IMMEDIATE GROUND SUPPORT, AFTER DEVELOPMENT OR STOPE FACE EXPOSURE, CAN PREVENT FALLS OF GROUND.

B Vorster, Sales Manager, Minova RSA
D Franklin, Sales Manager, Minova RSA

ABSTRACT

Falls of Ground is one of the highest causes of incidents, accidents and fatal injuries in our mines today.

These falls of ground may occur as soon as the face is exposed after blasting or after machine cutting. The falls of ground can also occur after support has been installed.

There are many reasons why these falls occur before and after supporting of the face. It is therefore important to support the exposed face as soon as possible to prevent the falls of ground. It is also very important to support the face with the correct support products and to support the face as designed and required by the mining engineers.

The possible reasons for falls of ground, possible support methods and the products available will be discussed in this presentation. In typical conventional narrow vein stoping operations, the use of conventional temporary support components to offer some support to workers, whilst the permanent and generally more elaborate support system gets installed or constructed, still results in injuries to people.

The author wishes to discuss the following items in this paper:-

- Introduction
- Basic face behaviour after exposure
- Controllable Parameters
- Mining Engineers support designs
- Primary and Secondary Support
- Products available for prevention of falls of ground

INTRODUCTION

Falls of Ground is one of the highest causes of incidents, accidents and fatal injuries. These falls of ground may occur as soon as the face is exposed after blasting or after machine cutting. The falls of ground can also occur after support has been installed. There are many reasons why these falls occur before and after supporting of the face. It is therefore important to support the exposed face as soon as possible to prevent the falls of ground and to support the face with the correct support products; and to support the face as designed and required by the mining engineers.

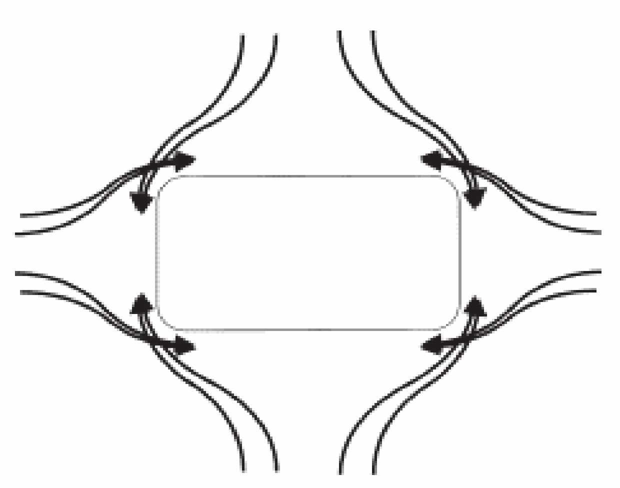
The possible reasons for falls of ground, possible support methods and the products available will be discussed in this presentation.

BASIC FACE BEHAVIOR AFTER EXPOSURE

Before mining commences, the rock environment is subjected to stress. The vertical stress is caused by the weight of the overlying rock, while the horizontal stress is largely unknown. These stresses may be generated by plate tectonics. Therefore, the stresses are generated by the continental plates pushing against one another.

Stresses are also caused when dyke intrusions force the rock mass apart to create routes for the molten lava. When mining exposes the rock face for the first time it does not cause the stresses, but redistributes the stresses that are already locked in the rock.

When roadways and tunnels or even stopes are created, there is a concentration of stresses around the edges of the excavations.

