



**Safety in Mines Research Advisory Committee**

**Interim Project Report**

# **The development of an effective face area support system for tabular stopes**

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# Executive Summary

This report is an interim report of a two-year project, the first phase of which ended at the end of March 2002. The report therefore highlights progress made to date only.

In SIMRAC project GAP708, eleven innovative means of reducing the rock-related hazard in the vicinity of the stope face were investigated. A linked prop and headboard system, named the remotely advanced headboard system, was identified as having the highest potential to significantly improve safety in the face area, while seemingly being a practical system that should not be difficult to implement and maintain.

The objective of this project is to develop the remotely advanced headboard concept and test prototypes. The primary outputs of the research are:

Design and manufacture of a prototype (Phase I)

A risk assessment of the support system (Phase I)

Quasi-static and dynamic surface tests (Phase II)

Underground trials (Phase II)

The design process and the manufacture of a prototype are completed. The final design is a combination of all the original concepts i.e. from the original link-bar system to the crank system, and finally to the crank slider system. Despite the serious practical engineering shortcomings of the previous concepts, their advantages were incorporated into the crank slider system. The crank slider system is thus more flexible and its expected to be more user friendly.

This headboard system is based on a headboard system developed by the Chamber of Mines Research Organisation in the early 1990's.

Initial laboratory tests on the beams indicate that plastic deformation is unlikely to occur up to tip loads of 20 tons.

A risk assessment was performed on the system to identify sources of potential hazards that could be associated with the use of the support system. Recommendations on appropriate controls to minimise the hazards are also prescribed.

The second phase will commence with a surface mock-up trial to be followed by a load-deformation test in Savuka test rig. It is expected that a suitable underground site would have been found after the test to enable underground trials to commence in May/June 2002.

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# **1 Collaboration with suitable manufacturer of the Support System**

A number of support-system manufacturers were contacted for a possible collaboration. They included: HPE, Elbroc, Unique Engineering, Wellprop, NOVATEK, Grinaker and Mine Support Systems. NOVATEK was eventually identified as the most suitable manufacturer for collaborative work. This is because of NOVATEK's manufacturing capability and its willingness to contribute, in both financial and human resource terms, to the success of the project.

## **2 Finalising the design of the support-system unit**

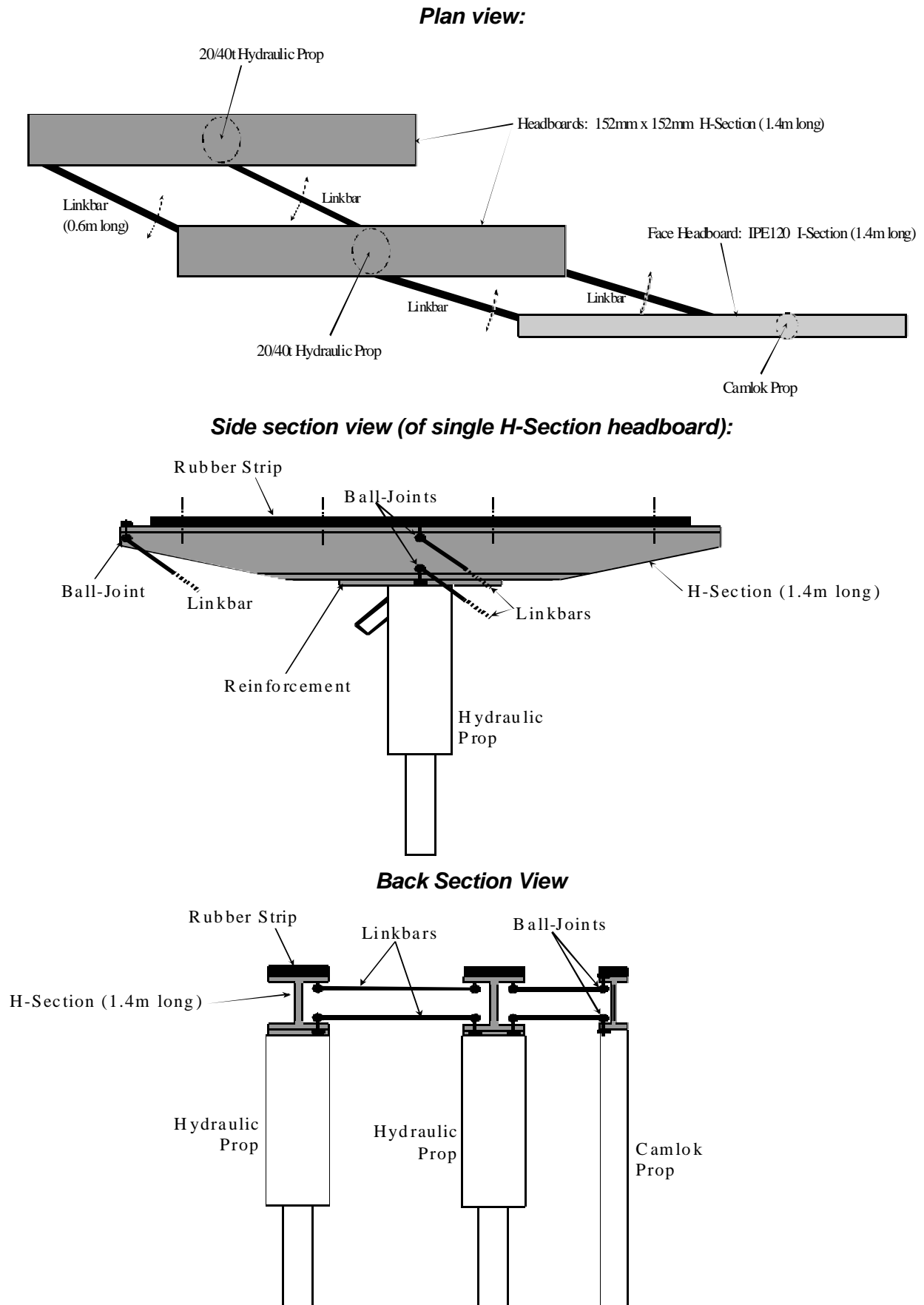
### **2.1 History of the Walking Stope support**

The final design of the support combines all the components from the original designs. The advantages from previous concepts were incorporated into the final design, and the shortcomings were modified in order to produce practical and workable solution.

