REVIEW OF FACE AREA SUPPORT FOR AMANDELBULT NO. 2 SHAFT AND SUBSEQUENT INTRODUCTION OF CABLE ANCHORS

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Abstract

Rustenburg Platinum Mines, Amandelbult Section, part of the Anglo Platinum Group, is a platinum mine situated in the Bushveld Igneous Complex, 80 km north of Rustenburg, South Africa. Mining of the tabular orebody is done at a stoping height of 1.2 to 1.8 m in an underhand stoping configuration. The rock engineering personnel at No. 2 Shaft were faced with the challenge of addressing a large, and increasing, number of falls of grounds in the face and back areas. The cumulative fall of ground data, recorded over a period of one year, indicated that 80% of the falls were 3 m thick in these areas. The support being used at this time was 1 m tendons and pencil sticks. To address the problem, the support resistance immediately behind the face area was increased dramatically as a first attempt to stabilise the face area and thereby stop the falls. 1 m long tendons were continued in an attempt to support the beam between the last line of support and the face. The larger falls of ground in face areas were stopped by this step, but smaller falls of ground continued. Large falls of ground still took place in back areas. Fall of ground data indicated that the thickness of hangingwall that had to be supported in face areas was just less than 1.5 m. Therefore the 1 m long tendons were replaced by 1.5 m cable anchors in the face area. RSS/Mesh grout packs were introduced to support back areas at the stage where pencil sticks were beyond their yielding capacity. The number of falls of ground in face areas was dramatically reduced. This support system has now evolved into “timber-less stopes” where the fall out thickness is supported by means of cable anchors and grout packs only.

1. INTRODUCTION:

Rustenburg Platinum Mines, Amandelbult Section, Part of the Anglo Platinum Group, is a platinum mine situated in the Bushveld Igneous Complex, 80 km north of Rustenburg, as shown in Figure 1.

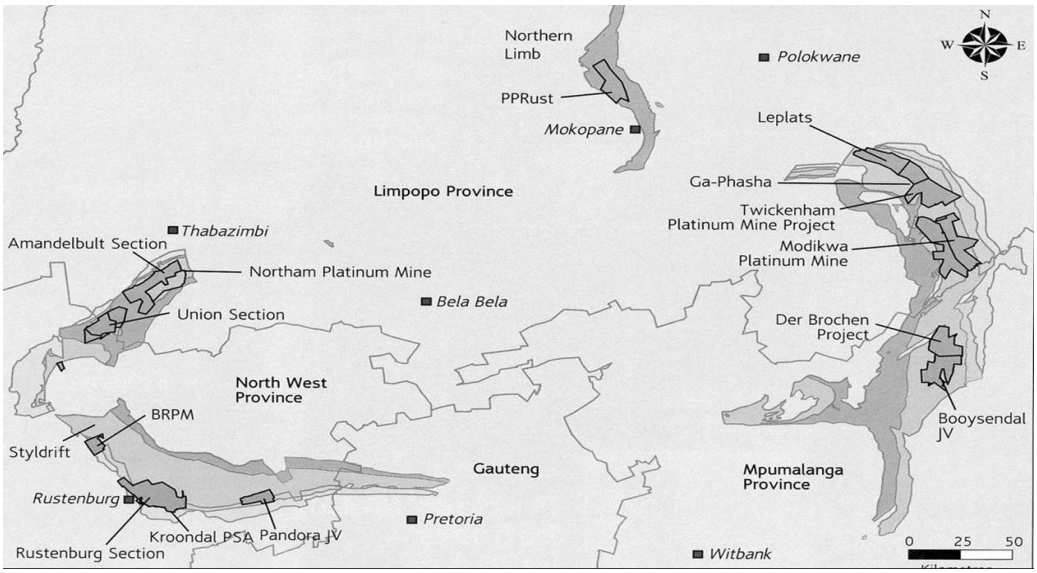

Figure 1 Location of Amandelbult inside the Bushveld Igneous Complex

Mining of the Merensky reef, which is the primary of the two platinum bearing reefs, has progressed to considerable depths. It has been mined from 30 m below surface to a depth of 1000 m at Amandelbult No. 2 Shaft (see Figure 2). The planned depth of mining at this shaft will be approximately 1200 m below surface. Hangingwall conditions of the Merensky Reef in this part of the mine are mostly extremely poor with a RMR of upper Class IV to Class V (unmineable) in some places.

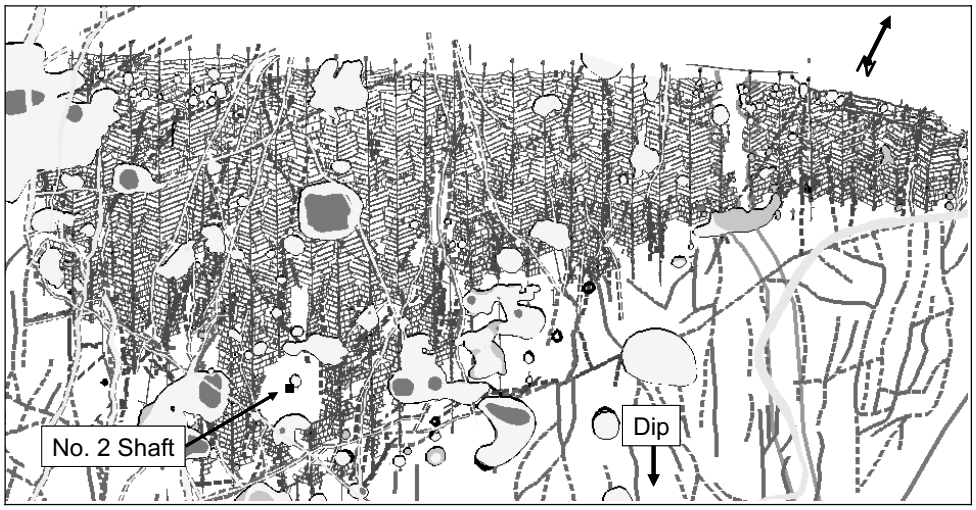

Figure 2 Extent of Merensky mining at No. 2 Shaft

The Merensky Reef at Amandelbult is typically mined in underhand stopes with breast panels as shown in Figure 3. Stability pillars are left at 100 m intervals and strike ("chain") pillars cut 33 m apart, centre to centre, to provide support between the stability pillars.

