

**Final Project Report**

**GAP 611**

**Realistic Dynamic Stope**

**Support Testing**

**WD Ortlepp**

**Research Agency : Steffen, Robertson and Kirsten**  
**Project Number : GAP 611**  
**Date : August 2000**

# Table of Contents

## Summary and conclusions

<b>1</b>	<b>Background .....</b>	<b>1</b>
<b>2</b>	<b>Introduction .....</b>	<b>2</b>
<b>3</b>	<b>Description of Facility.....</b>	<b>3</b>
<b>4</b>	<b>Testing Procedure .....</b>	<b>5</b>
4.1	Theoretical considerations .....	5
4.2	Controllable variables and test constraints .....	8
<b>5</b>	<b>Results .....</b>	<b>9</b>
5.1	Duropak 600 mm x 600 mm.....	9
5.2	Proof tests.....	10
5.3	Free standing tests on Mondi packs.....	11
5.4	Test on Elbroc rapid-yield hydraulic props .....	11
5.5	Six 200 mm dia Ebenhauser 2000 timber elongates.....	13
<b>6</b>	<b>Video Monitoring.....</b>	<b>15</b>
<b>7</b>	<b>Acknowledgement .....</b>	<b>17</b>

Photographs 1 to 11

Figures 1 to 7

**Appendix 1**

# GAP 611

## Summary and Conclusions

The development project GAP 611 comprised essentially four phases: design, construction, proof testing and a brief programme of testing of actual supports.

The project was driven by the perception that existing support testing equipment could provide only a quality control function. To stimulate development of innovative types of support and support accessories that would overcome some of the limitations of existing systems, required the development and construction of a completely different type of facility. The two most important differences compared with conventional testing procedures would be the provision of a discontinuous roof surface which would be subjected to dynamic loading.

Since nothing like it existed anywhere else the total design process had to start from scratch.

The performance parameters were set at providing an energy impulse of 300kJ with displacement rates of several metres per second.

The impulsive energy would be generated by dropping a mass of 10 000kg from a height of 3 metres to impact at a velocity of 7.7 m/s upon the target 'rock mass'.

The target mass was represented by a discontinuous but compact arrangement of steel-clad concrete blocks which would transmit and disperse the concentrated impact load downward on to a collapsible roof. Carefully designed, shaped concrete blocks would represent the fractured hangingwall layer of the stope, the stability of which would be determined largely by the support system under test. The other determinants of stability would be the energy of the impulse and the initial boundary conditions. The boundary conditions could be varied to some degree. Depending on these conditions and on the areal effectiveness of the support system, the hangingwall layer would have the potential to collapse between support units.

By August 1999, the design was completed in most details and construction of the reinforced concrete structure that constituted the stope was commenced. The steel superstructure was completed before the end of November but commissioning of the hoisting arrangements incurred significant delays.

Initial testing and proof-testing revealed the need for improvements in the techniques for managing the assembling and disassembling of the test structure. Improvements have been effected but it appears improbable that a complete test cycle can be completed in less than 5 days.

The three full tests on hydraulic props, timber elongates and linked timber elongate systems demonstrated that such testing can provide vital understanding of the behaviour of the support units under dynamic loading. The video-cam monitoring gives unique visual insight into the detailed response of support units to the dynamic forces that operate for a very brief period of time. This is obviously something that would be quite impossible to do in a real underground situation.

The linking of the elongates in the final test gave a most encouraging indication of how the facility can be used as a 'testing ground' for innovative developments. In particular, techniques for preventing collapses between support units and over the work area between the front line of support and the stope face can be explored.

There can be little doubt that the facility could also serve a vital training function for specialist support teams.

Finally the conviction is expressed that it is important that opinions and suggestions be solicited from the production people on the mines as well as from rock engineering staff in order that maximum benefit be obtained from the facility in the next few years.

# **SIMRAC REPORT GAP 611**

## **1 Background**

Testing of timber stope support units commenced in the early 1940's using the 1000 ton Mohr Federhof hydraulic press which is still in use at CSIR MATEK.

With the introduction of concrete components in the mid 1960's comprehensive testing to determine performance characteristics of stope packs became widespread. Additional slow-loading hydraulic testing facilities were constructed.

The increased use of yielding hydraulic props in the late 1960's led to the development of rapid-loading, dynamic-recording test equipment by COMRO. The Terratek testing machine was able to load single props at a convergence rate of up to 3m per second.

