The groove mortar, a reliable method for testing the flameproofness of certain explosives

Jean Bigourd, J.M. Dassonville

THE GROOVE MORTAR, A RELIABLE METHOD FOR TESTING THE FLAMEPROOFNESS OF CERTAIN EXPLOSIVES

J.U. Bigourd and J.M. Dassonville

INERIS, B.P. n° 2, 60550 Verneuil–en–Halatte, France

For more than sixty years, cylindrical steel cannons (long mortar and short mortar) have been used in France to assess the safety of explosives with regard to firedamp. These testing methods are considered expensive mainly because a large number of shots are needed as a result of the low level of reproducibility. Also, using them with certain explosives, such as slurries and emulsions, is somewhat problematical. Taking into account the Polish expertise, CERCHAR (now INERIS) developed in the sixties a testing method in which the charge, placed in a steel groove mortar, is isolated from the methane–air mixture by an asbestos–cement plate. This method seems more attractive than those traditionally used, especially when it comes to distinguishing rock explosives from the more powerful permitted explosives.

INTRODUCTION

The first part of this document examines the factors which encouraged us to look for a new method for testing the flameproofness of explosives. The following parts indicate how the method was developed, together with a description of the present tests and a summary of the results obtained so far.

Explosives in French coal mines

Under French regulations, explosives designed for use in underground coal mines can be divided into three groups :

- group 1 (in French "explosifs rocher") : rock explosives, which are only allowed in the least dangerous driftings,
- group 2 ("explosifs couche") : coal getting explosives, which are mainly used for blasting operations with instantaneous firing, in main ventilation areas,
- group 3 ("explosifs couche améliorés") : improved coal getting explosives which can be used with short delay detonators, in the most dangerous working places where blasting is permitted.

All these explosives must have a good detonation ability and a low production of toxic gases when they detonate. For group 3 explosives, a low deflagrability is also required. With regard to safety in the presence of firedamp or coal dust, there is no requirement for group 1 explosives, unlike group 2 and 3 explosives for which tests must be carried out. For group 2, the approval conditions are not very severe, the main aim being to avoid ignition of a coal dust deposit as the result of a blown out shot. The approval conditions are more stringent for group 3. First and foremost, it means preventing the ignition of a cloud of coal dust (in an atmosphere which can contain a small amount of methane) in the case of exposure during delayed blasting.

Long mortar and short mortar trials

Here we are interested in flameproofness tests for group 2 explosives in the presence of firedamp. Traditionally, two types of cylindrical steel cannons are used to carry out these tests, i.e. long mortar and short mortar.

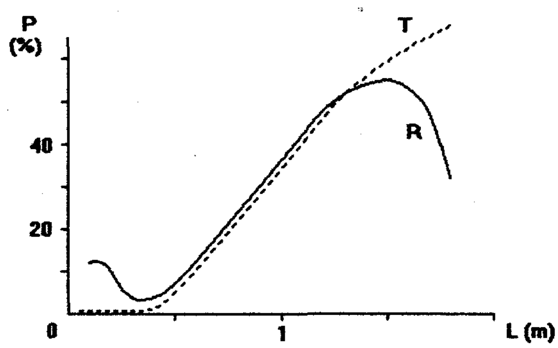
25ème Conférence Internationale des Instituts de Recherches sur la Sécurité dans les Mines, Prétoria, 13-17 septembre 1993, vol. 2, p. 133-139.

The long mortar method has been practised in France since 1907. The current procedure dates back to the 1930s (Audibert, 1931). The mortar bore is 2 meters long and has a diameter of 38 mm when new. The length of the charge varies from one test to another. It consists of one or more 30mm diameter cartridges. Inversely primed, it is pushed to the back of the mortar. The shot is fired without stemming.

The short mortar method was developed in the 1930s and the current procedure dates back to the 1950s (Loison, 1954). The mortar bore is 0.22m long with a diameter of 38mm when new. The charge is 0.18m long with a diameter of 30mm. Inversely primed, it is placed in the centre of the mortar. A steel disk, whose diameter is slightly smaller than that of the bore, is placed at the mouth of the mortar, simulating stemming. Its thickness can vary from one test to another, from 1 to 10mm or more.