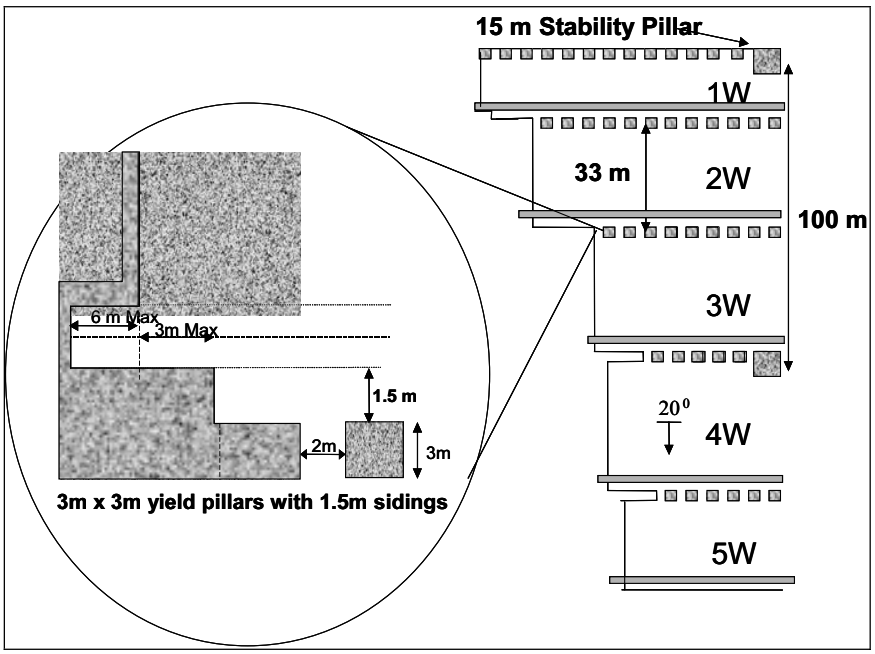

Figure 3 A typical Merensky stope lay-out

The internal panel support standard employed by Amandelbult No. 2 Shaft before this exercise consisted of pre-stressed pencil sticks, installed 5 m from the face on a 1.5 m by 1.8 m spacing, as well as 1.0 m long tendons, installed 0.5 m from the face before the blast on a 1.5 m dip spacing. This panel span and support was designed making use of the Voussoir Arch theory and checked with the fall of ground statistics (Figure 4).

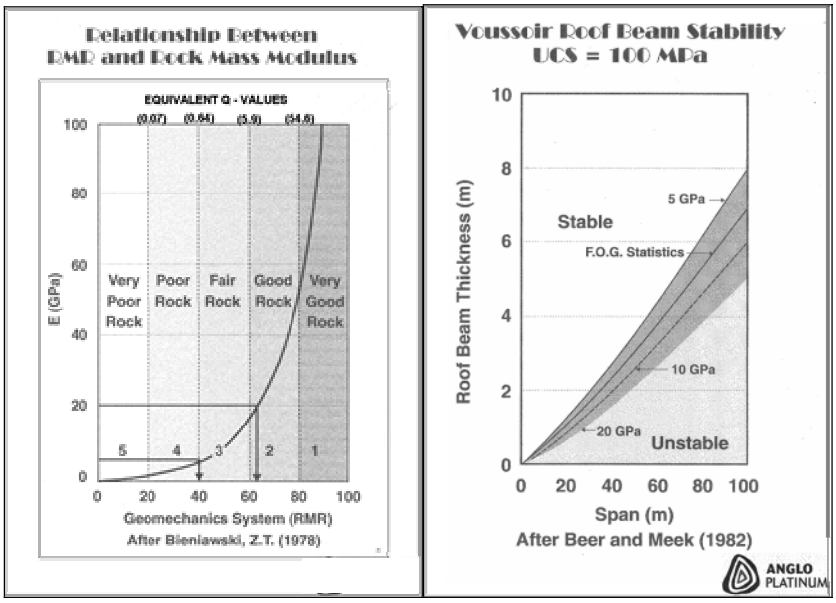

Figure 4 Relationship between RMR and RMM and Voussoir Arch charts used for panel and support design

This design prescribed 30 m panels and support with a capacity of 45 kN (equivalent to 1.5 m of hangingwall).

The support resistance provided by this support lay-out, including two rows of mechanical props, is shown in Figure 5. This support standard differed slightly from other sections on the mine in that support spacings were closed slightly due to the poor rock mass in the No. 2 Shaft workings. The demand quoted in the figures does not include any safety factor, but the capacity includes down-rated support units. The demand correlates with the cumulative falls of ground statistics.

