Quest for 'effective pack' support

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Journal Paper

Synopsis

Following on the design of good mining layouts and regional support systems, and the implementation of sound strata control practices, stope support is the ultimate strategy to combat the hazards of rockfalls and rockbursts. The primary function of stope support in intermediate and deep level mines is to stabilize the rock mass immediately surrounding stoping excavations, that is, the zone of fractured rock which behaves inelastically around stopes.

Support design is a process resulting in a support system which is both practical and meets or exceeds by a factor of safety the requirements for a particular geotechnical environment.

The aim of this project was to design a support system, which accommodates the factors of rockfalls and rockbursts. The pack support unit must be easily handled, less costly and can be used in stopes without any significant convergence.

The project tested the structural stability of packs to their expected deformation, in order to design a height to width ratio for stopes where little convergence is expected.

Introduction

There has been a constant stream of new development in Rock Engineering department over the years. Such developments are generally aimed at improving safety at the mines.

Following on the design of good mining layouts and regional support systems, and the implementation of sound strata control practices, stope support is the ultimate strategy to combat the hazards of rockfalls and rockbursts. The primary function of stope support in intermediate and deep level mines is to stabilize the rock mass immediately surrounding stoping excavations, that is, the zone of fractured rock which behaves inelastically around stopes.

Support design is a process resulting in a support system that is both practical and meets or exceeds by a factor of safety the requirements for a particular geotechnical environment.

In designing a stope support system to reduce the incidence of rock falls and to reduce the damage associated with rockbursts, a number of factors need to be taken into account, namely:

- volume of the rock to be supported
- stratigraphy and the degree of fracturing of the hangingwall strata
- influence of the local geology
- amount and rate of stope closure
- size and shape of the excavation
- probability of rockbursts
- duration for which the support is required.

Objective

Pack support has been the most used method of supporting underground stopes. It most probably is due to its characteristics of its low costs, easy installation and its natural strength.

This project is to design a support system, which accommodates the factors of rockfalls and rockbursts. A pack support unit, can be easily handled, is less costly and which is used in stopes without any significant convergence.

The project will test the structural stability of packs to their expected deformation, in order to design a height to width ratio for stopes where little convergence is expected.

Stope support elements

Timber prop

The typical face support element is the ordinary timber prop. Timber props have a number of qualities that make their use attractive in many situations. The most important of these are their lightness and their high support resistance at relatively little deformation. The latter characteristics makes them well suited for use in areas of restricted

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convergence, that is, close to the stope face, in ledging stopes and in sidings. Their main disadvantage is a comparative lack of yield properties.

Pack support

A large variety of pack support is available, with widely diverse load-deformation characteristics. The options range from relatively soft and weak skeleton packs, through mat and solid timber packs, a combination of concrete blocks and timber, grout packs with grout gravitated from the surface preparation plant, and a combination of elongates and framework of timber slabs, to the more recent innovation of end-grained timber blocks reinforced with steel mesh or wood fibres. These latter two types are supplied in modular sections, which interlock and can be engineered to provide a wide range of combinations of initial stiffness, yield force and strength. Thus the challenge to the design engineer is to define the support requirements, and then to choose the appropriate pack type to match the requirements in the most cost-effective support system.

Building packs must be installed as governed by the support standard in effect at that time. This means that the size of the pack must be correct for the stoping width at the point of installation:

- In general, a height to width ratio of 2:1 (using the narrowest width) is acceptable practice where significant convergence is expected.
- It should be noted, however, that large ratios maybe accepted in applications where little convergence is expected.

Pack support is passive, i.e. it develops resistance in reaction to deformation. It is very important to know how much deformation will the support be exposed to at different distances from the face. The support should be such that bed separation should be minimized.

It is also very important to know the amount of closure at the time of installation, closure as the stope advances, and closure characteristics of the stope.