In all cases the support unit would be loaded between smooth parallel steel surfaces producing end-conditions which differ widely from the actual situation underground.

In reality the rock surfaces between which support is to function are rough and sometimes non-parallel and discontinuous. Accidents due to falls of ground more frequently result from collapses of jointed or fractured rock between support units rather than from failure of the support itself.

In the belief that significant reduction in this type of safety hazard could be achieved by examining the response of stope support systems to dynamic loading under more realistic test conditions, SRK undertook to design, build and proof test a suitable testing facility.

A copy of the relevant pages of the formal proposal is included in Appendix 1 as a record of the main motivation rationale and the intended outputs.

## 2 Introduction

The project consisted essentially of three main phases: design, construction and proof testing.

In addition, to illustrate something of the capability of the facility five actual tests of support items were planned.

These included the following:

- Simple free-standing Durapak by Grinaker
- Single tests on 2-block Apollo timber composite and Vimbela light-weight concrete pack by Mondi
- Six Elbroc 400kN RHYP's at 1.5m strike spacing
- Six 200mm dia Ebenhauser 2000 timber elongates effectively independent
- Six 200mm dia Ebenhauser 2000 timber elongates inter-linked by wire rope links

The conceptual design had been completed in broad principle by the time that the formal proposal was made. Detailed design and the acquisition or manufacture of component parts commenced at the beginning of 1999.

The project was singularly fortunate when an offer was made by AngloGold to allow the facility to be built in a disused workshop at the Satellite Training Centre on Savuka Mine. Construction of the reinforced concrete floor of the test 'stope' was commenced on the workshop floor in mid-August 1999.

Construction of the steel superstructure commenced early in November 1999 and was completed within two weeks. Progress in commissioning the portal crane and the main compressed air hoist was hampered by small design faults and lack of explicit detail in some specifications that caused significant delays. Consequently the facility become operational only towards the end of April 2000.

### 3 Description of Facility

The essential components of the testing rig are the collapsible roof that represents the hangingwall of the stope and a falling mass or drop weight that provides the impulsive energy.

Figure 1 is a scaled diagram that illustrates the main features of the facility. Photographs 1 and 2 shows the main structures in their operating environment.

The collapsible roof comprises three clamped Voussoir beams each 3m long by 1m wide made up of 12 reinforced, high-strength concrete blocks 250mm thick, 500mm deep and 1000 mm wide.

Figure 2 shows the detailed shape and reinforcement of the hangingwall blocks. Twenty-three blocks were cast with a smooth lower surface with a mass of 350 kg each and 20 were made with a non-uniform, moulded undulating base with a mass of 380 kg each.

The blocks are assembled into beams on the workshop floor with 5 steel threaded bars providing a total clamping force of some 800 kN. This ensures that each beam retains its straightness while being manoevered into position and suspended between the decks and side beams of the 'stope'.

The two side-beams, two decks and the three Voussoir beams forming the collapsible roof are supported at the corners by four sturdy concrete pillars. The height of the pillars is normally 1,4m to provide a stope width typical of Carbon Leader stopes and most Main Reef, Vaal Reef or Basal Reef stoping situations.

By adding extension columns 600mm high, the working height of the test stope can be increased to 2.0m to be more representative of Ventersdorp Contact Reef stoping.

The dynamic load is imposed on the collapsible roof by dropping a solid steel cylinder of 10 t mass from the requisite height onto a load-distribution pyramid of steel clad concrete blocks. The compressed air hoist that lifts the drop weight is attached to a traversable trolley running along an I-section

girder forming the top member of a purpose-built steel superstructure. The superstructure also supports a working floor 6.6m above the workshop floor elevation.

The drop weight is not constrained by any form of track or guides but falls freely from a maximum height of about 3m to deliver a maximum impulse of 300kJ at an impact velocity of 7.7m/s. The variation of energy and velocity as a function of drop height is shown graphically in Appendix 1.

If the support under test fails completely, a maximum of 300mm of 'free' fall after impact is permitted before wire rope tethers became effective to decelerate the drop weight and gradually bring it to rest after a further maximum 400mm of travel. The upper ends of the tethers are attached to specially designed and manufactured load arrestors which absorb the surplus energy while ensuring that the peak load in each rope does not exceed 100kN. The impact of the drop weight is taken on a 70mm thick mild steel plate which is faced with a 30 mm thickness of impact resistant steel. The concentrated impulsive force is distributed through a 4-layer pyramid of steel clad concrete blocks which are linked together in rows to facilitate removal and re-assembly. A layer of 10mm thick conveyor belt at the base of the pyramid provides protection to the top of the concrete roof blocks.