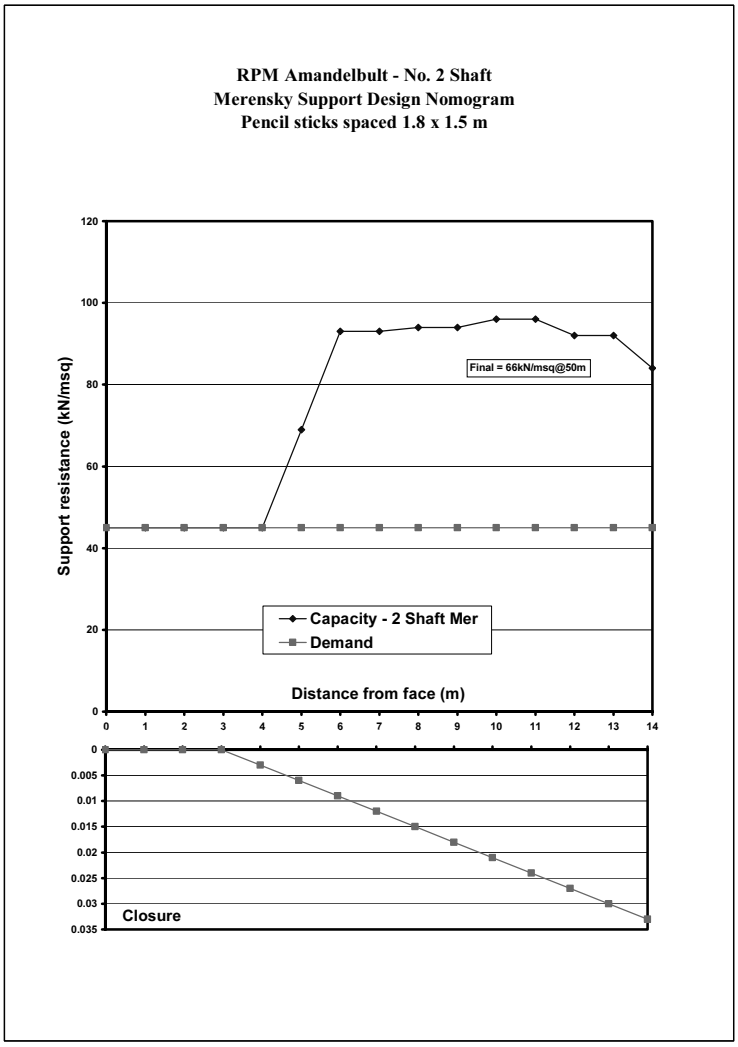

Figure 5 Original No. 2 Shaft Merensky support capacity

2. BACKGROUND:

A steady increase in the frequency and thickness (height) of falls of ground has continued, in spite of the more stringent support standard, as can be seen from the fall of ground data (Figure 6) that has been recorded over 12 months by production and rock engineering personnel on the shaft.

One has to remember that most of the smaller falls would not have been recorded as they are often simply cleaned for the production cycle to continue. This doesn't change the fact that the support resistance, especially in the face area, had to be increased dramatically.

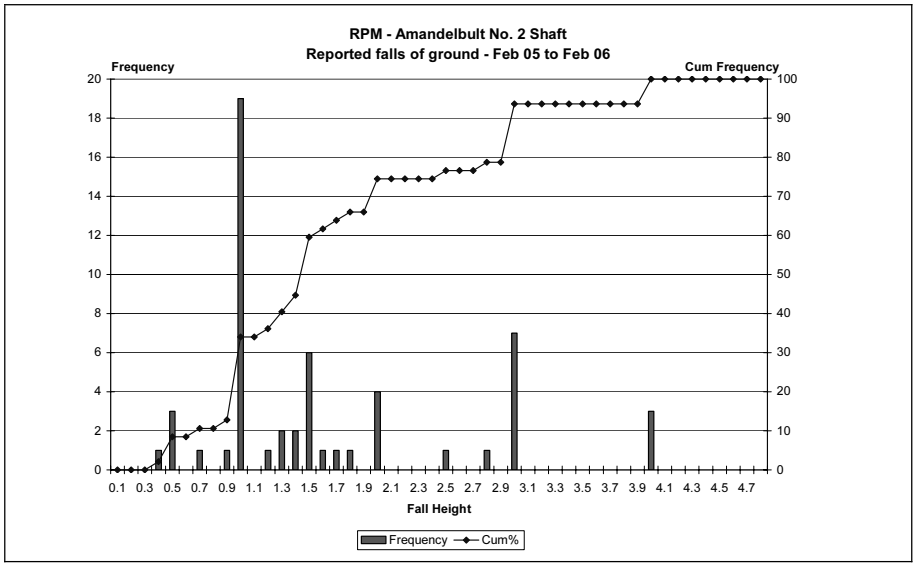

Figure 6 Face area falls of ground data over the period February 05 to February 06

Core drilling into the hanging wall of one of the stopes, where reasonably poor conditions were encountered, confirmed that natural breaks, dipping sub-parallel to the reef (stope), occurred more than 4 m into the hangingwall. The face support was therefore required to stabilize blocks and wedges, thereby creating a reinforced beam.

Figure 7 Core from one of the hanging wall holes at No. 2 Shaft

From the accumulated data it became evident that the approximate height of hangingwall to be supported was in the region of 3 m (90 kN/m^2).

The "historical" role of the in-stope roof tendons that were being installed was to support smaller blocks in the face area, preventing block rotation, and to stabilise the beam formed between the pencil sticks and the face. As these units did not penetrate the fall-out thickness of the area they were excluded from the support design calculations.

Field studies in the industry indicated that an increased support resistance closer to the face assists with stabilizing the face area as well. This effect is, however, very difficult to quantify. The support resistance in the No. 2 Shaft Merensky stopes was subsequently increased by reducing the dip spacing of pencil sticks from 1.5 m to 1 m. The spacing therefore became 1.8 m on strike by 1 m on dip. The support to face distance was also reduced to 4 m (after the blast). The support resistance provided by this standard, including two rows of mechanical props, is shown in Figure 8.

