Standing Support Alternatives in Western Longwalls

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Abstract

Western mines have had limited choices for standing support. Wood cribs were often too soft and unstable. The introduction of the Can support in the early 1990's provided a very effective alternative and remains the dominant form of tailgate support. Water-filled prestressing cells are now used to cap the Can and preload it to provide an active roof load. The Cluster Prop, consisting of three timber wedge props bundled together, provides more capacity than an equivalent sized Can support and improves transport efficiency. However, the Cluster Prop is less stable and does not maintain a consistent load throughout its loading profile. Pumpable roof supports are another alternative support, but they have not been proven in high deformation environments. Alternative supports are also being used in longwall recovery operations. These include the Rocprop and Omni Prop, which are extendable support systems. They also provide active roof loading which can be beneficial in these applications. Specialty supports, such as the Sand Prop and Spider Prop, have also been introduced into western longwall operations. This paper compares the performance characteristics of these various support systems.

Introduction and Historical Perspective of Western Support Applications

Gateroads and longwall recovery rooms require proper support to ensure successful longwall operations regardless of geographic region, but various circumstances make this particularly difficult for western U.S. longwalls. Nowhere in mining is the compatibility of secondary supports more critical than in western mines where convergence is often an order of magnitude greater than in most eastern mines. In particular, the stiffness of the support must be compatible with the ground reaction to avoid premature support failure or unintentional damage to the roof and floor when the support is too stiff and catastrophic failure of the roof when the support is too soft (figure 1).

Historically, timber cribs and posts have been the dominant form of secondary support. However, the demands placed on these supports by longwall mining, coupled with the low-strength, short supply, and increasing cost of mine timber in western U.S. mines, have necessitated the development of alternative support systems. Beginning in the mid 1990's, the National Institute for Occupational Safety and Health (NIOSH) in conjunction with various support manufacturers promoted the development of innovative support systems. The goal was to (1) design supports that are more

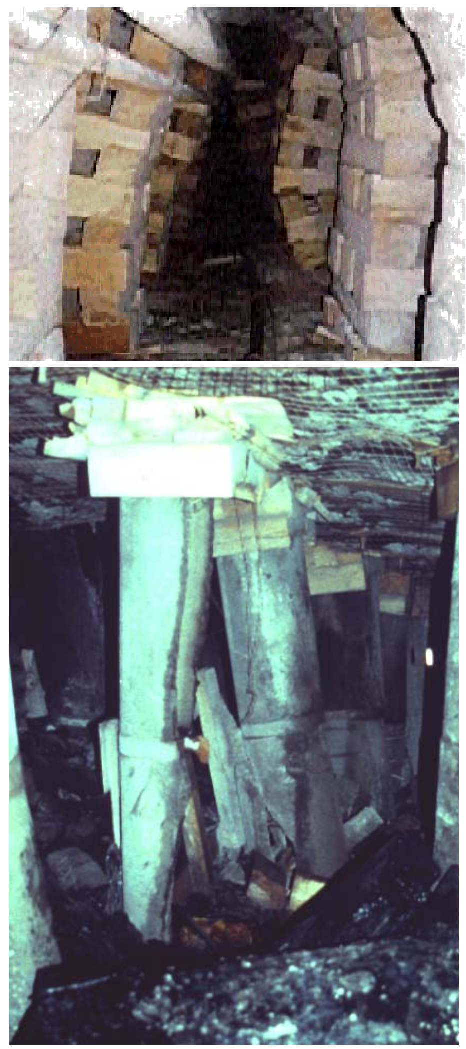


Figure 1. The compatibility of standing support with the loading conditions is essential for western longwall operations.

compatible with ground behavior, particularly the high deformation conditions found in western mines, and (2) develop cost-effective alternatives to conventional wood cribbing that reduce material handling injuries and provide equally or more effective ground control. A report published in the 15th International Conference on Ground Control in Mining documented these initial support developments (Barczak, 1996).

Figure 2. Confined Core Crib (3C) support was the first viable alternative to wood cribbing in western longwall tailgates.

