INVESTIGATION INTO TEMPORARY ROOF SUPPORT PRINCIPLES

Winton Gale[1] and Craig Stemp[2]

ABSTRACT

An investigation was undertaken in regard to Temporary Roof Support (TRS) systems incorporated into miner bolters. Two and three dimensional modelling was utilised to document the effects a TRS system may have on the surrounding underground environment. TRS systems were found to have little if any effect on strata stability about a simulated roadway but are considered capable of providing protection against minor roof falls where the operator is within the defined protection zone. Each system requires the combination of mesh, bolts and support points to provide a protective zone to the operators. In difficult conditions there is no substitute for bolting as close to the face as possible and the concept of a zone of influence about a support point, as indicated by industry guidelines is not considered as a suitable protection zone.

INTRODUCTION

Since the inception of TRS systems in the 1970's, continued improvements and developments have been an ongoing process. However, a definition as to what TRS systems are suitable for and capable of is required. This study has assessed some of the main assumptions and preconceived concepts in regards to TRS systems.

TRS systems are designed to comply with the recommendations of MDG35.1 (Industry and Investment NSW 2010) where they are designed to 'temporary support' the working roof by means of a loading device until permanent support is installed. TRS systems are designed to act as an operator protection system for a situation where skin failure of the roof may cause fatal or serious injury. However, the name can be taken quite literally alluding to the idea that a TRS can in fact impart some level of stability to the immediate roof. These guidelines state that they are in fact not designed to support the entire weight of the roof however, but it is unknown to what, if any degree of stability is imparted into the strata. Design constraints resulting from TRS systems have also extended the support distance to the cutting face significantly in some instances. It is well known that roadway stability in difficult conditions is optimised by placement of bolts as close to the face as possible, though it is also undetermined what advantages or limitations TRS systems may have in such a situation.

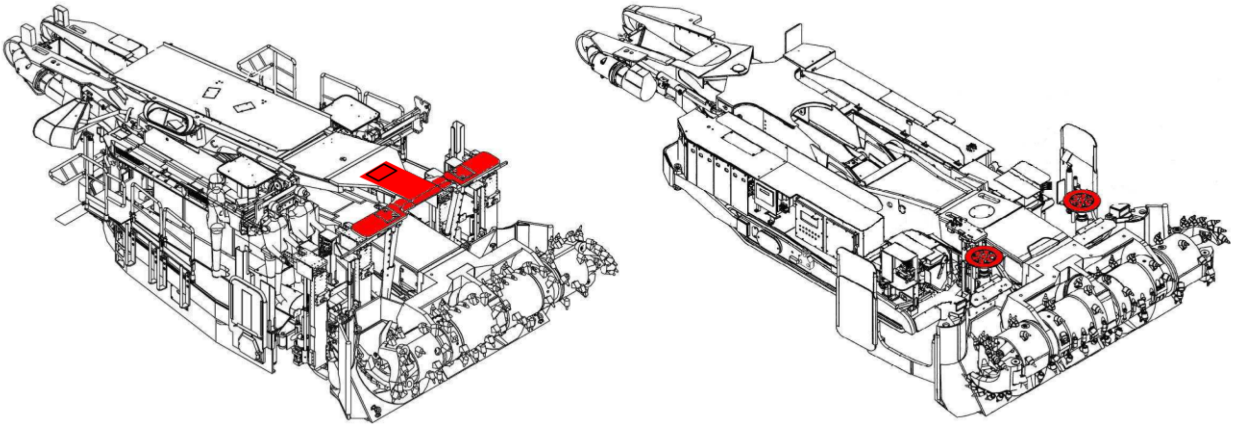
MODELLING ASSESSMENT OF TRS EFFECTS ON ROADWAY STABILITY

The main program of work was to develop a three dimensional numerical model of a typical roadway geological section and assess the effect of generic TRS systems on immediate and long term roof stability. The software used was FLAC3D, which is a program used for geotechnical modelling by SCT and is considered to represent the state of the art. The failure mode chosen represented a laminated geology exhibiting properties of bi-linear hardening or softening.