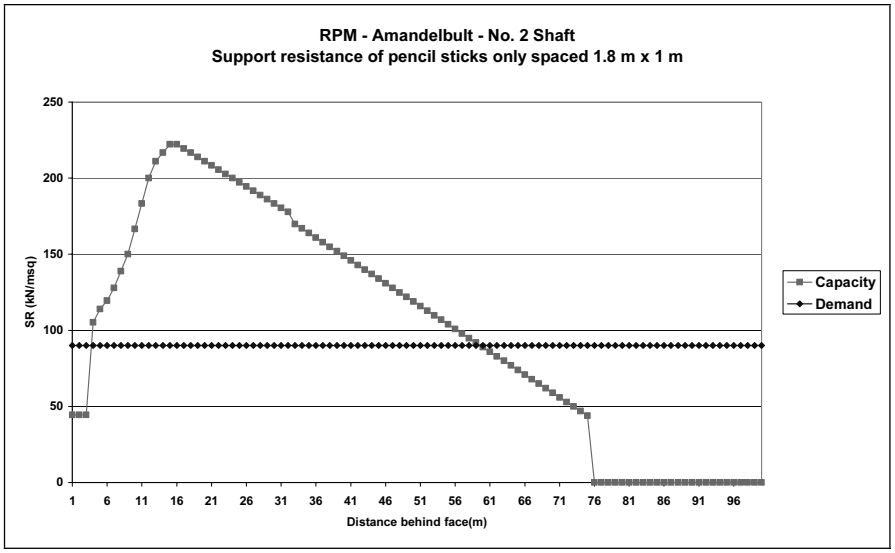

Figure 8 Support capacity of the 1.8 x 1 m pencil stick spacing, installed 4 m from the face

3. OBSERVATIONS AND DISCUSSIONS:

Two major inadequacies of the above-mentioned support layout are:

- the lack of support resistance in the far back area (Figure 8), i.e. after the pencil sticks reach the end of their deformation range at approximately 50 m from the face. The steady increase in closure in the back area results in the "weakening" of pencil sticks as the face progresses further from them. This results in further falls approximately 3 m high in the back areas. Falls in the back areas destabilise gullies to such an extent that a number of them had to be abandoned in spite of extreme support measures (caused by an over-run or cantilever).
- the lack of support resistance in the face area. A large number of the recorded falls occurred in the face area.

A few fall of ground incidents revealed that the 1 m long tendons were ineffective for the support of narrow wedges (key-blocks) and brows in face areas. They effectively render support to a confined beam only, due to the lateral force that they provide until the boundary of the beam daylights, when the lateral confinement is removed and falls of ground occur (as shown in Figure 9).

Subsequent analysis of the fall of ground data revealed that 95 % of all face area falls for this area have a height of just less than 1.5 m. These falls have occurred in spite of the more stringent pencil prop standard. Any remedial action should therefore increase the support resistance in face areas.

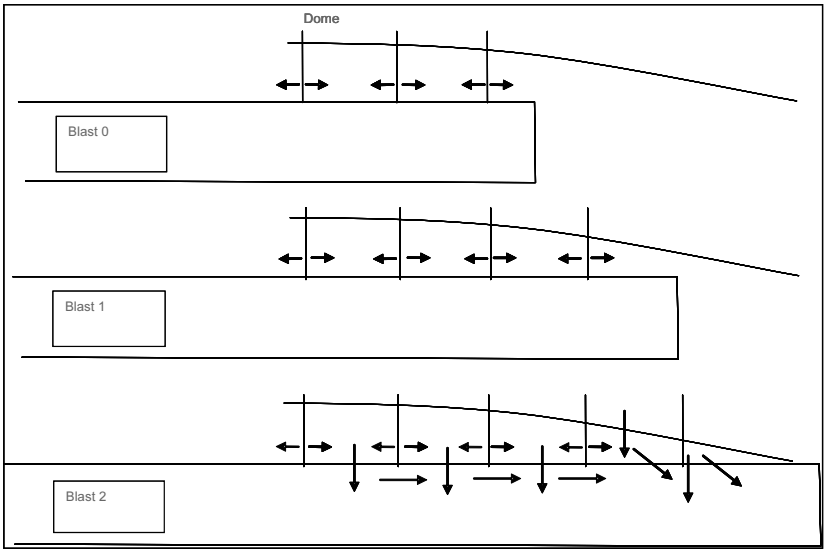

Figure 9 Mode of failure of hanging wall face area

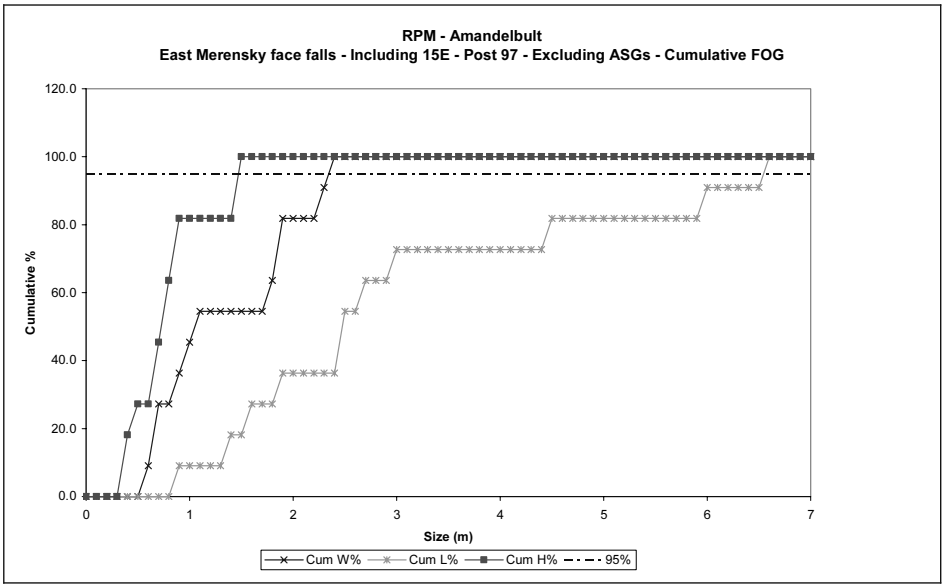

Figure 10 Cumulative falls of ground in face areas of the mine excluding Merensky West Section and gullies