#### **2.1.1 Link-bar system**

The original concept consisted of link bars linking two H-section headboards together. The main components are shown in Figure 2.1. A plan and section view are given to indicate the linked headboards and hydraulic props.

The three headboards are linked together by 0.6-m-long solid rods, which are connected to sealed ball joints.



**Figure 2.1** Schematic indicating the principal components of the remotely advanced headboard system

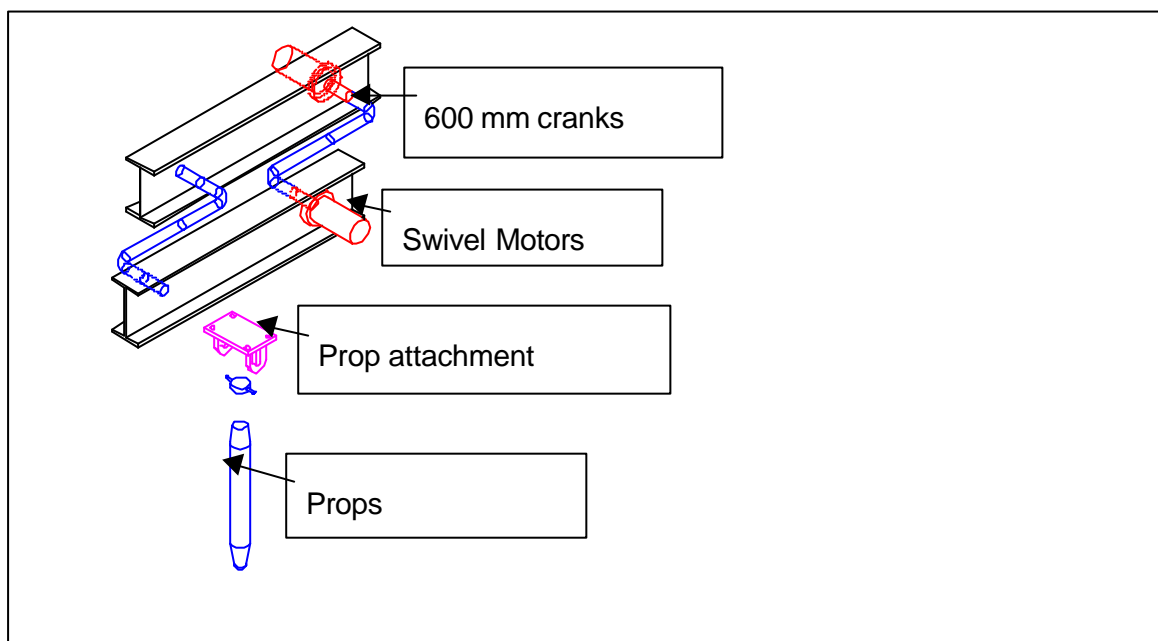
### 2.1.1.1 Shortcomings

A weak point of the system is the ball and socket joints, which have to be perfectly sealed in order not to let any dirt into the system. Practically sized ball joints would be inadequate to carry the required loads. In other words too large joints would be required for this application.

There is no flexibility in this system to allow for various advancing distances. The headboard size would not be able to carry the required loads unless large steel sections were used.

### 2.1.2 Crank system

This system replaces the link bars with 600-mm-long cranks. Rotary actuators then drive the cranks.



**Figure 2.2 Crank system**

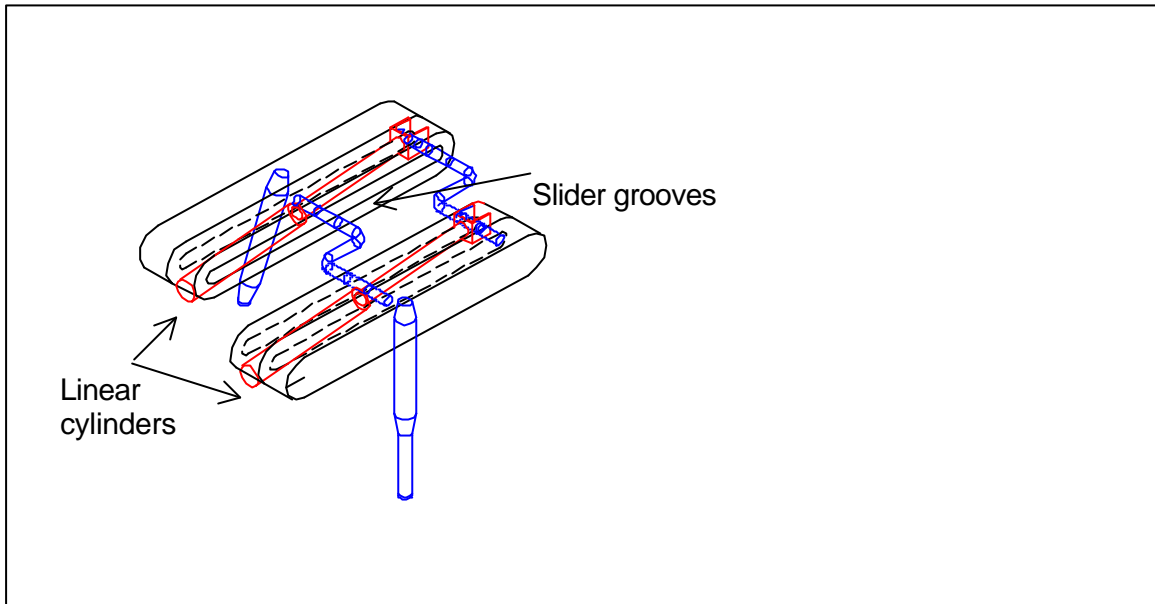
#### 2.1.2.1 Shortcomings of the Crank System

The initial calculations indicated that too large an I-beam section (254 x 146 mm) would be required to support the loads. The cost of rotary actuators is very high (approximately R 300 000 per actuator). The crank length of 600 mm is impractical because the fully retracted length of the prop is approximately 700 mm. This means that when the system is being moved the entire length of the prop will be dragged along the footwall and is likely to stop against joints in the footwall.

