Testing stemming performance, possible or not?

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Synopsis

The ability of an explosive to break rock is influenced considerably by the extent of confinement in the blasthole. It is believed that confinement is improved by the use of adequate stemming. The aim of this paper is to present the results of the first and second stages of developing a stemming performance testing rig for small diameter boreholes. The rig was used to compare and contrast the performance of different designs of products. The results showed that different stemming products have differences in terms of their functionality, which can have a major impact on the efficiency of rock breaking. Two test procedures were used, one through the exclusive use of compressed air and the second using a purpose-built high pressure test rig with small quantities of explosives.

Both tests were used to identify and evaluate the ability of various stemming products to resist the escape of explosive gas through the collar of a blasthole. An investigation was done to determine the types of stemming products most commonly used in South African underground hard rock mines, and these products were used during the tests. The first stage of tests using compressed air only did not prove adequate to predict with certainty the pressure behaviour in the borehole of a particular product under high pressure conditions.

The purpose-built high pressure test rig also did not prove to be a very effective tool to test stemming products under high pressure conditions. The test rig incorporated only the effect of gas pressure on the stemming product, and excluded the effect of the shock wave. This study therefore proved that to take into account only the gas pressure generated in the blasthole is not sufficient to effectively test stemming product performance.

Keywords
explosive, break rock, confinement, blasthole, stemming performance testing.

Introduction

A literature study was conducted to assess the available field of knowledge in relation to explosives in rock breaking and, more specifically, the interaction of stemming materials with the explosive and the surrounding rock mass during the blasting process[1]. The first-phase tests were conducted at low pressure utilizing compressed air, and the second-phase tests were conducted at higher pressures utilizing ballistite (i.e. smokeless propellant made from two high explosives, nitrocellulose and nitroglycerine). The main objectives of this research weres to see if it was possible to develop a stemming performance testing system, and to investigate the possible relationship between low pressure compressed air tests and higher pressure ballistite tests.

Conceptual model of research

Brinkmann[1] has indicated that the primary mover of rock during a blast is gas energy (i.e. the heave energy generated by the rapid formation of gas). The loss of this gas energy through the collar of the blasthole results in a loss of heave energy and therefore less movement in the broken rock during a blast (Cancec *et al.*[3]). This could lead to poorer blast results (Eloranta[3]). Work by Esen[4] and Otuonye[5] indicates that the behaviour and performance of stemming materials is based on the basic principal of resistance to movement (i.e. friction). It was concluded in these studies that the use of frictional force calculations should increase the accuracy of the estimated ejection times of stemming. Thermodynamic principals also have the potential to predict the pressure changes in a blasthole (Kopp[6]). Britton *et al.*[7] developed a methodology for the calculation of borehole pressure generated by an explosive. It was concluded that a thermodynamics-based approach permits equilibrium explosive gas pressure to be calculated for initial and final state conditions while neglecting the rate of change.

Underground tests were performed to analyse the influence that factors other than stemming would have on the blasting results. The underground tests were conducted in a conventional production stope at Townlands shaft, a platinum-producing vertical shaft of

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Anglo Platinum. This production stope used conventional drill and blast mining methods. Blastholes were drilled at 80° angles to the face in a staggered pattern. The spacing between holes was 400 mm with a hole diameter of 32 mm.

The influence that factors such as changes in geology, water, inconsistent hole diameter, human behaviour, and the Hawthorne effect have on the results of the study is difficult to determine, due to the complexity of their interdependencies. It was therefore important to analyse some of these different factors that could be measured in underground tests. Three different parameters were measured. Before the blast the hole depth was recorded, and after the blast the advance and the socket depth were measured. It can be seen from Figure 1 that during shifts where holes were drilled shorter, the advance for that blast was negatively impacted. All these blastholes were stemmed in the same way where practically possible. Figure 1 indicates the impact of inconsistent drilling depths on advance as well as the socket length. The inconsistently drilled lengths are indicative of poor drilling discipline (Figure 1). The daily advance is compared with the drilled length as well as the socket length in Figure 1. The reasons for the inconsistencies in the length of the drilled holes that can be observed between shifts 6 and 9 are unknown.