The setting load of hydraulic props or the pre-load in timber elongates is usually about 200kN. With as many as 9 support units being tested at any one time, the total upthrust against the collapsible roof could be as much as 1800kN.

As the combined weight of the roof, pyramid and impact plate is about 230kN it is necessary to provide holding-down ties to hold the roof in position while the support is being pre-stressed.

Under the collapsible roof the holding-down force is provided by six or eight flexible ties made from 975mm lengths of 36mm dia hoist rope. The lower ends are socketted into 'ferrules' which could be located at various positions along the length of two face-to-face channel box members which are integral with the reinforcement of the cast concrete of the stope floor. The box members are aligned N-S (in the strike direction) directly beneath the outer edges of the central Voussoir roof beam. The upper end of the flexible tie is



clevis-linked to a short length of threaded 40mm dia steel rod which passes through the appropriate hole in a length of channel which rests on and retains the shoulders of the roof blocks as indicated on figure 2.

The decks are each held down by 4 lengths of 40mm dia steel rods screwed at the lower end into foot-plates which locate in the same box members in the stope floor. The threaded upper ends of the tie rods pass through holes in the decks where each is secured by a 12 mm thick washer and standard nut.

The side-beams are similarly secured by ties which locate into built-in box members directly below, cast into the reinforced floor.

For the sake of simplicity, Figure 1 does not show the lines of support to be tested or the tie-down rods under the decks or side-beams.

The side-beams have a calculated weight of about 95kN each. The collapsible roof beams weigh 42kN when made up from roof blocks which have a smooth under surface and 46kN when formed from blocks which have the under surface moulded to represent a typically rough stope hanging wall. The portal crane which is used to lift and position these components is equipped with a central 5 t capacity electric hoist to handle the collapsible roof beams and the decks (shown in figure 1) and a 10 t chain-block hoist at each end to lift the side-beams when required.

## **4 Testing Procedure**

### **4.1 Theoretical considerations**

The two principal features that operate together to make the GAP 611 test stope totally different from any other testing facility are its collapsible roof and the dynamic perturbation provided by the distributed impulse loading.

It is believed that these features considerably increase the degree of variability of loading conditions that can be imposed and under which a greater variety of failure modes of the support function can occur.

This versatility of the test stope may appear to impose more onerous demands on the capability of most support types but it is felt that it is more realistic and more conservative for the designers of support for deep-level stopes to do so. However, it is important to stress that the facility does not purport to simulate reality in respect of the vulnerability of the roof to collapse or in respect to the rates at which the dynamic phenomena manifest themselves.

Although the industry has assumed a convergence rate of 3m/s as a suitable criterion for the design of stope support SRK did not feel constrained to do the same. Since it rapidly becomes impractical to handle a drop weight of more than 100kN it is in any case necessary to drop from a height of at least 3 metres to achieve a total energy of impulse that would match the levels of support density often advocated for rockburst conditions.

With the drop weight falling from a height of 3.0m, the velocity of impact is  $7.67\text{ms}^{-1}$  generating a kinetic energy of 295kJ.

Because of their inertial mass, the starting velocity of the load-distributing pyramid and the roof blocks will be considerably less than the velocity of the striking mass (the drop-weight). The theoretical velocity can be determined from consideration of the equations of the conservation of momentum.

If the 'struck' assembly was assumed to be a perfectly elastic continuum with a coefficient of restitution of 1.0, its velocity would be  $5.1\text{ms}^{-1}$ . If it were perfectly plastic with a coefficient of restitution of zero its start velocity would be  $2.56\text{ms}^{-1}$ . These theoretical velocities would only be attained if there were no other external forces acting. This is never the case during a test because there is always the resistance of the support being tested and this is usually substantial.

However quickly the roof blocks are brought to rest by the support, it is permissible to accept that their initial velocity is akin to the peak particle velocity (PPV) that acts during a seismic event at the interface of the 'layer' of loosened rock which constitutes the immediate hangingwall. It is this layer which is potentially shaken down when there is no support in place and which is accelerated downward to create the **load demand** which the support has to contend with when there is support in place.