### 2.1.3 Crank-slider mechanism

This system is a combination of the crank system and a sliding system. The cranks in this system are 250-mm long. These cranks are to negotiate brows of a maximum height of 250 mm. The sliders are used to achieve the necessary advance of 600 mm. The system has two linear cylinders, which provide the advancing as well as the rotational motion of the system. The

rotational motion is necessary to lift one headboard such that a prop can engage the footwall. The headboard envisaged for this system was fabricated sections, welded together.



**Figure 2.3** *Crank Slider system*

### 2.1.3.1 Shortcomings of the crank slider mechanism (Dual Linear cylinder)

The advance rate is fixed, which means that no intermediate advances can be achieved with this system.

To rotate one headboard the system relies on the slider reaching the end of its stroke and then raising the other headboard.

In order to complete one cycle of motion the cranks must perform a 360° revolution and this would entail designing a complicated cranking mechanism.

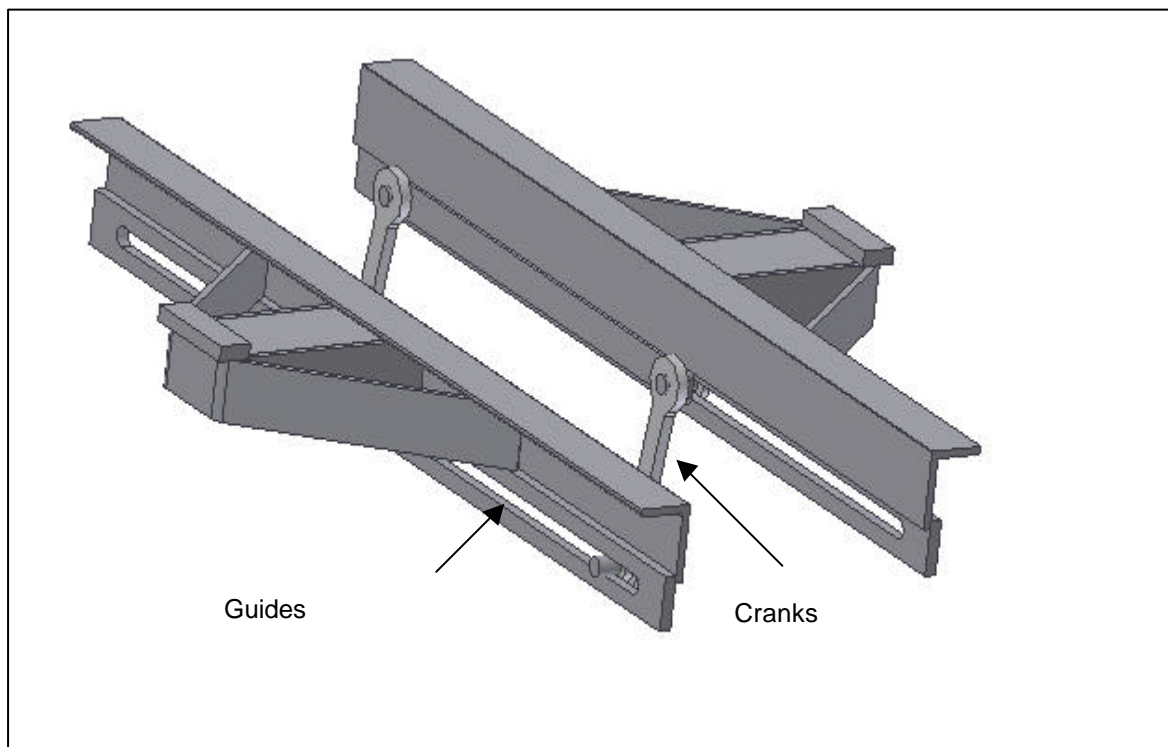


### 3 Final support system

#### 3.1 The current system (crank-slider mechanism with one rotational cylinder and one linear cylinder)

This operates in a similar way to the above system except that a short cylinder is used to do all the rotational motion and the linear cylinder does only the advancing.

This headboard system is based on a headboard developed by the Chamber of Mines Research Organisation in the early 1990's. It makes use of a force-apportioning lever. The principle of force apportioning is to share the prop force between the beam and a metal pad so as to limit the force carried by the relatively weak beam. The relative lengths of the lever arms determine the proportion of force carried by the beam and pad. The beams carry a sufficient load to provide rockfall protection only, while the aggregate beam and pad are sufficient to control rockburst energy.



**Figure 3.1**     *The final concept*

This system is designed in a way that overcomes all the shortcomings of the previous concepts and provides a practical, workable solution.

The cranks of the previous system are still being used but the length of the cranks has been reduced to 250 mm. The motion of the crank is also limited in that moves of only 45° from the horizontal are required as opposed to 90° of the previous system.

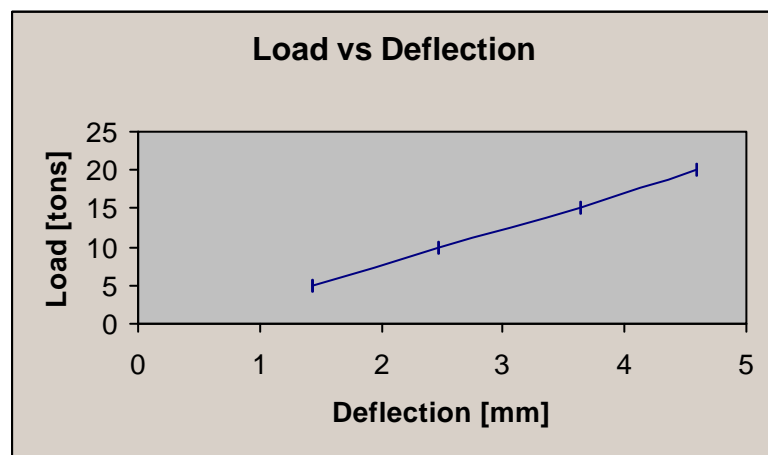
This system is flexible in that it allows variable advancing distances.

### 3.1.1 Deflection test and finite-element analysis of the headboard

In order to check the deflection of the headboard it was placed under a press and loaded sequentially to 5,10,15 and 20 tons. The loading was carried out three times in order to get an average deflection reading. After loading the headboard, the load was removed and it was checked to see if the deflection had returned to zero. On all occasions, the deflection readings returned to zero after the load was removed. This showed that no plastic deformation occurred.