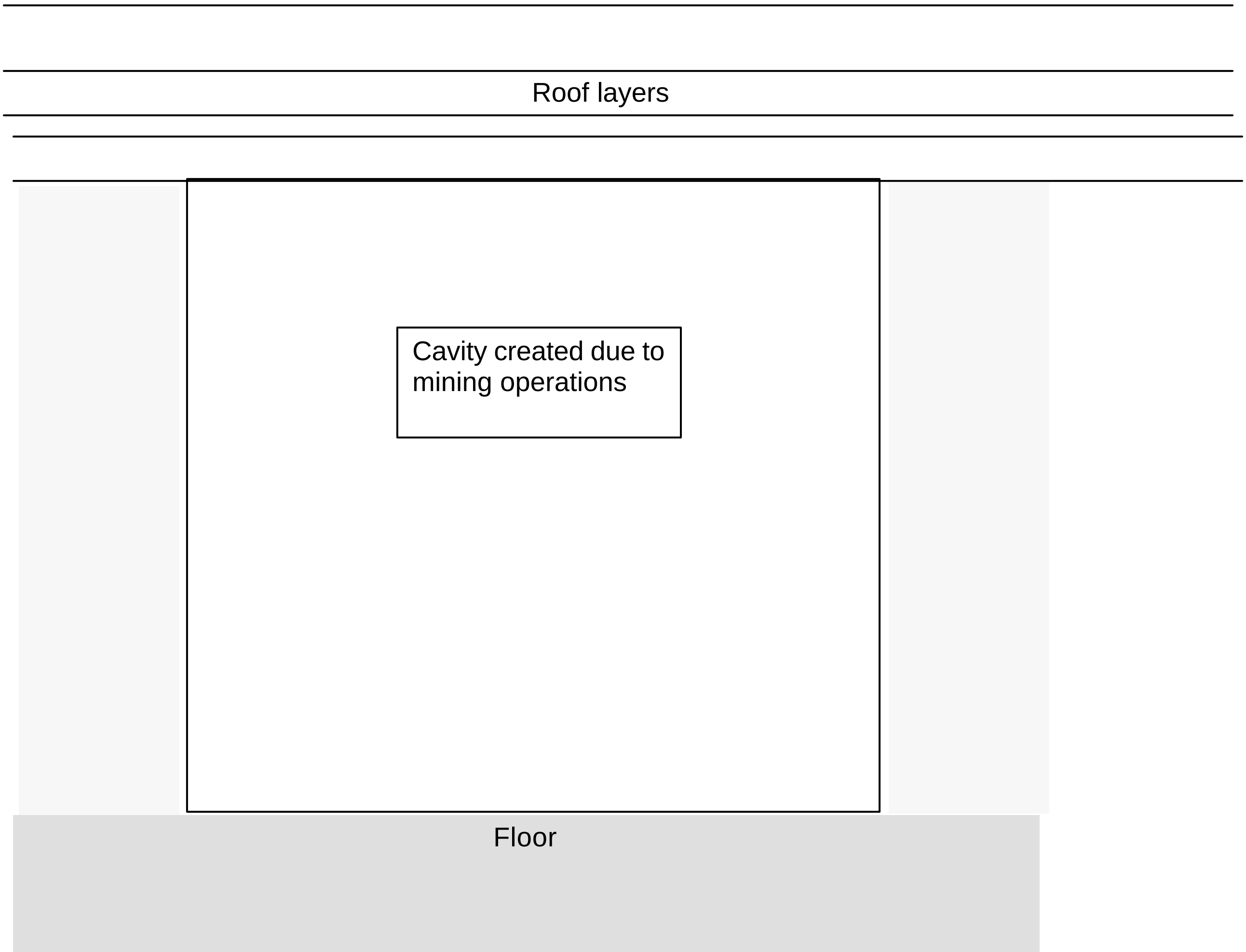


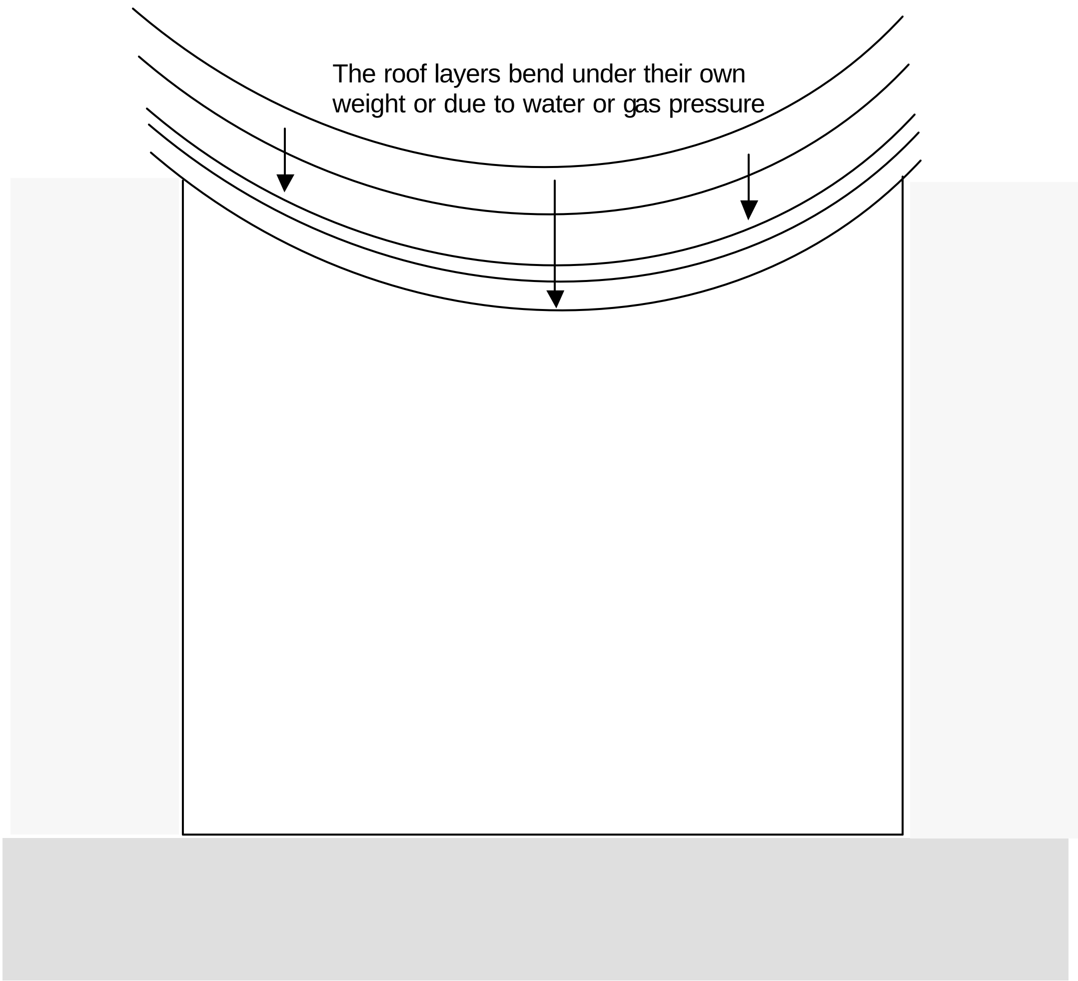
This causes the horizontal stresses in the roof to magnify, whist the vertical stresses in the sidewalls are magnified.