It is believed to be very difficult to measure this initial velocity and no attempt was made to do so. Intuitively it is felt that it would be much closer to that expected from an elastic system than that expected from a perfectly plastic system. A value between 4.0 and 4.5m/s or between 50% to 60% of the impact velocity seems reasonable.

Depending on the deformation behaviour of the support, the roof blocks will normally be brought to rest within several millimetres or several tens of millimetres. The simple way to describe the performance of support is thus to observe the displacement behaviour of the concrete blocks and to record the shortening of individual support units.

Provided that the behaviour of the loading system is repeatable, the relative capabilities of different support systems can thus be compared when similar loading conditions are imposed.

From the geometry of the load distribution pyramid (LDP) it is evident that transient loads and energies will be largely concentrated over the central roof blocks and will diminish rapidly outwards. Also it is likely that their distribution will be a function of the spacing between supports and possibly also a function of the stiffness of individual support.

From the above considerations it becomes evident that the test facility should be regarded simply as providing the **means to compare the relative capacities of different support systems** at similar spacings under conditions that are more realistic than is possible to create in standard laboratories.

The relative movement between roof blocks will be a function of the support spacing, the support stiffness and the friction force acting across the interfaces between the blocks. The method of clamping the Voussoir beams together gives a measure of control over the friction effect.

## 4.2 Controllable variables and test constraints

The range of testing conditions that can be imposed include:

- variation of imposed energy between 10kJ (say) and 300kJ.
- support spacing, in strike direction, varying from 0.75m (with 2 roof blocks 'free') to 1.75m (with 6 roof blocks 'free').
- the initial axial clamping force in the Voissoir beams can be varied between 10kN and 300kN.
- the clamping can be rapidly reduced to zero after different, pre-determined amounts of beam displacement (convergence).
- the roof condition can be made plane and relatively smooth or irregularly undulating.

Because of the non-uniformity of the imposed dynamic loading and the lack of constraint or confinement in the dip direction (E – W), it is necessary that the pattern of support must be exactly the same under each of the three Voussoir beams. Each beam essentially represents a two-dimensional strike section through the stope except the load distribution is not repeated identically for each. The loading on the East and West beams would be similar to one another but the centre beam is subject to a considerably more intense load.

Although this non-uniformity of the imposed transient stresses makes interpretation of results more difficult it is believed that, in that one respect, the test situation does model reality where often the intensity of rock burst damage in a stope is very non-uniform.

To minimise bending stresses in the side-beams the lines of support units in the 3m by 3m test area are extended eastward and westward to fix the location of props along the centre lines of the side-beams. The hold-down ties are installed as closely as possible to these lines – see figure 3 and photograph 3.

Similarly, it is desirable to reduce bending and torsional effects in the relatively slender decks so the supports and hold-down ties are located accordingly.

Extending the support outwards under the side-beams and decks serves the following purposes:

- It stabilises and increases the dynamic stiffness of the 'stope' surrounding the collapse area.
- It provides more realistic boundary conditions for any system of 'safety catch-nets' between supports or of prop inter-linking to prevent collapses between support units.
- It increases the sense of realism if the facility is used for training purposes.

## **5 Results**

The limited number of tests which had been proposed were carried out with the enthusiastic co-operation of the respective support suppliers. They understood that the motivation, to some extent at least, was the need to check and develop the operational effectiveness of the facility and to gain experience of its limitations. It was not expected that comprehensive quantitative descriptions of the characteristics of the support would necessarily be achieved.

### **5.1 Duropak 600 mm x 600 mm**

A free-standing pack consisting of 14 layers of 600 x 300 x 100 modules of light weight cellular 'concrete' was assembled in the middle of the test floor. Two successive impulses of 100 kJ were imposed and the mean pack height determined after each drop

The energy/compression characteristic is shown in figure 4(a) and the appearance after the second impulse is given in photograph 4.

Applying a third impulse was not possible because the drop weight had passed the free-fall limit.

The quick-release mechanism for the drop-weight was shown to work satisfactorily and the load-arresting system operated in a perfectly stable manner.

The rapid-yield behaviour of the pack was impressively stable with virtually no rebound evident.

## **5.2 Proof tests**

Four 600mm x 600mm Duropak packs were spaced at 1,5 m skin-to-skin within the 3m x 3m test area together with two pre-stressed mine poles along the length axis of the centre Voussoir beam – see photograph 5 (a).