**Table 3.1** Load and deflection data for the headboard from press tests

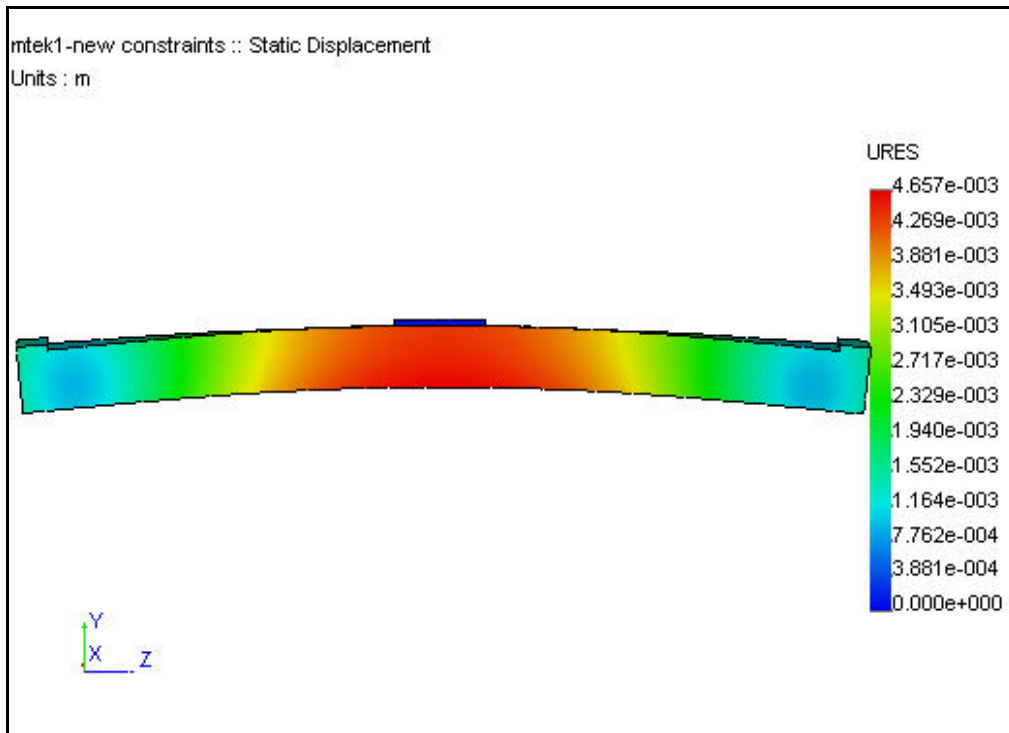
Load [tons]	Load [kN]	Deflection [mm]			
		1st Reading	2nd Reading	3rd Reading	Average
5	49.05	1.46	1.48	1.35	1.43
10	98.1	2.42	2.43	2.53	2.46
15	147.15	3.64	3.63	3.61	3.63
20	196.2	4.7	4.54	4.51	4.58



**Figure 3.2** Load vs deflection for the Miningtek headboard from the finite element analysis

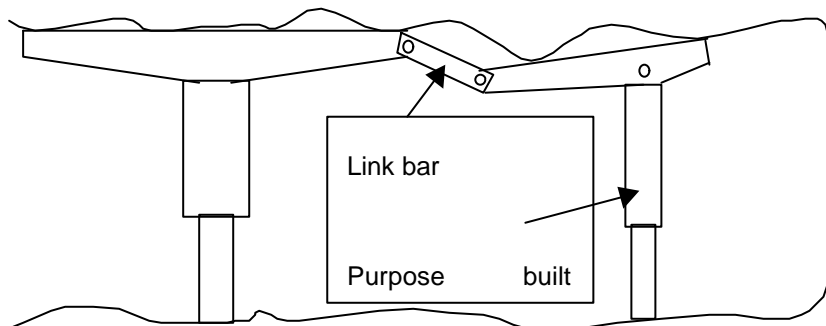
A basic finite-element analysis was performed and the results of the analysis matched well with the actual tests performed.

From Figure 3.2, it can be seen that the finite-element model gave a maximum deflection of 4.66 mm (at 20 ton loading) as compared to the actual test which gave a maximum deflection of 4.58 mm.



**Figure 3.3** *Front view showing the position of maximum displacement from the finite element analysis*

### 3.1.2 The temporary-support concept



**Figure 3.4** *The temporary support concept*

The temporary support hinges on the forward headboard of the support system via a link-bar. This mechanism gives the temporary support more stability, which means that it could be installed by one operator. The procedure will entail the operator to first position the temporary headboard and prop, and then activate the purpose-built hydraulic prop from a remote location.

The link bar will give the required flexibility to clear brows but still act as an anchor point enhancing the stability during installation, contributing to improved areal support. Removal of the temporary support will be initiated remotely by relieving the pressure in the hydraulic prop. Retrieval of the temporary support system via the link-bar is envisaged with the operator still