Accurate data on falls in face areas since the last change to the support standard (1.8 x 1 m) is not available yet. A number of faces have however been lost and had to be re-raised due to dangerous hangingwall conditions and falls of ground in spite of the implementation of this reduced support spacing.

4. PROBLEM DEFINITION:

The need for support that can penetrate beyond the historic fall-out thickness, provide a high support resistance and provide a pre-load that could assist with beam building was realised. This support obviously had to be tendons and had to be installed in a limited stoping width (from as low as 1.2 m).

There was also a secondary need for support with a high support resistance and a large yield range to "take over" from the failing pencil sticks in the back areas.

5. PROPOSED AND IMPLEMENTED SOLUTION:

A few (economically) available tendons were roughly evaluated. They included:

- longer tendons: discarded due to their mode of operation;
- coupling bolts: discarded due to the difficulty of grouting them;
- shell anchored tendons: were at first discarded due to expense and the need for cumbersome secondary equipment. New lightweight cable anchors and equipment were however introduced to the market at the time of this investigation and it was therefore decided to trial this support type.

A pattern of 1.5 m long anchors in combination with the current pencil stick standard and systematic installation of grout packs, installed as shown in Figure 11, was therefore evaluated.

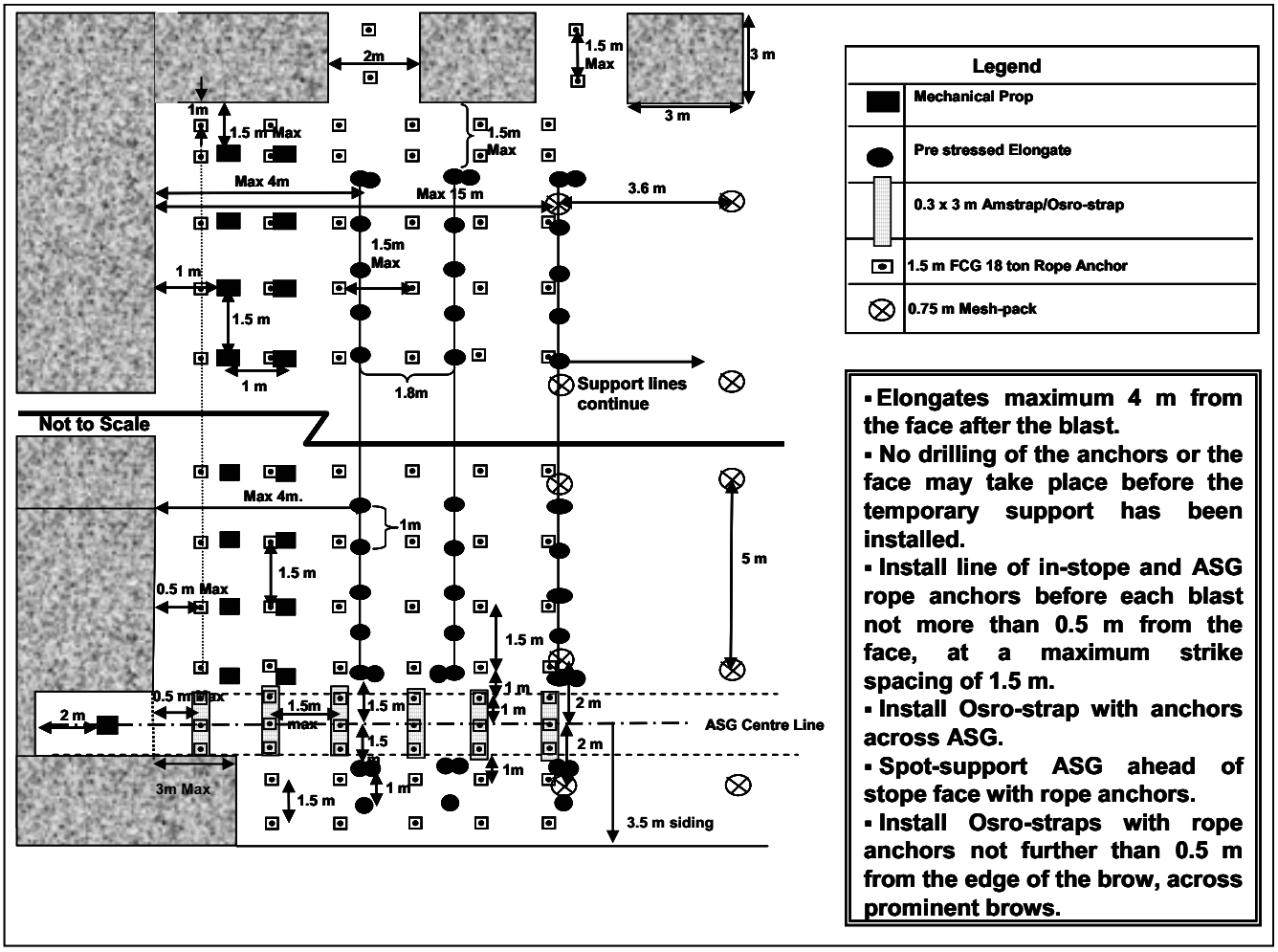

Figure 11 Proposed cable anchor support standard

13 mm Diameter full column grout-able cable anchors (shown in Figure 12), with a support capacity of 140 kN and that could be preloaded to 40 kN were subsequently trialled.