Four scenarios were simulated; a pad type TRS, T-bar type TRS, non-TRS (same face to bolt distance as TRS cases) and a control case (minimal bolt to face distance of 1.2 m). Roadway dimensions were 5.2 m wide by 3.2 m high. Distance from face to bolting horizon for TRS and non-TRS cases were 2.8 m + 1.2 m sumped into the floor. Roof bolts were installed every 1.2m in a 6 bolt pattern. TRS layouts are illustrated in Figure 1a and 1b.

[1] SCT Operations Ltd Managing Director. Email: wgale@sct.gs , Ph: +61 2 4222 2777 :

[2] SCT Operations Ltd Mining Engineer

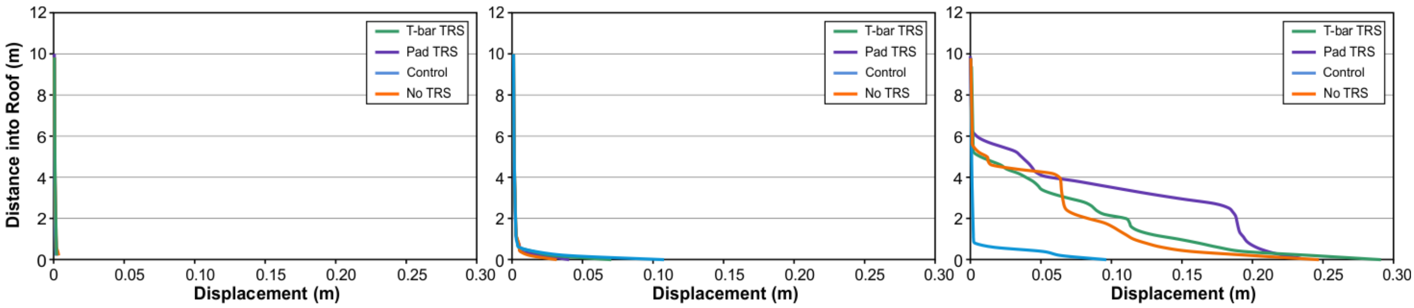


a) T-bar type TRS (Adapted from Industry & Investment NSW 2010). b) Pad type TRS (Industry & Investment NSW 2010).

Figure 1: TRS designs used in this study.

Two main parameters for analysis were used in the interpretation of results, these being displacement profiles and velocity values. Regions of skin failure that are most likely to fall can be located using velocity values within the model.

In each case the model was run up until the final cut and then left to equilibrate with TRS supports engaged. The stress levels applied to the model were varied to assess the situations of no roof failure to that of initial roof failure. Roof failure was initiated under moderate to high stress condition. The areas of skin failure developed from the roof are presented in Figure 2a, 2b and 2c for the four cases.



a) Low stress environment. b) Medium stress environment. c) High stress environment.

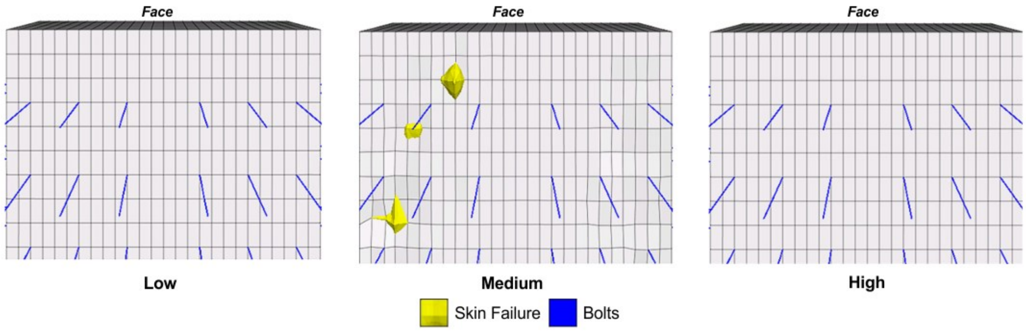
Figure 2: Roof displacement profiles 10m from the face for various stress environments.

The displacements that occur at the roadway centre, 10 m outbye of the face are presented in Figures 3a, 3b and 3c. The plots show roof displacement at various distances into the roof.

Over the range of stress environments the Control Case had the lowest degree of skin failure with the non-TRS had the highest degree. The TRS cases showed that skin failure was not prone to develop above the primary pad but rather around it, inbye and to the sides.