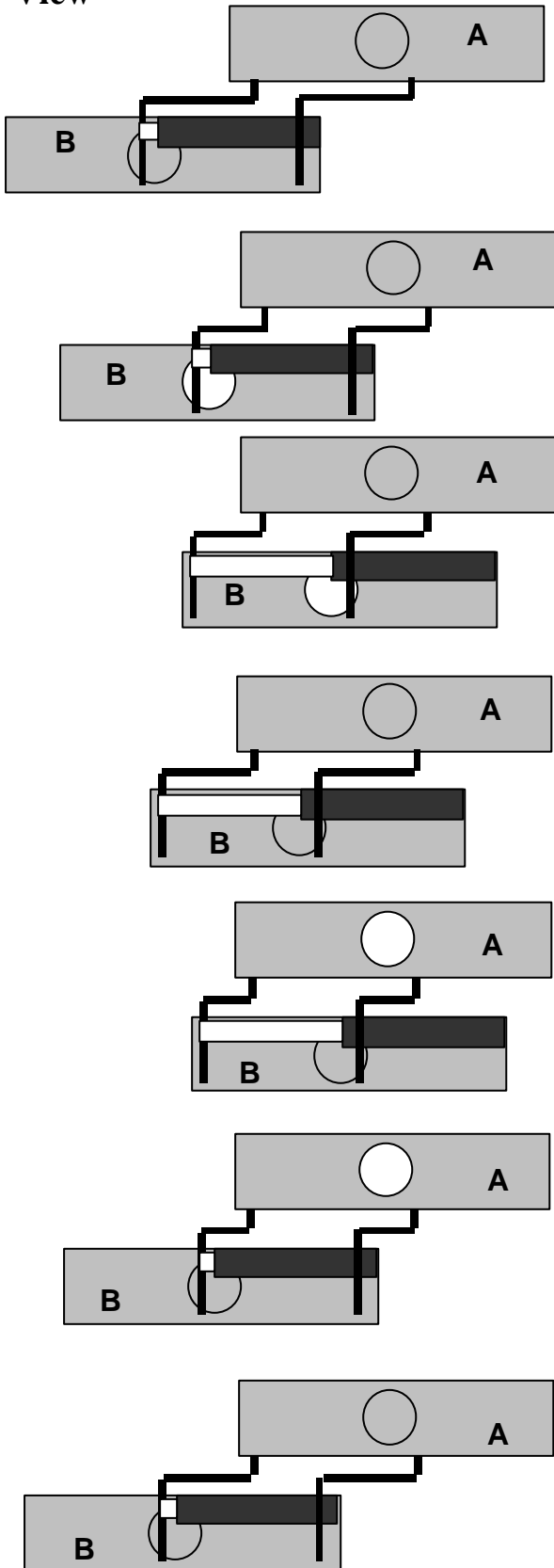
under the main headboard. Storing of the temporary system on the main headboard is also being investigated.

## **3.2 The advancing-mechanism concept**

The sequence below will result in an advance of approximately 600mm and has therefore to be repeated in order to achieve the required advancing distance. This concept produces a continuous range of 600 to 1200mm advance.

It is foreseen that any system will tend to migrate down-dip as it advances on strike and it was therefore decided to keep the “steps” small and controlled. A means to “steer” the system will be incorporated but will require manual intervention to change the advancing direction. This will be achieved by allowing manual adjustment of headboard A in the new direction before it is forced against the hanging wall since the advancing cylinder is within that headboard.

**Plan View**



Both props extended and active against hangingwall

Down dip prop (A) retracts and headboard drops due to gravity on the crank rotation. The Crank is restricted to a rotation less than 45°

The advancing cylinder attached to the headboard A and the back crank is extended and headboard A moves towards the face.

An offset crank mechanism on the front crank in headboard A (not shown) rotates the front crank in order for headboard A to lift up towards the hangingwall before the prop is extended to activate the support

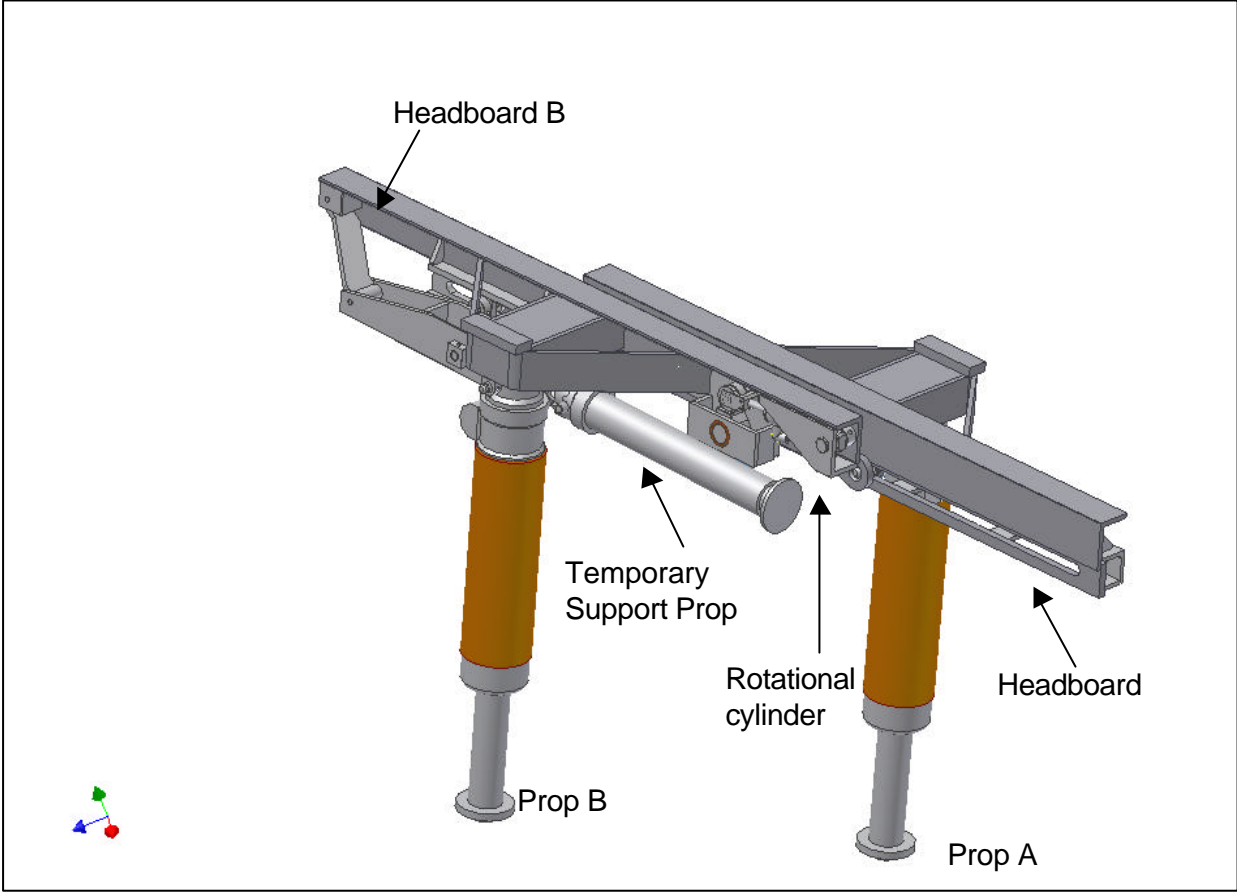
Next the prop in headboard B retracts and the headboard drops on the cranks. Again the rotation of the crank is limited to less than 90°

The advancing cylinder in headboard A contracts and pulls headboard B forwards

The offset mechanism on the front crank is then again activated to headboard B against the hangingwall before the prop is extended.