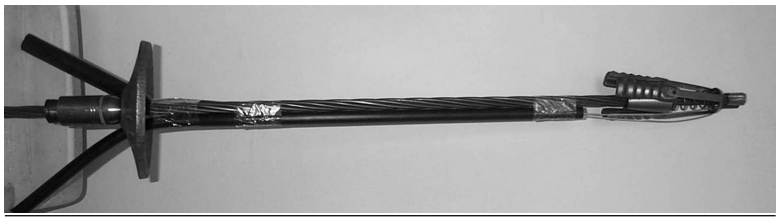

Figure 12 "Light weight" (13 mm diameter) cable anchor

Ancillary equipment provided for use with the new generation "light-weight" cable anchor was equally light weight and easy to use (shown in Figures 13 and 14).

Figure 13 Hydraulic pump used with light weight cable anchor

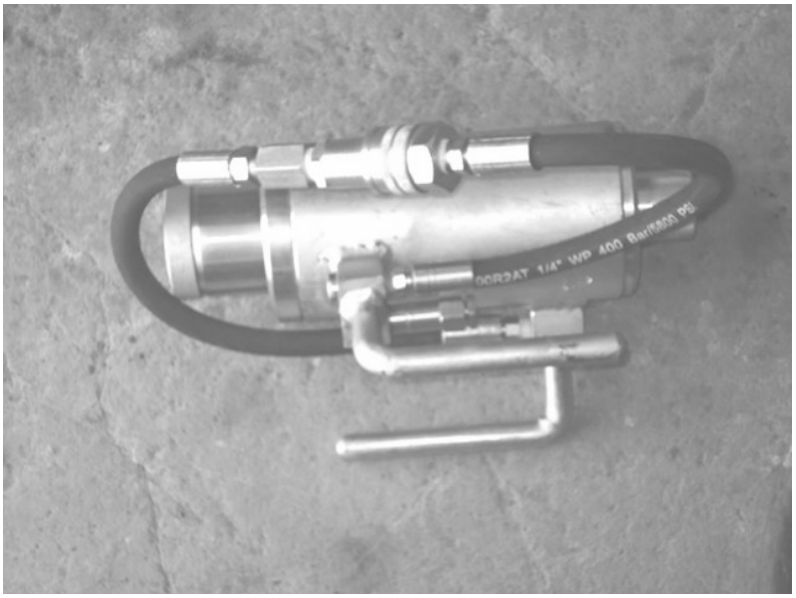

Figure 14 Hydraulic jack used with light weight cable anchor

0.75 m Mesh/RSS packs were introduced in the back areas to provide support when the total closure exceeded the yielding capacity of pencil sticks.
The support system was trialled in a few panels and after just a few weeks it became evident that the objectives have been achieved in spite of it being a very expensive option. The system was subsequently rolled out to more than 60 other panels in just over three months.

This support system has the following advantages:

- the support resistance supplied by the tendon in the face area can now be included in the design capacity due to it penetrating to beyond the required hangingwall thickness and the "95% fall-out thickness" (as shown in Figure 15);
- the pre-load supplied by these tendons acts in the direction of the tendon and thus in the direction of required support. The hangingwall is therefore clamped by this action;
- a very high support resistance is maintained close to the face area, thereby assisting with stabilisation of the face area (as shown in Figure 16);
- strapping can be installed with anchors, previously not possible with tendon support.
- packs start working optimally when pencil support starts failing in the back area, thereby stabilizing the back area. A support resistance equivalent to 3 m of hangingwall is maintained in the back area (as shown in Figure 15);

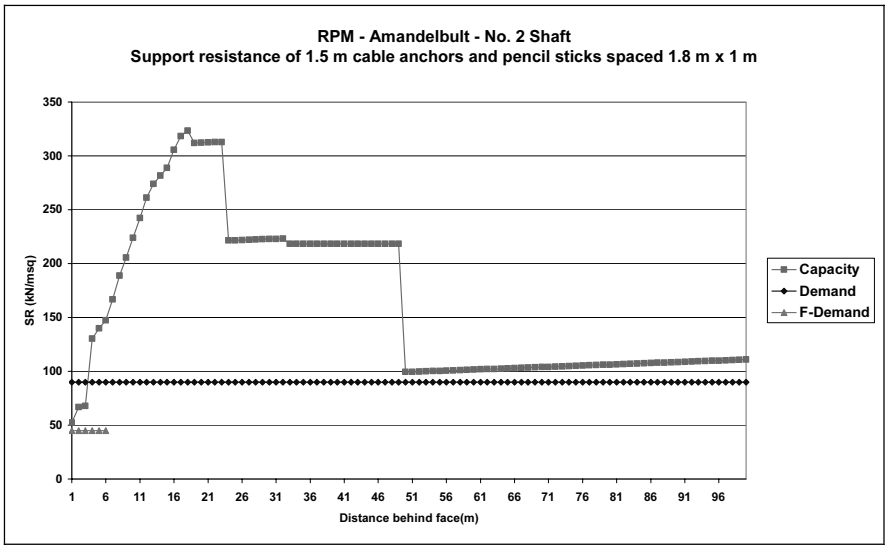

Figure 15 Support resistance of implemented standard, face and back area including pack support

