COALTECH

Final Document

Test Report

Vibrant Roadheader Trial

Brandspruit Colliery

J Maaren

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EXECUTIVE SUMMARY

The Vibrant Roadheader trial is about much more than simply testing a machine and seeing if it works. It is of crucial importance that the cost of capital mining equipment in South Africa becomes more cost effective in the medium and long term. From the experience gained in testing the ELMB-75C Vibrant Roadheader it has been learnt that this Vibrant Roadheader sets a firm foundation to build forth form towards this ultimate strategic end.

The other primary objectives of the trial was to evaluate the fundamental rock cutting ability of the vibrating technology to effectively break rock intrusion types commonly encountered in South African coal mines. Towards this end, a standard Vibrant Roadheader was imported from China and adapted to conform to our local flame proofing requirements. After identifying an appropriate mine (Sasol's Brandspruit Mine) and specifying a series of tests, the adapted machine was then deployed and tested from March to October 2006.

*This report is effectively divided into two partition*s, the first covering operational issues and findings (Section 2 and 3) and the second covering engineering or research issues and findings (Section 4 and 5). The rest of the report is included for the sake of completeness, comprehension and clarity.

For a conclusive result to be obtained on the ability of the Vibrant Roadheader to cut sand stone intrusions, one of two outcomes had to be achieved. Either the machine had to break the rock at reasonable rate, or, the machine had to be damaged, severely worn or broken by this attempt. In spite of a sustained effort to achieve one of these two outcomes, neither option could be attained nor could any conclusion to the Vibrant Roadheader's fundamental ability to cut these sandstone types be reached. In its current form, the Vibrant Roadheader is simply too light, flexible and under powered.

However, despite this result, *a significant amount of learning and experience was obtained.* It is now understood what modifications are needed to the current embodiment of the Vibrant Roadheader to obtain a conclusive result on its fundamental ability to cut the sandstone types. Further, a few niche coal cutting applications were identified for which the current embodiment IS ideally suited, especially considering that a non-vibrating unit (which is much cheaper) is also available from Aerosun. The two most important niche applications in order of importance are firstly in cutting burnt coal before and after passing through a dyke, and secondly in cutting remnant coal ahead of dykes and while establishing new production sections after passing through dykes and other geological disturbances.

During the November 2006 Aerosun visit to South Africa, meetings with the DME, CSIR, Brandspruit, Industry Leaders, the Coaltech Management Team (CMT), the Chamber of Mines and the Engineering Subcommittee took place. A report on the meetings and their outcomes was compiled and issued to the CMT. The way forward was also discussed with Aerosun, whom are now sending another high level delegation to South Africa in March 2007, to build upon the foundations laid.

Since highly sensitive negotiations are currently ongoing between Coaltech and Aerosun and the nature of the information contained in this report is of strategic importance to Coaltech and its member organisations, **the contents of the report** is to be considered **highly confidential** and may **not be exposed or distributed to anyone outside Coaltech**.

PREFACE

A primary problem in South African coal mining is the intrusion of hard geological disturbances into the coal seams, commonly referred to as sandstone lenses and floating stone. Existing high production coal mining equipment is easily damaged by these stone intrusions, resulting in very expensive, time consuming repairs. The only currently available viable alternative means of extracting this coal is by means of drill and blast techniques (which are comparatively expensive, yields relatively low production volumes and damage the surrounding strata with the blast concussion, producing unstable ground conditions and safety concerns). The net result of this is that coal mines leave the bulk of this stone intruded coal behind un-mined and write off this reserve. National lost reserve estimates due to this intrusion problem vary from 20 % to 30 % of the total coal reserve, representing billions of Rands in potential revenue.

In 2000, rumours started to surface from China that they had developed a vibrating cutting head roadheader technology capable of cutting sand stone bodies at reasonable production rates. After a sustained interaction with China regarding this technology, a breakthrough was achieved in 2004 when Coaltech was invited by the parent manufacturing company to visited China and observe the new coal cutting technology first-hand.

For the past two years the engineering committee has concerned itself with obtaining and testing one of these vibrating-head coal cutting machines, known as the ELMB-75C Vibrant Roadheader. After a few more technical visits to and from China to negotiate and purchase a unit (Figure 1), the first ever exported Vibrant Roadheader from China was delivered to the appointed South African colliery (Sasol Brandspruit Mine) in December 2005, where the unit was adapted to conform to our own national flame proofing standards, before being deployed to conduct an operational underground trial.

Figure 1: Collage of a few photos during the visit to China

The Vibrant Roadheader trial at Sasol's Brandspruit Mine colliery commenced in March and was recently concluded in October 2006.

ACKNOWLEDGEMENTS

The invaluable assistance, commitment and effort received from staff at Sasol Mining Central Workshops, Brandspruit Mine, Aerosun and Coaltech in conducting this trial is gratefully acknowledged. Without the contributions made by the Coaltech member organizations, this trial would not have been possible.

The following lists of people are specifically acknowledged:

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Explolabs & DME	Kobus Joubert – Director (Explolabs) Anthony Coutinho – Senior Inspector (DME)
Past Management Involvement:	JJ du Preez, Ertjies Ernst, Wayne Webster

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GLOSSARY OF ABBREVIATIONS, SYMBOLS, TERMS AND DEFINITIONS

All abbreviations, symbols, terms and definitions are included in the body of text or are common English abbreviations.

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1 INTRODUCTION

Figure 2: Brochure model of the ELMB-75C

The Model ELMB-75C Vibrant Roadheader (Figure 2) is part of a series of coal extraction machinery manufactured by Aerosun Corporation, which is a subsidiary of China Aerospace Science & Industry Corporation (CASIC), with all components made in China. The mode of cutting is by means of a longitudinal axis boom type pineapple-head radial cutter.

Scope of application

Model ELMB-75C Roadheader (Referred to as '75C' or 'Vibrant Roadheader' hereafter) is an integrated machine designed to operate in underground workings of any shape. The Vibrant Roadheader can mine in coal headings with an inclination of up to ±16° and material with a Protodyakonov coefficient of f = 7. The maximum effective cross section that can be cut while stationary is 17 m^2. A model SZ-2D2 loading mechanism (manufactured by Jiangyin Coal Machinery Factory) is incorporated into the Vibrant Roadheader. Telescopic belt conveyers, shuttle cars, scraper conveyer, etc. can be used as transfer loading equipment behind the machine.

Characteristic features

- The Vibrant Roadheader is highly adaptable and completely driven by hydraulic power, except for the cutting and hydraulic pump motor (electrical), and is built compliant to prevailing Chinese flame proofing standards.
- All hydraulic loops are provided with heat exchangers to ensure continuous operation.
- The Vibrant Roadheader is 2.2 m high when fitted with the canopy and offloading boom extension) and can operate in headings higher than 2.5 m. The minimum cross sectional area that can be excavated is approximately 6 m^2.
- The Vibrant Roadheader is equipped with a vibrating device in its cutting head to greatly increase its capacity to cut harder materials.
- The Vibrant Roadheader is fitted with stability jacks to the back of the machine. This also assists in maintaining flotation while operating on bad ground conditions.
- The machine is equipped with explosion and dust suppression water sprayers, integral to the cutting head (also called a 'wet head') and on the cutting boom, fitted

directly behind the cutting head. Additional explosion and dust suppression sprayers are fitted to the loading throat of the machine.

- There are various safety interlocks integral to the electrical control systems. The electrical control is built for ease of control, safe and reliable operation and is equipped with two cutting motor power indicators, one of which assists the driver to gauge the level of loading on the cutting head during operation.
- The speed of cutting motions can be varied to adapt the rates to the hardness of material being cut, so as to optimise cutting rates and reduce pick consumption rates.

Primary specifications

Outline dimensions:	8.2 × 2.0 × 2.2 m (L x W x H)
Blade width:	2 m (2.5m when fitted with side plates)
Weight:	23.4 ton
Total installed power:	130 kW
o Cutting Motor:	75 kW
o Hydraulic Motor:	55 kW
Max. height of reach:	3.59 m
Max. width of reach:	4.85 m
Sectional form of heading:	Any shape (at maximum reach – Trapezoidal shape: at top 3.7 m, at bottom 4.85 m, with a height of 3.6 m)
Technical cutting hardness:	f = 7 (as a rule of thumb: UCS = 70 MPa)
Cutter head rotation speed:	35.6rpm
Cutter head swing speed:	2 set rates (adjustable by technicians)
Cutter head maximum swing angles (75C):	Upper 46° Down 24° Left/right ±40°
Depth of ripping reach:	240 mm below horizontal
Conveying type:	Double-chain flight scraper conveyer
Scraper size:	Ø18 × 64 mm circular chain
Loader type:	Star wheel
Conveying capacity:	100 m^3/h (± 700 m^3/shift)
Tramming type:	Caterpillar Crawler type
Travel speed:	Dual speed, 2.5 or 5.2 m/min
Mean specific compression:	0.14 MPa
Pressure of various loops:	Various pressure loops
o Cylinder:	14MPa
o Travel:	20MPa
o Scraping:	16MPa
o Loading:	10MPa
o Vibration:	19MPa
Oil tank volume:	530 liters
Oil Type:	68# anti-wear hydraulic oil
Supply voltage:	1140 V (actually used at 1000 V)
Flame proofing:	Compliant, and intrinsically safe
Dust and explosion suppression sprayers:	Wet-head, with additional sprayers
o Source:	Underground water pressure
o Supply pressure (min/max):	15 / 30 bar
o Pressure booster fitted:	No (optional extra)
o Free flow requirement:	Q = 80 l/min

1.1 SA Mining Conditions

Test site selection was based on a tender process. Three mining groups responded. Through a majority vote at the Engineering Committee meeting, May 2004, it was decided to run the trial at Sasol's Brandspruit Mine (Figure 3). The test site specification essentially required the availability of coal (including soft stone) and three rock intrusion types within the coal seam, namely sandstone floors and roofs, sandstone lenses (also called floating stone) and dykes (also called dolerite intrusions). Each response was evaluated on its own merits, since generic specifications could not be drawn up to adequately specify all mining conditions and geology encountered in the South African coal mining industry.

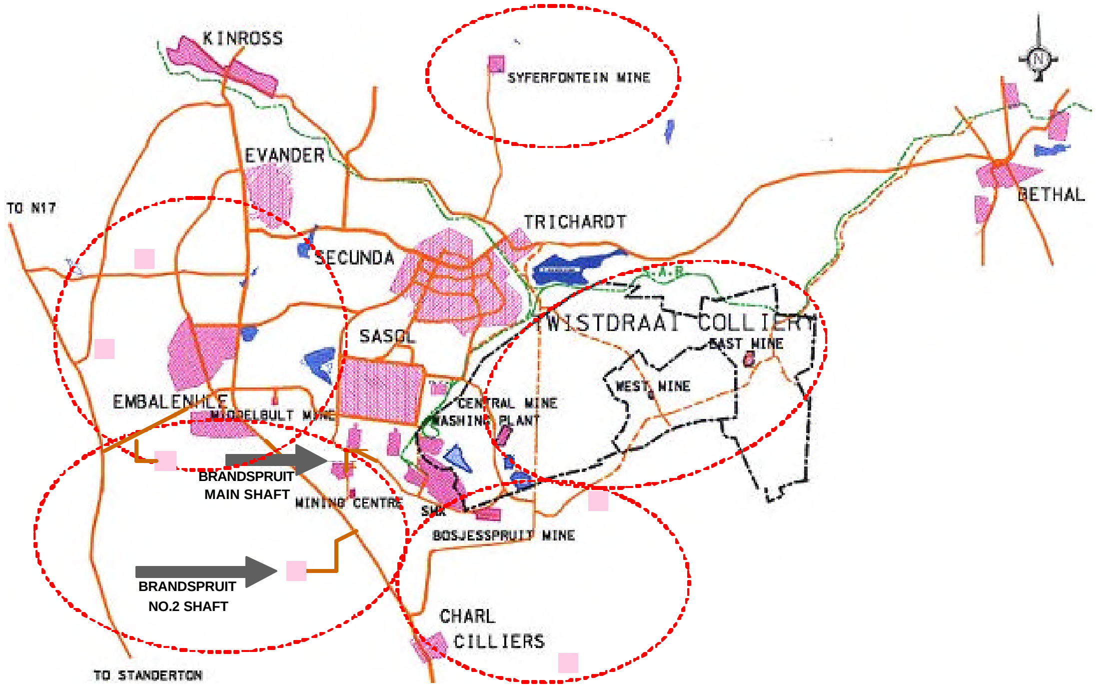

Figure 3: Area selected to test the machine (courtesy of Sasol)

A modified test procedure was followed. Initially, two complete test procedures were written[1]. However, actual test site conditions and mine-specific safety considerations required that the originally proposed split phased testing sequences not be followed.

In spite of the fact that all mining conditions cannot be found in a single coal mine, mining conditions at the Sasol Brandspruit test sites are considered representative of mining conditions that are roughly comparable to general wide-seam coal mining conditions encountered within the Witbank coal fields. Two test sites were used. The first test site was focused on coal cutting tests, while the second was focused on testing stone cutting abilities. Both test sites used were located in standard board and pillar mining sections, manned and managed by one of Brandspruit's stone work teams. Table 1A (Appendix 1) lists the generalised Geological Exploration detail for the area where the Vibrant Roadheader was tested. Table 1B (Appendix 1) lists additional geotechnical information for the No 4 seam.

Additional test results conducted on the sandstone floor and roof samples collected (Table 1C, Appendix 1) specific to the stone cut with the Vibrant Roadheader are shown in Table 1D (Appendix 1).

1. Maaren. J. 2005. Vibrant Roadheader Test Programme. *Coaltech Test Procedure. 2005-0346.* Johannesburg: CSIR, NRE: Mining. *Original Version:* June 2005, *Revised Version:* March 2006

1.2 Coal Mining Sector Expectation

The following list represents a client specification of what industry expects from an ideal machine capable of cutting stone intrusions found in South African coal seams. The list is compiled from industry feedback during the trial:

1.2a.1. To cut through dykes with a UCS of 190 to 200 MPa;
1.2a.2. To cut down brushing (Sand stone with a UCS of 90 to 100 MPa or Shale's with a UCS of around 40 M Pa), for conveyor drive installations;
1.2a.3. To be considered a production machine, at least 40 000 tons of coal must be cut per month. For non-production consideration, 6 000 to 10 000 tons should be produced in sections which have in-seam stone bands and mud shale (with a UCS of around 90 MPa and 30 to 40 M Pa, resp.);
1.2a.4. To compensate for lower production rates, it is essential that the machine's purchase and repair price stays low and that spares are readily available and their supply reliable;
1.2a.5. To stay competitive, pricing strategy must keep the machine marketable;
1.2a.6. To assure local compatibility, the OEM must incorporate mine and industry specific design changes into new machinery, which may be required locally;
1.2a.7. To minimise local alteration requirements and time lost to affect these modifications, the OEM should engineer and manufacture the machine to comply with our flame proofing and other relevant legislation and standards, specifications for U/G equipment;
1.2a.8. To standardise and reduce costs, Coaltech Engineering should come up with a standard specification for the machine, which encapsulates all BHPB, Anglo Coal, XSTRATA, TOTAL and other coal mining company requirements into a single standard specification to be submitted to the OEM;
1.2a.9. To grow the local coal mining industry, a low-cost efficient mechanised coal extraction machine is needed for the local smaller coal mines, whom cannot afford the very expensive continuous miners (called a CM or CM's hereafter) currently on offer in South Africa;
1.2a.10. To speed up access for production sections through stone work developments, a machine is needed to cut coal and burnt coal at rates significantly higher than drill and blast rates and that does not damage the adjacent geology with the blast concussion; and
1.2a.11. To ensure free and fair competition between local suppliers of high production machinery, a new entrant capable of significantly undercutting current pricing is needed (thus assuring the lowest cost per ton and maybe even higher tonnages).

Eleven operational applications have been identified from industry feedback for the practical application of a non-production type of coal and stone cutting machine (for which the only practical alternative technique generally is only the drill and blast method):

1.2b.1. Cutting coal with lenses;
1.2b.2. Mining through burnt coal;
1.2b.3. Developing through up and down throws;
1.2b.4. Mining through bad ground/overlay (CM's are sometimes also used, at the risk of loosing the machine);
1.2b.5. Replacing a CM with "Super" sections - with two to three machines at half the cost of a single CM;
1.2b.6. Brushing of belt ways and roadways through coal (also done with CM's, but at cost of lost production);
1.2b.7. Smoothing of the floor in roadways;
1.2b.8. Cutting through remnant coal ahead of Dykes, left due to strategic extraction of the section;

1.2b.9. Cutting sumps and water traps into the floor;
1.2b.10. Removing bad roof – mechanised baring & removing loose rock after blasting through brittle material, e.g. after holing through a dyke (also done manually); and
1.2b.11. Re-establish the section after going through a dyke.

1.3 Selected Tests and Pass Criteria

One of the primary objectives of the trial is to validate that the machine is able to cut various rock types commonly found in the South African coal mining industry, by using the vibration technology built into the cutting head (Figure 4). The Vibrant Roadheader was not designed to be a serious production machine. It is stressed that there was thus no production expectation from the machine and consequently, there was also no focus on measuring any specific production rates by the machine.

From a cutability perspective, pick wear or damage and relating it to tonnage mined was monitored. Since the trial was the ideal opportunity to quantify additional parameters such as some data indicative of machine reliability and longevity was also collect.

To assure statutory compliances, additional test program procedures were adopted, based on mine operational and health and safety (H&S hereafter) Codes of Practice in force at Brandspruit Mine. Further, the OEM (Aerosun) was in attendance for the first two weeks of the underground trial to assure effective training and safe operation of the machine. Since the original test procedure could not be blindly followed (see Section 1.1 above), the detailed implementation of the testing procedures was assessed and amended as new learning was obtained.

What became apparent throughout the trial was that in order to obtain a conclusive result on any of the proposed tests, fundamentally, either or both of two preconditions had to be met. These are:

- The machine must break the rock; and/or
- The rock must damage, wear or break the machine.

Figure 4: The business end of the Vibrant Roadheader – the cutting head

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2 ACHIEVED OUTCOMES, RESULTS AND DISCUSSION

The Vibrant Roadheader trial was essentially completed early in October (except for a production trial currently underway at Brandspruit to benchmark the production capability of the current embodiment of the vibrating technology in the ELMB-75C Vibrant Roadheader). In spite of the very unfortunate outcome that neither of the two fundamental prerequisite to obtaining a conclusive test result (Section 1.3 above) was met in any of the stone cutting tests conducted, very valuable learning was obtained that should greatly benefit the South African coal mining industry (Section 3) as a whole. The fundamental prerequisites were essentially not met due to various embodiment design reasons, as detailed in this report. The relatively short duration of the trial also played a role, but to a lesser extent.

Aside from the learning obtained, this section also explains the reasons for obtaining inconclusive test results.

2.1 Planned Tests

Four groups of cutting tests were planned, namely Coal (and soft stone), Sandstone floor and roof, Sandstone Lenses (also called Floating Stone) and Dykes (also called Dolerite Intrusions).

2.1.1 Coal Particle Size Distribution Cutting Test

The aim of the Particle Size Distribution (PSD) test was to quantify the ability of the vibrating technology to produce fewer fines while cutting the coal, relative to alternative un-activated processes. The coal cutting test (which is also the least strenuous cutting condition to expose the machine to) was also used as a training program to allow Aerosun to train and certify competent local operators and trainers, and to allow the operators to gain experience in using the machine.

Results

The Vibrant Roadheader cuts the hard Sasol coal effortlessly. Initially the OEM 'zig-zag' cutting pattern was used, but proved ineffective. Numerous other cutting patterns were tried. Eventually, a 'central reaming' process was used, where the cutting head is sumped into the middle of the face, and then the cutting head is motioned in a counter clockwise widening spiral from the sumping point. This reaming method proved to be the most successful and productive method.

Initially coal was cut using the vibration mechanism fitted. However, due to the rate at which the cutting head can pass through the coal seam, its effectiveness is minimised in that the instantaneous rate of cutting head motion starts to approach the instantaneous backward motion rate of the picks, which ultimately negates the 'hammer' effect sought with the vibration technology. Coal is cut most effectively with the vibration mechanism switched off.

During downward and sideway cutting strokes with the cutting heads, the body of the Vibrant Roadheader was prone to inadvertent sudden movement, causing a safety risk for people around the machine and reducing the rate of cutting and the accuracy of the cut. The problem was especially prevalent when cutting vertical strokes, resulting in slanted sidewalls ('leaning' out at the top, i.e. tunnel is wider at the roof). To overcome this problem, the rate of cutting motion had to be reduced. Additional consequences from this unplanned machine movement is that it is very difficult to cut relatively smooth sidewalls (which display a typical vertically aligned waved pattern) and that cutting long strait tunnels requires close monitoring on an ongoing basis.