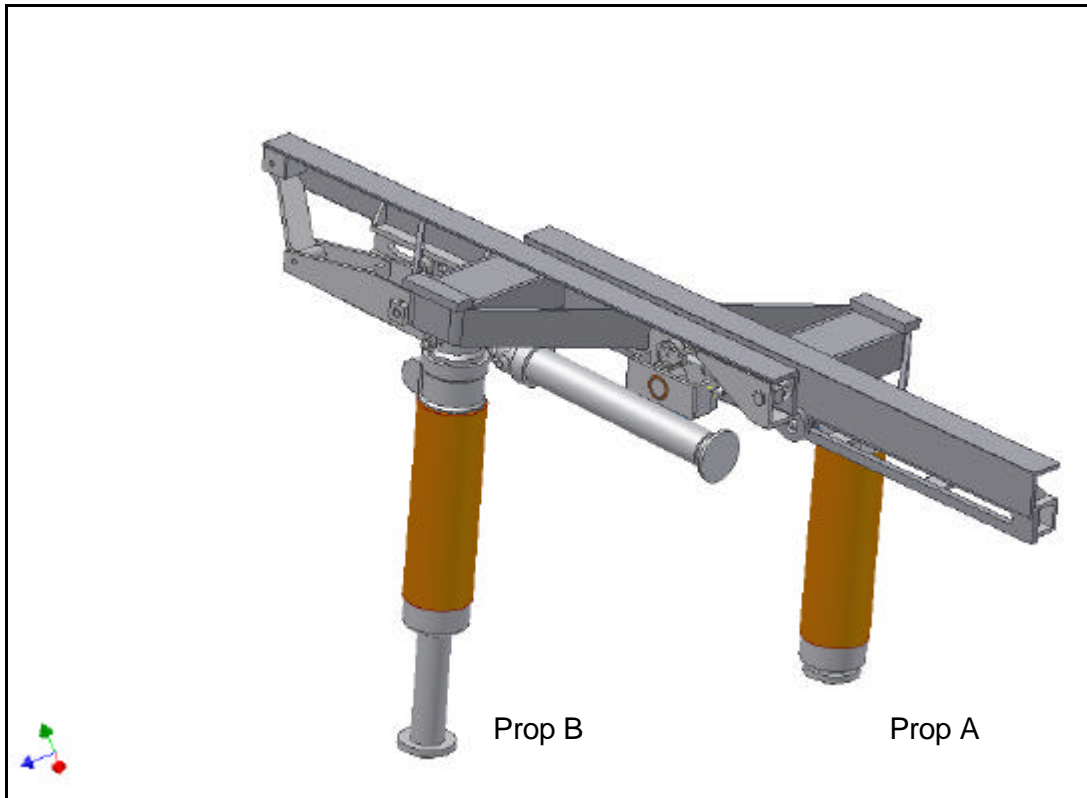
### 3.2.1 Advancing mechanism (3D)

Figure 3.5 shows the position of the system once the temporary support has been stored away and the face blasted.



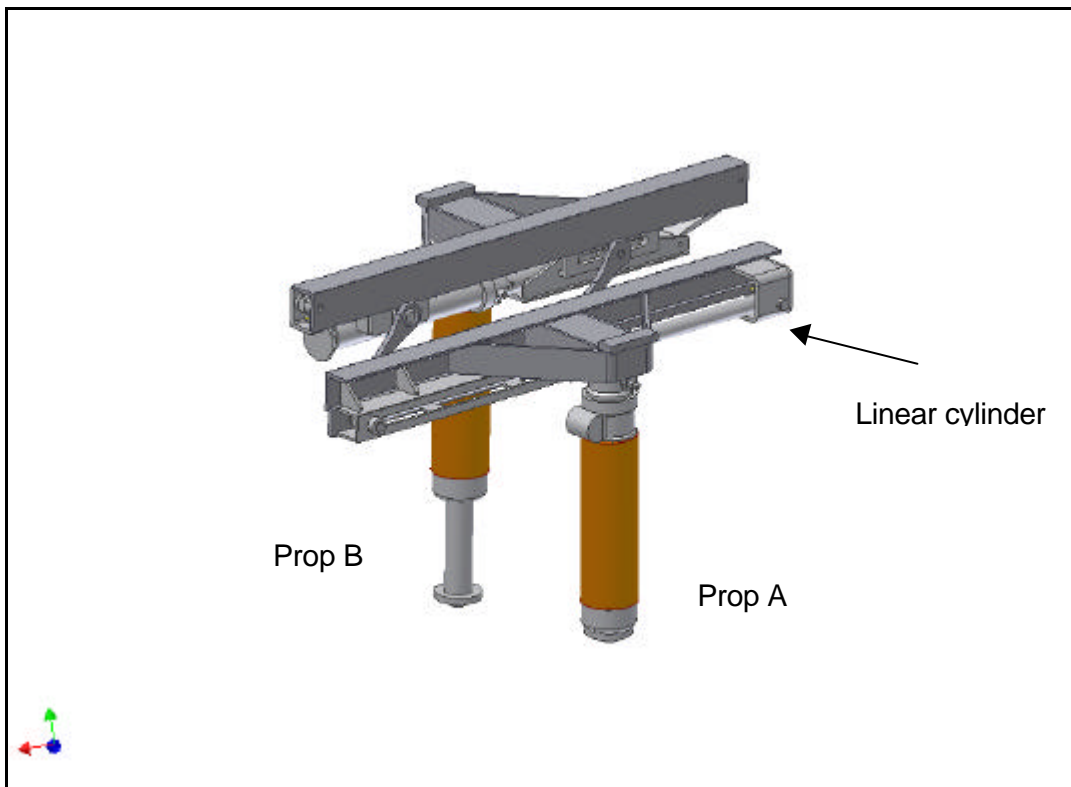
**Figure 3.5 Step 1 – The starting position**