Characteristics of support units

The factors that are important in the design of a support unit for a particular set of conditions are:

- *Peak strength* is the maximum strength that the unit can provide.
- *Stiffness* is the initial slope of the force-deformation curve. High stiffness is important in low closure rate stopes in order that the support unit builds up support resistance rapidly. Prestressing is a way to generate effective high stiffness in other low units.
- *Yieldability* is defined as the amount of deformation a unit can withstand while sustaining a significant load bearing capability. Little yieldability thus limits the application to areas where low amounts of closure are expected.
- *Yield force* is the load bearing capacity of a unit at various amounts of compression.

It must be noted that units made where the grain is orientated perpendicular to the direction of compression provide good yield but poor stiffness characteristics. But where the grain is parallel to the direction of compression, higher stiffness but poor yieldability are achieved.

It is imperative to know the characteristics of the pack by testing the unit under controlled conditions to obtain its load-deformation curve.

As part of the project, two types of packs were used for tests purposes: packs with construction of end and parallel grain components, which provide both good stiffness and yieldability characteristics.

55 x 49 x 11 cm Timrite Lexus: stope support pack

It is manufactured with a 11 cm rise slab and two 11 cm rise split slabs on the sides. The blocks' 13 cm rise material are cut to 11 cm length. It weighs approximately 17.4 kg. The Timrite Lexus is an economical timber pack with good initial stiffness and relatively low ultimate stiffness. The configuration is such that the material is used efficiently and the performance is enhanced by the use of end grain blocks. (Figure 1.)

55 x 27 x 11cm Timrite Lexus: stope support pack

The 55 cm Half Timrite Lexus is designed to be an economical timber pack with high initial stiffness and relatively low ultimate stiffness. It is a modular unit consisting of two 55 cm split slabs and two end grain blocks from13 cm rise slabs. The unit is spin drilled together. The unit width is 27 cm, and it weighs approximately 6 kg, see Figure 2.

Figure 1—55 x 49 x 11 cm Timrite Lexus: stope support pack

Figure 2—55 x 27 x 11 cm Timrite Lexus: stope support pack

These unit was also meant to be a supplement to the 55 x 49 x 11 cm Timrite Lexus, see Figure 3.

Factors influencing pack performance

The rule of thumb has been applied ever since packs were used as permanent support in underground mining, and it has served the industry very well. Looking at the issue of costs, can we go for a larger height to width ratio? Let us take a look at various factors concerning this subject.

Pack configuration

Timrite design a range of products to carry a majority load around the perimeter of the pack. In simple terms, the wider the load bearing surface, the more stable the structure will be in compression.

It is important to note that the outer extremities of the pack be used to bear load. If this is the case, then the pack will survive being built higher, irrespective of height to width ratio. That is, it is insufficient to have a solid pack with little non-load bearing timber around it.

Overhang

The timber overhang designed into packs is not there simply to 'enlarge' the size of the pack. It is there for an important reason. The layers of the pack are turned at 90° to each other, so that under compression, the layers interlock and give the structure tensile strength in two directions. Under these conditions, the timber within the structure of the pack is deformed, but the overhang acts like a clamp on the layers above and below, to stop them from moving, thus keeping the structure of the pack intact.

Closure rates

The higher the rate of convergence, the lower the height to width ratio (2:1) should be. Conversely, the lower the rate of convergence, the higher the pack can be (>2:1). As it is known, the higher pack H:W ratio causes the pack to buckle.

The load generated by a buckling pack is slightly lower than that one which does not. However, if the buckling is severe, it will not be catastrophic. The largest concern is more the visual effect. If a pack buckles, people tend to believe that it does not carry any load. Bear in mind that if convergence is low, buckling will also be small.

Figure 3—55 x 49 x 11cm Timrite Lexus

Life of a pack

The life expectancy of the pack is also important, and to a certain extent, goes hand in hand with the closure rates. A pack supporting a travelling way or gully is required to work efficiently for the life of the stope, and should not buckle. These packs are normally built large (2:1), and are therefore not a problem.

Pack support used at the face support is however, is different. Once in the back area, the area is swept and barricaded off. Any buckling should thus not be of a concern as the workers should not re-enter this area. Buckling of the unit may result in a slight reduction in load carried, but in the back areas, the pack will be generating more than enough load in any event.