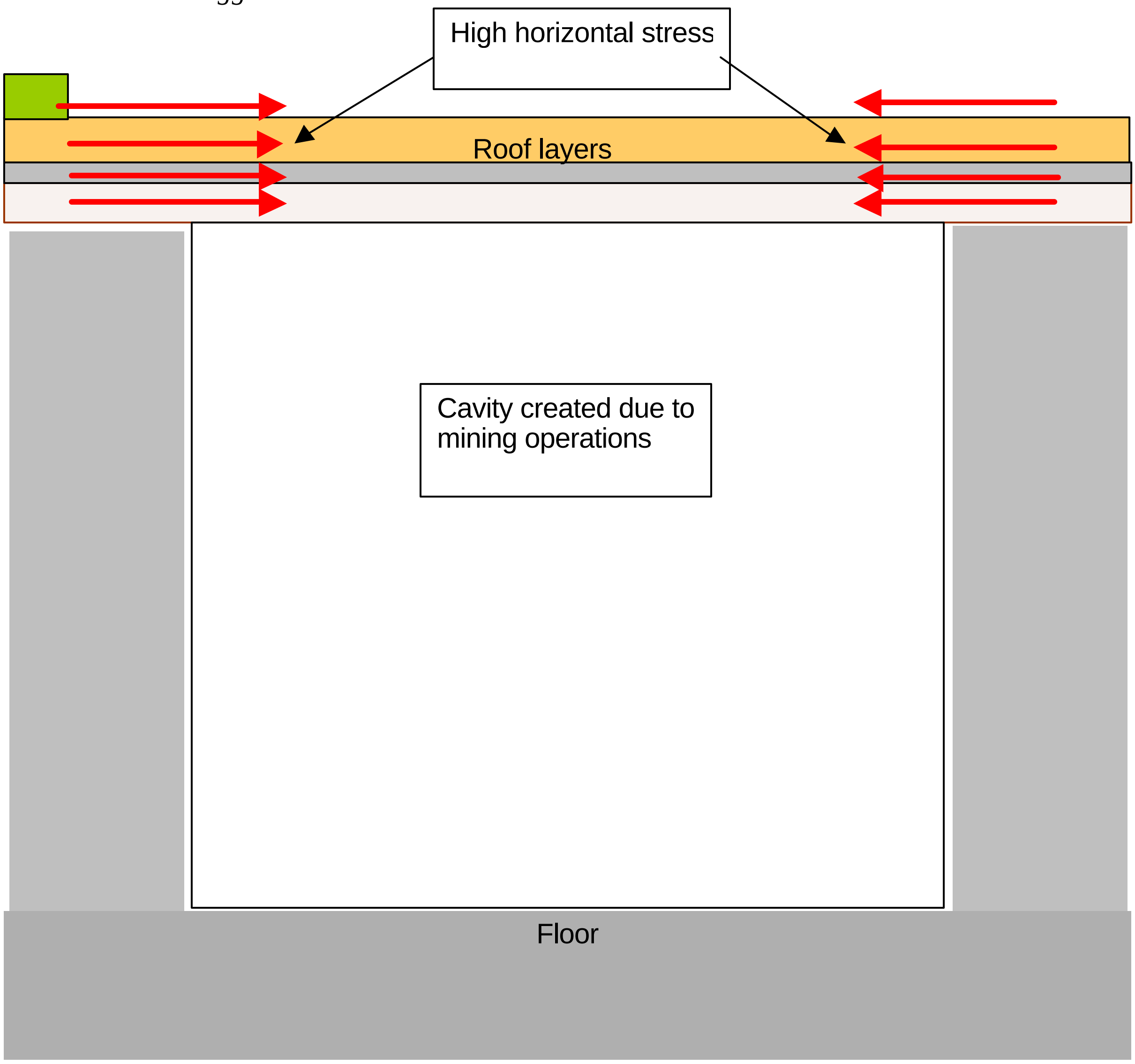
We have so far only discussed the influence of the external stress environment on the roof and sidewalls. The roof and sidewalls can still go through many changes. The first is gravity, where the roof and sidewalls want to fall down. The earth's gravitational pull is causing the roof and side-walls to move inwards and downwards.

Geological discontinuities can also change the mechanical behaviour of the rock structure. These discontinuities could be joints, faults, dykes and slips. A joint is a natural discontinuity which basically cuts the roof beam into two separate pieces, allowing it to cantilever. A fault is a joint where movement has taken place. A dyke is a molten lava intrusion into the rock mass. A slip is a small cut into the immediate layers of roof or sidewall.

Exposure to water and air can cause deterioration of the immediate rock which causes roof and sidewall failure and possible collapse. The change in the humidity affects the roof and sidewall stability, where the rock can become much weaker due to the exposure to moisture. Water also makes the rock weather more rapidly which results in stable slabs becoming unstable and falling down. During the rainy season the water flows down the joints and faults and then acts as a lubricant, unlocking the friction and allowing movement. Water can also dam up on a strong layer of rock and cause increased stress/weight on the immediate roof. This stress/weight can cause the failure of the roof and cause it to fall down.




The roof layers bend under their own weight or due to water or gas pressure



CONTROLLABLE PARAMETERS

To prevent unplanned collapses and falls of ground, the controllable parameters have to be used in such a way as to counter the negative stresses and situations. The three main controllable parameters are excavation width, time of support installation and the characteristics of the support system.

<u>Tunnel/Stope or excavation width</u>: The amount of roof sag is linked to the width of the excavation. The wider the excavation, the bigger the possibility of roof sag. The first step to be taken when encountering bad roof conditions is to decrease the excavation width. This explains why high extraction mining and intersections are prone to roof falls. Roof support design is only intended to support the weak material underneath the more competent layers

above, and not to support the main beam itself. Thus if the excavation is made wider than the design the stability of the roof beam is affected and falls can occur.