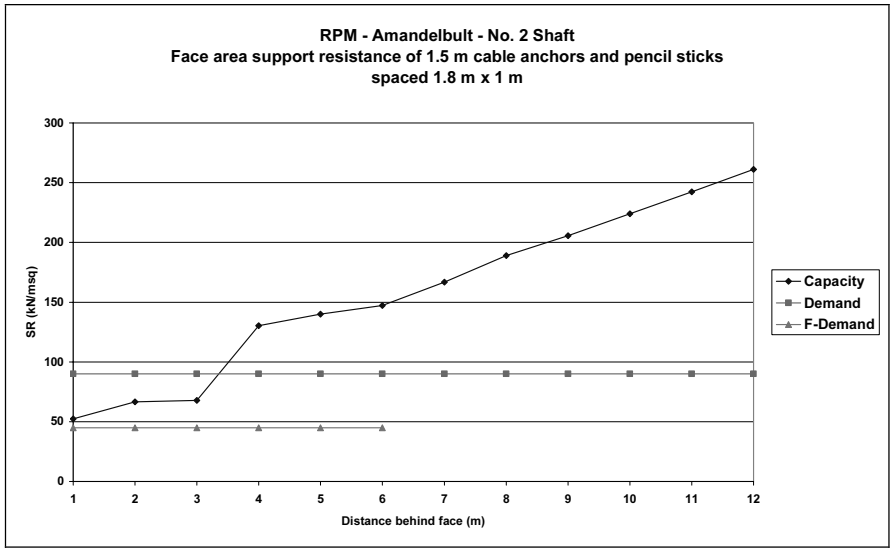

Figure 16 Zoomed view of face area support resistance

Although there is a reporting system implemented on the mine to attempt to capture all falls of ground, they are most often only reported when loss of production took place. Reported falls of ground were drastically reduced from an average of 12 in January 2006 to 1 in April 2006 (as shown in Figure 17).

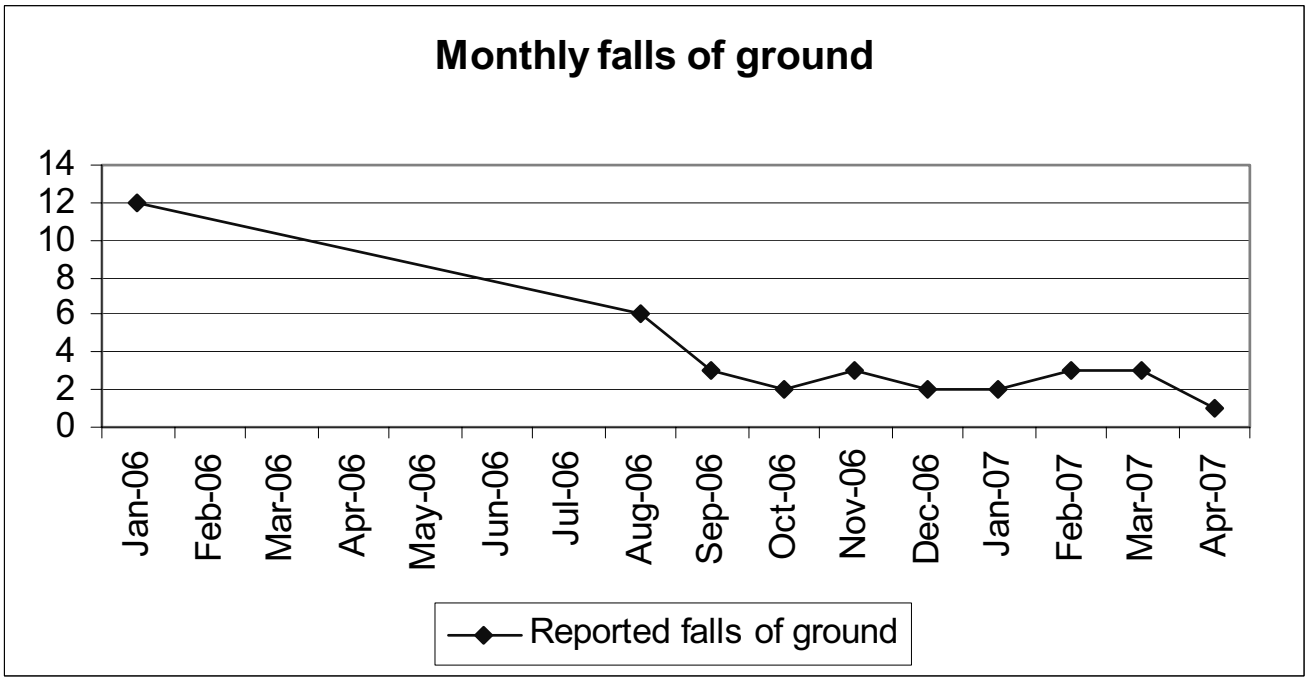

Figure 17 Reported falls of ground causing interruption of production

The cable anchor support system has the following disadvantages:

- the support system is very expensive. Tendon support costs increases by 140%. Total cost went up by 50% excluding the labour. Two additional crew members had to be signed on.
- requires considerable capital outlay for equipment required per panel;
- the number of sets of equipment required to prevent lost blasts due to equipment failure is twice the number of panels;
- difficult to control the length/depth of installation;
- quality control of the inserted grouting is difficult;
- equipment requires extensive back up servicing. A workshop (Figure 18) had to be erected, equipped and staffed at each shaft where the system has been deployed.

Figure 18 Workshop at shaft for repairing hydraulic equipment

Although not yet properly quantified, it is obvious that the advantages of the system far outweigh the disadvantages if one only considers the additional blasts achieved (a panel would previously have been sterilized by a fall of ground), not to mention the safety benefits being drastically improved.