Cut coal from the reaming process is qualitatively coarse (i.e. from observations only). The sprayer system effectively controls the amount of respirable dust levels to well below industry acceptable norms (Table 2A and 2B, Appendix 2).

The loading spade is too far behind the cutting head, resulting in a cut coal muck pile forming below the cut face (Figure 5), up to 1.4 m high. When cutting the lower half of the face, this cut coal is then reground to a fine mix. The muck pile also buries the cutting head when making the lower passes, which hinders the operator from accurately controlling floor cutting height, resulting in a slightly uneven floor and occasional ridges that foul with the loading spade under the muck pile when the machine advances for the next cut. Sometimes the operator continued to cut coal while the shuttle car was away, unloading. Normal advance times then often slowed down while moving forward due to the sheer volume of the muck pile created.

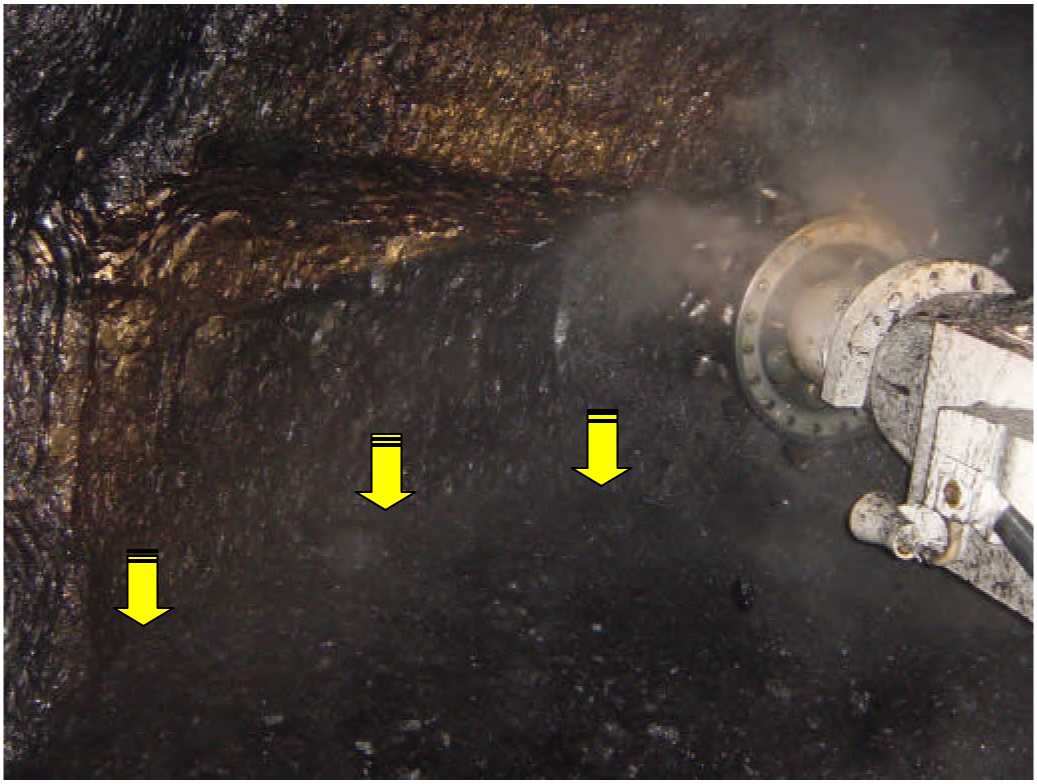

Figure 5: Muck pile forming below cutting head (below arrows)

From 15 March to 4 May 2006, 65 m of tunnel was cut through coal, 4.8 m wide, 3.4 m high (i.e. with a cross sectional area of approximately 16.3 m^2 or a total volume of approximately 1060 m^3). The highest shift advance rate achieved during the cutting test was just less than 10 m, with an average advance rate of 6 m per shift obtained. The full coal seam, including a little floor and approximately 400 mm of the shale layer above the coal seam, was removed. Cut coal was initially removed with an Aimco and later by a shuttle car. Only one shuttle car was available for the trial. The shuttle car could not be effectively loaded (approximately loaded to 1/3rd of its capacity only). Generally, cutting operations were interrupted for a period at least equal to the loading period, while the shuttle car offloaded. Loading and offloading times were roughly equally split and resulted in a 14 to 16 minutes cycle (where a ‘cycle’ constitutes a cutting/loading and offloading loop).

Cutting operations were initially significantly interrupted by inspections and checks too. However, the total logged cutting time on the cutting motor hour meter indicated 56 hours. The cutting motor current is only registered if it is higher than 60 % of maximum rated operating current for the cutting motor. Manual timing records indicate that the actual cutting times are approximately 30% longer than that indicated on the hour meter.

Discussions

The unplanned movement of the Vibrant Roadheader is indicative of one of two machine characteristics: it is either overpowered or underweight. Subsequent testing in the roof (Section 2.1.4) eliminated the overpower cause and emphasized that the machine is somewhat underweight for our harsh mining conditions.

Due to the designed embodiment geometric relationship between the cutting head location and the position of the loading spade, cut coal cannot be loaded at the same time that it is cut. This results in the creation of a cut coal muck pile exiting against the face. In order to advance forward for the next cut, the full face has to be cut down to the floor level to prevent the spade from ramming against the uncut section of the face. The net result is that the cutting head passes through the muck pile a number of times, regrinding and pulverising the cut coal into a predominantly fine composition.

Because of the regrinding, it became superfluous to conduct the PSD test on the cut coal since the test results would not accurately indicate the ability of the vibrating technology to produce coarse cut coal.

To effectively clear away cut coal and to smooth out the floor somewhat, operators of the Vibrant Roadheader have learnt to keep the loading spade in close contact with the floor while advancing (to the extent that the front portion of the cat tracts are a little off the ground and only the rear section drives the machine forward). When the muck pile occasionally becomes too big, the volume of material to be processed by the conveyor is too much and the machine battles to move forward in the normal manner, leaving the impression that the machine is somewhat ‘stuck’. When the loading spade fouls with the occasionally formed ridges on the floor below the muck pile, this hindrance is sometimes mistaken to be due to loading issues and results in timely delays until the operator realises that the spade is fouled and slightly lifts the spade to advance. A ‘floating’ spade principle may alleviate this problem to a large extent.

The loading boom extension modification was aimed at allowing a standard 12 ton shuttle car to park sufficiently close to allow offloading. Due to the fixed embodiment of the boom behind the Vibrant Roadheader and the relative narrowness of the cut tunnel behind the machine preventing the shuttle car from manoeuvring side to side, the shuttle car was only loaded to approximately 1/3rd of its capacity. The ineffective filling of the shuttle car necessitated more frequent trips to the dump site located some distance away than would otherwise have been necessary. The net result was a significantly reduced advance rate.

Considering the manual timing data captured, it indicates that on a continuous basis the Vibrant Roadheader would cut the 65 m of tunnel in around 73 hours (or in roughly 10 shifts). If the loading efficiency were increased to optimal levels, greatly significant improvements in cutting rates can be expected with minimum achievable shift rates estimated to exceed at least 12 m (which is only double the currently achieved average cutting rate per shift). This equates to a minimum sustainable production rate of around 290 ton per shift or 13 900 ton per month.

2.1.2 Soft Stone Cutting Test

During the coal cutting tests from 15 March to 4 May 2006, approximately 400 mm of the shale layer above the coal seam, was removed. In the coal face, there were also sporadic bands of mudstone, up to 250 mm thick.

Results

The Vibrant Roadheader cut through the shale and mudstone as easily as it cut through the coal. There was no practicable way of obtaining any noticeable differences in any performance measurements between cutting the coal and the shale or mudstone.

Discussions

From the Geotechnical data contained within Table 1B (Appendix 1), the UTS for the shale (or siltstone) varies between 40 and 80 MPa. No siltstone specific to the test site was sent away for laboratory testing. However, this test is indicative that the Vibrant Roadheader should be able to cut at least the lower UCS strength shale formations with relative ease and at comparable rates to that of cutting coal.

2.1.3 Floor Cutting Test

The floor at the test site is a fine grained laminar sandstone deposit. Lab tests conducted at the CSIR Geomechanics Laboratory (Table 1C and 1D, Appendix 1, samples F, H and J) indicate UCS strength values of around 70 to 90 MPa.

Results

Figure 6: Cutting a sump into the sandstone floor

A 4.5 m^3 sump (Figure 6) was cut in two hours into the sandstone floor on the 8th of March 2006, measuring 6.1 m long, 3 m wide and 500 mm deep at the deepest part of the 'wedge'. The machine was fairly stable throughout the process and conducted the task with relative ease. After cutting the sump, no picks needed replacement due to tip-wear (though some were replaced due to failure of the retaining circlips). Generally, the same picks were used throughout the initial coal and stone cutting tests.

During the cutting of the sump, the loading system proved unable to remove any significant amounts of cut stone from the cut sump and extreme regrinding of the cut rock occurred. Together with the dust suppression water, this resulted in a fine paste forming in the cut cavity 'mud-bath', eventually fully engulfing the cutting head.

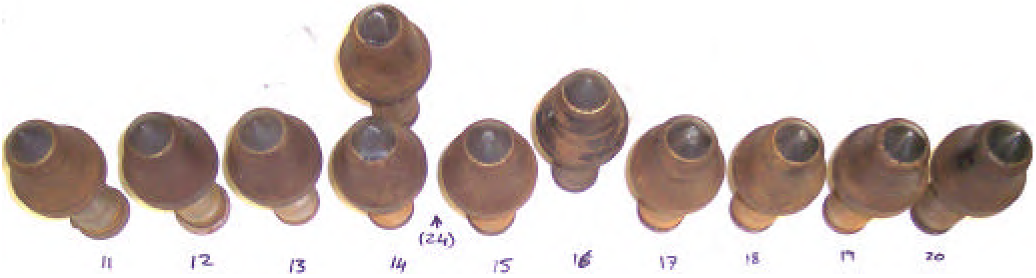

Figure 7: Full spiral of picks removed after cutting sump

After completing the sump cutting test, the picks were inspected (Figure 7). Though the pick tips generally did not show any signs of significant wear, except for two pick tips that had fractured (Figure 7, pick 14 and 24, 'coincidentally' located in the same position in their respective spirals), most pick shanks were found to be very loos in their respective pick boxes. Subsequent measurements proved that significant wear on the pick box had occurred (Table 2B, Appendix 2).

<u>Discussions</u>

Preliminary stone cutting results were very encouraging. Initial advance rates seemed comparable to drill and blast. However, the loading problem (causing severe regrinding of the cut material – see below) means that a secondary muck removal process will be required, which will drastically slow down the progress rate.

The cutting test did manage to show that very little pick wear occurred and that the Vibrant Roadheader is capable of cutting sandstone at 'reasonable' rates (reasonable being a very subjective term). The rate achieved during the tests was approximately 2.25 m^3 per hour. This is too slow for major development work, but sufficiently fast for ancillary mining tasks such as slyping, levelling of roads etc. Significant improvements in cutting rate is however possible (discussed next in Section 2.1.4).

The regrinding of the cut stone in the floor is so severe that the fine paste formed acts as an extreme 'grinding paste' between the pick shank and the un-sleeved pick holder, resulting in excessively high wear rates to these interfacing parts. As a direct result of this severe pick holder wear and the anticipation that six air crossings into the floor had to be cut, plans were immediately put into place to order a new cutting head from Aerosun, fitted with our 'own' pick boxed which incorporated a removable hardened sleeve. However, the next set of tests proved challenging and the sump cutting test was not extensively repeated. Since subsequent cutting tests in stone were all conducted in the face or roof, the regrinding problem did not reoccur and further pick shank wear was not significant.

2.1.4 Roof and Lens (Floating Stone) Cutting Test

The roof at the test sites is a course grained massive sandstone. Lab tests conducted at the CSIR Geomechanics Laboratory (Table 1C and 1D, Appendix 1, samples A, B and C) indicate UCS values of around 50 to 60 MPa (thus being 'softer' than the floor in the areas, Section 2.1.3). The lenses (which were only available at the second test site) are a medium grained sandstone and are located just below the contact layer with the sandstone roof. No reliable lens sample (from blasting activity) could be obtained and consequently, no lab tests were conducted on the lenses. The additional geotechnical averages UCS values for the mine indicates that the medium grained sandstone UCS is between 50 and 70 MPa (Table 1B, Appendix 1). However, as a rule of thumb, it is known that many lenses commonly found in the coal mining environment are higher than this, with UCS values between 120 and 150 MPa occasionally being quoted.

As part of the roof and lens cutting trial an incline through a sandstone roof and a 'black dyke' was to be cut, where after burnt coal in the new heading was to be cut, after passing through the dyke.

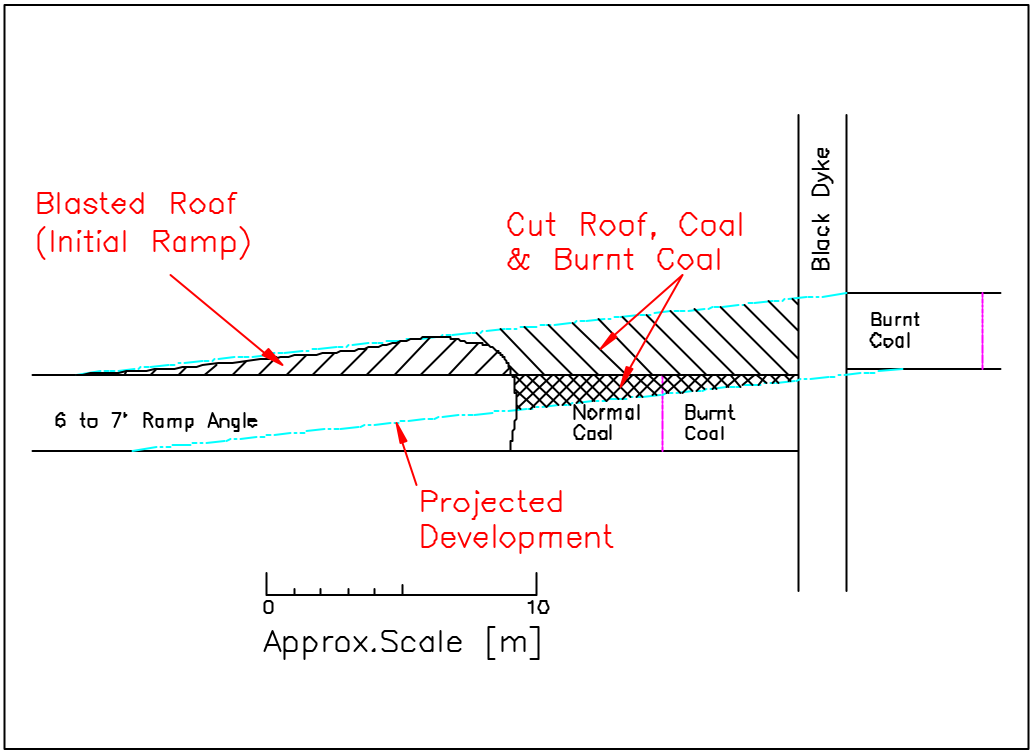

Figure 8: Second Phase incline cutting layout

Figure 8 shows a schematic layout of the planned cutting. The first part of the roof was to be blasted and the material used to create a ramp to ride the Vibrant Roadheader on to decrease the reach to the roof. The contact layer between the roof and coal seam effectively formed a low entry point to sump the cutting head into, before ripping the new face (i.e. old roof).

<u>Results</u>

Similar results were obtained for cutting the roof and cutting the lenses and are thus grouped together in this report, in spite of the fact that the tests were conducted independently. No distinction is made between the two cutting conditions, unless specifically indicated in the body of text.

The ramp can be considered bad ground, in spite of a measure of compaction. The Vibrant Roadheader cat tracts slipped on and dug into this bad ground when thrusting forwards to sump the cutting head, preventing penetration and causing the machine to list towards the dug-in cat tract side. Further, in spite of utilising the ramp to reduce the reach distance to the roof, the Vibrant Roadheader could only reach the blasted roof just below its maximum reach capability.

In spite of the softer roof conditions (compared to the floor sand stone – Section 2.1.3), the picks could not penetrate the roof sand stone. Instead, the picks scraped over the surface of the stone, scratching instead of cutting, causing increased levels of dust.

It was also observed that the Vibrant Roadheader was very unstable when cutting hard material at the limits of its upper reach. The stab-jacks sank into the bad ground and altered the position of the machine, pulling it back as they extended, reducing the sumping depth into the face. The loading blade pushes on the floor in a single central contact load point (which acts as the front stabilising point) and proved not to be very effective at this task when reacting cutting loads generated by the cutting head when extended far out to either side.

It was observed that the entire Vibrant Roadheader, and especially the cutting boom, shook and shuddered severely when cutting the roof, causing the cutting head to bounce around when in contact with the roof or lens. The cause for this excessive movement was investigated concurrently to continuing the tests. Amongst other contributory causes identified, it was found that severe wear had occurred in the pivot points of the boom and its central rotation turret, directly contributing to the excessive movement of the cutting head.

Lens cutting tests highlighted that the Vibrant Roadheader is underpowered. It was observed that every time the picks bit into an edge of a lens or was pushed hard against the roof, the cutting motor would invariably trip if the cutting head did not deflect or bounce away.

Discussions

In order to obtain a conclusive test result, either the picks must penetrate and break the rock and/or the machine should suffer some form of severe damage. Neither prerequisite outcome occurred.

The high levels of dust generation and the lack of penetration into the cut stone is a classic result of insufficient applied force when cutting rock by a mechanical means. The mechanical consequence of this scraping action is that the pick tips are worn at highly accelerated rates and that very little material is removed at anything close to a reasonable rate.

The loose ground condition of the ramp is not an exceptional condition to expect in areas where the Vibrant Roadheader could foreseeably be deployed. In order to assure sufficiently available thrust to sump the cutting head into materials harder than coal, an alternative mode of generating this thrust has to be considered. Increasing the mass of the machine will help, but may not be the optimal solution required. A hydraulic thrust system, with stinger support from the roof and/or sidewalls may provide multiple solutions, such as addressing the thrust, stability and low mass issues, simultaneously.

The stab-jacks work off one lever and the hydraulic circuit is flow split. The result of this embodiment is that the two rear stab-jacks cannot assist in levelling the machine to the desired cutting direction once one side has sunk into bad ground or when the machine stands on uneven ground. Amongst other measures (listed in Section 4), independent control of the stab-jacks is required to overcome this limitation.

The stability and stiffness of the overall machine has to be greatly improved before an assessment of the Vibrant Roadheader's ability to cut the roof or higher lying lenses can be made. The excessive play due to wear in all joints has to be greatly improved. High hardness bushings are commonly used to overcome this problem.

Another area to be addressed to increase the overall stiffness of the machine entails a few changes to the hydraulic cylinders and circuits. Load locks on all four cutting motion cylinder (on both ports of each cylinder) should greatly decrease the amount of extension rod movement due to cutting reactive forces being fed back to the cylinders. The rate of cutter head movement can be controlled by the operator by making small movements with the control lever. However, this method is impractical since it places a huge reliance upon operator skill and vibration feedback to the operator makes it virtually impossible to maintain the desired position of the cutting control levers. A better solution is to incorporate a continuously adjustable flow control valve into the hydraulic circuit to control and match cutting motion rates to required values.

The amount of power available for the cutting process (in the form of cutting torque and cutting thrust forces) has to be increased. Without an increase in available power and an increase on overall stiffness the ability of the Vibrant Roadheader to cut the sandstone in the roof and in lenses cannot be assessed.

The roof and lenses are a more homogeneous mass of sandstone. Though the floor is harder than the roof, the laminated nature of the floor creates weaker boundary layers to assist in the process of chipping off broken material during cutting. These laminate boundaries were not present in the roof massive sandstone deposit, nor in the lenses. As was observed during the Dyke Cutting Test (next section in this report), the Vibrant Roadheader is capable of breaking very hard stone formations, which, as a rule of thumb, are generally also much more brittle than the 'softer' tone types. The lack of parting planes and the relative 'toughness' of the roof and lens sandstone also contributed to the inability of the currently embodied Vibrant Roadheader to cut this material.

The big question: "To what extent can the inability of the Vibrant Roadheader to cut the roof and lenses be attributed to the lack of overall stiffness, power and other embodiment design criteria of the machine or be attributed rather to the sand stone's material properties and the machine's fundamental technological ability?" is very difficult to answer. Since the fundamental prerequisites were not met, this question cannot be answered with any reasonable degree of certainty.