Over the last forty years, our institute has carried out a very large number of long mortar and short mortar explosive tests, for the approval of new formulae and, in particular, for the inspection of explosives used in coal mines. With time, it has become increasingly obvious that both methods pose a number of problems in the case of relatively powerful explosives and do not always enable groups 1 and 2 to be distinguished.

When using the long mortar test, for example, figure 1 represents the probability of firedamp ignition as a function of the charge length. The solid line shows the behaviour of a typical group 2 explosive according to the ignition frequencies obtained in about 500 tests in which the charge had 10 different lengths ranging from 0.1 to 1.8m. The dotted line shows what it was thought happened in the past. Consequently, it was believed that by carrying out a reasonable number of shots, the characteristics of a given explosive could be determined by its charge limit (maximum charge which does not cause ignition in a fixed number of tests, usually five). When compared with what really happens, there is obviously no basis for the notion of charge limit. What is more, the state of wear of the mortar has a certain influence on the results, leading to a lack of reproducibility since it is not financially possible to change the mortar for each test. Thus, the ignitions observed with the smallest charges were mostly obtained when the mortar was new (first ten shots).



– Figure 1 –
Long mortar ; probability (P) of firedamp ignition as a function of the length (L) of the charge ; (T) old theory ; (R) reality.

Tests versus reality

Originally, according to Coward (1962), the steel mortar was chosen, in preference to blocks of rock or coal, for simplicity in preparation and with the reasonable hope of greater reproducibility of results. The tests carried out in the different experimental mines (Nagy, 1959 ; Meerbach, 1961, Cybulski, 1963) enables the official tests to be compared with the practical conditions. From these tests, it emerges that, generally speaking, the use of steel makes the tests more severe but, in certain cases, would seem to introduce artifacts. For example, it has been observed that variation in a parameter can have the opposite effect in a test and under the corresponding practical conditions.

However, the Polish slot mortar test, where a layer of clay separates the explosive charge from the methane and air mixture is an exception. It gives results in the vicinity of those obtained under similar conditions, for rock and coal, in the Barbara experimental mine (Cybulski, 1963). In 1965, we started developing a similar test which would enable us to do away with long and short mortar for the approval of group 2 explosives. This is the test which is presented here.

DEVELOPMENT OF THE GROOVE MORTAR TEST

The Polish slot mortar is a cylindrical steel mortar, a sector of which is removed over a certain length. It is therefore relatively fragile when powerful explosives are fired. To obtain a more resistant apparatus (figure 2), we milled a shallow, trough-shaped groove on one side of a block of steel. This groove, designed for 30mm diameter cartridges, has a depth of 40mm and a width of 50mm (figure 2). Provided the charge is correctly placed in the groove section using a suitable device, a free space of at least 10mm can be left between the charge and the steel, in order to reduce the wear of the mortar.

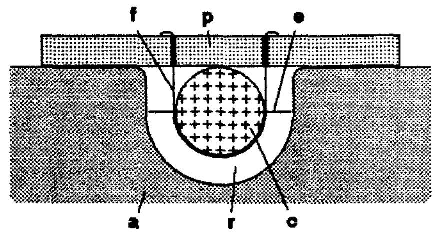
By covering the groove with a plate of material comparable to rock, we can simulate the case of a mine hole whose lateral confinement is reduced during firing of the round. To encourage lateral expansion of the gas rather than axial expansion (figure 3), the groove is filled with clay tamping (humidity 15 %), over a length of 100mm, on either side of the charge (in a long mortar shot, this amount of clay, used as stemming, largely reduces the risk of firedamp ignition).

We conducted several tests in which the groove was covered with a clay plate. We obtained comparable results to those of the Barbara experimental mine. With a group 2 explosive, a thickness of 10 to 20mm of clay was sufficient to prevent ignition of the firedamp when the length of the charge was between 200 and 500mm. However, making the clay plates was difficult and expensive. We decided to replace the clay by asbestos-cement, a material which is commercially available in plates of various thicknesses and which simulates rock fairly well. Both materials have similar densities but behave differently when an explosive charge detonates into contact with them. X-ray flashes show that blasting of asbestos-cement is faster than that of clay, for the same thickness of material. Since the shot fumes are not contained as long, it can be expected that the asbestos-cement will be a little less effective than the clay in preventing firedamp ignition.