Condition of hangingwall and footwall

When a pack is tested in a press, for example to a H:W ratio of 2:1, buckling is rarely seen under these circumstances, where the surfaces are smooth and parallel. In situations where the surfaces are not smooth and parallel, point loading can occur, and packs may buckle.

Consider the underground situation. Some places have excellent conditions where the hangingwall and footwall are relatively smooth and parallel. The correct blocking and pre-stressing of the units is thus also essential.

Prestressing

The type and positioning of the prestressing should be considered. The two main types of prestressing are hydraulic steel plates and grout filled bags. Both of these systems have advantages and disadvantage but do not fall under the scope of the investigation. The original grout based pre-stressing system was designed to be placed at the top of the pack against the hangingwall, to take the shape of the hangingwall, and to minimize the point loading of the pack under compression, by equalizing the load over the entire surface of the pack.

Laboratory testing: Reatile Timrite

Press tests

Two different units were used to build different packs as follows:

- Test 1—55 x 49 x 11 cm Timrite Lexus built 1 unit per layer, 10 layers (1.1 m) H:W 2:1
- Test 2—55 x 49 x 11cm Timrite Lexus built 1 units per layer, 12 layers (1.32 m) H:W 2.4:1
- Test 3—55 x 49 x 11cm Timrite Lexus built 1 unit per layer, 14 layers (1.54) H:W 2.8:1
- Test 4—55 x 27 x 11cm Timrite Lexus built 2 units per layer, 14 layers (1.54) H:W 2.8:1
- Test 5—55 x 27 x 11cm Timrite Lexus built 2 units per layer, 12 layers (1.32) H:W 2.4:1
- Test 6—55 x 27 x 11cm Timrite Lexus built 2 units per layer, 10 layers (1.1) H:W 2:1.

Quest for 'effective pack' support

Packs were built in the 10 MN press and pressed through 500 mm of deformation at the rate of 30 mm/min.

These curves (Figure 4) demonstrate a good correlation between pack height and performance. The following points are noted:

- The lower the pack, the higher the initial stiffness
- The yield load is reduced with the higher packs. This extent of difference was not expected. The yield loads should, theoretically, be very similar
- The initial post yield stiffness for each of the packs is similar. The increased pack heights will affect the ultimate stiffness, but since the gradient of the post yield curves is low, this effect, visually, is minimized. The pack heights is only really visible after 300 mm of deformation, where the load generated by the higher packs flattens off, while the 2:1 pack continues to increase load.

See Figures 6–8 pictures were taken after every 100 mm of deformation.

A pack built with this unit (2 units per layer) results in a slightly less stable pack, especially at higher H:W ratios. There is a slight reduction in initial stiffness as the packs are built higher, but yield loads are essentially the same. Ultimate stiffness, up to 150 mm of closures, are very similar, and then buckling of the packs results in a variation of generated loads. Even though the packs buckle, there is no catastrophic failure, and packs maintain load above 500 kN. See Figure 9–10.

Underground visit (H3 Shaft)

H3 is a very old shaft and most of the places are mined out. I visited a remnant stope of which the surrounding area is all mined out. They used the 75 x 75 x 11 cm packs at the ratio