The first alternative to the wood crib in western mines was the Confined Core Crib or 3C support (figure 2). The 3C support was developed by John Frederick at Southern Utah Fuel Company (SUFCO)[1] and successfully employed for years in the SUFCO mines (Frederick, 1994). The 3C support is a corrugated steel container filled with minus 3-inch (76.2 mm) pumice rock that was readily available at the Utah mine site. The steel container provides confinement to the pumice rock as it was loaded by the convergence of the mine entry. Initially the 3C is a very soft support due to the void ratio of the pumice fill, requiring over a foot of convergence to provide a reasonable degree of load resistance. However, despite this soft response, the support performed adequately in the two-entry yield pillar tailgates in the SUFCO mines where moderate floor heave, occurring prior to the longwall panel front abutment, caused sufficient convergence to compact the fill material and thereby stiffen the support for improved performance as the face approached. The 3C support was the predecessor of the Can support. The Can support, as shown in figure 3, has replaced wood cribbing and continues to be the dominant form of standing support in western mines today.

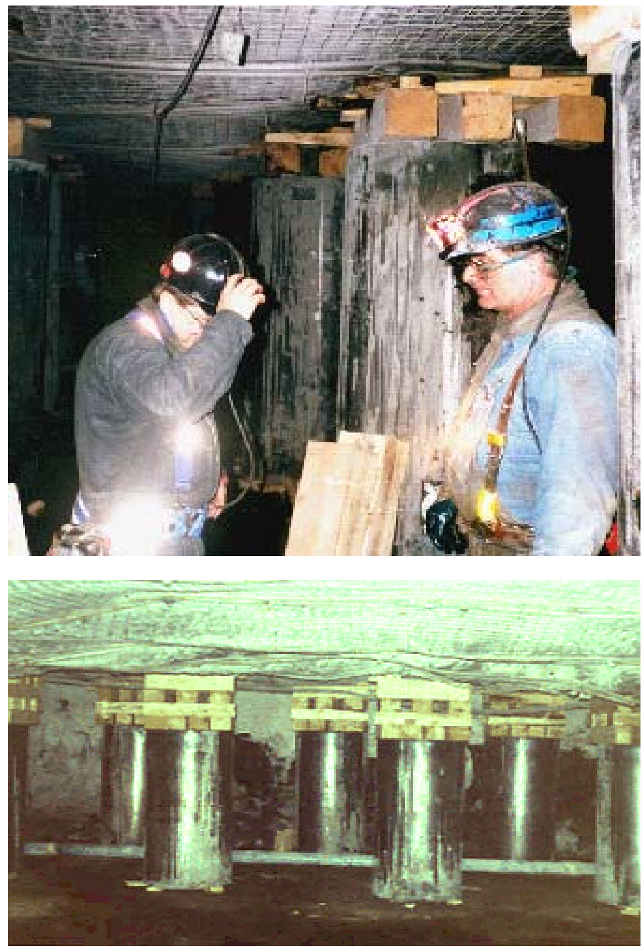
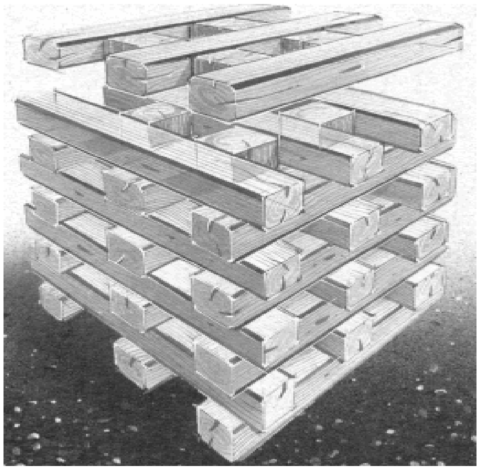


Figure 3. The Can support has replaced wood cribbing and is now the dominant secondary support used in western tailgates.