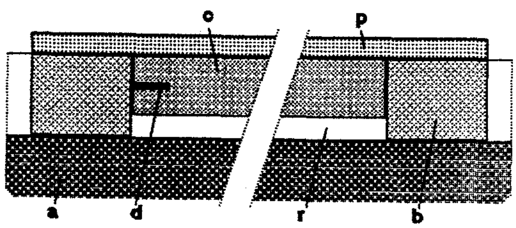
In our first tests, we used 80mm wide asbestos-cement plates. Firedamp ignition occurred for the group 2 explosives, regardless of the thickness of the asbestos-cement plate (6 to 60mm), even for small charges (100mm long). 1/25th second photographs, taken with an argon flash, showed that the blasting fumes get between the asbestos-cement and the steel, causing a large amount of luminosity on either side of the plate. This probably explains the ignitions observed. By increasing the width of the plates, we then obtained results which had a closer resemblance to those of the Barbara experimental mine. The width of the asbestos-cement plate is now fixed at 200mm. We also make sure that the plate is in close contact with the steel. When the edges of the groove are too uneven for this to be possible, we grind the surface of the steel block or we change the groove.

We varied the thickness of the asbestos-cement plate so as to determine the minimum thickness which does not result in ignition after 10 shots, for a fixed charge length. These tests were carried out with different batches of a group 2 explosives. For these batches, the ballistic mortar work ranged from 78 to 87 % of the picric acid strength. For charges with a length of 300mm or more, the minimum thickness varied considerably from one batch to another, increasing with the ballistic mortar power measured. For charges of 100 or 200mm, the results were more regular – a minimum thickness of 6 or 10mm. We chose to impose an asbestos-cement plate thickness of 6mm and vary the length of the charge from now on in order to determine the charge limit.

2



3



– Figures 2 and 3 –
Groove mortar ; cross and longitudinal sections ; (a) steel block ; (b) clay tamping ; (c) charge ; (d) detonator ; (e) lug ; (f) iron wire device ; (p) asbestos–cement plate ; (r) groove.

THE CURRENT GROOVE MORTAR TEST

Our firedamp test gallery consists of a 12m long steel outer wall with a diameter of 2m, closed at one end and open at the other. A sheet of paper, inserted in a slot located 5m from the closed end divides the gallery into two sections – the firing chamber between the paper and the closed end, and the expansion chamber. The firing chamber, where the air and methane mixtures are produced, has a volume of $11m^3$. The sides are protected with steel armour at the closed end and with an inside concrete coating on the cylindrical part.

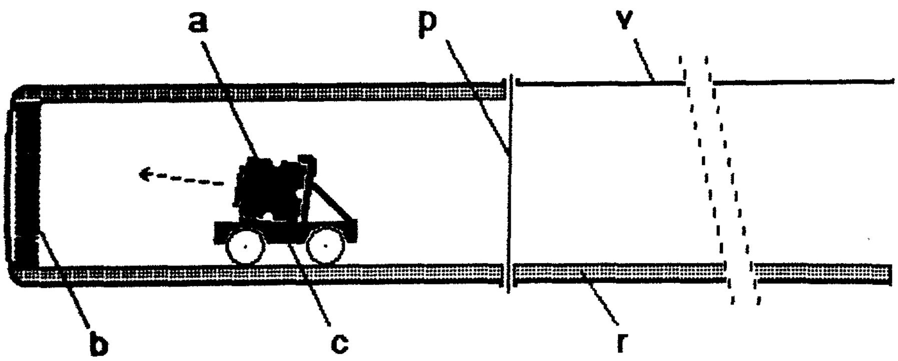
At present, the groove mortar consists of a steel block attached to a cart. The block is 1.2m long and has a square section with a side of 0.35m. It has a groove on each of the four main faces, so that its position can be changed by rotating the block one quarter turn. The groove used is that facing the closed end of the gallery when the mortar is positioned in the firing chamber (figure 4). During the test, the distance between the groove and the closed end of the gallery is 2.5m.