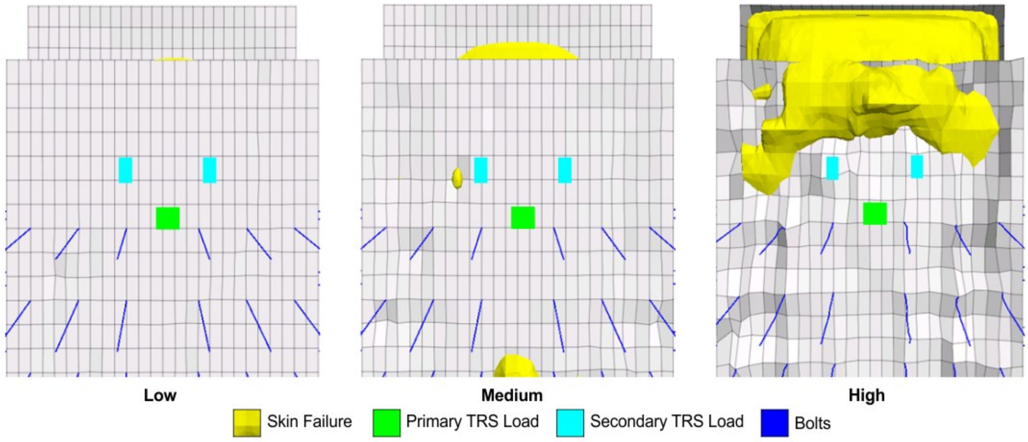
The placement of bolts as close to the face, as demonstrated in the control model, provided the best result. In situations where there is a large distance to face, stress levels are able to facilitate significant strata failure without any restraint provided by the roof bolts. As the distance to face length increases there is a noticeable trend that these regions of high deformation form a network of fractures which allow the roof to collapse. This is the result of unreinforced rock fracture zones having a reduced ability to confine the fractured roof causing a redistribution of stress higher into the roof section and thus creating potential for propagation of strata failure higher into the roof.

The roof displacement results from the TRS and non-TRS cases demonstrate that a TRS system has little or no influence on the deformation process. It was noted that the only impact of the support pads was that the skin failure was withheld from developing in the immediate area of the support pads.

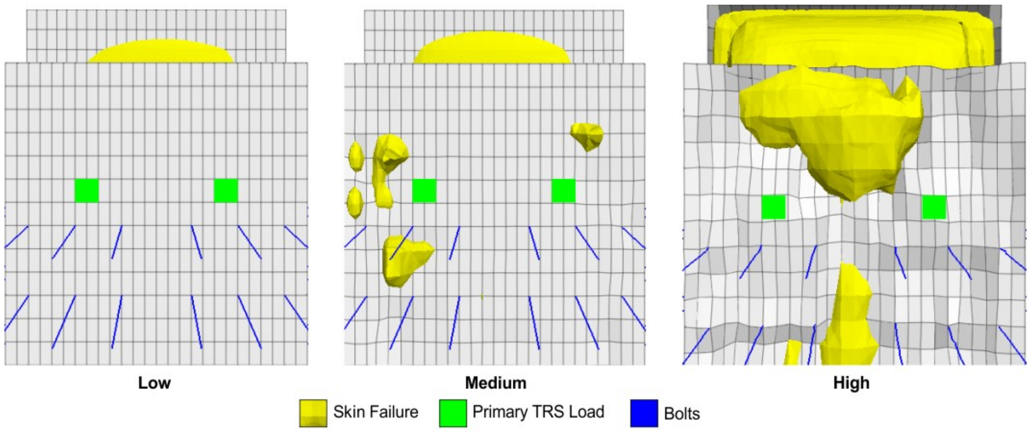


NB: Minor skin failure developed in relation to model accuracy.