The impact that stemming had on any of the factors mentioned above was not distinguishable due to the complexity of the interdependencies of these factors. The aforementioned factors led to the decision to build a laboratory testing assemblage that can separate the underground conditions from the analysis and focus on the ability of a stemming product to resist the escaping of gases through the collar of a blasthole. The rest of the study focused on the related laboratory tests.

Stemming product selection

Five generic stemming products were selected for experimental tests. No names were allocated to the products to ensure impartiality and to avoid favouring a specific manufacturer or brand type. A survey was done to identify hard rock mines in South Africa that use stemming products. The survey included 16 mining houses that used the following five common stemming products: homogeneous clay capsules (product a), homogeneous gravel capsules (product b), polyurethane foam (product c), mechanical plugs (product d), and heterogeneous gravel capsules (product e). An example of each of these stemming products was chosen for the experimental testing.

Research design and methodology

The testing was conducted using two different methods. The first method involved compressed air and the second ballistite tests to generate higher pressures in a purpose-built stemming testing rig. The compressed air test rig was constructed, and the ballistite test rig was an existing assemblage that was altered to suit the purpose of the study. The main purpose of these two methods was to determine if the behaviour of stemming products tested at low pressures compared to stemming behaviour at higher pressures. The assumption that an equivalent increase in pressure during the compressed air tests and the ballistite tests would have a similar effect on the deformation characteristics of each of the stemming products, which would therefore display similar resistance to gas pressure was also investigated. Control tests were also conducted. During these tests no stemming was used and the testing rig acted as a restricted vent. The results obtained were used as a baseline in the study.

For the compressed air testing method, a 1 m x 1 m granite block was used, in which a hole was drilled through the block (Figure 2) representing a blast hole in an underground mine. The diameter of the hole was 34 mm and the length 1 m. A steel pipe delivering compressed air was securely connected to the one side of the hole shown by position (a) in the sketch. The stemming product to be tested was placed in the hole from the opposite side, shown by position (b)). A steel tube was secured with resin into the block (Figure 2). This tube served as an anchor for the compressed air line (a), which was connected to a compressed air source. A thread was cut inside the steel tube to accommodate the compressed air coupling shown in Figure 2.

A pressure transducer was connected to the compressed air line in order to measure the change in air pressure witht time. A gate valve was installed between the pressure transducer and the compressed air source. Once the stemming product was positioned in the hole, the gate valve was opened. The pressure change was then measured and this information was captured by a data recording system.

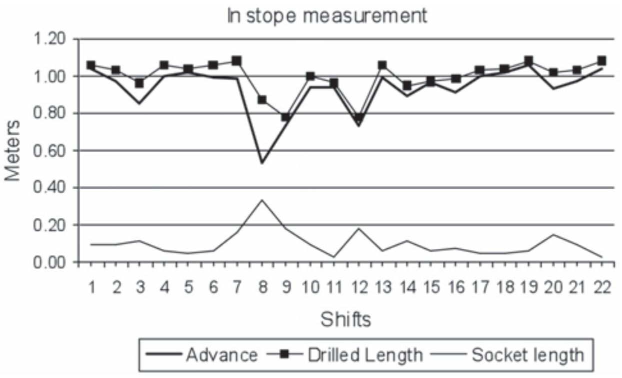

Figure 1—The measured average daily advance, drilled length, and socket length

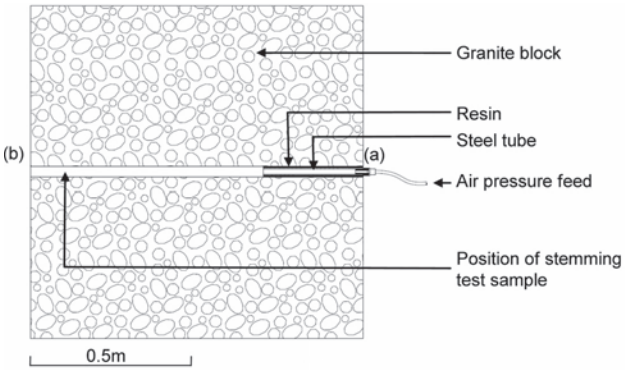

Figure 2—Sectional view of the granite block

Descriptive statistical and probability distribution methods were used during this study. Box and whisker plots were used to statistically analyse the compressed air test results. Box plots provide a quick, graphical approach for examining the data, without the need to test the assumption of the statistical distribution of the data. This eliminated the risk of incorrect assumptions about the distribution of the pressure results obtained. Incorrect variance calculations will heavily affect the accuracy of the statistical analysis, which will ultimately affect the conclusions.