The next step (Figure 3.6) is then to disengage prop A from the footwall so that headboard A can move forward. Once the prop is retracted headboard A drops down 250 mm under its own weight. (Figure 3.7)



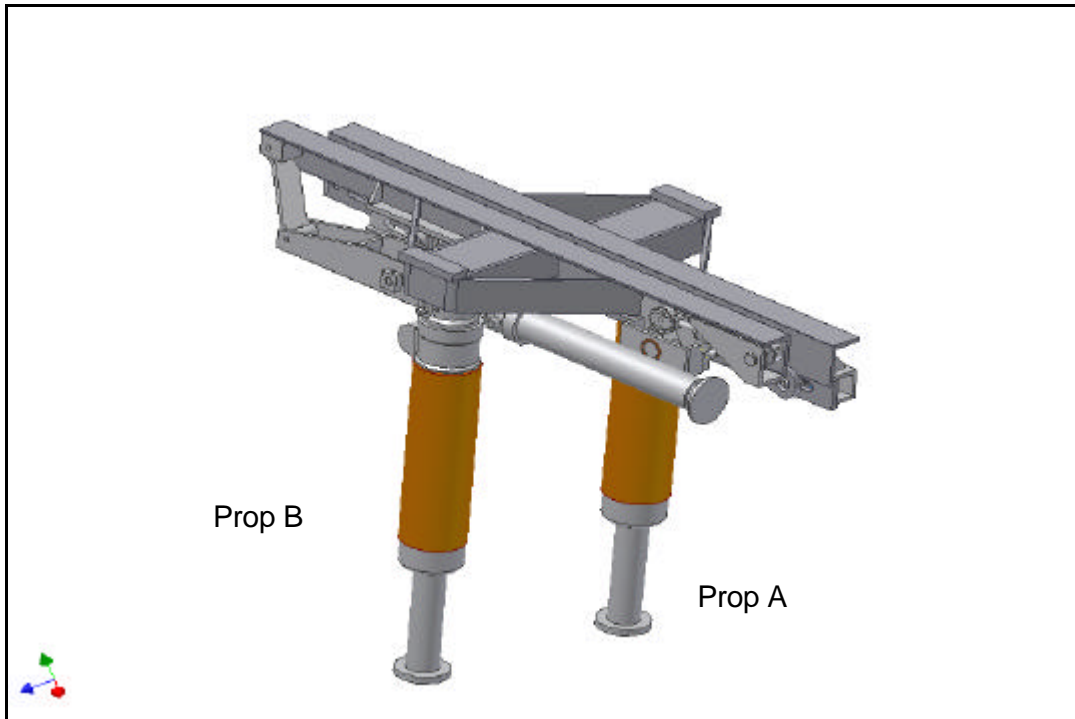
**Figure 3.6**     **Step 2 – Prop retracted**

The following step is then to move headboard A forward. Figure 3.7 shows this step from a different view.



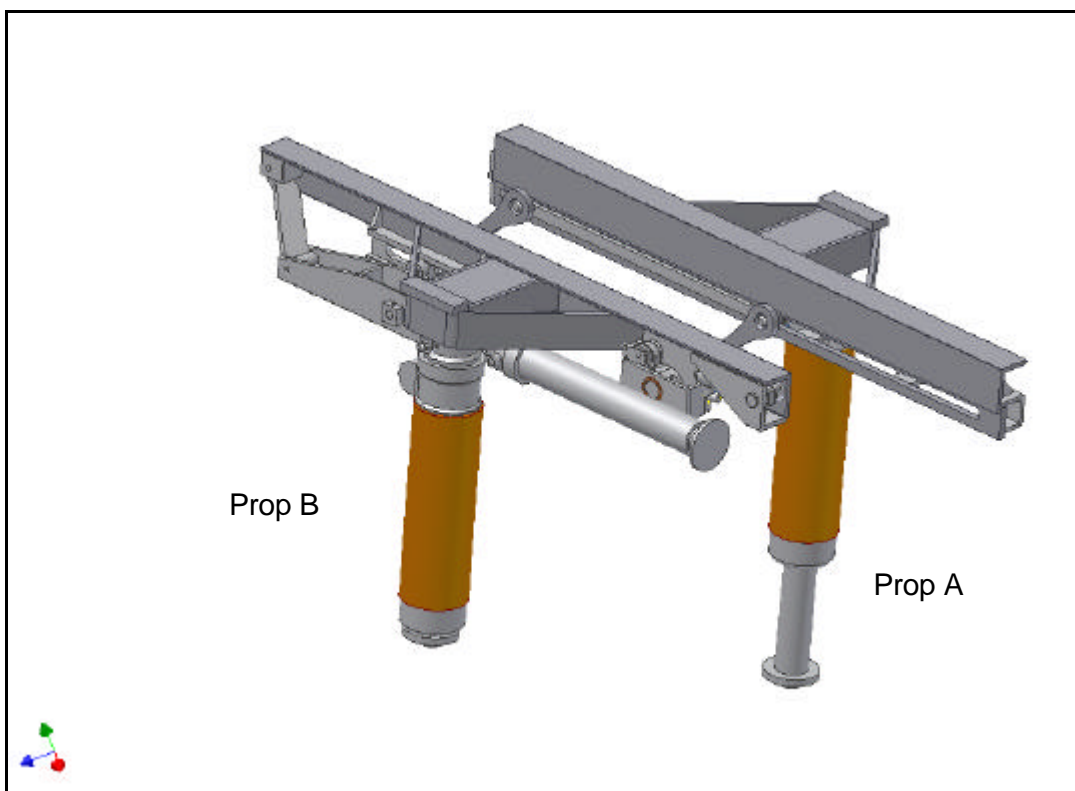
**Figure 3.7**     **Step 3 – Headboard moves forward**

Once the headboard has moved the rotational cylinder extends and headboard A is rotated up against the hangingwall. The prop is then extended again (Figure 3.8).