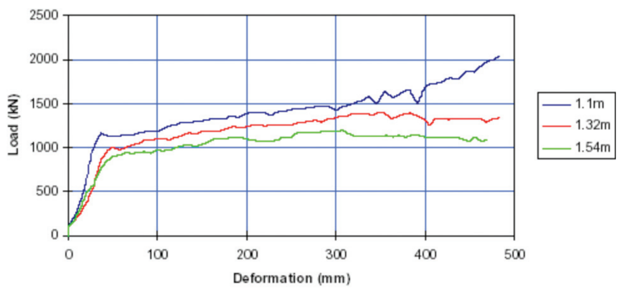

Figure 4—Results 55 x 49 x 11 cm

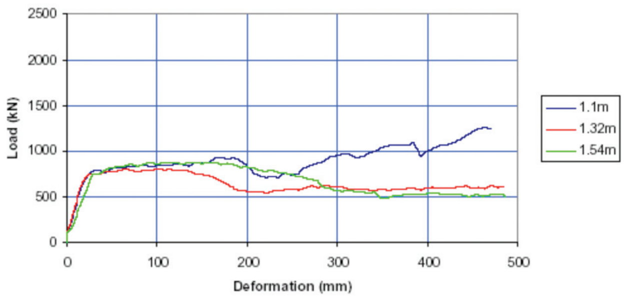

Figure 5—Results 55 x 27 x 11 cm

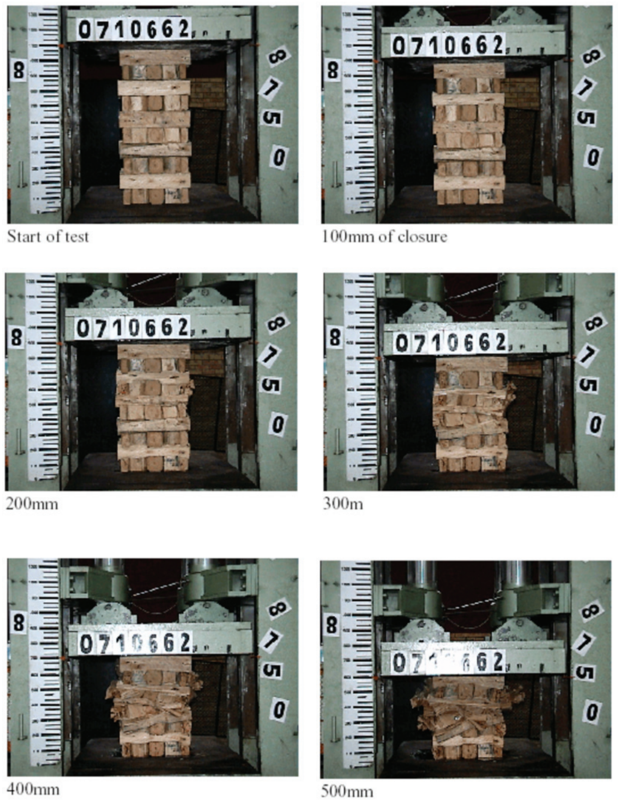

Figure 6—Test 1: 55 x 49 x 11cm Timrite Lexus 1.1 mH

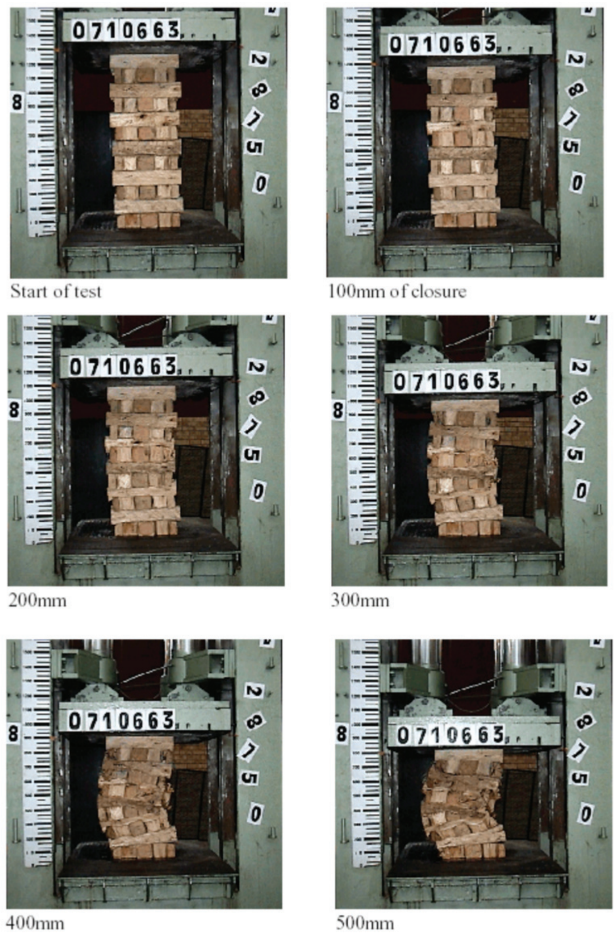

Figure 7—Test 2: 55 x 49 x 11cm Timrite Lexus 1.32 mH

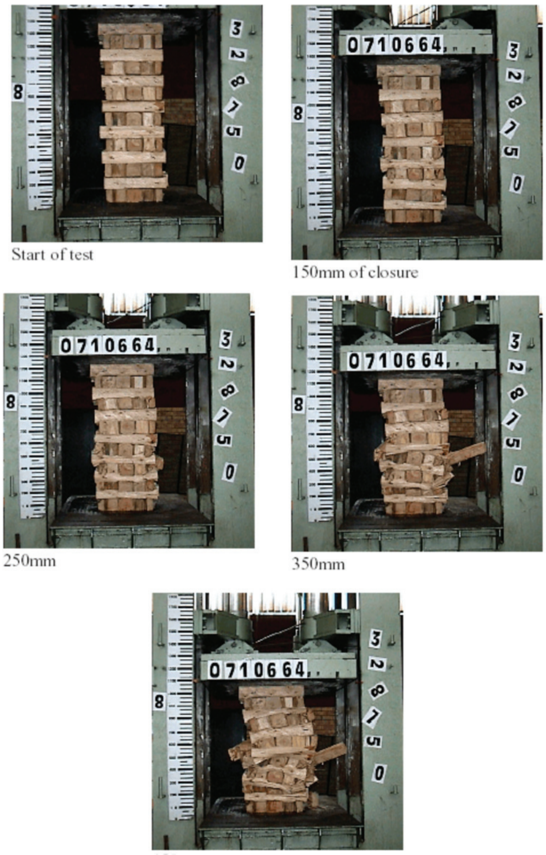

Figure 8—Test 3: 55 x 49 x 11cm Timrite Lexus 1.54 mH