The box plots shown in Figure 3 indicate the distribution of the peak pressures for all the products tested. The products are arranged from the highest median value on the left to the lowest on the right. The narrowest distribution, as well as the lowest pressure, was compared to the results obtained from the control test.

The ballistite experimental work was done with a purpose-built stemming testing rig (Figure 4). As mentioned previously, this device was an existing assemblage that had to be converted into a stemming testing rig for the purpose of this study. The device consisted of a pressure chamber made from thick-walled steel as well as an outlet pipe welded to a reaction chamber. A thick circular support plate was attached to the reaction chamber at the pipe connection. The support plate ensured a secure connection between the pipe and the reaction chamber. The reaction chamber was equipped with a safety valve, and six swing-bolts were added to its circumference. These bolts kept the door shut during deflagration, but allowed access to the reaction chamber during the loading process. A rubber seal was placed between the door and the reaction chamber to ensure that no gases escape during deflagration. A pressure transducer, attached to the reaction chamber (Figure 4), measured the pressure change in the chamber during the deflagration process. Pressure was generated inside the reaction chamber by the deflagration of the ballistite.

For the ballistite experimental work, the stemming product to be tested was inserted into the steel outlet pipe from the open-ended side (shown in Figure 4, position a). Once the stemming product was correctly positioned in the hole, a specific amount of ballistite was measured and positioned inside the chamber. This was followed by the deflagration of the ballistite using the shot exploder and an electric detonator. As with the compressed air tests, the pressure transducer measured the pressure change inside the reaction chamber during the detonation process.

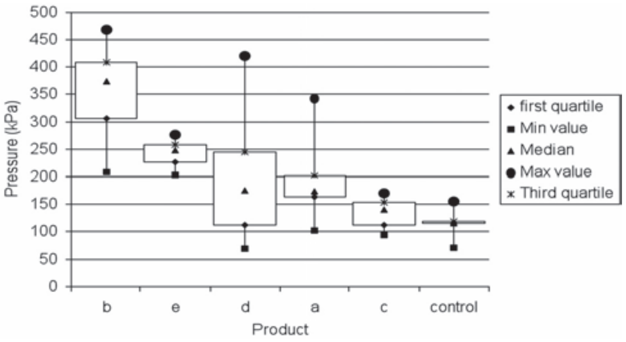

Figure 3—Box plot distribution for the low pressure tests of all the products

Figure 6 illustrates the box plot distributions for each of the products, the result of the control test, and the box and whisker plots indicating the lower, middle, and upper quartile distributions. The triangles indicate the median of each of these distributions. The products have been arranged in decreasing median value and the extreme outliers excluded from the data analysis. The limiting value of the extreme outliers was taken to be three times the interquartile range.

Table I indicates the median pressures that the different stemming products were able to resist during both the ballistite and the compressed air tests. The products have been ranked according to the median value of their pressure