The asbestos–cement plate used is 6mm thick, 200mm wide and at least 200mm longer than the charge being tested. Every 100mm along its main axis, the plate has two small holes (2mm diameter), 30mm apart and symmetrical around the axis. A thin wire device (1mm diameter) through the two holes is used to attach the charge (cartridge diameter 30mm) to the plate. The wire device has two 10mm long lugs to ensure that the charge will be centred in the groove.

The groove is filled with clay (15 % humidity) along 100mm on either side of the future location of the charge. The charge–plate assembly is then placed and held placed with adhesive tape. After the methane–air mixture has been produced, firing takes place.

The length of the charge can take a series of values in an approximately geometric progression (..., 80, 100, 125, 160, 200mm, ...). It is varied from one test to another, in order to determine the charge limit.

Table 1 gives the charge limit obtained for various group 1 and 2 explosives, as well as the density of the explosive and its ballistic mortar strength (in % of the picric acid work). Explosives a, b, c, d and A are TNT sensitised explosives. Explosives e, f, g and B are NG explosives. Explosive h is an emulsion. In group 2, explosives A and B contain approximately 20 % sodium chloride.



– Figure 4 –
Test gallery with groove mortar in test position ;
(a) steel block ; (b) steel plating ; (c) cart ;
(p) sheet of paper ; (r) concrete coating ; (v) steel shell.

Table 1

Group	Explosive	Density	Ballistic mortar work	Charge limit (mm)
1	a	1.10	105	50
1	b	1.25	111	50
1	c	1.25	112	30
1	d	1.25	119	30
1	e	1.35	112	30
1	f	1.30	121	30
1	g	1.55	131	15
1	h	1.18	95	100
2	A (batch 1)	1.10	83	{ 160 160
2	A (batch 2)	1.15	87	{ 125 200
2	A (batch 3)	1.10		125
2	B (batch 1)	1.30	79	200
2	B (batch 2)	1.35	79	160

The charge limit has a length equal to or greater than 125mm for group 2 explosives, and less than or equal to 50mm for typical group 1 explosives. The charge limit (100mm) is between the two previous groups in the case of the emulsion h which is not especially designed to be a safety explosive. These results seem fairly well related to the power of the explosives determined by ballistic mortar.

CONCLUSION

Determining the charge limit using groove mortar with a 6mm thick asbestos–cement plate is a method which could replace our traditional long and short mortar methods for evaluating the flameproofness of group 2 explosives in the presence of firedamp. It has the following advantages over traditional methods :

- it can be considered more realistic in the light of information obtained as the result of tests carried out in various experimental mines ;
- it is sufficiently reproducible and enables group 2 explosives to be distinguished from classical group 1 explosives with only a small number of tests ;
- its use with powerful explosives of the emulsion type pose little problem, since it uses a relatively resistant apparatus ;
- as a result of the last two points, it is less expensive.

REFERENCES

Audibert E., 1931, "The testing of explosives", paper presented at the First Conference, Buxton.

Coward H.F., 1962, "Research on the Incendivity of Coal–Mine Explosives : A Review", S.M.R.E. research report no. 210.

Cybulski W., 1963, "Investigations on safety of explosives in presence of methane and coal dust, in coal and sandstone as well as in steel mortars", paper no. 24 at the 12th Conference, Aix les Bains.

Loison R. and Thouseau G., 1954, "Risque d'inflammation du grisou par le tir au mortier avec plaquette de bourrage", Annales des Mines, (English version : S.M.R.E., paper no. 26, 1955).

Meerbach H. et al., 1961, "Versuche zur Zündung von Schlagwettern unter Grubenbedingungen", paper no. 17 at the 11th Conference, Warsaw.

Nagy J. et al., 1959, "Hazards of Cut–off Explosive Charges in Multiple Blasting of Coal", paper no. 19 at the 10th Conference, Pittsburgh.