2.1.5 Dyke Cutting Test

From the roof cutting tests conducted is was obvious that the Vibrant Roadheader would not be able to sump into the dyke. For this reason, a small start-up hole was blasted into the dyke. From here it was attempted to cut the dyke using the reaming method used on coal. Later, the dyke was blasted through and the Vibrant Roadheader was used to brush away the blast fractured rock until the homogeneous base rock was exposed.

Results

The reaming cutting method did not produce satisfactory results. The Vibrant Roadheader initially removed some material (blast fractured), but once the hard base rock started being cut, progress was very slow.

At one point during the reaming cut in the dyke, the cutting head wedged solidly into the start-up blast hole and the one side of the Vibrant Roadheader lifted clear off the ground due to the reactive torque generated before the operator stopped the cutting motor (a reflex reaction).

After blasting through the dyke, the Vibrant Roadheader was used to brush away loose and blast fractured material. This material was removed at a fairly high rate and with relative ease. Pieces of loosened dyke were easily broken further by the cutting head. Throughout this process the Vibrant Roadheader shook violently at times and the cutting head bounced around significantly due to an overall lack of stiffness.

Since it was clear that this particular embodiment of the Vibrant Roadheader was at risk of being damaged before the end of the planned series of tests and that the ability of the Vibrant Roadheader to cut through dyke was a ‘bonus’ application, further testing in the dyke stopped. Instead, the opportunity to cut burnt coal directly behind the dyke presented itself and was grasped.

Discussions

Though the Vibrant Roadheader was not able to cut the dyke, loose pieces of rock were broken with ease, without damaging the cutting head or picks. The lack of stiffness (as observed by the shaking and movement of the cutting head) is a major contributor to the inability of the machine to cut the dyke. Obviously, the hardness of the homogeneous dyke is another, but the fact that the machine could break the loos rocks without visible damage to the picks is encouraging.

What this test indicates is that with the Vibrant Roadheader one would not heave to fear accidental contact between the cutting head and any hard rock adjacent to the material being cut. In other words, this is a good attribute for any mining machine.

The near-accident with the machine highlights the need for a safety interlock that monitors the longitudinal roll of the machine. If it measures a certain inclination beyond a preset value, it should cut out the cutting motor immediately, especially if available power is increased.

2.2 Opportunistic Tests

Subsequent to concluding the Dyke Cutting Test, the opportunity arose to test the Vibrant Roadheader in the Burnt Coal, directly adjacent to the dyke. Since the Vibrant Roadheader was a test machine and is equipped with a wet head and the ventilation into the test site was good, it was decided to see what the machine could do in burnt coal. Traditional mining through burnt coal is by means of drill and blast and is a very hazardous process. The largest drawback from drill and blasting is the damage to the friable burnt coal due to concussion, requiring elaborate support to maintain the structure over time.

2.2.1 Burnt Coal Cutting Test

Four roads through the burnt coal were cut. After informing the DME they immediately suspended further testing in burnt coal. In spite of this, valuable learning was obtained.

Results

Cutting rates through the burnt coal is faster than by means of drill and blast methods. However, the Vibrant Roadheader does not remove the coal so fast that methane release becomes significant. Throughout the tests, methane levels were continually closely monitored. Methane build-up was so low that no readable measurements were encountered.

The burnt coal was cut in a similar fashion to the coal cutting tests earlier. It was observed that the burnt coal broke out in big manageable pieces.

The sites where the burnt coal was cut out with the Vibrant Roadheader were monitored for a four month period, before being bricked off. Other than standard roof bolt support, no straps needed to be installed. After four months, the sides of the tunnels through the burnt coal still did not show any significant signs of degradation and crumbling.

Discussions

Even the DME is excited about the test results obtained during the burnt coal cutting trial. The following lists of pro's and cons were identified during discussions at the mine following the conclusion of the tests. Urgent follow-up is needed to ensure this exciting outcome is capitalised upon.

Advantages:

- Due to no blasting operations, there is no concussion to disrupt the geology in the vicinity;
- Smoother side walls, with no crushing;
- Faster developing in burnt coal;
- Less dust exposure to people working down stream of machine;
- Safer for operators;
- Less people in the face;
- Less support needed; and
- Reduced mining costs.

Disadvantages:

- Increase risk of faster gas releases (but controllable with proper ventilation);
- DME to be conferred with to exempt the Vibrant Roadheader to cut burnt coal.

2.2.2 Coal Production Testing

Following the conclusion of the trial to test the Vibrant Roadheader's ability to cut stone intrusions into the coal seam, it was decided by Coaltech in consultation with Brandspruit to conduct a coal production trial to benchmark the production capability of the current embodiment of the Vibrant Roadheader. Revenues generated from the trial will be used by Brandspruit to offset costs incurred to date in conducting the trial at Brandspruit.

Results

Ongoing: No results available yet.

2.3 Other Results

These results are determined from data common to all the tests conducted during the trial of the Vibrant Roadheader.

2.3.1 Pick Consumption

Any future equipment should be fitted with pick box sleeves to maximise the economic life of the boxes.

At the start of the trial, the cutting head was fitted with 32 'Chinese' picks, incorporating a Ø25 mm 'bullet' carbide tip. 320 'equivalent' Kennametal picks were also procured, incorporating a Ø22 mm C3 Cap tip. The OEM picks are secured with a circlip directly fitted to the pick stem. The Kennametal picks are secures with a '3-piece circlip' (two half collets and a circlip holding it all together).

Figure 9: Loos fitting circlip (left) and groove wear (right)

For most of the first two days of the trial, coal was cut with vibration active. On the third day, a sump was cut, also with the vibration active. Only two picks had a small chip broken off (see Section 2.1.3). Twelve more picks showed signs of light wear. The other eighteen picks still looked like new. It was however noticed that most of the pick retaining circlip grooves showed signs of significant peening on the contact edge between the pick stem and the circlip. The circlips should normally fit tightly into the recessed groove (not so in Figure 9, left), and the edges of the groove should have sharp perpendicular edges (which in Figure 9, right, have been peened to a 45º chamfer). This was determined to result from inertia effects causing the picks to rattle in the pick holder when active vibration is used without significant torque loading being applied to the cutting head. During the subsequent continuation of the coal cutting trial without vibration, two picks 'fell out' due to prior damage. At this point all the picks from one of the three lacing spirals (i.e. Picks 11 to 20 picks, Figure 7, Section 2.1.3) were removed for analysis purposes (Table 2B, Appendix 2) and replaced by Kennametal picks. Only two more picks were later replaced (with one 'Aerosun' and one 'Kennametal' pick, due to poor retention into the pick holders caused by prior damage) before the end of the coal and floor cutting trials. After concluding these two trials, all picks were removed and all the pick shafts and boxes measured (results are listed in Table 2C, Appendix 2).

From Table 2C, it is clear that all pick boxes had experienced severe wear on their bores (except for one measurement, all measured diameters are larger than the 'new' diameter condition). It is also very clear that the manufacturing tolerance on the Aerosun picks ('A' in Table 2C) varies very much. The Kennametal picks ('K' in Table 2C) seems to be made closer to an average shaft diameter of 29.8 mm, and thus also shows up yellow in the table (i.e. above the size tolerance for the Aerosun picks). Also noteworthy is that the Kennametal picks in the second spiral ('S2' in Table 2C) worked a slightly shorter period than the Aerosun picks in the third spiral ('S3' in Table 2C), yet qualitatively are worse off for wear than the Aerosun picks.

Measurements also indicated that shank wear directly behind the pick head was slightly less than the shaft wear at the other end of the pick (closest to its circlip). This wear (and that to the pick boxes) is thought to predominantly originate from the grinding past formed during the floor cutting test (Section 2.1.3, above).

Subsequent to concluding the stone cutting test, the picks were still in a serviceable condition. The picks rotated well inside the pick holders, showing signs of even wear. Since very little data could be collected on the volume of stone cut (Section 2.1.4, above), no information on the longevity of the picks can be stated with any degree of certainty. However, considering the amount of 'abuse' the picks were exposed to during the test, consensus amongst the test personnel is that their condition is better than what was expected.

2.3.2 Dust Suppression

The dust suppression system worked exceptionally well. Airborne dust levels were continuously measured (Table 2A, Appendix 2) and indicate contamination levels of between 0.35 to 2.5 mg/m^3, depending on where the measurement was taken around the machine, but were generally lower than in other areas measured on the mine. Dust levels were captured in the inlet air stream to the test site, in the operator cabin, in the air extraction flow side of the machine and in the exhaust air stream from the test site.

The perception existed that the water flow levels were higher than required (between 40 and 58 liters/min). This had two opposing results. First, the amount of spray produced was tremendous, wetting everything it came into contact with. It also created a very wet air, heavy with water that is excellent to suppress explosions. Conversely however, it was difficult for the operator to see (his face mask continuously was wet) and caused excessive amounts of slush/mud to forming in the test areas.

Plans were put in place to obtain a new range of nozzles to reduce water consumption, while simultaneously improving atomisation. After fitting, the DME visited the machine and was very impressed with the level of spray provided, in spite of the achieved drop in flow rate through the nozzles.

2.3.3 Operational Outcomes

An important operational issue observed relates to a safety concern in that the boom cutting method employed by this machine creates a slight inherent overhang in the cut coal seam. In essence, since the boom rotates three dimensionally about a central pivot point, a spherically shaped face (with rounded corners against the sidewall/roof interface) is cut. The side wall corner radius relates to the cutting drum diameter and the face radius relates to the boom arm swing length. The net result is that the face overhangs its lower part by up to one meter or so at the road heading, depending on the height to which the roof is cut. The side walls are relatively straight down, except when the tunnel is cut to the maximum reach of the machine, where the sidewalls start to overhang by up to 0.5 m per side.

The cut roof and sidewalls are irregular in shape (waved perpendicular to the direction of the roadway), due to the swinging action inherent with this boom-type Roadheader. Operator skill and machine stability were found to be the most significant factors in controlling this condition. At best, a small measure of waviness will remain.

Since the operator is sitting on the left hand side of the machine, conventional ventilation airflow (as applied at Brandspruit) from right to left cannot simply be applied, since dust is drawn over the operator. For the first test site special changes were made to adapt ventilation to improve levels of operator exposure. For the second test site the direction of air flow could not be changed. Ideally, operator position should be a specifiable purchase criterion for the Vibrant Roadheader.

It was observed that cutting two parallel paths to result in a wider travelling way than the reach of the machine, was currently impractical. The primary reason for this relates to machine instability (however operator experience can minimise the instability concern by controlling the rate of cutting – at a cost of lost overall productivity) and relatively low mass.

Initially, machine stability was fair at best, but as the trial progressed it was learnt that since the cutting head turns counter-clockwise (from operator perspective), all cutting directions had to be in a counter-clockwise direction. Cutting in the opposite direction of cutter head rotation resulted in the head tending to 'walk' over the material (primarily due to the low mass of the machine, which would then suddenly move or heave unexpectantly). For the mass of the current machine, the total fitted power in the machine is more than is necessary to move the machine by pushing the boom against any fixed point. As a result, operator skill in limiting the boom motion rate during the cutting process is the most important factor currently available to improve machine stability.

From the operator's perspective, approximately 35 % of his field of vision of the cutting face in front of him is obscured from view during cutting by the body of the machine in front of him. Initially, this was thought to be a significant factor. However, the current operators later acknowledged that there was enough of the boom spill point visible to give them a good indication of where the cutting head roughly was. This did however result in a slightly uneven floor after cutting (and occasional ridges). The operators quickly learnt how to accurately control the cutting head sideway motion within this blind spot without the need for external assistance. The 'centre ream' cutting method is particularly flexible in accommodating this visual limitation.

The only operational stoppages and breakdowns attributed to problems on the machine (other than the jammed conveyor) were due to water penetrating sensitive control panel areas, one hydraulic hose chafing through, and three broken Grousers on the cat tract. The machine was washed down every day with jetted water. On one occasion, water entered the cutting motor housing, causing an earth leakage fault. On two occasions, the intrinsically safe operator control panel got wet inside, preventing the machine from starting up. All three water related faults were simply resolved by drying out the cavities, which soon restored functionality. Replacing the Grousers was simple, since the machine is able to lift itself completely off the ground using the loading spade and two stab-jacks.

Implemented ergonomics on the machine are insufficient to cater for the requirements applicable to our South African men. The seat, control lever layout, dial location, etc all need to be revised or redesigned.

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3 DIRECTLY APPLICABLE BENEFITS

The following two categories (Section 3.1 and 3.2) present possible applications for which the Vibrant Roadheader with its currently identified capabilities and shortcomings is suited. For some applications, no or minor modifications are required and a few don't even require the vibration capacity at all. For others, the embodiment of the Vibrant Roadheader has to be altered to either adapt to operational height limitations (Section 3.2.1) or to enable a re-trial of the fundamental vibration technology base (Section 3.2.2) that should achieve conclusive results to the unanswered outcomes of this trial, as detailed in this report.

3.1 'Minimal Modification' Applications

The following applications are viable with either the current embodiment of the Vibrant Roadheader, or with two moderate modifications (to the loading spade and the off loading boom). The required level of modification is defined for each application.

3.1.1 Low Production Coal Cutting Applicability

The Vibrant Roadheader can be used as is to cut coal seams, if the size of the removed coal and the rate of removal are not of primary importance. Else, the loading spade and the offloading boom first have to be modified. Vibration is not required.

3.1.2 Burnt Coal Cutting Applicability

Burnt coal is discarded. In the short-term, the machine can be used effectively for this application without the need for any modification. Permission from the DME to utilise the Vibrant Roadheader for this specific application must immediately be sought. In the long run, the loading spade and offloading boom will have to be modified to bring this application to fruition in mainstream mining. Vibration is not required.

3.1.3 Other Applications

The Vibrant Roadheader (with minimal modification) can be used for most of the potential operational applications for the machine, as identified in Section 1.2b. These are 1.2b.2*, .4, .6*, .7, .8*, .9, .10 and .11* (* denotes vibration not required). However, to improve productivity for these applications, the two major modifications to the loading spade and the offloading boom need to be implemented first.

3.2 'Major Redesign' Applications

The following two applications seem ideally suited to the identified capabilities of the existing Vibrant Roadheader. However, before the Vibrant Roadheader can be utilised for these applications, a few major modifications have to be implemented, requiring the redesign of a substantial part of a few sub-systems on the machines, to realise.

3.2.1 Low-seam Coal Miner

By improving the loading and offloading capacity of the existing machine and redesigning the chassis to lower the overall height of the machine to below 1.2 m will embody a coal mining machine that will find immediate application within the low coal seam mining groups. Vibration is not required.

3.2.2 Larger Machine

Since power, mass and stability need to be improved, modifying a larger EBZ-120 or EBJ-132 Aerosun Roadheader to accept the ELMB-75C vibrating cutting boom arrangement seems like the most cost effective way of obtaining a machine that should be able to achieve a conclusive result to all the sand stone cutting tests conducted during this trial. Simultaneously, the opportunity would exist to test the coal cutting production rate by this bigger brother of the Vibrant Roadheader before implementing the changes, if the modification was implemented locally. Section 4 details the extent of these modifications and sub-component redesigns required. Figure 10 (Appendix 3) contains the base specifications for the larger EBJ-132 Tunnelling Roadheader. From this specification, the machine should be capable of mining up to 1000 tons of coal per 8 hour shift (calculated at 70 % of its loading capacity) and sells for around R 2.5 m per unit. Figure 11 (Appendix 3) contains the specifications for a EBZ-120 Tunnelling Roadheader, which is also larger than the ELMB-75C Vibrant Roadheader.

4 IDENTIFIED SHORTCOMMINGS

The lists of following technical review findings serve as a point of departure from which the modification and upgrading of the machine can begin. Though reasonably factually founded, some of these points reflect personal opinion or desires from various people involved in the testing of the Vibrant Roadheader. They are specifically included because of their thought provoking prospect. Ultimately, a design and review team will have to work through these lists and change them into concretely applicable specifications and designs.

4.1 Design Fundamentals

This list of modification and upgrading considerations defines issues that need to be understood or addressed before undertaking any modification or redesign exercise:

- Cutting paths are very close (probably because this is a dedicated stone cutting head design). It is not optimised for coal and burnt coal cutting. The close cutting paths contributing to the generation of fine coal and duff;
- The machine is too light for its side and downward thrust capacity and operator skill is required to prevent unplanned sudden movement of the machine to the side or from lifting at the front;
- Coal is cut best without vibration, but is reground very fine. The regrinding is predominantly caused by the ineffective loading ability of the machine;
- Two parallel roads are difficult to cut, mainly because the machine is too light and slips sideways when 'slyping', especially on the right hand side (where machine lifts and slides away most);
- Vibration (frequency and amplitude) VS slew cutting rate is not defined or understood (the limit as to how fast the head can be moved before the vibration becomes ineffective has to be understood, as well as the efficiency of the vibration mechanism before ideal cutting boom motion rates can be fixed or set);
- The machine is capable of lifting itself easily with the boom when cutting the floor, risking sudden sideway movement as the head rolls over the ground (this has not happened, but is perceived to be a risk);
- When cutting dyke, the machine jumps around too much (too light);
- Fundamentally, the machine is capable of breaking the dyke stone formation, but very slowly. Practically, the machine fails this test because it is unable to cut the dyke at a reasonable rate;
- The cut rock in a sump is not removed at all, resulting in severe regrinding of the cut rock into a fine paste;
- When cutting against the roof, the cutting head sprayers let a lot of dust through;
- When sumping the head into a stone face, the picks 'bounce' off the rock and push the machine backwards (this is worst if the machine is standing up a loose ground incline);
- The vibration cutting technology seems to work with varying degrees of efficiency, dependant upon the specific material being cut – it may need to have a variable frequency and cutting rates may have to be adapted to cut various rock types;
- A mine should be able to order the machine with driver position either LHS or RHS, dependant upon their own ventilation direction (which have not been standardised throughout the SA coal mining industry);
- To aid sumping, the cutting head may need to be fitted with a forward/backward vibration system;
- More stabilised cutting is observed when cutting reaction forces push the cutting head down;
- We could consider using alternate pick types (e.g. 'Frustum', DCP, 'Cycloidal' Tool or other type of material/design);
- The coal loading and cutting rates have to be drastically increased before the bigger mining groups will consider using the machine to cut coal. For dedicated

coal cutting in smaller mines, the machine (with two moderate modifications as mentioned in Section 3.1) should present a viable, cost effective solution to their current drill and blast mining;

- The simple hydraulic fault finding dial device and the 'posi-stop' mechanism fitted to the tramming drive train are two technological innovations implemented by Aerosun that are very effective and are significantly cheaper than other options currently employed on our own mining equipment;
- A lot of duff is created during cutting. Ensure that the cause and origin is well understood.

4.2 Operational Considerations

The following nine subsections query or provoke further thought on issues that have to be understood from the list of fundamental issues listed in Section 4.1 above.

4.2.1 Sparking When Cutting Sandstone

Sparking and hot chafers observed.

- Are sprayers effective?
- Are additional safeguards needed?

4.2.2 Ineffective Loading

Loading very ineffective for coal and other rock types; and jams easily.

- Is spade improvement possible and likely?
- Is boom conveyor improvement possible and likely?
- Is extensive modification needed and to what degree for which applications?

4.2.3 Fine Coal Produced

Cutting paths are very close and produced cuttings are very fine.

- Is coal cutting head optimised for coal cutting?
- Is correct size and length of pick used?
- Is cutting head designed for simple interchange and/or onsite exchange (between 'coal-cutter' and 'stone-cutter')?

4.2.4 Low System Stiffness

Overall stiffness of the cutting-boom, chassis and structure allows for too much flexibility and movement of the head during cutting.

- What contributes to the lack of stiffness?
- What can be done to greatly improve stiffness?

4.2.5 Low on Power (i.e. torque and force thrust)

The cutting motor trips when picks bite on protrusion and force to thrust cutting picks into the stone is too low to ensure effective penetration (the machine seems unable to reach its mechanical limits and cannot cut the rock).

- What control system parameters can safely be changed to reduce many of the trips?
- What are the interface and technical limitations to fitting a bigger electric motor or for using an alternate actuator system or technology?
- What can be done to increase the force exerted onto the cutting head?
- What hydraulic and geometric improvements can be used to improve the stability of the machine?

4.2.6 Low Effective Mass

The effective mass available to assist in the cutting process is too low. When cutting floor or cutting RHS side-wall, reactive loads lift and move the machine.