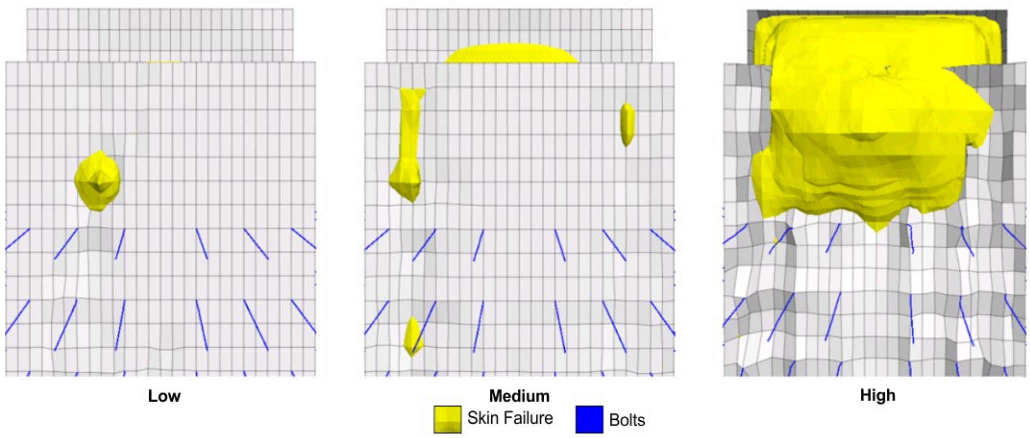
a) Control case for range of stresses.



b) T-bar type TRS case for range of stresses.



c) Pad type TRS case for range of stresses.



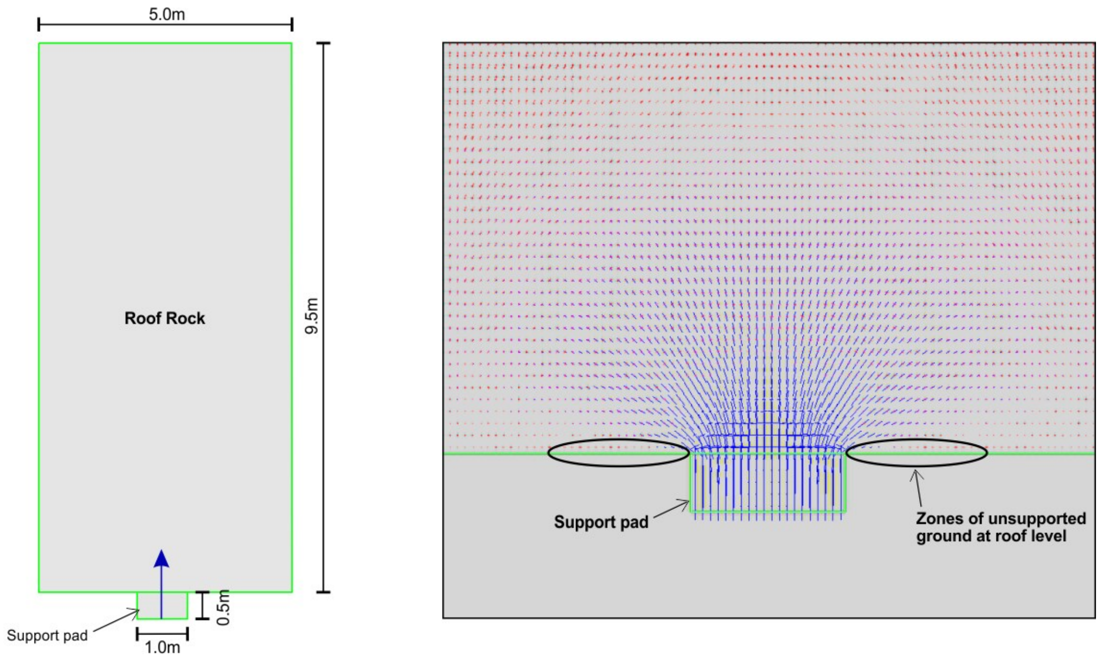
d) Non-TRS case for range of stresses.

Figure 3: Top view skin failure for various scenarios modelled.

ASSESSMENT OF A SUPPORT PROTECTIVE ZONE

This section deals with the action of a TRS support point in providing protection to personnel under the MDG35.1 guidelines. A two dimensional model was used to analyse the support point and the area of support and protection created. The code used for the computer modelling is FLAC2D, a two dimensional numerical modelling program widely used within the industry. FLAC2D represents a two dimensional cross-section of the roof area above a TRS support. The model represented a pressure test on roof strata and using elastic and Mohr-Coulomb failure criteria. The stress in the strata was only gravitational and did not include the effects of fracture and stress distributions.