Time of support installation: The further the rock face advances from the last line of bolts or support, the greater the unsupported roof span. As discussed above the greater the roof/road width the greater the possibility of failure. If a roadway or tunnel is left unsupported for any length of time, deflection can occur, which causes the roof to bend and cracks to appear. The bigger the cracks the more air and moisture will seep in, reducing the rock's strength, causing even more deflection. These cracks are there just waiting for the slightest disturbance, which can then cause falls of ground. The problem also arises that the longer the roof is left unsupported the bigger the possibility that someone will move underneath this unsupported roof.

Characteristics of the support system: The support system begins by identifying the mechanism of roof falls in the area. The second step is to then design a suitable support system, taking into account the geological and stress conditions. Consideration must also be taken of the equipment available, the support materials that are available and the level of training of the work force.
This aspect will be covered in more detail in point four of this presentation.

Massive roof fall along joint plane

MINING ENGINEERS SUPPORT DESIGNS

Mining Engineering or specifically Rock Engineering is a professional science that takes many factors into consideration when designing roof and sidewall support. Only the basics will be discussed without attempting to address the detail.

It is very important that the Mining Engineer/Rock Engineer applies the correct calculations and formulations to support the required roof and sidewall. Attention on the costs involved in installing the required support and the support materials itself must be taken into consideration.

The first step is to determine the load on the system, including gravity and the presence of horizontal stresses. Next, the system has to be able to withstand the imposed loads. This is achieved by balancing the length, diameter, spacing of the proposed support method.

The load calculation should take into account the loads imposed from a force point of view, as well as establishing a stable beam. In cases where high horizontal stress is the main cause of roof instability, it is essential to concentrate on the stiffness of the support system.

Unfortunately rock is an extremely variable material: it can be strong or weak, massive or bedded and both major and minor structural features are common. In addition the magnitudes of the rock stresses are unlikely to be known in detail. Due to these complications, many support design methods have been developed and these are often specific to particular rock and stress conditions.

Different support methods have been used over a wide range of rock conditions. In shallow mines where rock is strong and stresses are low, rock failure may be purely gravitational. Design methods for these conditions concentrate on joint geometry and the prevention of block movement and failure.

In deep mines with weak rock, failure is predominantly stress driven, with shear failure through the rock mass and along planes of weakness such as joint planes. Design methods for these conditions concentrate on rock mass behaviour and the prevention of rock shear.

There are regulations and standards or codes of practice which govern the design and design method that can be implemented. The first requirement for any support design is to comply with the relevant standards and regulations.

PRIMARY AND SECONDARY SUPPORT

Primary support:
This is the support that should be installed immediately after face exposure. Once the face has been exposed, numerous reactions occur that affect the stability of the roof and sidewalls. The primary support should therefore be installed as soon as possible to protect the workers, and to prevent further instability.

The design and implementation of your primary support is very important. The support must be efficient and cost effective while providing excellent roof control. Examples of primary support are the fast setting resin capsules, mechanical anchors, friction bolts and even thin sprayed liners. The thin sprayed liners are sprayed on immediately after the blast to protect the roof and sidewalls whilst loading of the material is done.

Secondary support:
After the face has been supported temporally to protect the workers and allow for the loading of the face, a second round of long term support is installed. This secondary support is only implemented if the condition of the roof and sidewalls are so poor that additional long term support is required. Secondary support may also be installed if the primary support is not sufficient to protect the workers or machinery, or the roof and sidewalls have deteriorated to such an extent that additional support is needed.

Secondary support is also installed after major falls of ground and can be installed when mining through very poor badly burnt ground. An example of secondary support is mesh and shotcrete, steel archers, cement support products and thin sprayed liners.

PRODUCTS AVAILABLE FOR PREVENTION OF FALLS OF GROUND

There are numerous products available that could be used to assist the mine, contractor and engineer to prevent falls of ground. Previously, the main consideration when considering and comparing the different support systems was whether the support was active or passive. Active support is installed with pre-tension, while passive support only generates reaction once the rock mass starts moving. Recently however, the concept of stiff support is receiving attention.