Machine is unable to thrust cutting head into sandstone (cat-tracks slip on ground). The machine's stability is also adversely affected by the low mass.

- What can be done to improve the machine's design to optimise it for maximum mass availability to assist in the cutting process?
- What are the overall size and mass limitations for the machine (and for which applications do these limitations apply)?
- What changes to the stab-jacks can be made to assist in improving the 'available' mass for cutting operations?
- Would using a bigger base machine produce significant benefits over modifying the existing unit?

4.2.7 Slow Tramming Rate

The machine trams regularly in and out of working areas to allow for support to be fitted. The available tramming rate is much too slow for production requirements. The machine is also very limited in the range that the unit can be trammed.

- What can be done to speed up existing tramming componentry significantly (at least 3 to 4 times faster, forward and in reverse)?
- What are the physical and technical limits to fitting faster tramming componentry or for using an alternate actuator systems/technology?
- What can be done to improve the effective tramming range of the machine?

4.2.8 Ineffective Cutting Ability

The vibrating action definitely improves the cutability of numerous rock types. The effectiveness of the technology is determined by vibration amplitude and frequency, as well as pick design and type. However, the machine is unable to penetrate rock at reasonable cutting rates to make it practical in a production environment.

- What are the technological key factors affecting vibration efficiency?
- Can the mechanism/technology be improved by considering alternative materials and geometry?
- Is the design optimal?
- What are the fundamentals affecting pick choice and design?
- What alternative pick-based technologies are available?

4.2.9 A Value Engineered Solution?

The base cost of the machine is very low. The technical design issues identified suggests that there is scope to improve overall value by means of applying value engineering principles.

- Is there scope to incorporate Value Engineering principles and techniques?
- Is Coaltech or Aerosun prepared to pay for services towards this end?

4.3 Technical

A slight measure of overlap (repetition) in the lists below is necessary, since some of the issues listed highlight multiple implications and areas of improvement possible. The majority of these listed issues can be simply addressed. A few will require serious thought and design planning to overcome.

4.3.1 Component Selection Issues

- Staple locks not to SA standard
- Staple lock staples (clips) vibrate loose and fall out;
- No fire retardant hydraulic hose used;
- Start key not unique and easily tampered with (i.e. 'jippoed');
- Cutting head seems to rust from the inside – causing the Water sprayers to block easily – solution needed (e.g. select an alternate component material or apply a preventative measure such as an epoxy coating to inner surfaces).

- Some bolts holding cover panels on machine vibrating loose – fit 'Surelock' washers (or equivalent) to all panel cover bolts, else an appropriate 'Locktight' product;
- Electric motor cooling ducts seem to corrode and may ultimately rust through – compromising explosion proofing and electrical integrity – consider same solutions as for the internal rust problem on the cutting head;
- The Chinese picks seem to wear slower than the Kennametal picks – investigate our options to standardise on the Chinese picks – the current high cost is an issue;
- Use mine-specific voltage supply electric motors.

4.3.2 Process Logic Issues

- Reconsider logic of only counting cutting motor operating hours if loaded above 65 % of motor current rating is a achieved – we additionally need actual running hours – to evaluate utilisation on an ongoing basis additional to understanding the working load placed on the machine;
- No 'loadlocks' are fitted to the slewing cylinders;
- Loadlocks are only available on the downward stroke side of the lifting cylinders (and are not directly fitted to the cylinder ports), allowing the cutting boom to lift under reaction forces acting upon it during cutting operations – resulting in a lack of stiffness and instability during cutting – Loadlocks should be fitted directly to both cylinder ports of the lifting AND slewing cylinders and must also incorporate over-pressure relief – in case of rock fall onto cutting boom;
- All lever motion direction and/or action direction should be synchronised with the activity direction – reconsider logic;
- Continuous oil level monitoring and safety interlock into control system, with a trip warning light is needed (monitor the oil level directly above the oil-pump takeoff port – to compensate for inclination angles while cutting downhill);
- Cutting head pineapple-shape and cutting boom arc geometric relation results in a spherical front-face and waved sidewall conditions after cutting – operator skill and consideration of this phenomenon is a critical factor in minimising this effect – consider automated means of improving this outcome;
- Flight conveyor powering logic should be revised (consider driving the loading stars directly or independently) and increase the installed power to the conveyor chain to reduce blockages of coal in the conveyor;
- Cutting motor trips often without indicating excessively high instantaneous loads, while on other occasions indicate high averaged cutting loads without tripping – the impression exists that motor tripping is erratic – evaluate trip logic;
- Adaptable variable flow control on cutting motion rates should be considered to stabilise the cutting action to a constant and ideal rate – Operator control and adjustment is needed to enable adaptation of the required cutting rate to the prevailing conditions in the area the cut is made in;
- Consider the request by mining personnel to have two (or more – perhaps variable) cutter head rotation rates, specific to cutting coal or cutting stone – additional cutting rates may even be required, dependant upon the specific stone/rock types considered;
- Evaluate the control logic actuating the stab jacks to enable assist in levelling the machine to the required cutting line on uneven ground or when one cat-track sinks into bad ground – possibly need independent control or single multi-function control lever and valving;
- Review overall system controls to minimise reliance upon operator skill to effectively utilise and protect the machine (possibly incorporate this requirement with the need to improve the surface shape of side-walls, roof, floor and face after cutting with the machine);
- Need LED faulty indictor for operator panel contact fault – it needs to determine if any of the systems are not functioning properly or if any connector or component looses supply power – a failsafe design is needed;

- Evaluate possibility of combining all the cutting motion control lever mechanism actions into a single multi-axis control lever (e.g. one-handed joy-stick type of control);
- Review stab-jack hosing logic to synchronise lever action to operating direction (currently stab jack action is opposite to lever actuation direction);
- Consider logic required to allow machine tramming control by means of foot pedals only;
- Review logic to optimise combined tramming and cutting ability, which will be especially important when executing non-bulk-material cutting applications.

4.3.3 Safety Issues

- The machine needs a longitudinal tilt interlock mechanism – interlocked with cutter motor cut-out (when cutter head 'bites', the torque is high enough to throw the machine over under certain operating conditions);
- Disengage all hydraulic levers or isolate flow circuits for the conveyor and vibration activation levers after a hydraulic motor trip or the machine has been locked out or shut down – interlocks are needed;
- Prevent direct access to the drive coupling between the hydraulic motor and its gearbox(currently this hole is open);
- The operator often 'hangs' out of side of cab to see better, especially when tramming – he is more exposed to the risk of rock fall (take this into consideration in the canopy design process);
- The cutter and sidewall/roof geometric interface results in a small radiused brow forming between side wall and roof;
- A trapezoidal shaped tunnel cross section is created (with curved sidewalls – narrowest at the top) when cutting at maximum reach – overhangs created thus are of concern;
- The machine is ideal for burnt coal cutting: Investigate requirement and apply for exemption from the DME to deploy the Vibrant Roadheader for this task;
- The sudden unexpected machine movement is a safety concern;
- Generally, review all safety interlocks and identify any possible shortcomings (e.g. oil level low trip-out, especially when working on a decline since the oil take-off point is on the rear side of the storage tank);
- Hot lingering sparks are occasionally seen travelling long distances – define the risk;
- Review the machine layout and design by considering the safety of people working around the machine (e.g. the trailing cable is located on the operator 'blind' side of the machine – this poses a severe risk to the cable handler);
- Review dead-man switch mechanism and logic – it is too sensitive to operator movement (e.g. operator foot movement due to vibration);
- Additional lighting is needed to illuminate all dark areas ahead of and directly around the machine, especially on 'blind' side relative to operator;
- The Troulex methane monitoring system has to measure closer to the cutting head.

4.3.4 Design or Ergonomic Issues

- Machine needs a proper rear bumper to protect its vitals in this area;
- Tramming levers are too low and short – ergonomic issue;
- Cutting boom cylinders do not bleed easily – air is easily trapped, resulting in flexibility (we need to change the port orientation, layout and/or piping system to ensure quick and easy bleeding of air from the cylinders, without drawing the air back on return strokes);
- Operator cabin is too small/cramped – ergonomic design needed;
- Additional lighting is needed to illuminate all dark areas ahead of and directly around the machine;
- A mechanical dial needed to relate cutter potion to cutting face in cutting blind spots (which is approximately 35 % of the face);

- Tramming speed is much too low – need mining and travelling speed (forwards and backwards);
- Spade gearbox drain plugs are prone – a protective shroud is needed;
- Faultfinding hydraulic dial needs clearer labelling indicating the four system pressure functions tested (i.e. from top-left, clock wise: travel, loading & conveyor, return line and 5-valve set);
- Fixed boom pivot point results in a 3D spherical face ahead of the machine and a trapezoidal shaped tunnel cross section is created (with curved sidewalls – narrowest at the top – when cut at maximum sideway reach);
- Machine is levelled on three points (2 stab jacks at back, centre of spade up front). Consider revised stability jack layout – at least 2 points up front and one at the back (most stable);
- Spade/boom/cutter position interface is wrong – design results in ineffective loading of cut coal, causing severe regrinding of cut material resulting in excessive amounts of fines;
- Some coal falls off the sides of the spade;
- Circlip pick retainer system damages quickly while running the cutting head with the vibration active – it has been modified to a 3-piece circlip design – problem solved (we still only need to standardise the design and confirm that there are no impeding patent rights);
- When cutting 'down dip', loading of cut material is virtually impossible – must be improved;
- Geometric relations of the machine centre of gravity relative to the caterpillar tracks and the downward reach of the cutter head result in a 'stepped' gradual start to any decline cut (such as a sump) – this effectively results in a radiused entry profile (which may also be a positive outcome if compensated for in the planning of these decline cuts, since more length is needed for the decline);
- Spade does not lift high enough – hooks on the floor for slight changes in approach angle or on irregular floor protrusions and shapes;
- Impact damper spring may be needed on chain conveyor tensioning device – forward/reversing motion to dislodge stuck conveyor seems to stretch the flight chain links due to shock loading (we determined that the flight chain operates best when slack, else redesign to require tension);
- Operator seat is inadequate – needs redesign to incorporate South African ergonomic statistics and eliminate operator vibration exposure;
- Troulex methane meter often wetted and then fails to read. Need some splash and water mist cover, without affecting monitor readings. Possibly need to relocate unit, dependant upon the ventilation direction of the mine – it should be located diagonally opposite the ideal operator location;
- Flight conveyor jams very easily and needs a stronger motor (or an additional motor);
- Spade level control logic to be revised – need floating control mode to allow spade to lift over irregular shapes of the cut floor under the cut coal heap, that the operator cannot see are there and fixed position control mode to allow spade to be used for levelling purposes (also needs safety interlock – must not be lifted if machine has been raised off the floor using the spade for repair work etc.);
- Cutting motor is not water tight – leaks water into housing, causing shorts – may be indicative of a faulty flame proofing interface;
- Electrical connections in operator control box vibrate loose;
- Operator control box collects water and humidity – contacts corroding: need air tight seal, and may possibly need additional Silica Gel dryer medium assistance;
- Chain conveyor drive shaft mounting bolts vibrate loose;
- Common greasing points are needed in a few strategic locations on machine to service all areas requiring lubrication maintenance;
- Cutting head/spade interference interlock does not work effectively, all the time (causing occasional contact between the loading stars and the cutter boom, stopping the conveyor);

- Booster pump flow control valve vibrates open – causing a loss or increase of boost pressure and unreliable functioning – fixed by securing locking screw, but a more serviceable means without special tools is required;
- Slurry forms during ‘sump’ cutting – causing excessively high pick box wear rates (a new cutting head was obtained, fitted with hardened sleeves in the pick boxes);
- Water consumption is too high;
- The chain from the chain conveyor stretches too easily;
- Consider side/roof thrusting stab cylinder – integrate with hydraulic sumping thrust, to overcome weight limitation and slipping cat-tracks;
- Lots of play caused by high levels of wear in cylinder clevises and pivot points;
- Gaps in conveyor path let large amounts of duff and broken rock fall through front and back of machine;
- Loading boom should swing up/down and sideways to effectively fill a shuttle car;
- Machine is extremely unstable when cutting high, near maximum reach – the machine rocks on it’s tracks and cutting boom flexibility is amplified;
- The operator needs a screen with a cleaning system (e.g. flowing water), else use remote control;
- On inclines and bad ground floors, machine lacks traction;
- Stab jack base plate size is too small – sinks into bad ground floor – needs bigger footprint from a removable plates to improve flotation, stability and grip when on bad ground;
- Location of driver position needs to be reviewed to aid improved vision (against need to have driver further back to increase ‘reach’ into unsupported roof before pulling machine out to allow support to be fitted);
- Turret joint shows signs of severe wear and flexibility – review design;
- Conveyor gearbox output shaft leaks intermittently;
- All pick breaks experienced so far are due to flexibility movement knocking the picks into the rock in a direction other than along is centroid axis;
- Consider increasing the rear stab-jack length of travel to assist in cutting the initial step in making a sump in the floor – reduce effect of machine geometry on the start shape of the sump or decline;
- Need operator variable flow control to match required cutting motion rate to a constant and ideal rate, dependant upon prevailing conditions at the time of the cut;
- Consider incorporating a means to independently thrust the spade forwards to assist in the loading of the cut coal below the cutting head prior to cutting the lower traverse cuts;
- Review effectiveness of the loading stars – old joy coal loader is perceived to be more efficient by the ‘old hands’ at the mine;
- Consider the use of foot pedals to drive and control the motion of the machine, freeing up the hands to control other features simultaneously while cutting coal or positioning/tramming the machine;
- Standardise the design of the picks, pick holders and three-piece circlips to retain the picks (review patent issues too);
- Redesign stab jack base plates to eliminate the hollows in which dirt collects (dirt fouls with cylinder rod and stops full travel) – review overall design and layout;
- Eliminate all hollows and horizontal surfaces on which dirt collects as far as reasonably possible;
- Review water sprays, volumes, size of droplets, location and patterns needed;
- The two venturi nozzles should be relocated higher – currently they foul with the cut coal pile and consequently block and choke easily;
- Review the size of the venturi nozzles to ensure flexible and optimal cooling flow through motors and heat exchangers;
- Review possibility to implement and incorporate remote control on the machine – will need to rely on local expertise;
- Review hydraulic hose layout to eliminate rubbing and fouling with moving and vibrating parts chaffing the hoses;

- Improve access to and lever control of the water shut-off valve;
- Eliminate Troulex shutdown resulting from suddenly opening the water control valve (unit trips and then cannot easily be reset);
- Redesign canopy and conveyor boom for easier removal and fitting or consider a hydraulically secured raising and lowering design.

5 RECOMMENDATIONS

There is a dual recommendation forthcoming from this trial. Both recommendations have been alluded to in the described applications of Section 3. The functional differences between the two recommendations stems from the contrasting time frames required to implement the recommendations. Essentially, the two recommendations require a short- and long-term outlook.

Importantly, not all viable applications for the Vibrant Roadheader actually require the vibration capability. The vibration capability is only needed for applications cutting material other than coal and burnt coal. The base machine (ELMB-75A) is significantly cheaper than the Vibrant Roadheader (ELMB-75C). The 75A should operate at least as reliably as the 75C, due to the reduced reactive cutting forces imposed upon it when only exposed to cutting coal.

5.1 Short-term Recommendations

There are a few niche applications the current embodiment of the Vibrant Roadheader can perform, requiring only the minor modifications or upgrades of Section 4, which require no major changes to the structural design of the current machine used. These changes should take less than two months to implement on the present machine, before it can be deployed.

Negotiations should be entered into with Aerosun to supply an upgraded base model machine (without the vibration capability, i.e. an ELMB-75A, EBZ-120 or EBJ-132 machine) that incorporates our own flame proofing requirements and embodies the modifications and upgrades needed. Further, a joint partnership should URGENTLY be entered into to establish local Aerosun representation that will offer the backup and technical support needed for large scale imports of any future machines specifically built for the South African mining conditions, and to assure that through Coaltech its affiliates remain influential in guiding future development, deployment and capital cost structures and strategies.

Interaction with the DME should immediately commence to obtain certification to allow burnt coal to be cut with Vibrant Roadheader machine (or equivalent). This process could take some time to complete, but by establishing this immediate niche market for an Aerosun machine, it should act as a catalyst to stimulate future Aerosun coal cutting product development for South Africa.

It is also recommended that the currently ongoing coal cutting production trial at Brandspruit Mine be monitored closely. Recorded results should be obtained and stored together with the rest of the data from the Vibrant Roadheader Trial, for future reference.

5.2 Long-term Recommendations

After completing the coal cutting production trial at Brandspruit, the Vibrant Roadheader should be withdrawn from service (indefinitely). The cutting boom assembly, turret and material conveyance equipment should be removed from the current chassis and be disassembled down to its base subassemblies. These sub assemblies and their interfaces should be inspected for additional technical insight into possible areas requiring further improvement or modification, to augment existing data, thus assisting Aerosun in developing the various solutions needed to address the shortcomings of the current embodiment.

Negotiations should be entered into with Aerosun to accomplish the development of a larger capacity modified machine that incorporates existing vibration enabled cutting boom arrangement. Ideally, this modification should be done locally to enable the base machine (probably an EBZ-120 or EBJ-132) to first be tested in a coal seam without the modification, which will allow us to gauge the base machine's production potential for normal coal extraction applications.

Aerosun should design and develop both the upgraded standard (ELMB-75A) and upgrade vibration enabled (ELMB-75C) machine to address the shortcomings identified from this trial. Specific consideration should be given to lowering the overall height of these machines to allow the No.5 seam to be exploited. The joint partnership, mentioned in Section 5.1, is possibly the best vehicle to facilitate this development. This machine will not only open up a currently untapped market in the low-seam coal mining environment (No.5 seam), but will also find extensive application within small scale and anthracite mines, which still predominantly relies on non-mechanised extraction methods. The current embodiment of the Vibrant Roadheader (somewhat modified) seems ideally suited for this purpose.

6 FUTURE ACTIVITIES AND PLANNING

The Vibrant Roadheader trial is about much more than simply testing a machine and seeing if it works. It is of crucial importance that the cost of capital mining equipment in South Africa becomes more cost effective in the medium and long term. The Vibrant Roadheader sets a firm foundation to build form towards this ultimate strategic end.

6.1 Aerosun Visit

A fact finding delegation has been sent to South Africa with the aim of establishing a long term relationship that will mutually benefit us and Aerosun. They arrived on Monday, 20 November and Coaltech hosted their visit.

Our purpose with their visit was to convey the results from the trial in a cordial and factual manner, and to further the long term relationship between Aerosun and the South African coal mining industry, through Coaltech.

Meetings with the DME, CSIR, Brandspruit, Industry Leaders, the Coaltech Management Team (CMT), the Chamber of Mines and the Engineering Subcommittee took place. A report on the meetings and their outcomes was compiled and issued to the CMT.

6.2 Coal Cutting Production Test Benchmark

The coal cutting production test results will be out in early 2007. From these results it should be possible to correctly gauge the production potential of the currently embodied Vibrant Roadheader from Aerosun. These test results will be circulated through Coaltech to member groups when and as they become available.

6.3 Final Report

This is the Final Report on the Vibrant Roadheader Trial conducted at Brandspruit colliery and incorporates all industry feedback obtained during the Chinese visit and subsequently. It is issued to inform all members of the Coaltech Engineering Committee as to the outcome of the Vibrant Roadheader trial conducted under its auspices.

Since highly sensitive negotiations are currently ongoing between Coaltech and Aerosun and the nature of the information contained in this report is of strategic importance to Coaltech and its member organisations, the contents of the report is to be considered **highly confidential** and no portion or part may be exposed or distributed to anyone outside Coaltech and its listed member organisation representatives without first obtaining explicit and written consent from the Coaltech Management Team, currently Chaired by Mr Dick Kruger, Chamber of Mines.