The model base geometry is presented in Figure 4a. An initial elastic model was simulated where Figure 4b illustrates how the vertical stress “fans” out and is distributed above the pad. Immediately adjacent to the pad the vertical stress is minimal and in fact, horizontal tension is generated. It can be seen that along a zone marked on Figure 4b, no support to any broken ground would be generated.



a) 2D modelled geometry of a support pad. **b) 2D Modelled distribution of vertical stress.**

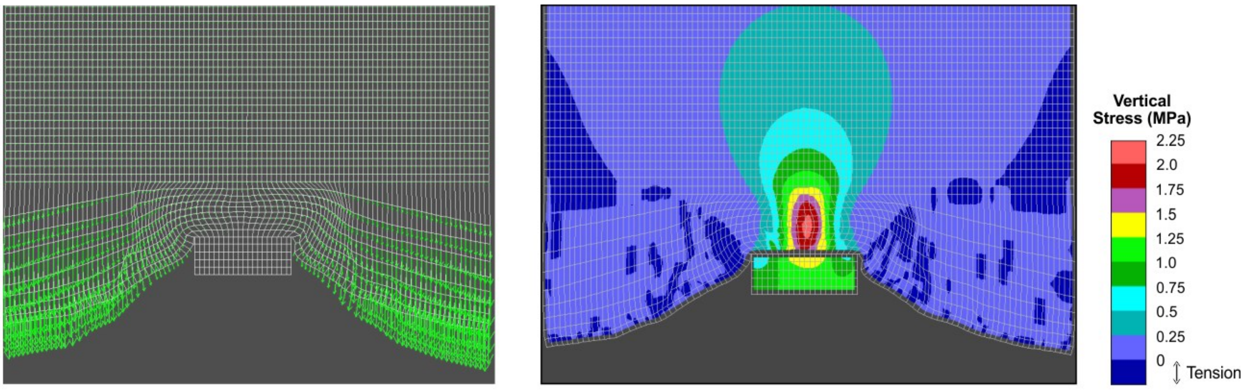
Figure 4: Elastic 2D model results.

A second model was run with simulated fractured strata for the initial 0.5 m into the roof. The results are presented in Figure 5a in terms of the displacement velocity of the rock. It can be seen that the fractured rock readily drops out about the support pad. The zone of influence of the pad is only to the edge of the pad. Outside the pad the material will drop. In fact, in the case of the fractured rock model, the stress distribution is modified significantly from the elastic case due to the fractured state and the ability of the strata to displace. The stress distribution associated with the failed rock case is presented in Figure 5b. This model shows that the area of influence of the support within a fractured rock mass can be minimal and is only reliably developed immediately above the pad structure.

The MDG35.1 has been used as a guide for design of temporary support systems. The TRS systems employed on Australian continuous miners are designed in response to a recommendation of MDG35.1 (Industry and Investment NSW 2010).

Section 3.6 of the document describes ‘Operator Protective Systems’. It is in this section that a reference to a ‘zone of influence’ is made.

For convenience the following extract has been reproduced from the MDG.



a) Displacement of the rock with fractured strata. b) Vertical stress distribution associated with the failed rock.

Figure 5: 2D model failure results.

3.6.4 Temporary roof support (TRS)

d) Be located within 1.5 m to the left or right of the rib, unless otherwise specified by the mines strata failure management plan or geotechnical engineer.

Note:
4. Typically, a TRS with a small pad contact should support at least 50 kN per support and is assumed to support roof area of 750mm radius around the TRS.

The distance of 1.5 m is considered to be derived from the 0.75 m radius or zone of influence. The 750mm zone resulting from the rib with the additional 750 mm created from a support combined together equates to a 1.5 m zone. This is presented conceptually in Figure 6. The modelling results show that there is no 'zone of influence' in a radius around a TRS, rather there is a caving angle directed up into the roof from the edge of the support.