Stiff support limits rock movement to the absolute minimum, while soft support allows movement to take place. Stiff systems also supply constraint to rock expansion and shearing due to high horizontal stresses.

Commonly used systems include:
- Mechanical anchor steel tendons
- Friction bolts
- Steel tendon bolts used in conjunction with resin capsules/cement capsules
- Fibre bolts used with resin/cement capsules
- Steel tendons used together with pumpable cement products
- Plastic meshing together with bolts
- Wire mesh and Shotcrete
- Thin sprayed liners, either cement or latex based

1. Mechanical anchor steel tendons

Mechanical anchored bolts or expansion shell anchors are a simple and widely available means of roof and sidewall support. This type of bolt gives immediate support after installation. The bolt is engaged by applying torque to the head of the bolt which in turn develops tension in the bolt head. Post cement grouting of the bolt can turn this bolt into a permanent anchor and prevent corrosion.

There are limitations to these bolts. The mechanism in which this bolt works limits their use in fairly hard rock conditions. Reliability depends on the amount of torque applied when installed. The bolt can loose tension through vibration after blasting. Corrosion may also occur where the rock contains water and this bolt is generally expensive.

Expanding shell end anchored bolt

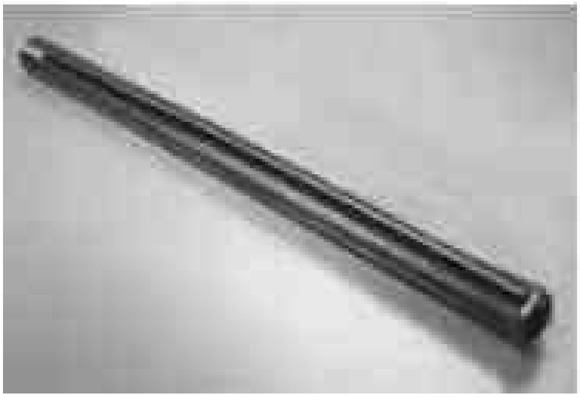
2. Friction bolts

Friction bolts ('split sets') are widely used in the hard rock mining industry where there is a high degree of bolting mechanisation and rock strata that are suitable for this system. These bolts work by utilising the friction generated between the strata and the bolt. Friction bolts should not be used for long term support, unless they are protected from corrosion. As it is friction bonded to the entire length of the hole it can be classified as a stiff support. But as it cannot be tensioned it is actually a passive support system.

Swellex bolts are friction bolts where the principal of operation is that having drilled a hole in rock to the required diameter and depth, the bolt is installed and a pump is used to expand the tubular bolt radically with water (or other incompressible liquid) at high pressure.

Advantages of Swellex bolt is quick and easy to install, wide expansion range, no resin or grout required and provides immediate support.

Swellex Type Bolt

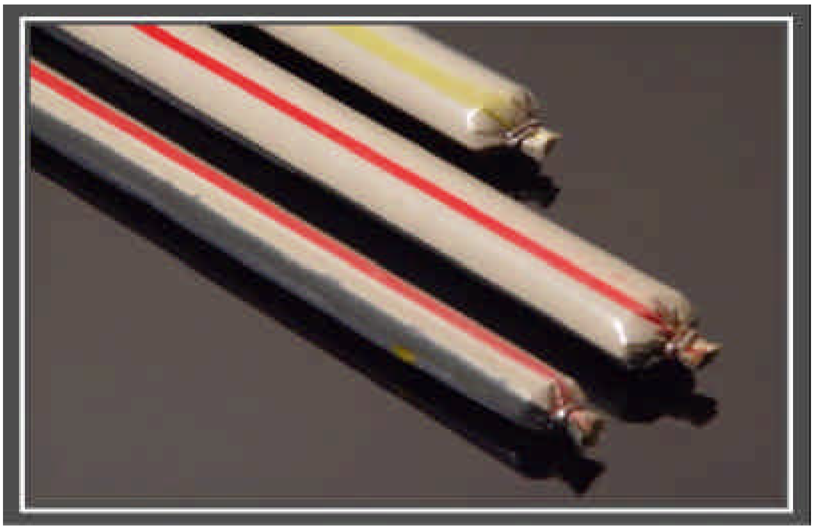


Split Set Bolt

3. Steel tendon bolts used in conjunction with resin capsules/cement capsules

Resin capsules are probably the most widely used type of grout material. Usually supplied in a two-component capsule, these are easy to use and install. Installation requires some degree of mechanisation and the relationship between the hole and bolt size has a large effect on the efficiency of the finished reinforcement. Installation involves spinning the bar through the capsule; the action then breaks the capsule and mixes the mastic and catalyst together. The resultant mix then hardens, fixing the bolt into the hole, almost instantly.

