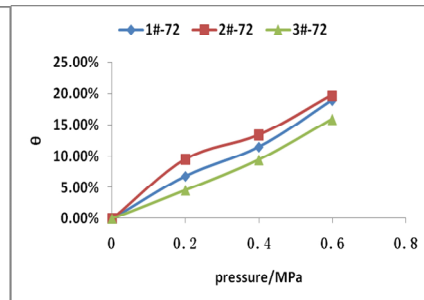Fig.8 T=36H, relationship between θ and pressure
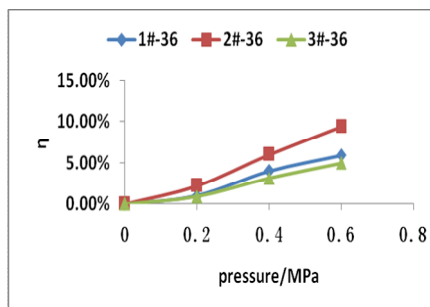
Fig.9 T=72H, relationship between θ and pressure
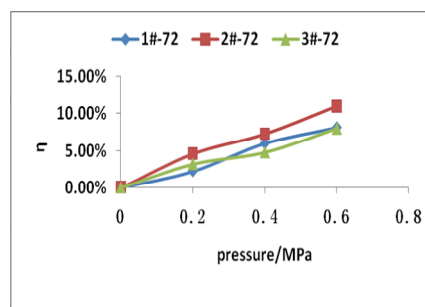
Fig.10 T=36H, relationship between η and pressure

Fig.11 T=72H, relationship between η and pressure

Data analysis

First of all, it is feasible to represent the how the denotation performance of emulsion explosive before and after soaking in water by using the detonation velocity and brisance. Parameters selection is reasonable for it is easy to distinguish the curves at different levels.

Secondly, the denotation performance of the 3 samples is weakened with higher deepwater pressure and longer soaking time, but the reduction is mild. That is, the emulsion explosives sensitized still show fine water-resistance under the pressure of deepwater. Structure determines the performance, so the water-resistance benefits from its special internal physical structure. Drops of saline solution of inorganic oxidant was protected by the oil-continuous phase, so once the emulsion explosive is dipped into water, the dissolution loss of inorganic oxidant salts such as ammonium nitrate will be protected to the maximum and water will be held back to enter into the emulsion matrix.

Thirdly, the water-resistance of these 3 explosives are: glass microsphere sensitized explosive is the best, following by the chemical sensitized one and the perlite sensitized one. The average compressive strength of glass microsphere sensitized explosive is 1.72MPa and in the experiment, its largest pressure was only 0.6MPa, as a result, only a few glass microspheres were broken under the deepwater pressure. Meanwhile, only slight the margin film damage was caused by the break up. The average compressive strength of hydrophobic perlite is 0.9MPa, close to that in the experiment—0.4MPa and 0.6MPa, therefore, more perlite were broken. Besides, the corner angles on its surface makes it easier to pierce the margin film under deepwater pressure, when the sensitization gas will be pushed out by the emulsion matrixes that are squeezed into the open gaps of the expanded perlite, resulting in sensitization failure. Exposed to the deepwater pressure for a long time, some sensitization gas is likely to bubble out of the chemical sensitized explosive.

Conclusions

After being soaked in deepwater for dozens of hours, the sensitized emulsion explosives were not changed so much in terms of their denotation velocity and brisance. The emulsion explosive remains superior water-resistance in deepwater. However, the water-resistant performance can be weakened differently owing to the different sensitizations. Therefore, in large construction of underwater blasting, the water-resistance of emulsion explosive is not the major factor reducing its denotation performance.

Since all of the experiments were conducted after releasing the pressure, the experimental results are not completely consistent with the results from field measurement, but this experimental study is of some theoretical significance for the construction of underwater blasting.

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