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Appendixes

Appendix 1

SECUNDA
COLLIERIES
NUMBER 4 LOWER COAL SEAM (Exploration information)(AD)
(No Roof & Floor contamination)

	AVERAGE	MINIMUM	MAXIMUM
Inherent moisture (%)	4.5	3.7	6.0
Ash (%)	24.3	20.2	32.3
Volatiles (%)	22.9	20.9	25.6
Fixed Carbon (%)	48.3	42.7	51.7
Calorific value (MJ/kg)	22.03	19.01	23.48
Relative density (g/cc)	1.58	1.53	1.67
Total sulphur (%)	1.26	0.58	1.78
HGI	59	56	63
Abrasiveness (mg/Fe/4kg)	255	157	347

Surface moisture (%)	3.0
Total moisture (%)	7,5

C4L ROM = 2% Roof & Floor contamination

Inherent moisture (%)	4.4
Ash (%)	26.4
Volatiles (%)	22.3
Fixed Carbon (%)	46.9
Calorific value (MJ/kg)	20.50
Relative density (g/cc)	1.62
Total sulphur (%)	1.23

Table 1A: No 4 Lower Seam Exploration Information

Geotechnical Information for the Number 4 Lower Coal Seam & related Karoo lithotypes

Average Work Index of Number 4 Lower Coal Seam = 14 KW/tonne

Average Uniaxial Compresion Strength (UCS) of the Number 4 Lower Coal Seam = 23

Micum Drum Hardness of the Number 4 Lower Coal Seam (50 revolutions)
Average size stability = 76%
Average size friability = 24%

Rock type	UCS (MPa)	UTS* (MPa)	Shear Stress (MPa)	Young's Modules (GPa)
Sandstone fine-grained	**70 - 120**	**5**	**18**	**13**
Sandstone medium-grained	50 - 70	N/A	N/A	N/A
Sandstone coarse-grained	30 - 50	N/A	N/A	N/A
Siltstone	40 - 80	6	8	10
Mudstone	**30 - 50**	**5**	**8**	**7**
Dolerite, Dyke	250 - 390	14	N/A	80
Coal	5 - 40	0 - 1	8	3 - 5

***Uniaxial Tensile Strength**

Number 4 Lower Coal Seam UCS (MPa) information

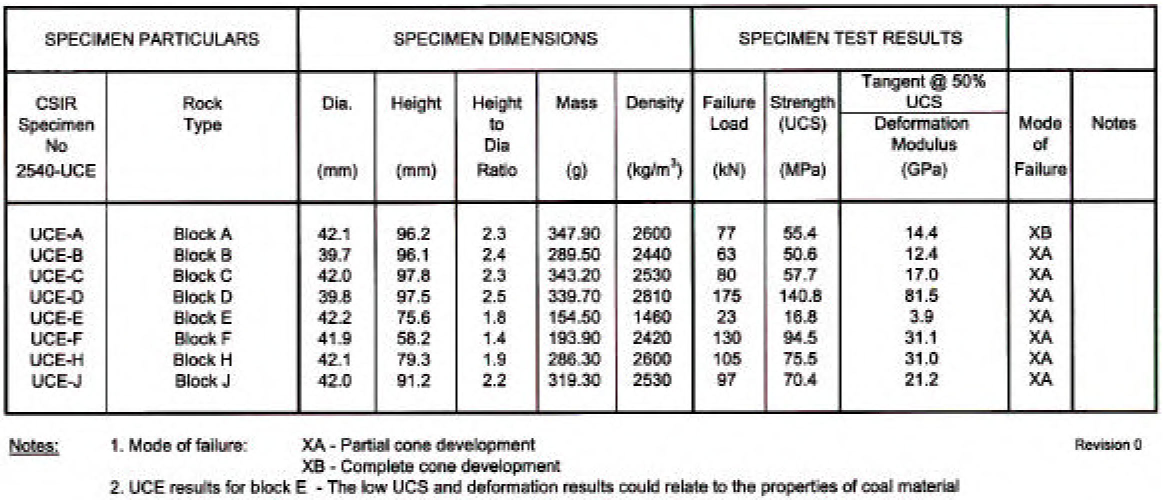
	Average (MPa)	Minimum (MPa)	Maximum (MPa)
C4L sandstone roof	78	56,5	90,4
C4L sandstone floor	72	N/A	N/A
C4L (coal)	21,9	11,8	28,1

Table 1B: Additional Geotechnical Information

No	Source	Tests	Tag	Size
A	30	All 4 (x2)	Roof Contact S-stone	Large
B	30	All 4	In-roof S-stone #1	Large
C	30	YM (+ UCS)	In-roof S-stone #2	Small
D	30	All 4	Dyke	Large
E	87A	YM (+ UCS)	Mudstone	Small
F	87A	YM (+ UCS)	Floor S-stone #1	Small
H	30	YM (+ UCS)	Floor S-stone #2	Small
J	30	YM (+ UCS)	Floor S-stone #3	Small

Note: Section 87A is the first test site and Section 30 the second test site.

Table 1C: Site specific samples collected



SPECIMEN PARTICULARS		SPECIMEN DIMENSIONS					SPECIMEN TEST RESULTS				
CSIR Specimen No 2540-UCE	Rock Type	Dia. (mm)	Height (mm)	Height to Dia Ratio	Mass (g)	Density (kg/m^3)	Failure Load (kN)	Strength (UCS) (MPa)	Tangent @ 50% UCS Deformation Modulus (GPa)	Mode of Failure	Notes
UCE-A	Block A	42.1	96.2	2.3	347.90	2600	77	55.4	14.4	XB	
UCE-B	Block B	39.7	96.1	2.4	289.50	2440	63	50.6	12.4	XA	
UCE-C	Block C	42.0	97.8	2.3	343.20	2530	80	57.7	17.0	XA	
UCE-D	Block D	39.8	97.5	2.5	339.70	2810	175	140.8	81.5	XA	
UCE-E	Block E	42.2	75.6	1.8	154.50	1460	23	16.8	3.9	XA	
UCE-F	Block F	41.9	58.2	1.4	193.90	2420	130	94.5	31.1	XA	
UCE-H	Block H	42.1	79.3	1.9	286.30	2600	105	75.5	31.0	XA	
UCE-J	Block J	42.0	91.2	2.2	319.30	2530	97	70.4	21.2	XA	

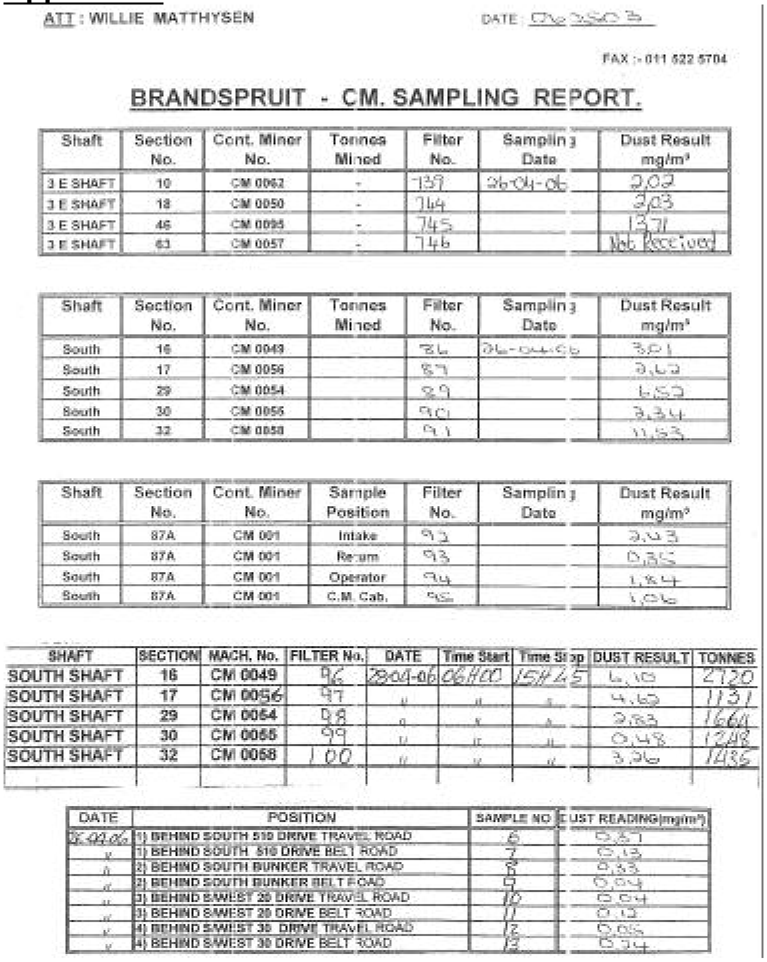
Notes: 1. Mode of failure: XA - Partial cone development
XB - Complete cone development
2. UCE results for block E - The low UCS and deformation results could relate to the properties of coal material

Revision 0

Table 1D: Results of Uniaxial Compressive Strength Tests

Note: A complete set of results from the CSIR Geomechanics Laboratory (in PDF format) is attached as loose pages at the end of this report.

Appendix 2



ATT : WILLIE MATTHYSEN

DATE : [illegible]

FAX :- 011 622 5704

BRANDSPRUIT - CM. SAMPLING REPORT.

Shaft	Section No.	Cont. Miner No.	Tonnes Mined	Filter No.	Sampling Date	Dust Result mg/m³
3 E SHAFT	10	CM 0062	-	739	26-04-06	2,02
3 E SHAFT	18	CM 0050	-	744		2,03
3 E SHAFT	46	CM 0095	-	745		13,71
3 E SHAFT	63	CM 0057	-	746		Not Received

Shaft	Section No.	Cont. Miner No.	Tonnes Mined	Filter No.	Sampling Date	Dust Result mg/m³
South	16	CM 0049		86	26-04-06	3,01
South	17	CM 0056		87		3,62
South	29	CM 0054		89		6,52
South	30	CM 0055		90		3,34
South	32	CM 0058		91		11,53

Shaft	Section No.	Cont. Miner No.	Sample Position	Filter No.	Sampling Date	Dust Result mg/m³
South	87A	CM 001	Intake	92		2,23
South	87A	CM 001	Return	93		0,85
South	87A	CM 001	Operator	94		1,84
South	87A	CM 001	C.M. Cab.	95		1,06

SHAFT	SECTION	MACH. No.	FILTER No.	DATE	Time Start	Time Stop	DUST RESULT	TONNES
SOUTH SHAFT	16	CM 0049	96	28-04-06	06H00	15H45	6,10	2720
SOUTH SHAFT	17	CM 0056	97	"	"	"	4,60	1131
SOUTH SHAFT	29	CM 0054	98	"	"	"	2,83	1664
SOUTH SHAFT	30	CM 0055	99	"	"	"	0,48	1248
SOUTH SHAFT	32	CM 0058	100	"	"	"	3,26	1436

DATE	POSITION	SAMPLE NO	DUST READING(mg/m³)
28.04.06	1) BEHIND SOUTH 510 DRIVE TRAVEL ROAD	6	0,37
"	1) BEHIND SOUTH 510 DRIVE BELT ROAD	7	0,13
"	2) BEHIND SOUTH BUNKER TRAVEL ROAD	8	0,33
"	2) BEHIND SOUTH BUNKER BELT ROAD	9	0,04
"	3) BEHIND S/WEST 20 DRIVE TRAVEL ROAD	10	0,04
"	3) BEHIND S/WEST 20 DRIVE BELT ROAD	11	0,12
"	4) BEHIND S/WEST 30 DRIVE TRAVEL ROAD	12	0,05
"	4) BEHIND S/WEST 30 DRIVE BELT ROAD	13	0,24

Table 2A: Sample of Respirable Dust Levels Captured

	Shank Diameters [mm]			Condition				Total
PickBox No	Head	Middle	End	C-clip	Tip	dD Front	dD Back	Deviation
12	29.35	29.68	29.48	Poor	Good	**-0.33**	**0.20**	**0.53**
15	29.32	29.65	29.50	Poor	Wear-H	**-0.33**	0.15	0.48
13	29.53	29.80	29.66	Poor	Good	-0.27	0.14	0.41
11	29.39	29.68	29.64	Poor	Good	-0.29	0.04	0.33
17	29.66	29.82	29.68	Wear	Wear-H	-0.16	0.14	0.30
20	29.60	29.72	29.54	Good	Good	-0.12	0.18	0.30
14	29.43	29.63	29.54	Poor	Chipped	-0.20	0.09	0.29
19	29.59	29.72	29.61	Wear	Good	-0.13	0.11	0.24
18	29.47	29.62	29.58	Wear	Wear-L	-0.15	0.04	0.19
16	29.79	29.77	29.74	Practically New		0.02	0.03	0.01
24	29.79	30.00	29.84	Wear	Chipped	-0.21	0.16	0.37
Min	29.32	29.62	29.48	N/A		-0.30	0.14	0.44
Max	29.79	30.00	29.84			-0.21	0.16	0.37
Avg	29.54	29.74	29.62			-0.20	0.12	0.31
Cross dMax	29.32	30.00	29.48			-0.68	0.52	1.20

Table 2B: Sample of pick shank wear rates measured.

Std Kennametal pick box length:	Std Aerosun pick box length:		New Diam. Cond.		Tolerance ±
61.4+/-0.3	min:	max:	Pick shaft:	29.6	0.1
	61.1	61.7	Pick box:	30.26	0.1
			Clearance:	0.66	(Est.)

Tip Wear Condition Legend (Qualitative)					
1	2	3	4	5	6
Like New	*Lightly Worn*	*Evenly Worn, Good Condition*	*Worn, w/ Small chips*	*Worn, w/ Large Chips*	*Severely Worn, or Broken*

Measurement Position	
Pick Head Side	P1
Middel	P2
Circlip Side	P3

Measurement Below Tolerance
Measurement Above tolerance
P2 Diam Larger Than P1 or P3

Removed Picks:

Pick No	Pbox Std	Pick P1	Pick P2	Pick P3	Pbox P1	Pbox P2	Pbox P3	*Pick Avg*	*Pbox Avg*	Date Removed	Pick Std
21	30.600	29.100		29.300	30.900		30.450	*29.200*	30.675	15 March 2006	29.6

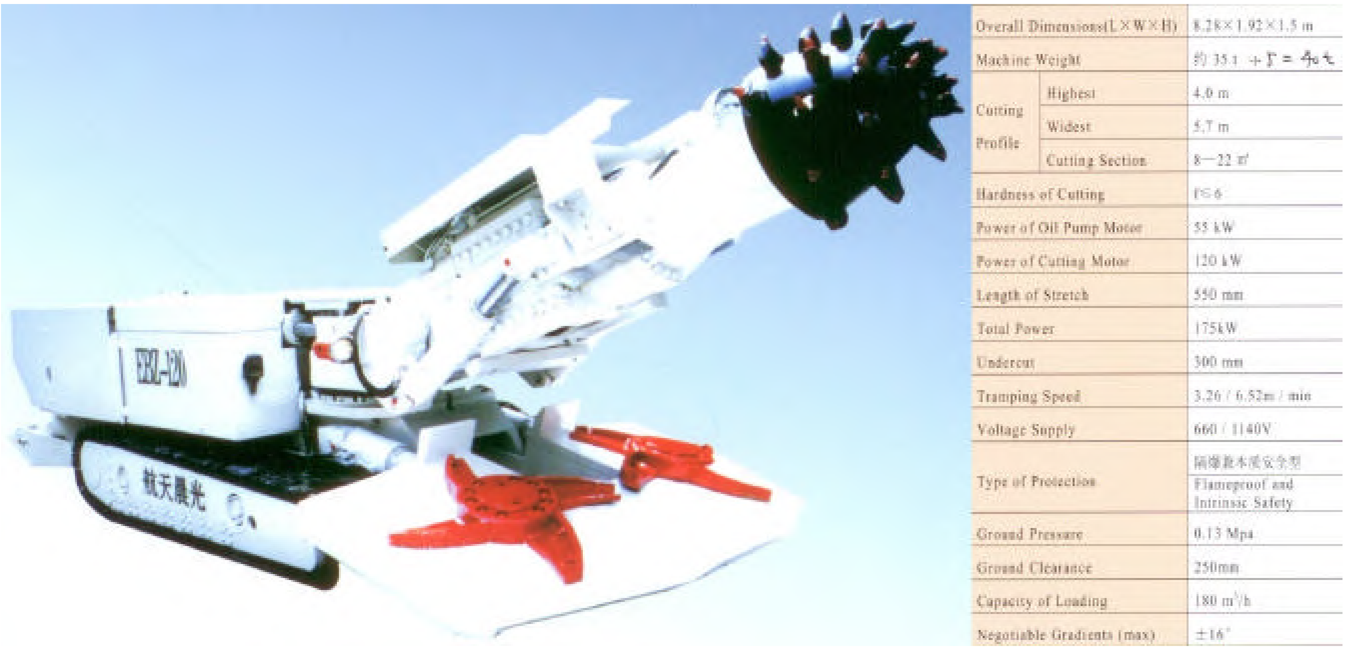
S1	Tip Wear S1	S1 pick P1	S1 pick P2	S1 pick P3	S1 box P1	S1 box P2	S1 box P3	*S1 Pick Avg*	*S1 box Avg*	dP S1 pick12	dP S1 pick 32	*dP S1 pick Avg*	dP S1 box 12	dP S1 box 32	*dP S1 box Avg*	Date Removed	Pick Type
1	2	29.700	29.905	29.825	30.725	30.585	30.885	*29.810*	30.732	0.205	0.080	*0.143*	0.140	0.300	*0.220*	16 May 2006	A
2	2	29.830	29.940	29.860	30.910	30.550	30.940	*29.877*	30.800	0.110	0.080	*0.095*	0.360	0.390	*0.375*	16 May 2006	A
3	3	29.510	29.830	29.720	30.965	30.725	30.730	*29.687*	30.807	0.320	0.110	*0.215*	0.240	0.005	*0.122*	16 May 2006	A
4	6	29.610	29.820	29.740	30.865	30.685	30.745	*29.723*	30.765	0.210	0.080	*0.145*	0.180	0.060	*0.120*	16 May 2006	A
5	3	29.785	29.830	29.405	30.915	30.985	30.635	*29.673*	30.845	0.045	0.425	*0.235*	-0.070	-0.350	*-0.210*	16 May 2006	A
6	3	29.630	29.790	29.635	30.770	30.850	30.695	*29.685*	30.772	0.160	0.155	*0.157*	-0.080	-0.155	*-0.118*	16 May 2006	A
7	3	29.930	29.910	29.890	30.795	30.565	30.515	*29.910*	30.625	-0.020	0.020	*0.000*	0.230	-0.050	*0.090*	16 May 2006	K
8	4	29.450	29.630	29.500	30.895	30.755	30.705	*29.527*	30.785	0.180	0.130	*0.155*	0.140	-0.050	*0.045*	16 May 2006	A
9	2	29.450	29.570	29.380	30.635	30.555	30.955	*29.467*	30.715	0.120	0.190	*0.155*	0.080	0.400	*0.240*	16 May 2006	A
10	1	29.780	29.835	29.715	30.595	30.525	30.885	*29.777*	30.668	0.055	0.120	*0.088*	0.070	0.360	*0.215*	16 May 2006	A
S1 Avg	S1 Avg	29.668	29.806	29.667	30.807	30.678	30.769	*29.714*	30.751	0.139	0.139	*0.139*	0.129	0.091	*0.110*		
S2	**Tip Wear S2**	**S2 pick P1**	**S2 pick P2**	**S2 pick P3**	**S2 box P1**	**S2 box P2**	**S2 box P3**	***S2 Pick Avg***	***S2 box Avg***	**dP S2 pick12**	**dP S2 pick 32**	***dP S2 pick Avg***	**dP S2 box 12**	**dP S2 box 32**	***dP S2 box Avg***		
11	4	29.830	29.850	29.920	30.125	30.805	30.705	*29.867*	30.545	0.020	-0.070	*-0.025*	-0.680	-0.100	*-0.390*	16 May 2006	K
12	5	29.860	29.880	29.900	30.715	30.515	30.995	*29.880*	30.742	0.020	-0.020	*0.000*	0.200	0.480	*0.340*	16 May 2006	K
13	5	29.820	29.865	29.820	30.914	30.735	30.715	*29.835*	30.788	0.045	0.045	*0.045*	0.179	-0.020	*0.080*	16 May 2006	K
14	3	29.840	29.850	29.830	30.965	30.765	30.805	*29.840*	30.845	0.010	0.020	*0.015*	0.200	0.040	*0.120*	16 May 2006	K
15	5	29.830	29.865	29.850	30.975	30.535	30.675	*29.848*	30.728	0.035	0.015	*0.025*	0.440	0.140	*0.290*	16 May 2006	K
16	4	29.825	29.870	29.820	30.895	30.705	30.785	*29.838*	30.795	0.045	0.050	*0.048*	0.190	0.080	*0.135*	16 May 2006	K
17	4	29.820	29.880	29.835	30.580	30.715	30.625	*29.845*	30.640	0.060	0.045	*0.052*	-0.135	-0.090	*-0.113*	16 May 2006	K
18	4	29.855	29.910	29.840	30.605	30.025	30.925	*29.868*	30.518	0.055	0.070	*0.063*	0.580	0.900	*0.740*	16 May 2006	K
19	4	29.730	29.815	29.750	30.880	30.535	30.525	*29.765*	30.647	0.085	0.065	*0.075*	0.345	-0.010	*0.167*	16 May 2006	K
20	3	29.840	29.920	29.810	30.935	30.930	30.955	*29.857*	30.940	0.080	0.110	*0.095*	0.005	0.025	*0.015*	16 May 2006	K
S2 Avg	S2 Avg	29.825	29.871	29.838	30.759	30.627	30.771	*29.844*	30.719	0.046	0.033	*0.039*	0.132	0.145	*0.138*		
S3	**Tip Wear S3**	**S3 pick P1**	**S3 pick P2**	**S3 pick P3**	**S3 box P1**	**S3 box P2**	**S3 box P3**	***S3 Pick Avg***	***S3 box Avg***	**dP S3 pick12**	**dP S3 pick 32**	***dP S3 pick Avg***	**dP S3 box 12**	**dP S3 box 32**	***dP S3 box Avg***		
21	3	29.660	29.775	29.760	30.955	30.785	30.535	*29.732*	30.758	0.115	0.015	*0.065*	0.170	-0.250	*-0.040*	16 May 2006	A
22	3	29.920	29.960	29.810	30.825	30.535	30.965	*29.897*	30.775	0.040	0.150	*0.095*	0.290	0.430	*0.360*	16 May 2006	A
23	4	29.620	29.510	29.270	30.985	30.750	30.785	*29.467*	30.840	-0.110	0.240	*0.065*	0.235	0.035	*0.135*	16 May 2006	A
24	4	29.450	29.730	29.575	30.720	30.515	30.535	*29.585*	30.590	0.280	0.155	*0.218*	0.205	0.020	*0.112*	16 May 2006	A
25	5	29.345	29.540	29.450	30.818	30.650	30.635	*29.445*	30.701	0.195	0.090	*0.143*	0.168	-0.015	*0.077*	16 May 2006	A
26	5	29.470	29.720	29.520	30.675	30.605	30.510	*29.570*	30.597	0.250	0.200	*0.225*	0.070	-0.095	*-0.012*	16 May 2006	A
27	4	29.180	29.330	29.110	30.585	30.935	30.975	*29.207*	30.832	0.150	0.220	*0.185*	-0.350	0.040	*-0.155*	16 May 2006	A
28	4	29.430	29.575	29.490	30.825	30.760	30.790	*29.498*	30.792	0.145	0.085	*0.115*	0.065	0.030	*0.047*	16 May 2006	A
29	2	29.550	29.610	29.510	30.760	30.600	30.595	*29.557*	30.652	0.060	0.100	*0.080*	0.160	-0.005	*0.077*	16 May 2006	A
30	1	29.760	29.885	29.730	30.545	30.995	30.905	*29.792*	30.815	0.125	0.155	*0.140*	-0.450	-0.090	*-0.270*	16 May 2006	A
S3 Avg	S3 Avg	29.539	29.664	29.523	30.769	30.713	30.723	*29.575*	30.735	0.125	0.141	*0.133*	0.056	0.010	*0.033*		
Loose	**Tip Wear L**	**L pick P1**	**S1 pick P2**	**S1 pick P3**	**L box P1**	**L box P2**	**L box P3**	***L Pick Avg***	***L box Avg***	**dP L pick12**	**dP L pick 32**	***dP L pick Avg***	**dP L box 12**	**dP L box 32**	***dP L box Avg***		
31	1	29.420	29.470	29.340	30.555	30.585	30.595	*29.410*	30.578	0.050	0.130	*0.090*	-0.030	0.010	*-0.010*	16 May 2006	A
32	1	29.815	29.820	29.640	30.550	30.900	30.815	*29.758*	30.755	0.005	0.180	*0.092*	-0.350	-0.085	*-0.217*	16 May 2006	A
Avg (All)		**29.673**	**29.772**	**29.664**	**30.764**	**30.677**	**30.751**	***29.703***	**30.731**	**0.098**	**0.108**	***0.103***	**0.087**	**0.074**	***0.081***		