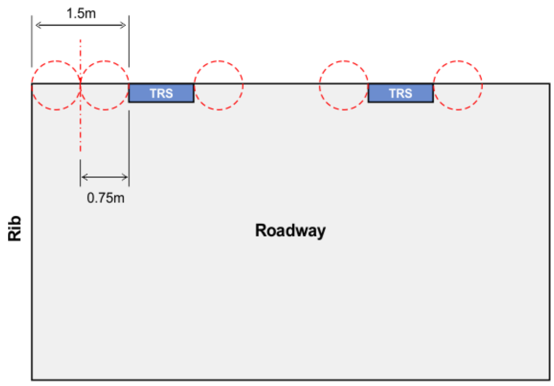


Figure 6: 1.5m constraint from MDG35.

This concept is similar to that of the action of a longwall support. There is no expectation of a zone of influence about the support canopy (certainly not 750 mm) but often the concept of a caving angle is used. This is presented conceptually in Figure 7.

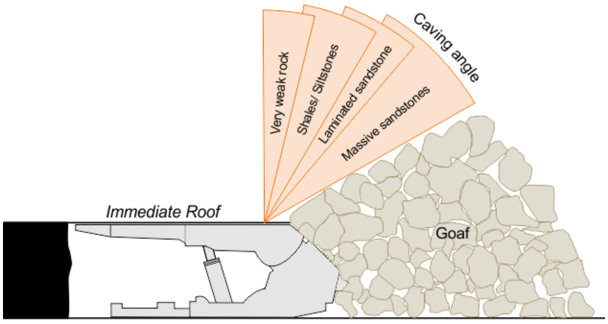


Figure 7: Caving angle of common rocks.

The caving angle is the angle at which separation of rock takes place in the roof and is typically seen at longwall goaf edges. The caving angle varies with the strength properties of a material, where weak materials such as laminites cave at steeper angles to the horizontal than stronger sandstone units. The zone of influence about a TRS pad (other than directly underneath) appears to be unrealistic and is not recommended to be used to assess operator protection zones associated with continuous miners.

ASSESSMENT OF OPERATOR PROTECTION ZONES

An Operator Protection Zone can be defined from the combination of TRS pads, the last line of roof bolts and mesh. The overall concept in the face area is that the mesh is pinned by the support pads, bolter head (timber jacks) and the last line of roof bolts providing a protected zone against small scale roof dropout. The geometry of the support pads and timber jacks creates this zone of protection.

Two cases of T-bar and Pad TRS designs are presented in Figure 8 on the basis of a flat roof environment. The situation was assessed from a plan view only considering the 2D environment. The pad TRS machine is illustrated in red and the T-bar TRS in blue. The darker shading represents the primary TRS load setting and the lighter represents the full load setting with additional secondary load (bolter jacks). The Pad type TRS arrangement however fails to produce a safe work area under primary load as the TRS pads are located beyond the immediate mesh module. However with additional secondary load (bolter jack) both systems are able to provide an adequate canopy.

These zones of protection are considered to provide a safe work area against minor skin failure roof drop out. The actual amount of material that the system can carry is dependent on the type of mesh and the location of the loading relative to the location of the support elements. This is a complex function, however considering the forces at the pad reaction points, typically 10-20 tonnes for a TRS pad and 2 tonnes for a single bolting jack, the mesh is anticipated to carry the type of roof dropout commonly seen at the face within typical interbedded/laminated strata. The nature of blocks that may dislodge in more massive or structured ground is difficult to pre determine. The capacity of the system under those conditions is best assessed by experimental trials.

CONCLUSION

TRS systems were found to have little if any effect on strata stability about a roadway, but are capable of providing protection against minor skin failure roof dropout where the operator is within the protected zone as defined previously. The operator protection zone is created by a combination of support points and the roof mesh. The degree of loading that an operator protection zone can withstand is thus a result of the combination of these factors (mesh strength, TRS load) and was not calculated in this study. It is suggested that a physical study be undertaken to demonstrate the load bearing capacity of such a system. The TRS pads and bolting jacks are a means to ‘pin’ the mesh inbye from the last row of bolts, thus creating a canopy for light localised roof drop out.

Each system requires this combination of mesh, bolts and support points to provide a protective zone to the operators. In difficult conditions there is no substitute for bolting as close to the face as possible. The use of a zone of influence about a support point, as indicated in MDG35.1 is not considered as a suitable protection zone.