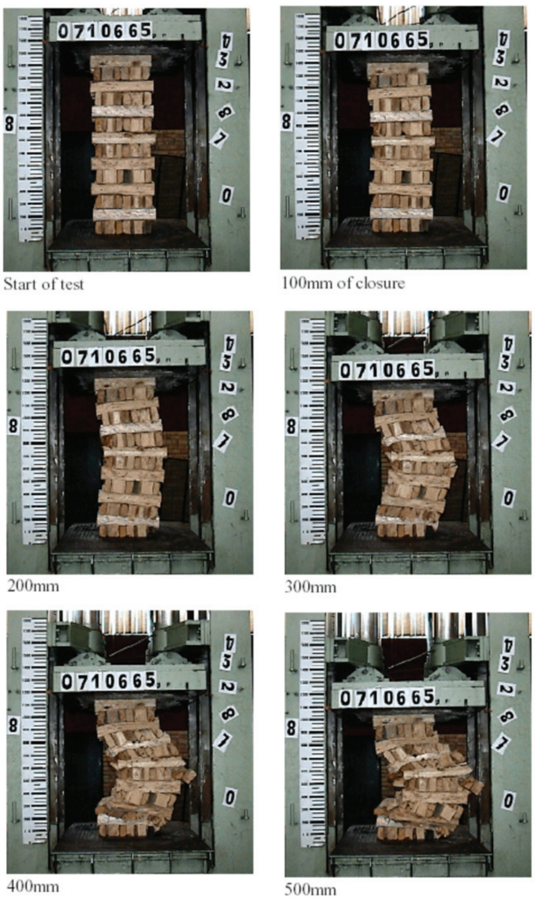

Figure 9—Test 4: 55 x 27 x 11cm Timrite Lexus 1.54 mH

of 2:1.The stoping widths vary from 1.5 to 2 m. See Figure 11. What was interesting was the fact that the stope was mined a long time ago (about 20 years back) but the installed pack support was still in relatively good condition. Does the appearance of a pack matter? Absolutely not; support is installed for the safety of people working in that area. (see Figure 11.)