Table 2C: Full cutting head measurements and calculated wear amounts.

Appendix 3

Overall Dimensions(L×W×H)		9.45×3.2×1.6 m
Machine Weight		约 43 t
Cutting Profile	Highest	4.5 m
	Widest	5.6 m
	Cutting Section	8～24 ㎡
Hardness of Cutting		f≤7
Power of Oil Pump Motor		110 kW
Power of Cutting Motor		132 kW
Total Power		242 kW
Undercut		230 mm
Tramping Speed		2.6 / 7.8m / min
Voltage Supply		660 / 1140V
Type of Protection		隔爆兼本质安全火花型 Flameproof and Intrinsic Safety
Ground Pressure		0.12 MPa
Ground Clearance		250 mm
Capacity of Loading		180 m^3/h
Negotiable Gradients (max)		±16°

Figure 10: Specifications for EBJ-132 Tunnelling Roadheader



Overall Dimensions(L×W×H)		8.28×1.92×1.5 m
Machine Weight		约 35 t +5 = 40t
Cutting Profile	Highest	4.0 m
	Widest	5.7 m
	Cutting Section	8—22 ㎡
Hardness of Cutting		f≤6
Power of Oil Pump Motor		55 kW
Power of Cutting Motor		120 kW
Length of Stretch		550 mm
Total Power		175kW
Undercut		300 mm
Tramping Speed		3.26 / 6.52m / min
Voltage Supply		660 / 1140V
Type of Protection		隔爆兼本质安全型 Flameproof and Intrinsic Safety
Ground Pressure		0.13 Mpa
Ground Clearance		250mm
Capacity of Loading		180 m^3/h
Negotiable Gradients (max)		±16°

Figure 11: Specifications for EBZ-120 Tunnelling Roadheader

Appendix 4

A Full set of PDF document copies is attached (next 11 pages)

TABLE : 2540-UCE

RESULTS OF UNIAXIAL COMPRESSIVE STRENGTH TESTS WITH AXIAL DEFORMABILITY MEASUREM

Sample Location:

SPECIMEN PARTICULARS		SPECIMEN DIMENSIONS					SPECIMEN TEST RESULTS				
CSIR Specimen No 2540-UCE	Rock Type	Dia. (mm)	Height (mm)	Height to Dia Ratio	Mass (g)	Density (kg/m^3)	Failure Load (kN)	Strength (UCS) (MPa)	Tangent @ 50% UCS Deformation Modulus (GPa)	Mode of Failure	Notes
UCE-A	Block A	42.1	96.2	2.3	347.90	2600	77	55.4	14.4	XB	
UCE-B	Block B	39.7	96.1	2.4	289.50	2440	63	50.6	12.4	XA	
UCE-C	Block C	42.0	97.8	2.3	343.20	2530	80	57.7	17.0	XA	
UCE-D	Block D	39.8	97.5	2.5	339.70	2810	175	140.8	81.5	XA	
UCE-E	Block E	42.2	75.6	1.8	154.50	1460	23	16.8	3.9	XA	
UCE-F	Block F	41.9	58.2	1.4	193.90	2420	130	94.5	31.1	XA	
UCE-H	Block H	42.1	79.3	1.9	286.30	2600	105	75.5	31.0	XA	
UCE-J	Block J	42.0	91.2	2.2	319.30	2530	97	70.4	21.2	XA	

Notes:

1. Mode of failure: XA - Partial cone development
XB - Complete cone development
2. UCE results for block E - The low UCS and deformation results could relate to the properties of coal material

Revision 0

TABLE : 2540-UTB

RESULTS OF BRAZILIAN TENSILE STRENGTH TESTS.

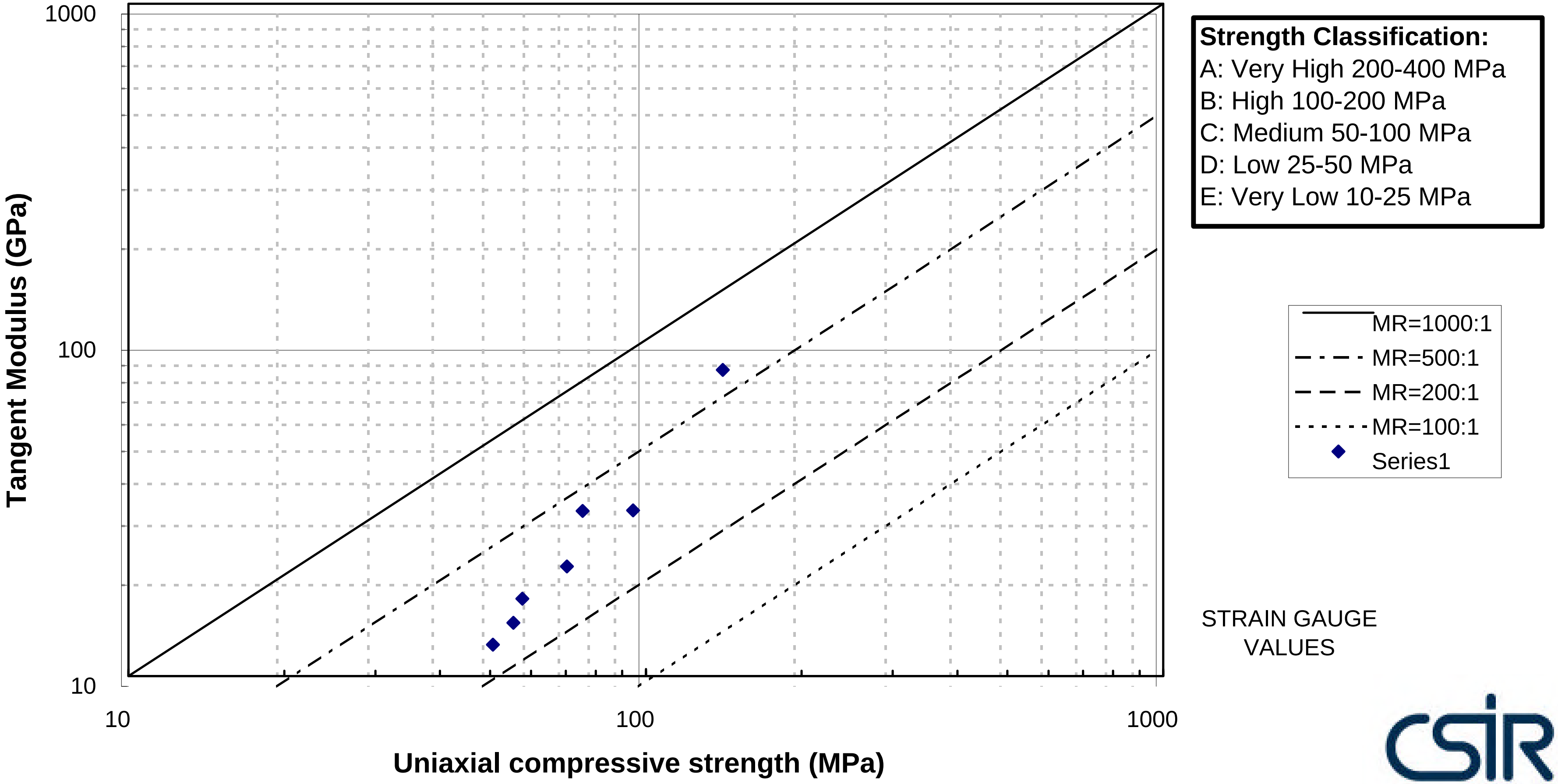
Sample Location :

SPECIMEN PARTICULARS			SPECIMEN DIMENSIONS				SPECIMEN TEST RESULTS			Notes
CSIR Specimen No 2540-UTB	Client No	Rock Type	Dia (mm)	Thickness (mm)	Mass (g)	Density (kg/m^3)	Failure Load (kN)	Tensile Strength (MPa)	Mode of Test/ Failure	
UTB-A	A	Block Sample A	42.0	20.9	69.90	2410	6.3	4.5	1:A	
UTB-B	B	Block Sample B	39.8	24.2	72.70	2430	7.1	4.7	1:A	
UTB-D	D	Block Sample D	39.5	21.0	71.80	2780	18.8	14.4	1:A	

Notes: Mode of Test/Failure:
1 - Massive, no visible discontinuities
A - Normal (Intact) Failure

Revision 0

FIGURE 2540-UCE: TANGENT MODULUS vs UNIAXIAL COMPRESSIVE STRENGTH



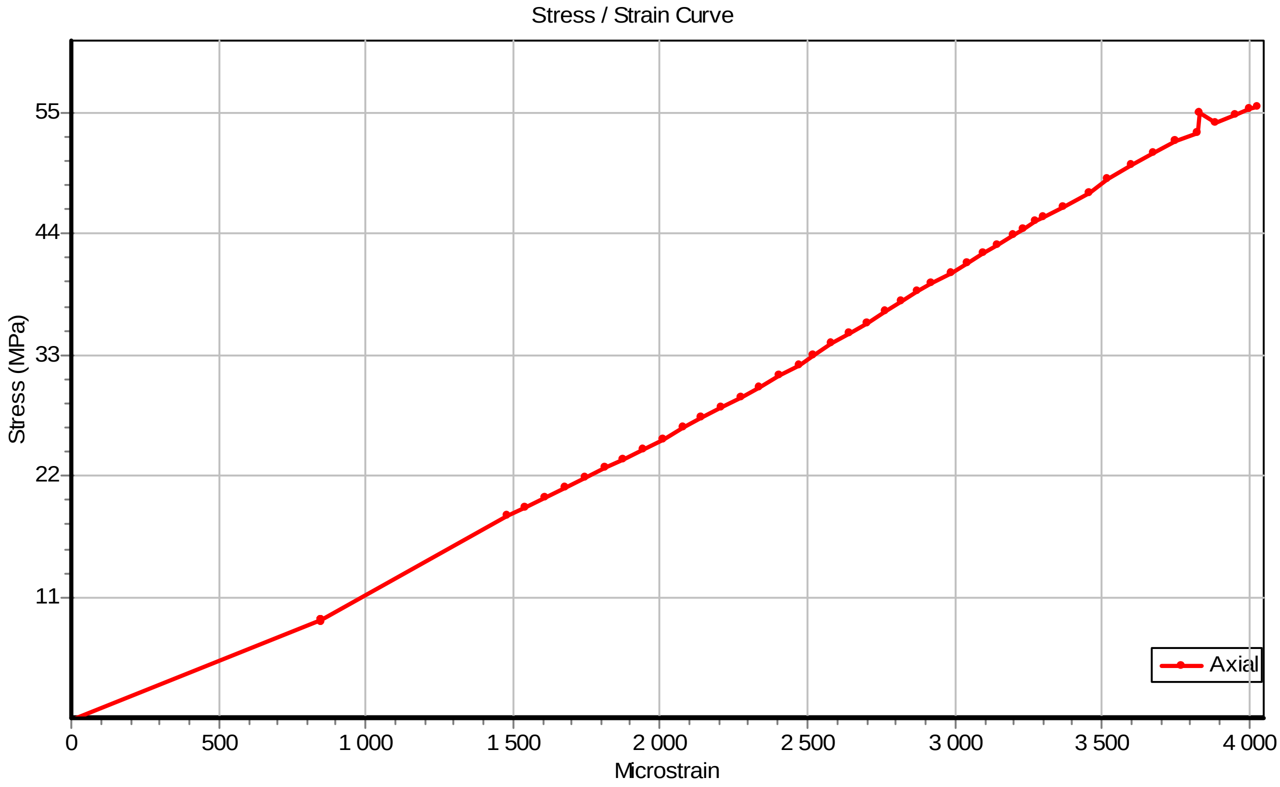
Strength Classification:
A: Very High 200-400 MPa
B: High 100-200 MPa
C: Medium 50-100 MPa
D: Low 25-50 MPa
E: Very Low 10-25 MPa

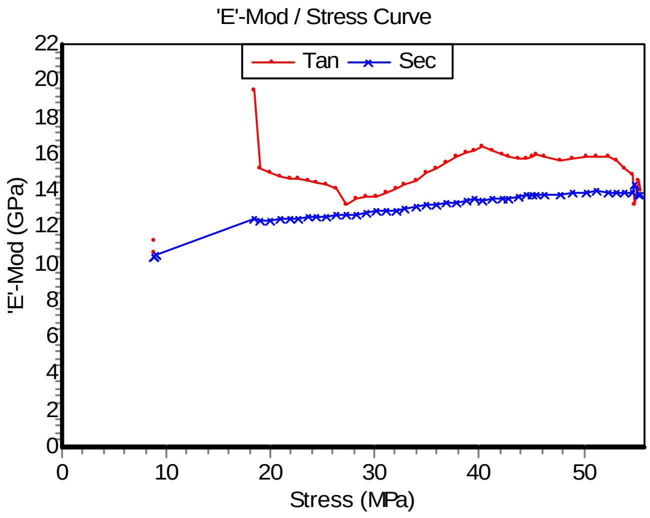
STRAIN GAUGE
VALUES

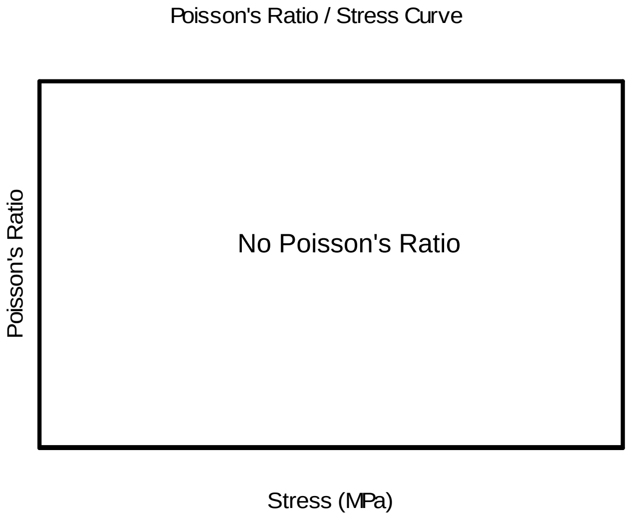
MODIFIED AFTER DEERE AND MILLER

Revision 0

GEOMECHANICS LABORATORY	UNIAXIAL COMPRESSION TEST WITH DEFORMABILITY MEASUREMENTS BY MEANS OF STRAIN GAUGES STRAIN GAUGE: (A+B) / 2	CSIR MININGTEK







'E'-Mod @ 30% UCS		'E'-Mod @ 50% UCS		
Tan:	9.9 GPa	**14.4 GPa**		
Sec:	12.5 GPa	12.7 GPa		
Mod Ratio: Tan @ 50% UCS:		UCS (MPa):	Toughness Index:	
260		55.5	Farmer (MPa): 0.1067	CSIR (MPa): 0.0955

TEST DETAILS

Date: 2006-09-06
Time: 09:58:51
Test Machine: KingTest
Range (kN): 2000
Falure Load (kN): 77.2
Tester: RM
Client: Jeroen Maaren

SPECIMEN DETAILS

Rock Type: ROOF CONTACT STONE LARGE
CSIR Number: 2540-UCE-AA
Diameter (mm): 42
Length (mm): 96
Mass (g): 348
Density (kg/m^3): 2601
Deg. of Sat.: LAB DRY