**Figure 3.8** *Headboard raised and prop extended*

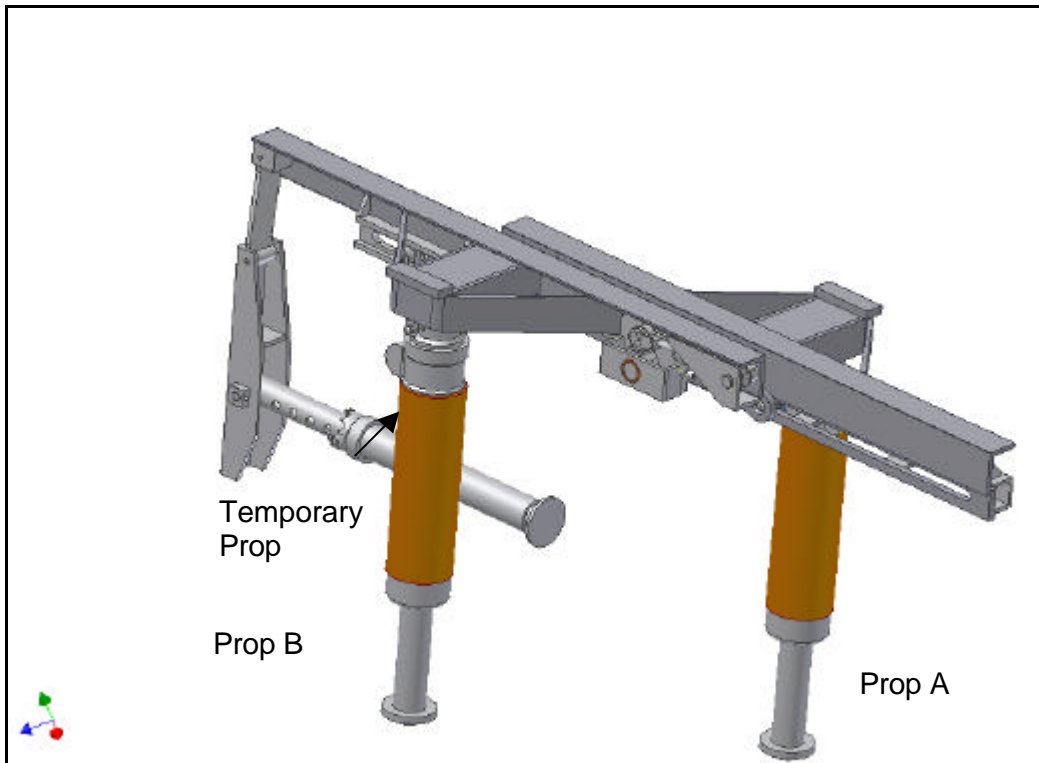
The next step is for headboard B to move forward. This is done in a similar manner to prop A by retracting prop B and the linear cylinder then moving headboard B forward (Figure 3.9).



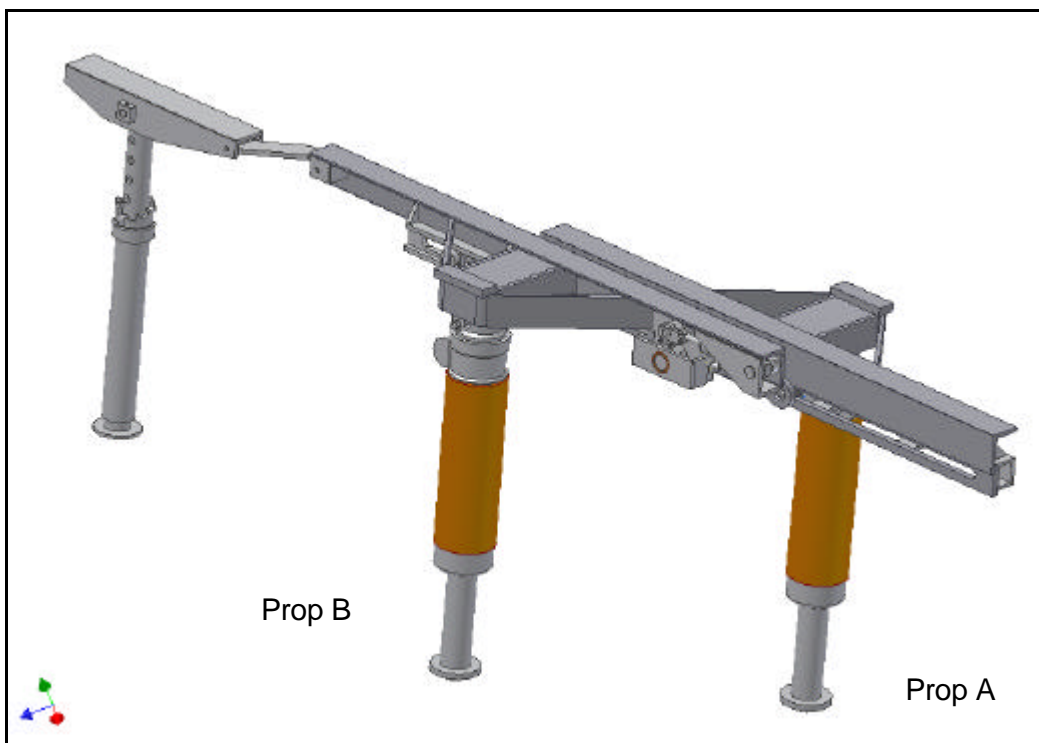
**Figure 3.9** *Prop retracted, Headboard lowered and moved forward*



The following steps involve extending the prop, raising headboard B and then extending the temporary prop. Figures 3.10 and Figure 3.11 show the method of extending of the temporary support.



**Figure 3.10** *First step to raise the temporary support*



**Figure 3.11** *Temporary support installed*

The benefit of installing the temporary support in this manner is that the personnel are still protected by headboard B. It is envisaged that the temporary prop will also be hydraulically operated but for concept-demonstration purposes a conventional Camlock prop is used.

Photographs of the developed walking beam support from different angles are shown in figures 3.12, 3.13 and 3.14.



**Figure 3.12** *Photograph (1) of the walking beam support.*



**Figure 3.13** *Photograph (2) of the walking beam support.*



**Figure 3.14** *Photograph (3) of the walking beam support.*

# Appendix

**Risk assessment** (Refer to attached document)