Comparisons between the original tendon support units and anchors have been carried out with use of the JBlock program but did not reveal any major differences. This can mainly be ascribed to the large support resistance 4 m from the face, delivered by the pencil props and the small difference in bond strength of the two support units.

6. FURTHER DEVELOPMENTS:

With the shortage of timber in the market and after the good working performance of the 1.5 m cable anchor, it was decided to conduct trial "timber-less" stopes. These timber-less stopes are supported by means of 1.5 m or 3.0 m cable anchors and RSS grout packs only (with only the timber required for building of the packs and those acting as "policeman sticks" present in the stope).

Two sets of panels are currently being mined on this support system, one on the UG2 Reef horizon (in a different section of the mine, shown in Figure 19) utilizing 1.5 m cable anchors and three so far on the Merensky reef horizon at No. 2 Shaft (shown in Figure 20) and results are very promising.

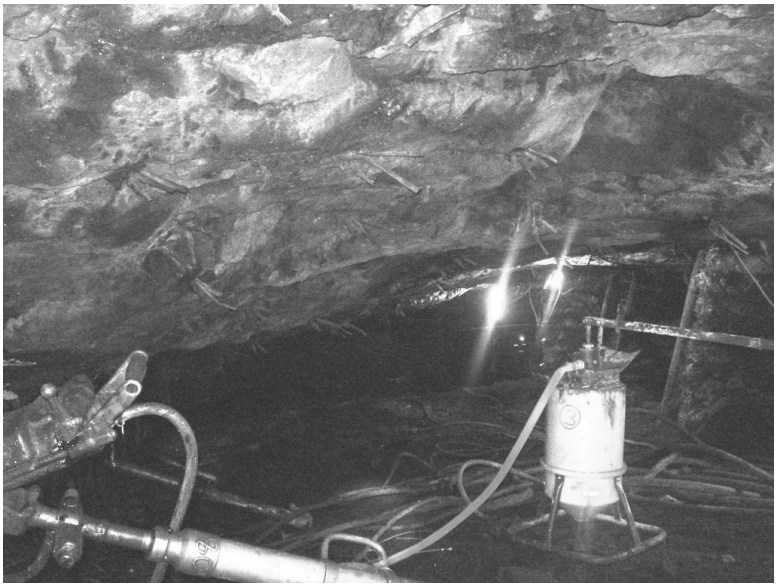

Figure 19 Timber-less UG2 Panel utilizing 1.5 m cable anchors and grout packs

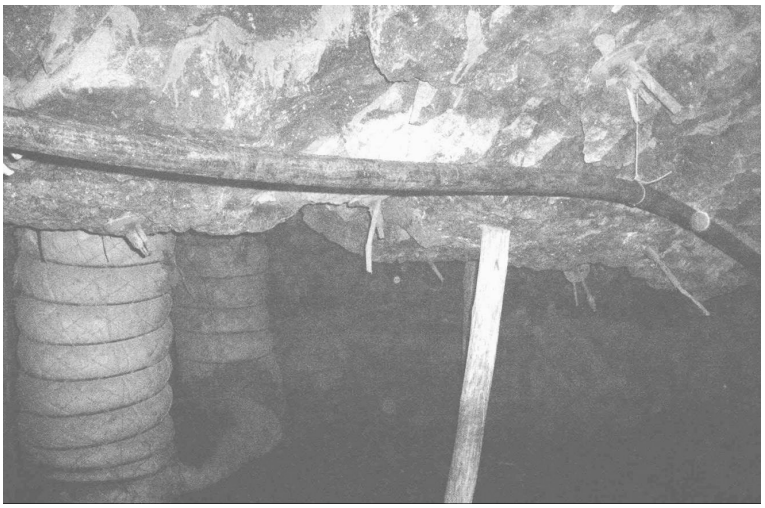

Figure 20 Timber-less Merensky panel utilizing 3 m cable anchors and grout packs

The theory used for these designs was a combination of stable beams and fall-out thickness.

The mine's worst face fall out thickness combined with the worst position of the first weak layer in the hangingwall was used for the UG2 panel to create a competent 1.5 m beam that will stand up to the spans that were created.

The No. 2 Shaft Merensky design similarly created a 3 m beam that will stand up to the panel spans that were created. Flexing of these beams is being resisted with RSS packs with a capacity equal to the fall out thickness.

A significant observation in the Merensky Reef trial is that virtually no closure is taking place in the back areas where the 3 m cable anchors were installed. This is quite the opposite from the behaviour with traditional pencil sticks, where relatively large closures were observed. This is indicative of a very stiff, competent beam that has been created through this support methodology by the reinforcing supplied by the cable anchors to a very poor rock mass.

The only obstacle in the way of full implementation of this support system is the difficulty in drilling of the holes. New improved technology drilling machines have reduced the drilling times from 43 minutes per hole to less than 20 minutes per hole (collar to collar). Roll-out into a full section will be executed once a solution for drill steel breakages has been found. Significant advances have already also been made in this regard.

7. CONCLUSIONS:

Moving from a rigid tendon to flexible cable anchors, which can be installed in any chosen length in a limited stoping height, combined with the reasonably large pre-load that they provide, has certainly proved to be the correct step in obtaining an efficient support medium for tabular platinum mining. The required support can be installed right at the face, where personnel spend most of their working shift, without interfering with cleaning operations. Using this support medium as the sole panel support, i.e. without timber, will definitely be rolled out to more panels once uninterrupted drilling of deep holes has been achieved.

8. REFERENCES:

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9. ACKNOWLEDGEMENTS:

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