An impulse of 200kJ was imposed which if it had been uniformly distributed across the collapsible roof, would have caused a compression of about 70 mm on each pack.

At impact the pre-stressed props failed and the centre Voussoir beam (which had been clamped with an axial force of probably between 100 to 180kN) collapsed as one unbroken beam. The northern mine pole 'kicked out' due to the rolling out of the somewhat over-inflated pre-stressing device – see photograph 5 (b).

The distribution of mean convergence of the packs and the energies absorbed (interpolated from the curve of figure 4) are shown in figure 5. The total energy absorbed by the four packs was 141kJ which amounted to 70% of the kinetic energy at impact.

Some damage was done to some of the concrete roof blocks but more as a result of difficulty in releasing the pre-stress in the packs and extricating the partially collapsed Voussoir beams than as a result of excessive applied impulse. All other structural and operational aspects of the design appeared to be capable of operating at full design capacity.

### **5.3 Free standing tests on Mondi packs**

The 2-block Apollo pack by Mondi Mining Suppliers (an end-grain timber composite) was subjected to an impulse of 100kJ. The resulting average compression (shown on figure 4b) indicates that the pack has a very stiff response. It was also very resilient with a rebound in the order of 150mm as estimated from a video-cam recorder. The rebound resulted in a pack so badly distorted that it was not possible to carry out a second drop.

The Vimbela is a 'poro-concrete' pack manufactured by Mondi which has similar yielding characteristics to the Durapak. It was also subjected to two impulses of 100kJ with compression of the structure measured at four corners after each drop. The mean convergence is plotted in figure 4 (c). The appearance of the pack after the second drop is shown in photograph 6.

### **5.4 Test on Elbroc rapid-yield hydraulic props**

Six Elbroc 400kN rapid-yield hydraulic props were arranged in two rows in the 'dip' direction, under the 3m x 3m collapsible roof. The central Voussoir beam had the moulded impression of a rough hanging wall on its lower surface. The dip lines of props were extended to underneath the centre position of the side-beams. Four additional rows of props stiffened-up the north and south decks and the ends of the side-beams. All props were equipped with extension pieces and head-boards – see photograph 7.

The system was subjected to two impulses of 70kJ and 150kJ. Convergence measurements were made after each drop using a simple tape-rule. Video records which could be re-played in such a way as to record the progressive falling of a roof fragment through 1.2m height across 9 video 'frames' for

example, were captured during each drop. Photograph 3 is an example of a video frame which shows the rapid emission of prop fluid during the first impulse. The duration of the jet was about one-fiftieth of one second.

The measured convergence and corresponding inferred energy changes are plotted against the prop positions in figure 6.

The axial clamping force in the Voussoir beams was estimated to be about 250kN. Following the first impulse of 70kJ sag at the centre of the west Voussoir beam was estimated at about 45mm. Estimating the relative movements between roof blocks of the centre Voussoir beam was more difficult because of the undulating surface of the 'rough' hangingwall, but maximum sag could have been as much as 150mm – see photograph 7. Slight opening of the gaps between roof blocks was visible.

The measured convergence across the props showed, somewhat surprisingly, that only the props under the southern end of the central Voussoir beam recorded significant positive closure. The stope widths at the other prop positions appeared to have opened slightly.

Study of the video records showed clearly visible outward movement of the tops of the props which was immediately reversed as the props settled back into their original position. There was also an apparent, but less obvious, rebound and recovery of the vertical component convergence.

A more likely explanation of the negative convergence probably lay in the fact that the sagging in the centre of the beams was accompanied by an uplift at the outer ends with slight rotation over the tops of the props. While the clamping force is maintained by tension in the steel bar along the beam axis, such a mechanism is possible.

After the second impulse of 150kJ the continuity of the central Voussoir beam was lost as the wedges which maintained the tension in the bar were kicked out and the four central roof blocks collapsed completely – see photograph 8. An increase in convergence, ranging between 7 and 35mm, relative to that after the first drop was measured at each prop – see figure 6.



Assuming that the yield resistance of each prop is 400kN, the total measured increase of 94 mm represents an energy change of 37.6kJ which is only 25% of the energy input of the second drop. Possible reasons for the difference between energy input and energy accounted for, include:

- real loss of energy through the slightly disrupted pyramid of the steel-clad load-distributing blocks which resulted from the first drop.
- under estimate of the amount of convergence suffered by each prop (part of the convergence is recovered by the resilience or re-bound)
- possible under-estimate of the average resistance load of the props. If the actual velocity of closure is higher than the 2.8m/s of the Terratek test machine in which the props are calibrated, the peak resistance could be considerably higher than the 400kN of the prop specification.