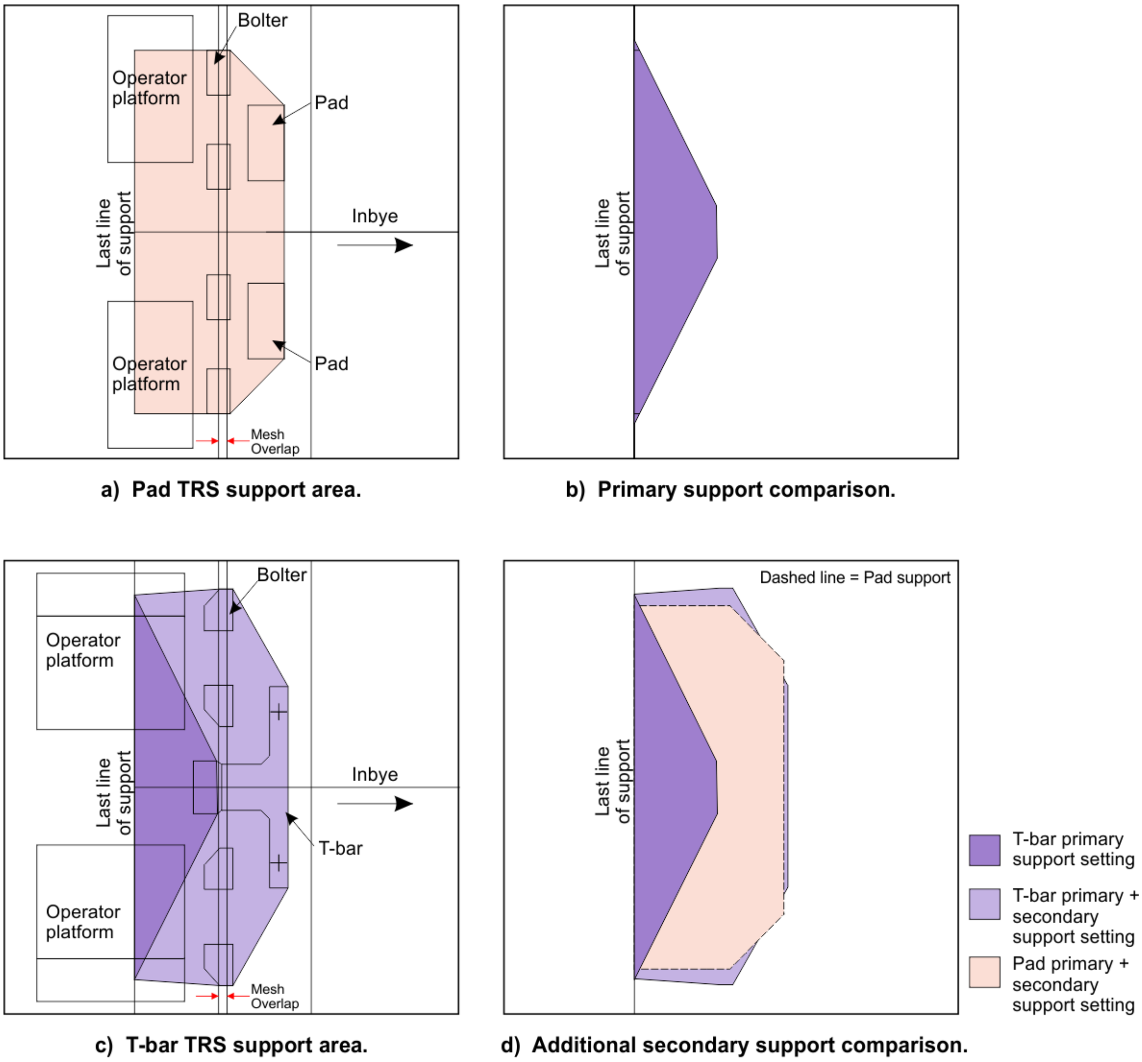


Figure 8: Flat roof environment protection zones.

REFERENCES

Industry and Investment NSW 2010, "Guideline for bolting and drilling plant in mines, Part 1: Bolting plant for strata support in underground coal mines, MDG 35.1" dated February 2010.

JOY Global 2013, “12ED25 Entry Development Machine, Roof Strata Control and Operator Protective System, Document Number: 5100016129” dated April 2013.