Test summary sheet: 2540-UCE-AA

07/09/2006 15:16:24

GEOMECHANICS LABORATORY

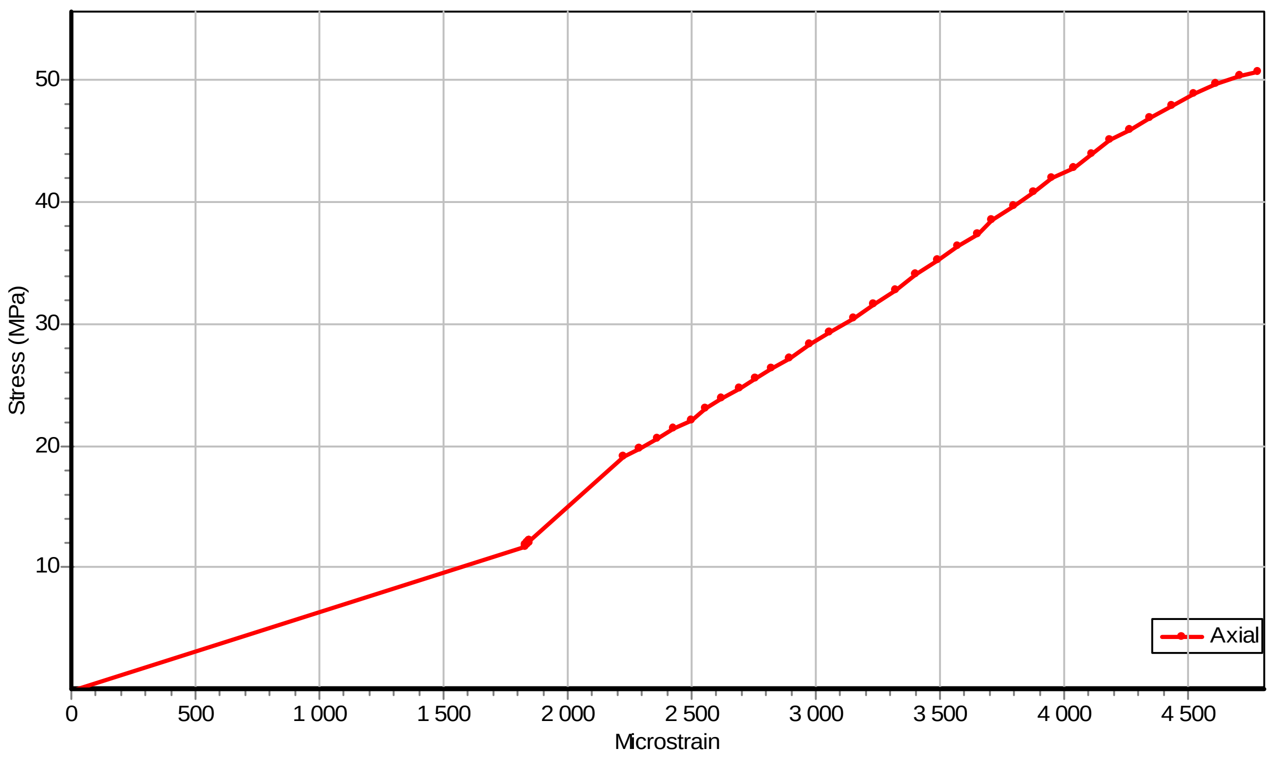
UNIAXIAL COMPRESSION TEST

WITH DEFORMABILITY MEASUREMENTS BY MEANS OF STRAIN GAUGES

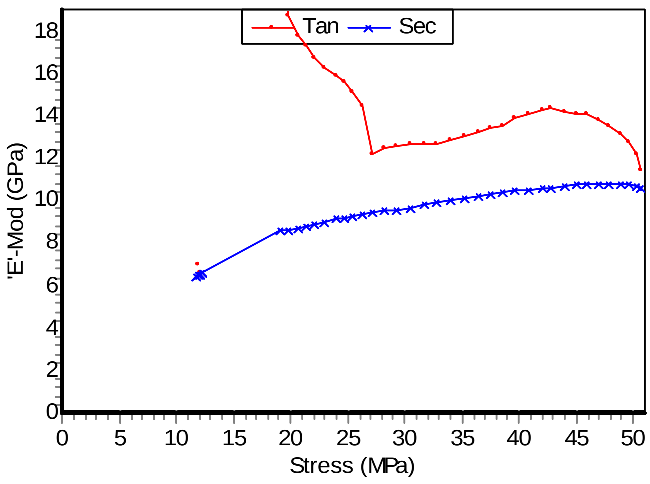
STRAIN GAUGE: (A+B) / 2

CSIR MININGTEK

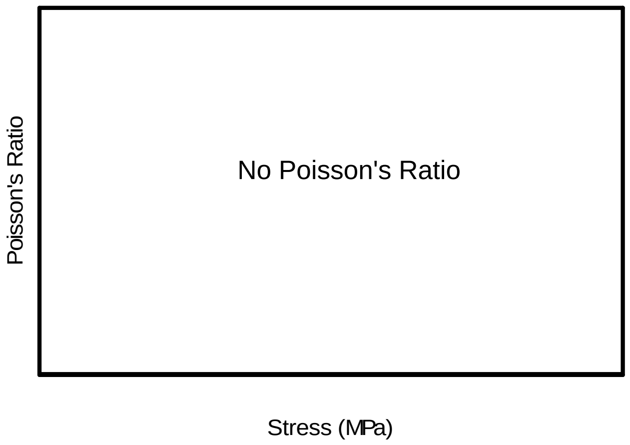
Stress / Strain Curve



'E'-Mod / Stress Curve



Poisson's Ratio / Stress Curve



'E'-Mod @ 30% UCS	'E'-Mod @ 50% UCS		
Tan: 0.0 GPa Sec: 8.6 GPa	**12.4 GPa** 9.2 GPa		
Mod Ratio: Tan @ 50% UCS:	UCS (MPa):	Toughness Index:	
246	50.6	Farmer (MPa): 0.1030	CSIR (MPa): 0.1076

TEST DETAILS

Date: 2006-09-06
Time: 11:51:31
Test Machine: KingTest
Range (kN): 2000
Falure Load (kN): 62.6
Tester: RM
Client: Jeroen Maaren

SPECIMEN DETAILS

Rock Type: Block sample B
CSIR Number: 2540-UCE-BB
Diameter (mm): 40
Length (mm): 96
Mass (g): 290
Density (kg/m^3) 2438
Deg. of Sat.: LAB DRY

Test summary sheet: 2540-UCE-BB

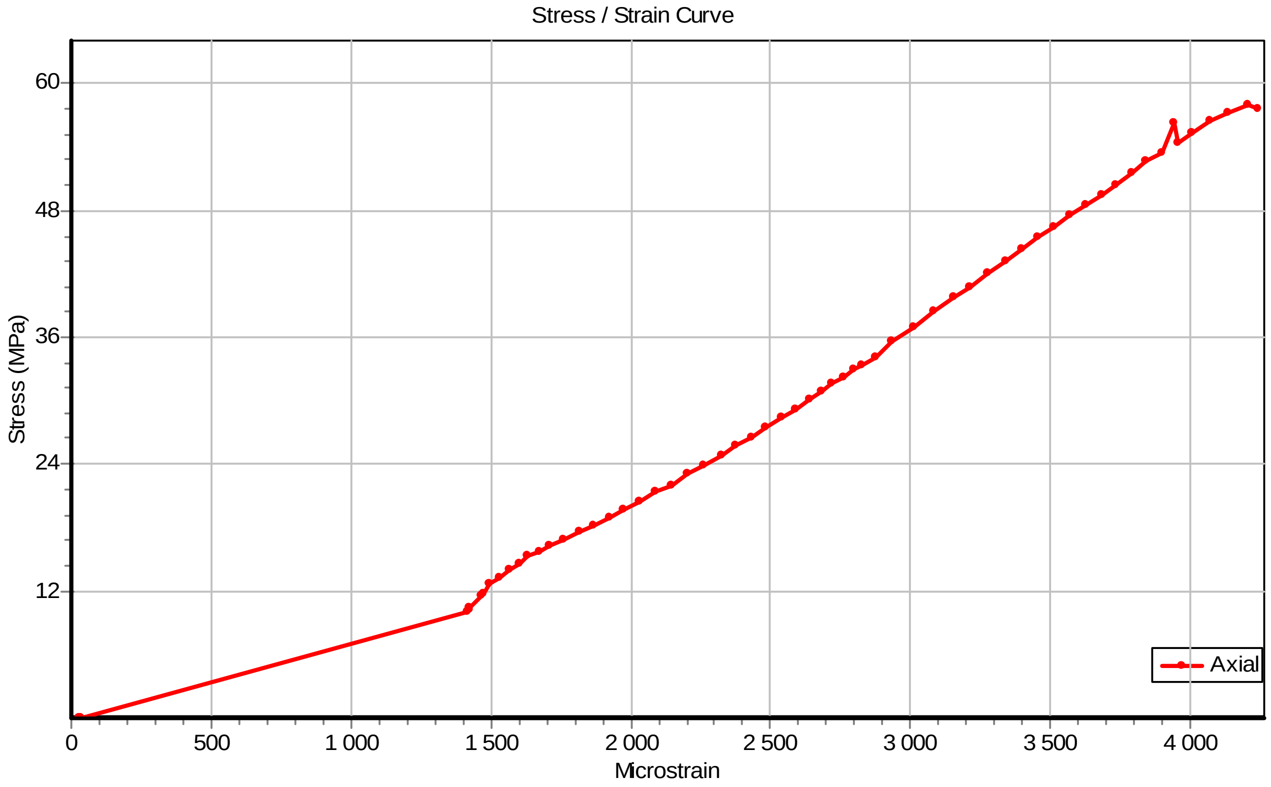
07/09/2006 15:11:52

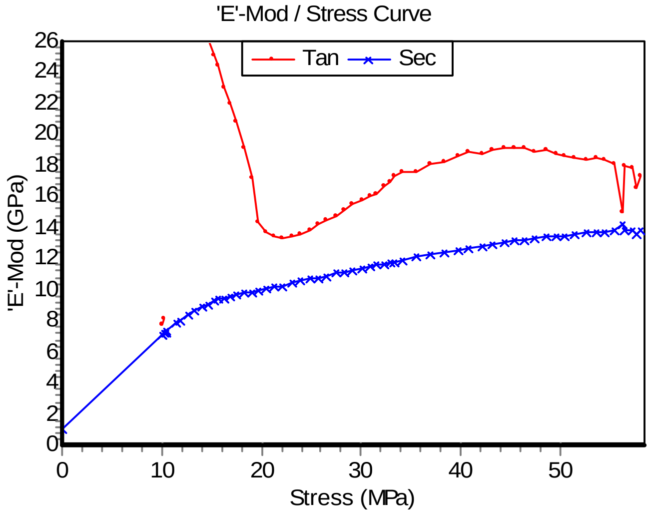
GEOMECHANICS
LABORATORY

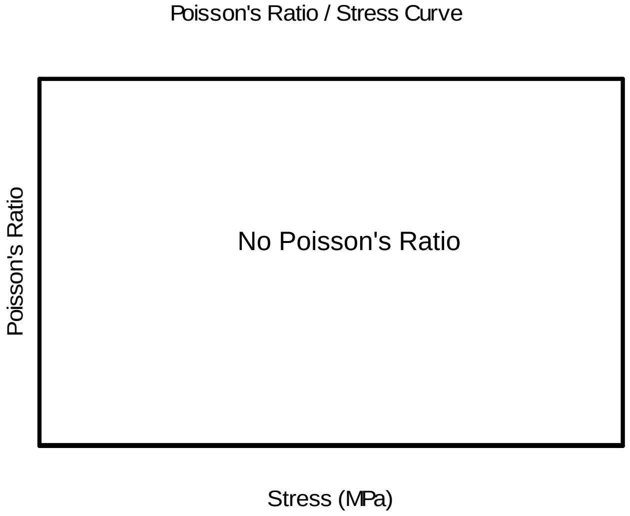
UNIAXIAL COMPRESSION TEST

WITH DEFORMABILITY MEASUREMENTS BY MEANS OF STRAIN GAUGES
STRAIN GAUGE: (A+B) / 2

CSIR MININGTEK







	'E'-Mod @ 30% UCS	'E'-Mod @ 50% UCS		
Tan:	13.4 GPa	**17.0 GPa**		
Sec:	9.7 GPa	11.3 GPa		
Mod Ratio: Tan @ 50% UCS:		UCS (MPa):	Toughness Index:	
293		58.0	Farmer (MPa): 0.0988	CSIR (MPa): 0.0881

TEST DETAILS

Date: 2006-09-06
Time: 11:12:10
Test Machine: KingTest
Range (kN): 2000
Falure Load (kN): 79.9
Tester: RM
Client: Jeroen Maaren

SPECIMEN DETAILS

Rock Type: Block sample C
CSIR Number: 2540-UCE-C
Diameter (mm): 42
Length (mm): 98
Mass (g): 343
Density (kg/m^3) 2548
Deg. of Sat.: LAB DRY

Test summary sheet: 2540-UCE-C

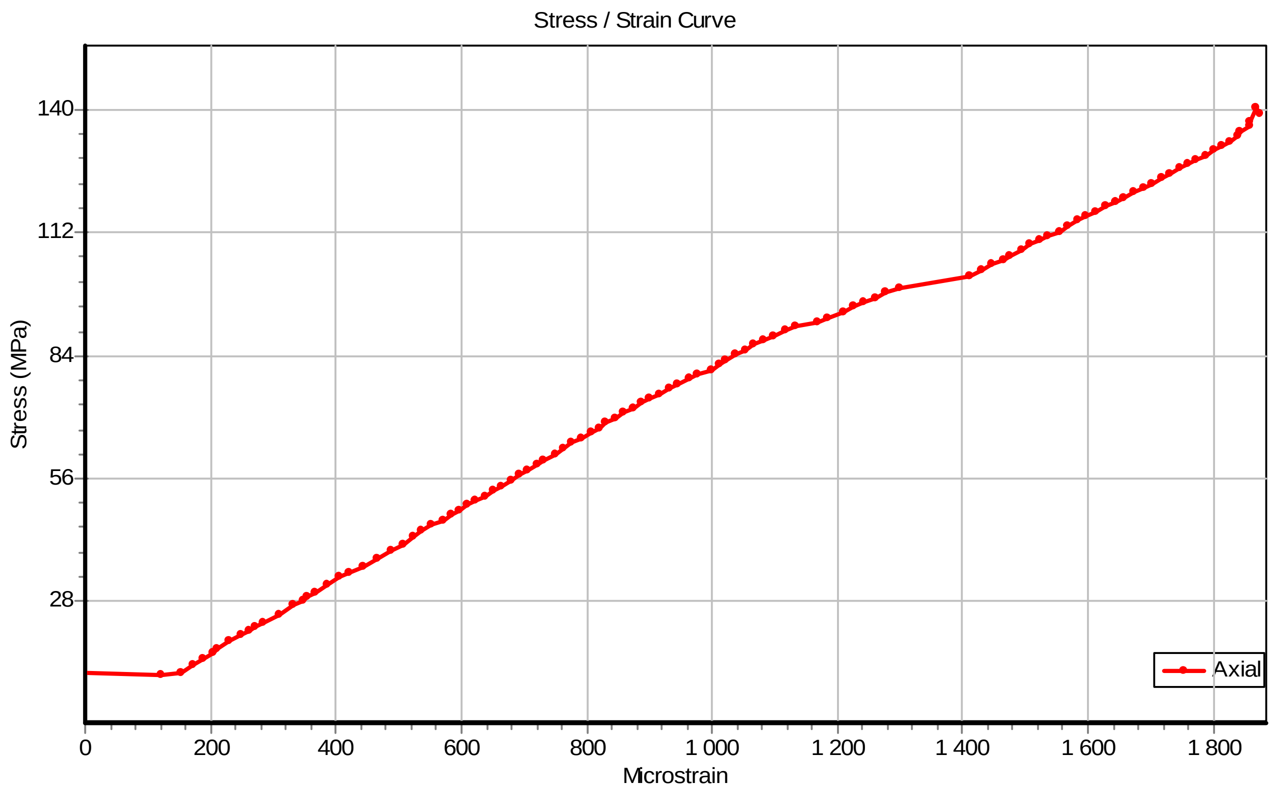
07/09/2006 15:18:29

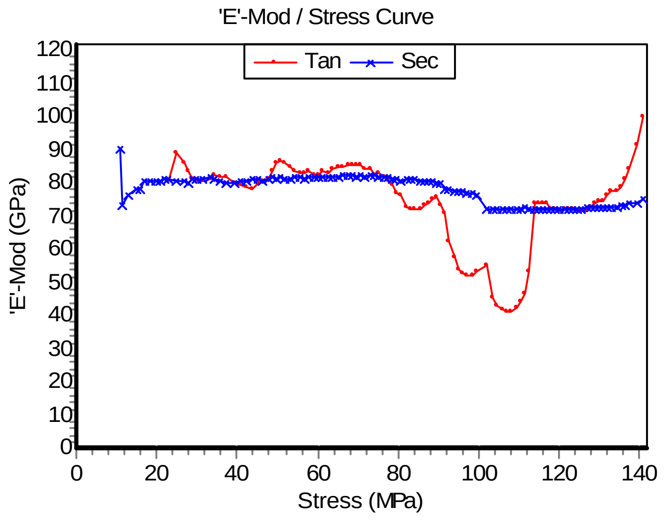
GEOMECHANICS
LABORATORY

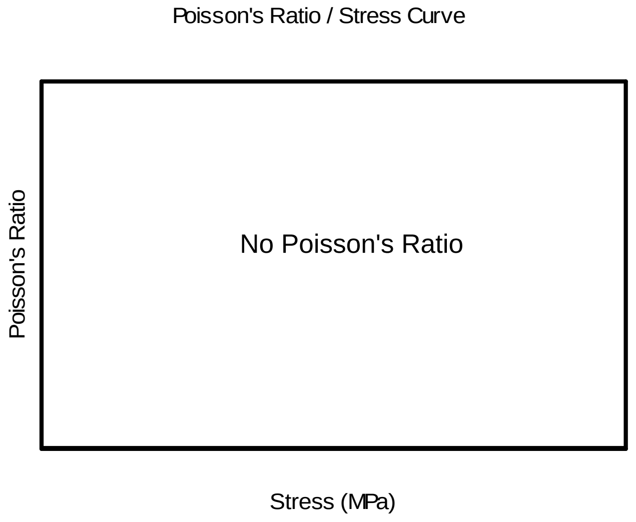
UNIAXIAL COMPRESSION TEST

WITH DEFORMABILITY MEASUREMENTS BY MEANS OF STRAIN GAUGES
STRAIN GAUGE: (A+B) / 2

CSIR
MININGTEK







'E'-Mod @ 30% UCS	'E'-Mod @ 50% UCS		
Tan: 86.7 GPa Sec: 80.9 GPa	**81.5 GPa** 82.3 GPa		
Mod Ratio: Tan @ 50% UCS:	UCS (MPa):	Toughness Index:	
579	140.8	Farmer (MPa): 0.1216	CSIR (MPa): -5.6230

TEST DETAILS

Date: 2006-09-06
Time: 11:29:44
Test Machine: KingTest
Range (kN): 2000
Falure Load (kN): 174.7
Tester: RM
Client: Jeroen Maaren

SPECIMEN DETAILS

Rock Type: Block sample D
CSIR Number: 2540-UCE-D
Diameter (mm): 40
Length (mm): 97
Mass (g): 340
Density (kg/m^3): 2810
Deg. of Sat.: LAB DRY