## **5.5 Six 200 mm dia Ebenhauser 2000 timber elongates.**

The third full system test in the facility was intended to gain insight into two different aspects of stope support. Firstly an indication would be gained of the effectiveness of fairly closely-spaced timber elongates acting separately. Secondly the effect of inter-linking of individual props as a means of preventing collapse of hangingwall between supports, would be explored in a preliminary way.

The test procedure adopted was identical, as far as possible, with that followed in the case of the test on the Elbroc hydraulic props. The important difference was that the 6 test elongates and the 14 surrounding elongates (under the side-beams and inner edges of the decks) were installed with a diagonally-crossed pair of wire rope links 'sandwiched' between the cut end of the timber pole and the concrete roof.

The wire rope link was formed from a 12mm dia strand of hoist rope with an aluminium-ferruled loop at each end, of 1.4 m total length.

The looped ends were drawn together with a length of polyethylene braided rope and then supplemented with a double 'ring' of 6mm flexible wire rope fastened with a Crosby clamp.

Care was taken to ensure that the links were effectively slack so that the small amount of convergence or sag expected from the first impulse of 70kJ would not be restricted in any way by the pressure of the links. Photograph 9 shows that the link crossing the top of the south centre elongate has been pressed into the timber by the small convergence of the first impulse. However, the slight sag visible in its extended length on either side demonstrates the lack of tension in the link.

This lack of tension in the links and the very small amount of relative sliding that was visible between the adjoining roof blocks, suggest that the 1.1m strike spacing between elongates (4 block kinematic freedom) was adequately close to maintain stability under a 70kJ energy impulse.

Photographs 9(a), 9(b) and 10 show that the second impulse caused considerable sliding of the roof blocks immediately to the north, before the tension in the link prevented further movement. Viewed from the east side photograph 11 shows the extent to which the roof blocks have moved before their arrest and the appearance of connecting ring of 6 mm flexible wire rope.

The amount of convergence measured on each elongate after the second drop is plotted in figure 7 together with the amount of energy inferred from the averaged deformation response of several 200mm dia elongates which had been tested under the Terratek testing machine.

These six energy values total 158kJ which is 72% of the combined energy of the two impulses. Safety and timing constraints prevented the measurement of convergences after the first drop of 70kJ. It is obviously necessary that a remote and relatively rapid means of measuring convergence should be developed. It was noted however the wedges which retain the tension in the axial tensioning bar had been 'kicked out' of the centre of Voussoir beam.

The clamping force had consequently reduced to zero before the second drop.

Despite the lack of convergence measurements it was clear that the yielding mechanism and the stability of 200mm dia elongates were adequate under moderate energy dynamic pulses under the more realistic conditions represented by the test stope.

It was further seen as most promising that relatively simple linking arrangements could prevent the collapse of roof blocks even when the constraint of the active clamping force had been removed.

## **6 Video Monitoring**

The use of high quality video camera and software (but not specialised ultra-slow motion equipment) was found to be very useful as an aid to understanding the duration and sequence of the dynamic episode of impact, movement and re-attainment of equilibrium. It is clear that it will be even more useful in the analysis of failure of any component of the support should such occur under higher-energy impulses.

The potential for using relatively simple video-visual recording for more advanced analytical studies such as the determination of rate of convergence has still to be explored.

It is self-evident that the video-recording will be invaluable as a technology-transfer medium and as an instruction aid when the facility is used for training purposes.

A simple edited version of the video record of the two main tests will be supplied with the hardcopy version of this report.

## 7 Cost Estimates

For estimating the cost when contemplating future use of the test facility it is necessary to consider two types of tests.

Low energy repetitive impact or controlled testing would involve low-energy impulses where monitoring of displacement and energy distributions would form the principal output. The main purposes of such testing would be analytical and fundamental research.

High-energy, disruptive testing would be necessary to meet the requirements for proof-testing of particular support systems and comparisons of performance of different types of support components. Visual documentation by means of video photography would be required in addition to routine measurements of energy and displacements.