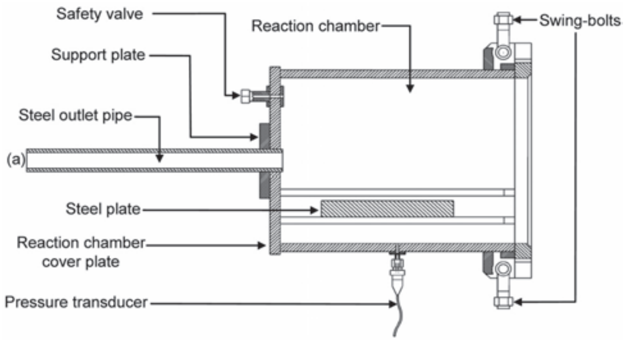

Figure 4—Sectional view of the pressure chamber

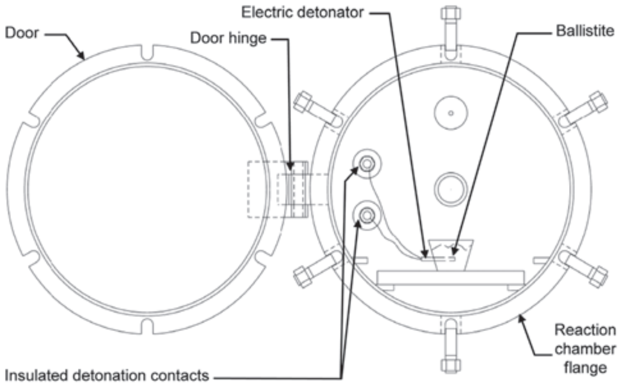

Figure 5—Reaction chamber viewed from open end with door in open position

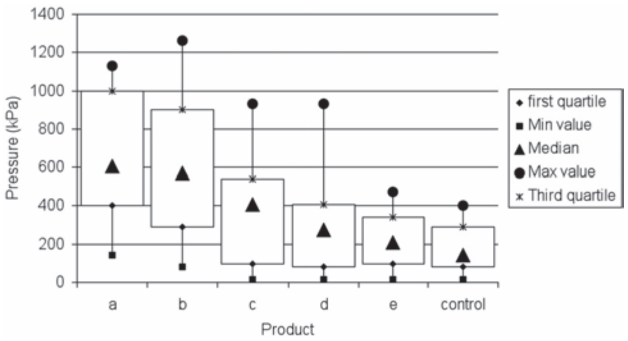

Figure 6—The quartile distribution for the products and the control test run

Table I

Ranking of products

Product	Compressed air test pressures		Ballistite test pressures	
	Median (kPa)	Rank	Median (kPa)	Rank
a	172.9	4	604.0	1
b	373.3	1	571.2	2
c	155.9	5	210.2	5
d	174.8	3	407.1	3
e	247.9	2	275.8	4
control	140.5	-	144.6	-

test results, with he product ranked 1 showing the highest resistance and rank 5 the lowest. The ranking order was determined according to these specific results and according to the specific conditions under which the tests were performed. The product ranking indicates how the products compared to one another during both tests in terms of their ability to resist gas pressure. The ranking order from the ballistite tests differed considerably to that from the compressed air tests. The results of the control test for both testing methods indicated similar resistance to pressure. Based on this fact, one could expect the test results for all the stemming products to be similar for both testing methods. This was, however, not the case due to the fact that the rate of pressure build-up for the ballistite tests was much faster than that of the compressed air, and this affected the deformation characteristics of each of the stemming products in a different way. This led to the difference in ranking between the two testing methods.

Conclusions

Neither the purpose-built compressed air nor ballistite pressure rigs proved to be capable tools to test stemming products. Compressed air and ballistite pressure tests allow some performance differentiation to be made, but in terms of performance prediction, the compressed air tests did not prove to be adequate to predict the pressure that a product can resist using ballistite. Assuming that an equivalent increase in pressure in the compressed air tests and in the ballistite tests would have a similar effect on the deformation characteristics of each of the stemming products, it could be concluded that the product that indicated the highest resistance to air pressure during the compressed air tests will also produce the same results during the ballistite tests. The lack of a good correlation between the ballistite and the compressed air test results will prevent the accurate prediction of a stemming product's pressure performance at detonation pressures.

This study has proved that there is a perceptible difference in the ability of stemming products to resist gas pressure in a blasthole when compared to the control tests. All the stemming products performed better than the control tests, but this is not a real indicator of the level of performance of the stemming products. The study also showed that the gas pressure generated in the blasthole cannot be the only parameter to be considered when determining the effectiveness of a stemming product.

Suggestions for further work

The deflagration pressures achieved during this study were some 1000 times lower than that of ANFO. A more comprehensive study should include the effect detonation pressures as well as the gas pressure in the borehole, shock waves generated by the explosive, and also the coefficient of friction of the surface of the stemming product as well as the inside of the blast hole. Such a study could make use of concrete blocks with small amounts of high explosives. Care should be taken to ensure that all the concrete blocks have exactly the same composition and the same curing time. Small explosions could be detonated in a number of these blocks and secondary effects such as fragmentation, flyrock, and velocity of detonation could be measured as an indicator of blast efficiency. The effect of the coefficient of friction should be incorporated and its effect on the results investigated.

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