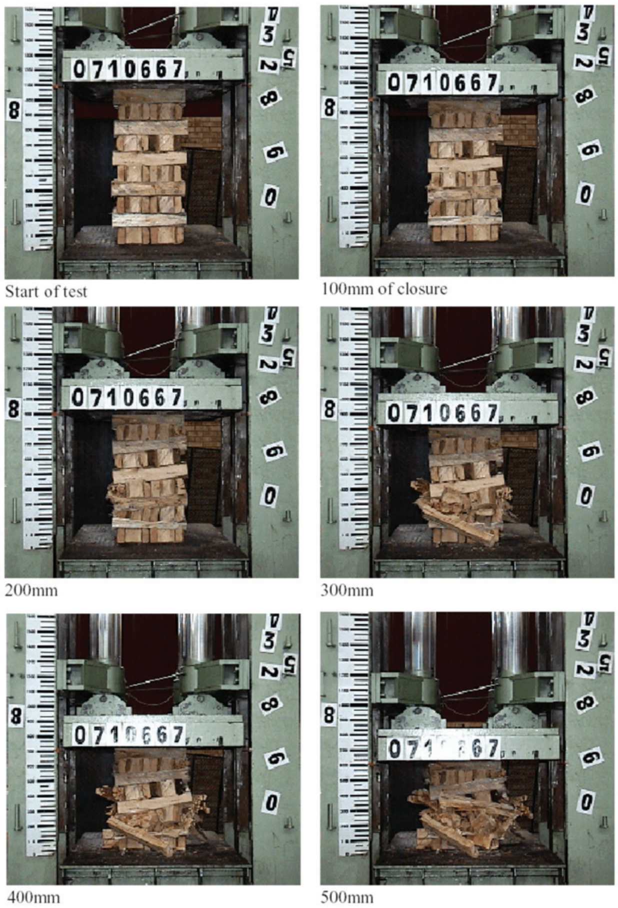

Figure 10—Test 6: 55 x 27 x 11cm Timrite Lexus 1.1 mH

Figure 11—No 3 Shaft

Table I

Comparison of 75s and 55s

	75s	55s
Panel length (m)	27.5	27.5
Stoping width (m)	1.5	1.5
Pack size (cm)	75 x 38 x 10	55 x 49 x 11
Tributary space: strike (m)	1.5	1.5
Tributary space: dip (m)	1.5	1.5
No of slabs	30	13
No of packs per line	7	8
Price for each pack unit (R)	14	16.39
Costs for a single build pack (R)	420.00	213.07
Costs for a line of pack (R)	3080.00	1650.54
Savings		1429.46

Comparison of the 75s and the 55s

At the spacing of 1.5 m of packs on dip and on strike you get a tributary area on which costs per m^2 can be calculated (see Table I.).

75s — 55s

R420/(1.5+0.75)2 — R213.07/(1.5+0.55)2

= R82.96 /m^2 — = R50.70/m^2

Therefore you save 39% of the costs per m^2 of rock you mine.

Conclusion

It has been proved that the larger H:W ratios (>2:1) can be applicable in stopes with low convergence. Therefore a H:W ratio of 2:1 should be given as a minimum. The actual ratio should be decided on by the mine personnel with the assistance of the rock engineer and the support manufacturer but ratios of up to 3: 1 may be acceptable.

The ratio decided on should be site specific and taking into account all the points outlined in this report.

Mining is a business and the aim at Harmony is to make maximum profit, requiring the production of more gold safely. If we can push the larger ratio on the mines, we can save more. The financial implication of such a change could be as much as 39%, and is thus worth further investigation.

Acknowledgement

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- Mining Product Development (Pty) Ltd.
- H2 and H3 shafts for assisting in the underground monitoring and observation of the performance of the packs.

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