Low energy repetitive impact tests:

Labour (5 days)	R 7250
Supervision (incl. conventional photography)	<u>R 2700</u>
	R 9950

Disruptive tests:

Labour (6 days)	R 8700
Supervision	R 2500
Video photography and editing	<u>R 3000</u>
	R 14200

Both estimates include travelling but exclude VAT.

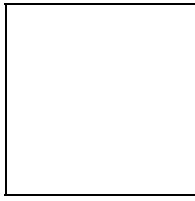
## **8 Acknowledgement**

The SRK project team wishes to record their appreciation of the encouragement and support provided by SIMROSS and Alan Naismith of AngloGold. Most of all our sincere appreciation is expressed for the constant help and constructive advice provided by Mr Terence Isherwood of the Satellite Training Centre and all his staff.



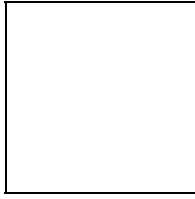
**Photograph 1:**

View towards the south, of the stope with the drop weight temporarily berthed at the centre of the stope floor. The portal crane is positioned near the north end of the stope and its legs largely obscure the four main columns which disappear into the gap in the roof where they support the hoist and traverse superstructure. The stairway which leads to the upper working floor is visible behind the west leg of the portal crane. The inverted concrete blocks of the centre Voussoir beam are visible in the centre of the middleground and the steel-clad load distribution blocks are stacked in the right foreground.



**Photograph 2:**

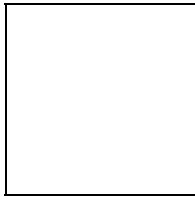
View north of main components of test stope – collapsible roof beams and load distribution pyramid are not in place. The box channels for anchoring the holding-down ties are visible in the floor of the stope. The drop weight is being hoisted to its permanent berthing place on the upper floor whose main supporting beams are visible against the dark background of the steel grid floor at the top centre of photograph.



**Photograph 3:**

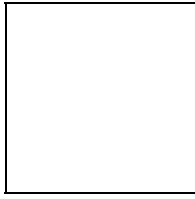
View eastwards, of the Elbroc rapid yield hydraulic props about one-hundredth of a second after impact showing release of props fluid.



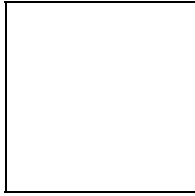


**Photograph 4:**

View of stand-alone Durapak pack after two impulses of 100 kJ each. The dropweight is stably balanced on the top of the yielded pack.



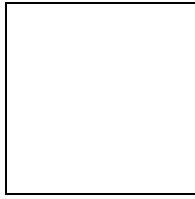
**(a)**



**(b)**

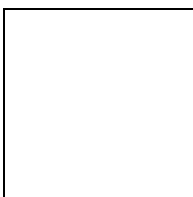
**Photograph 5:**

- (a) View south of Durapak packs under east and west Voussoir beams and 2 pre-stressed timber poles under centre beam.
- (b) Instant of collapse of centre beam.



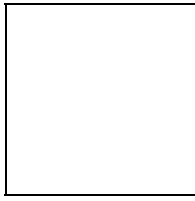
**Photograph 6:**

View of free standing Vimbela pack after two impulses of 100 kJ each. Drop weight is stably balanced on top of impact plate.



**Photograph 7:**

View west of southern row of hydraulic props the centre three of which were under test, after the first impulse of 70 kJ. Substantial sliding of the roof blocks of the rough central Voussoir beam is evident and considerably less relative movement between the smooth H/W blocks of the eastern Voussoir beam is visible in upper right corner of photograph.



**Photograph 8:**

View westward of four totally collapsed central blocks of centre Voussoir beam after the second drop of 150 kJ. The blocks are suspended by two flexible wire ropes that were loosely threaded through the top two holes (supporting bar holes) of the Voussoir beams. Little additional sliding appears to have occurred in the eastern Voussoir beam where the clamping tension bar is still in position.



(a)



(b)

**Photograph 9:** Detailed views from west of the top of the centre south elongate a) after the first impulse of 70kJ and b) after the second impulse of 150kJ



**Photograph 10:**

View from the west showing the centre elongate in the southern dip row and the considerable extent of the sliding movement of the adjacent roof blocks towards the north.

The mode of yielding of the Ebenhauser 2000 is also clearly visible.



**Photograph 11:**

Close view of the large amount of slip of the roof blocks of the 'central beam' before the restraining effect of the link ropes came into play. Note the tension in the connecting ring of 6 mm dia flexible wire rope.