Test summary sheet: 2540-UCE-D

07/09/2006 15:21:48

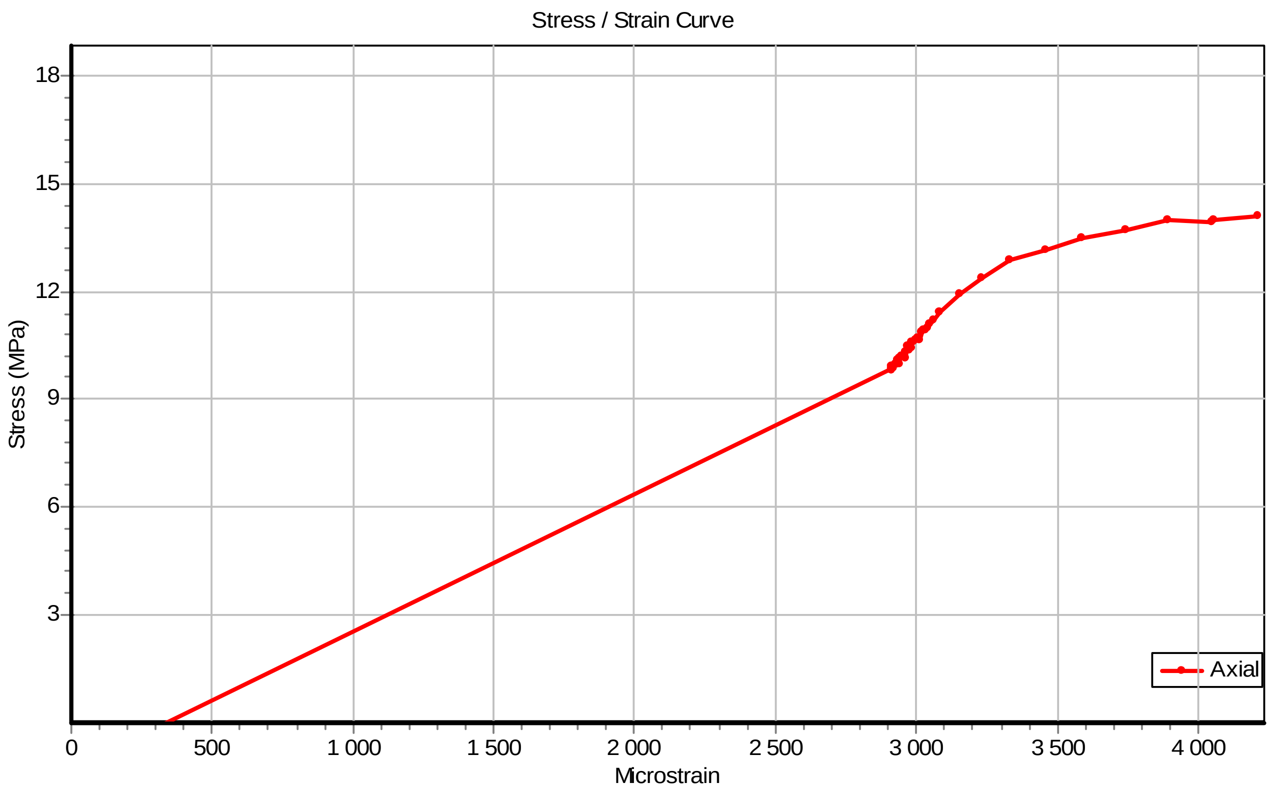
GEOMECHANICS
LABORATORY

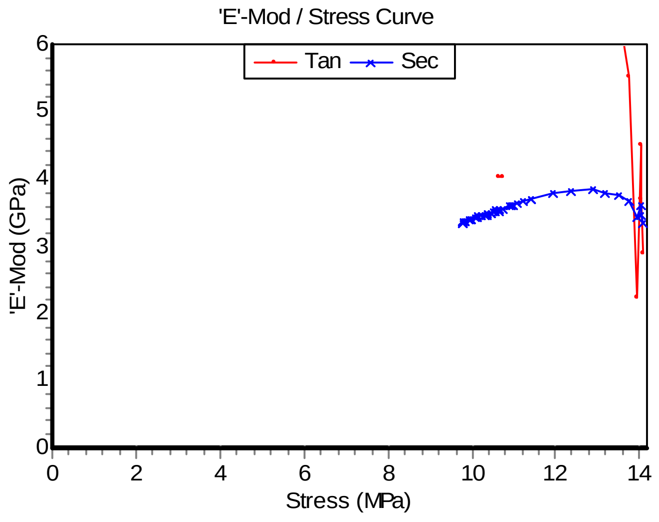
UNIAXIAL COMPRESSION TEST

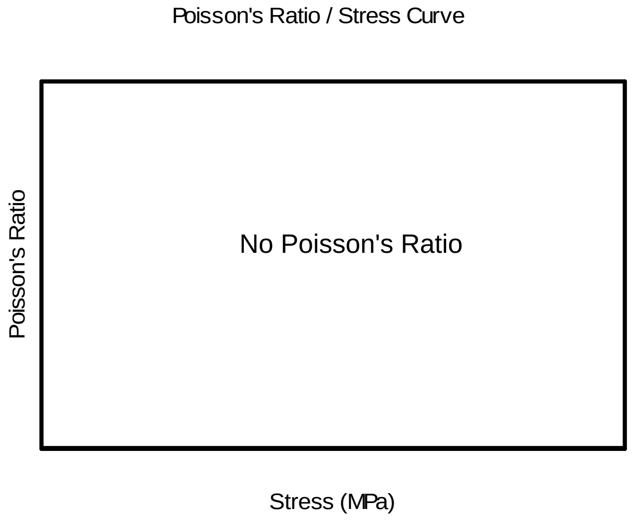
WITH DEFORMABILITY MEASUREMENTS BY MEANS OF STRAIN GAUGES

STRAIN GAUGE: (A+B) / 2

CSIR MININGTEK







	'E'-Mod @ 30% UCS	'E'-Mod @ 50% UCS
Tan:	3.9 GPa	**3.9 GPa**
Sec:	3.7 GPa	3.7 GPa

Mod Ratio: Tan @ 50% UCS:	UCS (MPa):	Toughness Index:	
232	16.8	Farmer (MPa): 0.0363	CSIR (MPa): 0.0285

TEST DETAILS

Date: 2006-09-06
Time: 13:03:44
Test Machine: KingTest
Range (kN): 2000
Falure Load (kN): 23.5
Tester: RM
Client: Jeroen Maaren

SPECIMEN DETAILS

Rock Type: Block sample E
CSIR Number: 2540-UCE-E
Diameter (mm): 42
Length (mm): 76
Mass (g): 155
Density (kg/m^3) 1465
Deg. of Sat.: LAB DRY

Test summary sheet: 2540-UCE-E

GEOMECHANICS LABORATORY

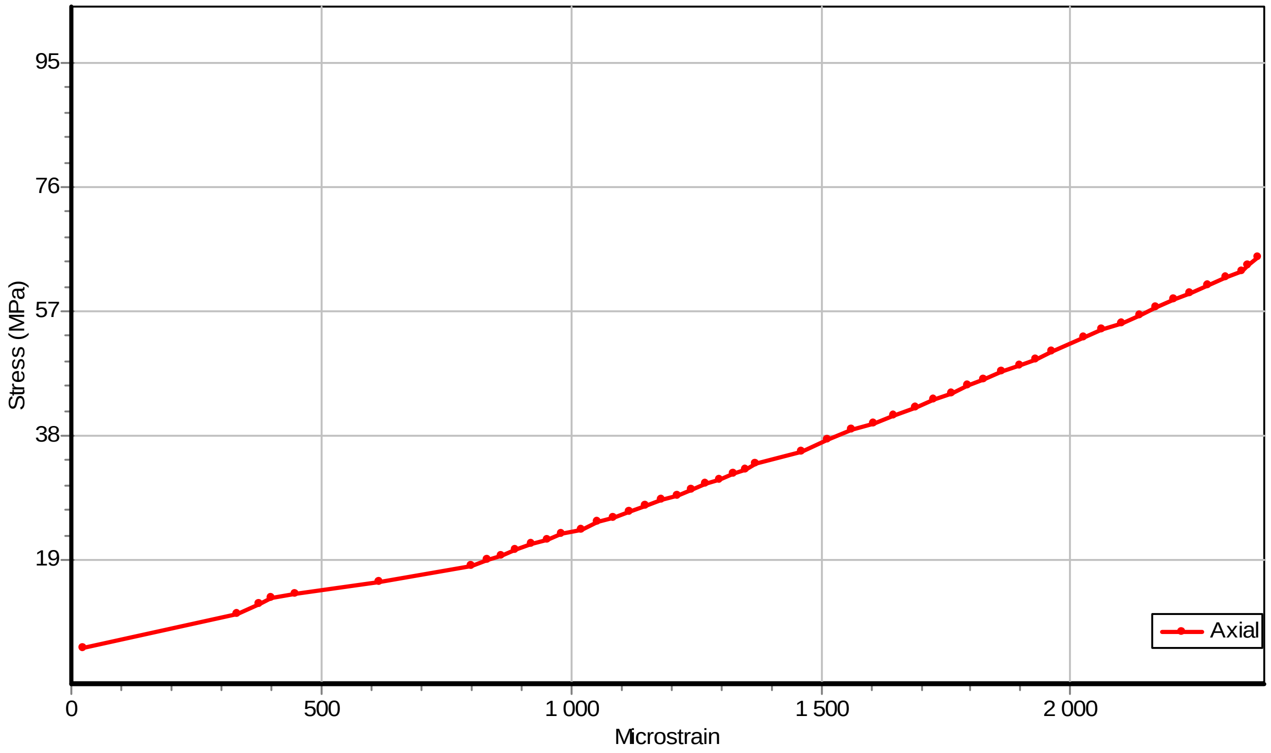
UNIAXIAL COMPRESSION TEST

WITH DEFORMABILITY MEASUREMENTS BY MEANS OF STRAIN GAUGES

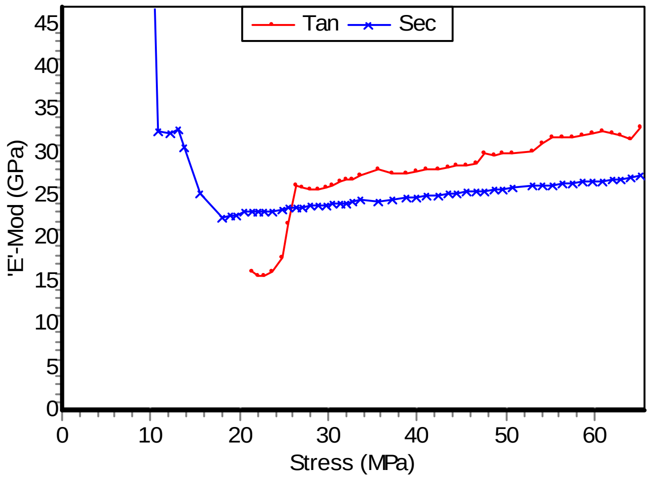
STRAIN GAUGE: (A+B) / 2

CSIR MININGTEK

Stress / Strain Curve



'E'-Mod / Stress Curve



Poisson's Ratio / Stress Curve

Poisson's Ratio

No Poisson's Ratio

Stress (MPa)

'E'-Mod @ 30% UCS	'E'-Mod @ 50% UCS		
Tan: 27.0 GPa Sec: 23.8 GPa	**31.1 GPa** 25.6 GPa		
Mod Ratio: Tan @ 50% UCS:	UCS (MPa):	Toughness Index:	
329	94.4	Farmer (MPa): 0.1435	CSIR (MPa): 0.0726

TEST DETAILS

Date: 2006-09-06
Time: 14:17:08
Test Machine: KingTest
Range (kN): 2000
Falure Load (kN): 130.1
Tester: RM
Client: Jeroen Maaren

SPECIMEN DETAILS

Rock Type: Block sample F
CSIR Number: 2540-UCE-FF
Diameter (mm): 42
Length (mm): 58
Mass (g): 194
Density (kg/m^3) 2421
Deg. of Sat.: LAB DRY

Test summary sheet: 2540-UCE-FF

07/09/2006 15:33:55

GEOMECHANICS

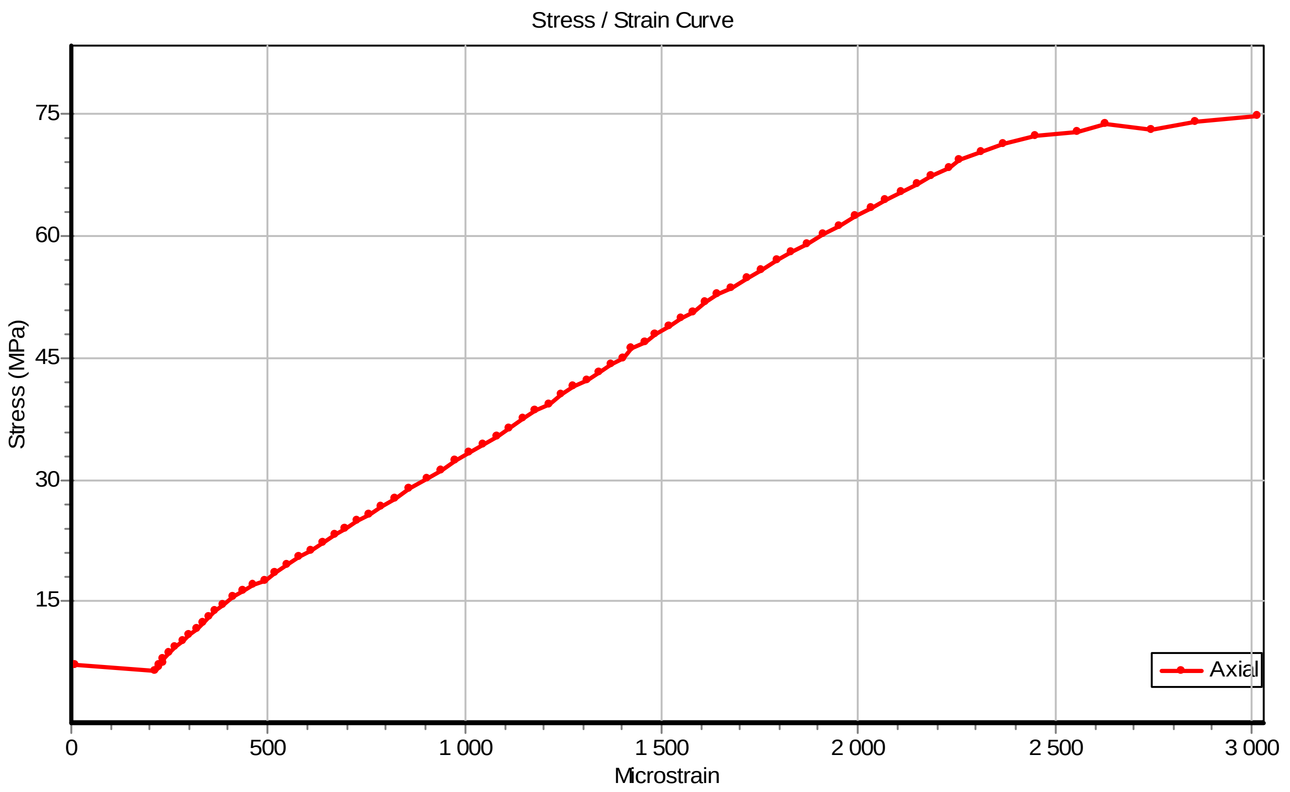
LABORATORY

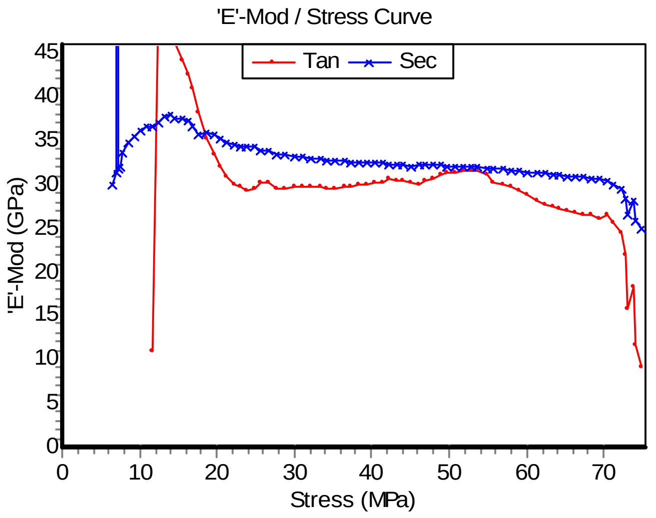
UNIAXIAL COMPRESSION TEST

WITH DEFORMABILITY MEASUREMENTS BY MEANS OF STRAIN GAUGES

STRAIN GAUGE: (A+B) / 2

CSIR
MININGTEK





Poisson's Ratio / Stress Curve

Poisson's Ratio

No Poisson's Ratio

Stress (MPa)

'E'-Mod @ 30% UCS		'E'-Mod @ 50% UCS		
Tan:	29.8 GPa	**31.0 GPa**		
Sec:	34.3 GPa	32.5 GPa		
Mod Ratio: Tan @ 50% UCS:		UCS (MPa):	Toughness Index:	
410		75.5	Farmer (MPa): 0.0920	CSIR (MPa): 0.1383

TEST DETAILS

Date: 2006-09-06
Time: 12:42:17
Test Machine: KingTest
Range (kN): 2000
Falure Load (kN): 105.0
Tester: RM
Client: Jeroen Maaren

SPECIMEN DETAILS

Rock Type: Block sample H
CSIR Number: 2540-UCE-H
Diameter (mm): 42
Length (mm): 79
Mass (g): 286
Density (kg/m^3): 2598
Deg. of Sat.: LAB DRY

Test summary sheet: 2540-UCE-H

07/09/2006 15:35:34

GEOMECHANICS LABORATORY

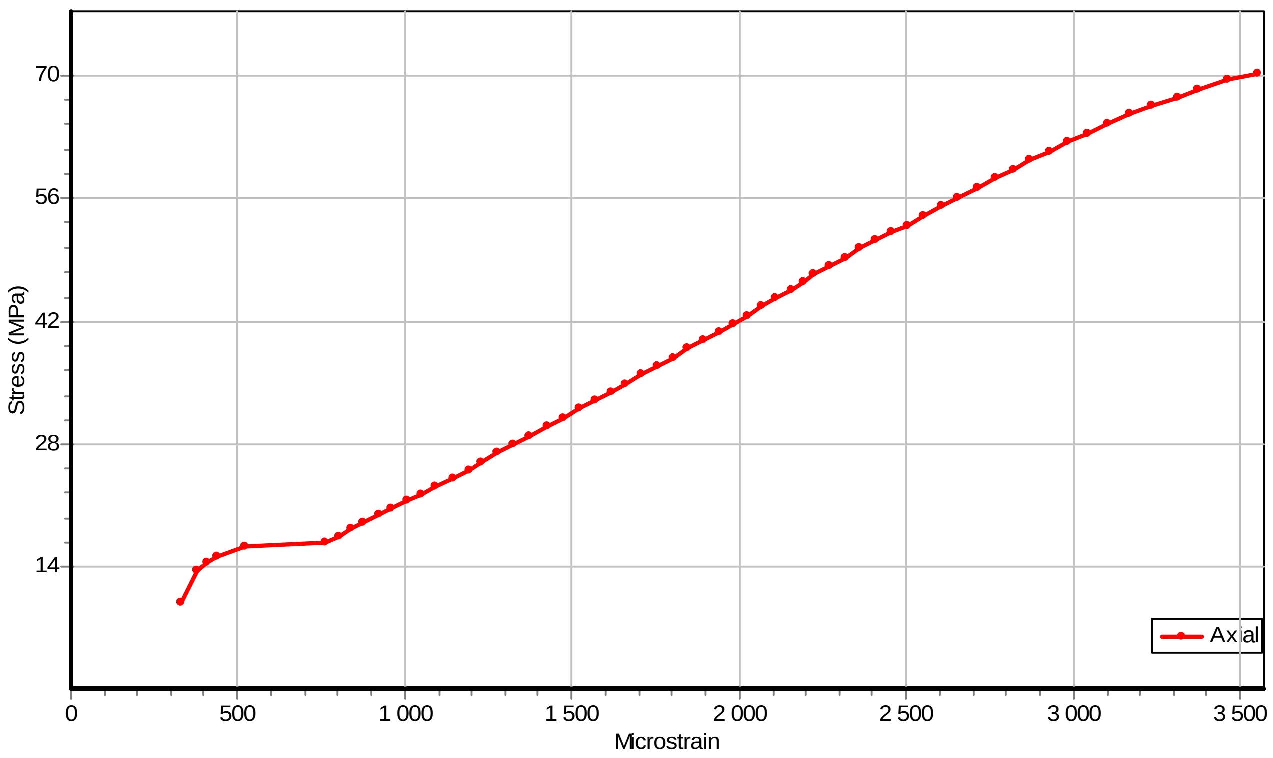
UNIAXIAL COMPRESSION TEST

WITH DEFORMABILITY MEASUREMENTS BY MEANS OF STRAIN GAUGES

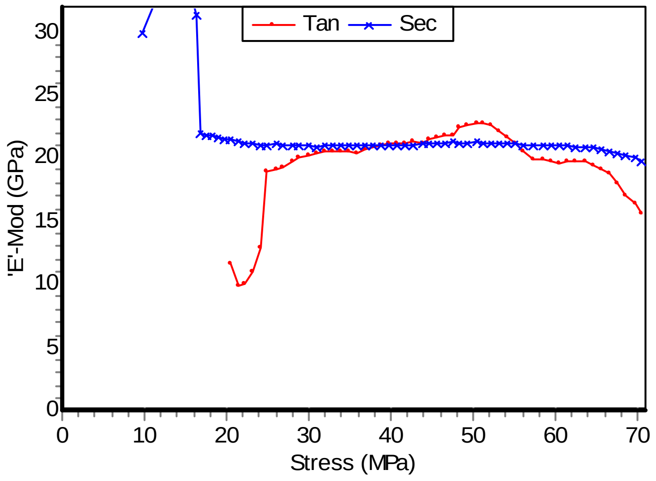
STRAIN GAUGE: (A+B) / 2

CSIR MININGTEK

Stress / Strain Curve



'E'-Mod / Stress Curve



Poisson's Ratio / Stress Curve

Poisson's Ratio

No Poisson's Ratio

Stress (MPa)

'E'-Mod @ 30% UCS	'E'-Mod @ 50% UCS		
Tan: 18.8 GPa Sec: 21.3 GPa	**21.2 GPa** 21.0 GPa		
Mod Ratio: Tan @ 50% UCS:	UCS (MPa):	Toughness Index:	
301	70.4	Farmer (MPa): 0.1168	CSIR (MPa): 0.1343

TEST DETAILS

Date: 2006-09-06
Time: 12:22:07
Test Machine: KingTest
Range (kN): 2000
Falure Load (kN): 97.5
Tester: RM
Client: Jeroen Maaren

SPECIMEN DETAILS

Rock Type: Block sample J
CSIR Number: 2540-UCE-J
Diameter (mm): 42
Length (mm): 91
Mass (g): 319
Density (kg/m^3): 2528
Deg. of Sat.: LAB DRY

Test summary sheet: 2540-UCE-J