Resin capsules come in a wide range of sizes and set times that are tailored to suit the needs of the strata control conditions. As the size and speed can be altered, it allows for a very flexible bolting design which can be tailored to meet nearly all bolting situations. Considering the quality of in hole support, this support medium offers good value for money.



Resin Capsules

Capsule Diameter Ranges	19 mm	21 mm	23 mm	25 mm	32 mm
Resin Setting Times	15 sec	30 sec	60 sec	120 sec	5/10 min
Capsule Length Ranges	380 mm	500 mm	600 mm	800 mm	900 mm

Steel tendon bolts have been widely used for many years. The most commonly used bar is the grouted steel rebar or threaded bar. These bolts are usually used in conjunction with resin or cement grouts and can be used as either tensioned or un-tensioned, for temporary and permanent support in a variety of rock conditions.

Cement capsules provides a good alternative to pumped cement grouts. These are low in cost and very simple to use. The nature of the cement encapsulation removes some of the problems associated with poor mix discipline that sometimes occur with pumped systems. The speed of set may be a limiting factor, as it may be the slow strength gain grout. The main application for cement capsules is in areas where hand held operations take place and immediate support characteristics are not essential.

Capsule Diameter Ranges	25 mm	28 mm
Setting Time Ranges	1/2 2 tons after 1 hour	1/4 4 tons after 1 hour
Capsule Lengths (Fixed)	320 mm	320 mm

4. Fibre bolts used with resin/cement capsules

Fibreglass dowels are often used as sidewall support where steel bolts are not suitable; for instance in Longwall Mining or where Stooping is contemplated. They are either grouted into holes with resin capsules or cement grout. Fibre bolts have a similar tensile strength compared to steel bolts, and have been successfully installed where Raise Boring is planned.

GRP Bolts

5. Steel tendons used together with Pumpable cement products

There is a wide range of Pumpable Cement Grouts available for use. These range from simple Portland cement mixes to pre-bagged, formulated grouts with highly engineered characteristics such as pre and post-set expansion. These systems are usually batch mixed using simple mixer and pump units.

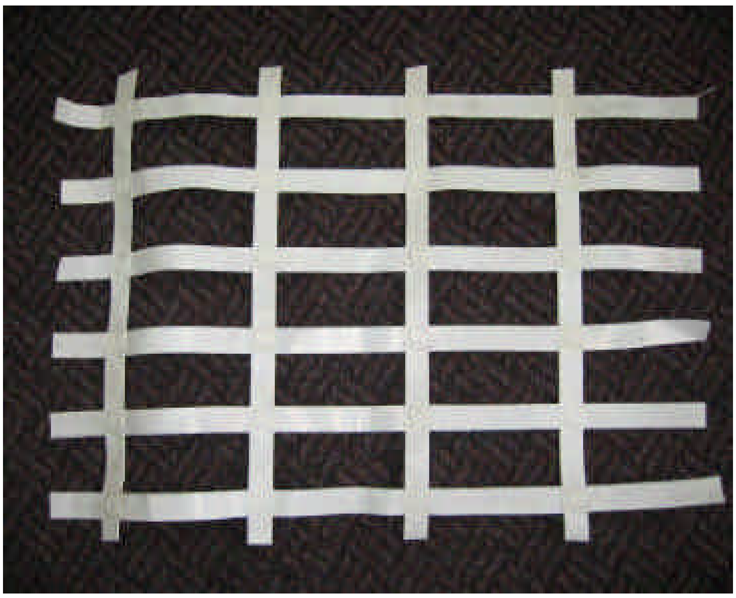
The nature of the grout allows for good penetration of the strata: full column grouting usually ensures a good bond between bolt and the strata. These grouts tend to be low cost but are subject to operator discipline. Uncontrolled addition of excess water adversely affects the performance of the grout. The new Pumpable grouts available removes the operator discipline when it comes to the amount of water added, as the grout when soaked in water only absorbs the correct water amount as required by the grout.

The main application for these types of grouts is for installing secondary support in conjunction with long tendon bolts.

6. Plastic mesh together with steel or fibre bolts

Plastic mesh can be used in areas where there is very friable and burnt ground. It is also used to prevent the small rock pieces from dislodging and causing larger roof or sidewall failure. In other words it keeps the key blocks in place.

The mesh is installed on the roof or sidewalls with steel bolts or Fibre bolts. Advantages of the plastic mesh are its light weight, durability and ease of installation. Injuries are also kept to a minimum as there are no sharp edges. Another benefit is that it can be sprayed on or covered with Shotcrete or a Thin Sprayed Liner to give additional support.



Typical Mesh

7. Wire mesh and Shotcrete

Wire mesh and Shotcrete are predominantly used in very weak, friable conditions like burnt ground or in densely populated long-term excavations like shaft sinking. The mesh serves as an area support, and therefore needs tensile strength. The mesh is firmly anchored by means of fully grouted steel tendon bolts, so that it is flush with the rock surface. Shotcrete is then applied onto the wire mesh. Shotcrete is a cement based product that adds the extra strength to protect the rock face. Fibre can be added to the Shotcrete to add strength to the final product. The Shotcrete isolates the rock from the atmosphere and protects the mesh from corrosion. It is essential to spray the Shotcrete onto the rock surface, which therefore requires the mesh to be flush with the rock surface. For most applications, a thickness of 50mm to 100mm is sufficient.

Mesh Covered with Shotcrete

8. Thin sprayed liners, either cement or latex based

With the demand for increased tonnages there is a requirement for faster cycle times. This means more faces are exposed at any one time and there is an increase in risk to the workers. The rate of advance exposes the workers to the small pieces of exposed rocks near the active face. Immediate protection of these workers has become very important, and therefore so has the support requirement.
Thin Sprayed Liners may solve this specific problem. The installation of immediate surface support using remote and rapid spraying techniques has the potential to minimise interference with the mining cycle. This immediate support provides the workers protection against falls of ground whilst allowing the increased tonnage demand.

Thin Sprayed Liners can be used for variety of support applications. Some of these include; Pillar support, face support, borehole linings, temporary support in ore passes and concrete shaft lining repair. The sealing properties of these liners open opportunities for applications other than rock service support. The liners could also be used to stop, reduce or slow down ground weathering, ground slaking and prevent water leakages.

The cement based liners are more cost effective but are more rigid and stiff than the latex based liners. The latex based liners allow for more defection and are slightly stronger than the cement based liner.

TSL Application

As mentioned previously Falls of Ground is a major cause of accidents and even fatals. In many cases such Falls of Ground could have been prevented if the correct support, as designed, had been installed directly after face exposure. Yes, Falls of Ground can still occur even after the roof has been supported as required. We must learn from these occurrences and use the knowledge gained to prevent further falls.

There are numerous products available in the market place that can assist in preventing these falls of ground. We have mentioned some, but there are too many variables to cover the complete range.

Some products are designed for general support and are used as your everyday support. These support products are readily available and can be used with some training.

There are support products however, that are designed specifically for very poor roof and sidewall conditions. These products are only used in specific areas and are designed for that situation only. They are not your day to day support products and can only be installed by highly trained personnel. These products are normally used when massive roof and sidewall failures have occurred or to prevent massive failures.

CONCLUSION

As can be learned from the presentation it is very important to support the face as soon as possible after exposure. There are numerous reasons why falls of ground occur, but these can be prevented by designing a support method and pattern, that can assist in the prevention of falls of ground. There are support products on the market that can assist and prevent these falls of ground, if they are installed correctly and timelessly

REFERENCES

Minova – Resin Bolting Handbook

AUTHOR

B Vorster, NHD Mining, Sales Manager, Minova RSA
D Franklin, Sales Manager, Minova RSA