The previously cited paper in the 15th Ground Control Conference also discussed several other developments in timber supports designed to enhance the stiffness of timber cribbing. These included the Hercules and Link-N-Lock wood crib developments by Strata Products USA (figure 4). Although the improvements in stiffness and stability were beneficial to conventional crib designs, the lack of good quality timber still made it impractical to utilize this technology on a consistent basis in western mines. A few trials and some spot applications of these supports continue today, but only in relatively small numbers compared to the Can support. The Propsetter support (figure 5) was also developed in the mid-1990's by Strata Products and has become one of the

[1]Mention of any company name or product does not constitute endorsement by the National Institute for Occupational Safety and Health.



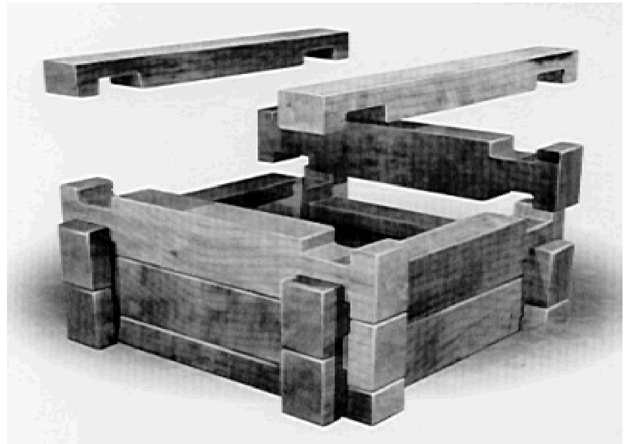


Figure 4. Advancements in timber supports, such as the Hercules crib (left) and Link-N-Lock crib (right) have overcome some of deficiencies in timber supports, but their application in western mines is likely to remain limited.

most commonly used longwall supports in eastern mines, but its use in western mines has been limited, in part due to its limited yield capability and stability in the 10+ ft (3.05+ m) mining height applications common in western mines. Other support technologies have not proven to be effective support solutions and are currently not utilized at all. These include: (1) the Mega Prop, (2) Variable Yielding Crib, and (3) Power Crib.

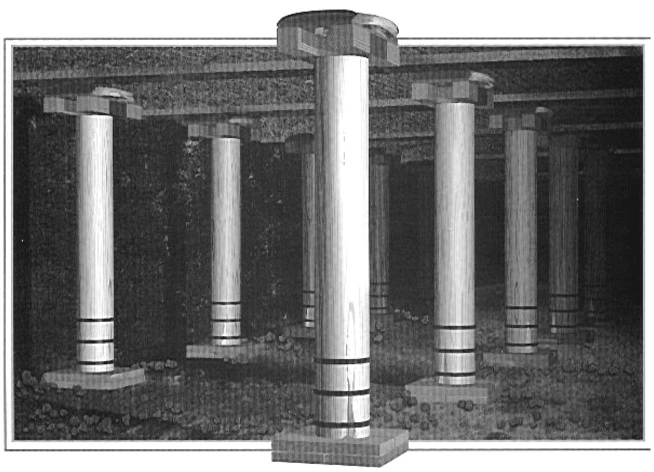


Figure 5. The Propsetter support has provided a yielding timber prop, and although it is one of the most commonly used supports in eastern longwall tailgates, its application in western mines is limited due to its yield capability and stability in the higher mining heights.

The purpose of this paper is to discuss enhancements to the Can support technology and recent support innovations that provide alternatives to the Can support for western tailgate applications. Specifically, the paper will address the use of a new prestressing technology for Can supports that will maximize its stiffness and help to offset the deficiencies caused by topping the Can with timbers. A new timber support called the Cluster Prop has been developed by Strata Products USA and has been successfully utilized in several eastern mines as an alternative to the Can support. Currently, trials of the Cluster Prop are underway in a few western mines. A comparison of the performance capabilities of the Cluster Prop with the Can support is included in this paper. Pumpable roof supports is another new technology that has performed well in eastern longwall tailgates and has recently been introduced to western mines, but the evaluation is incomplete on how well these supports can perform in high deformation environments. The paper also discusses a few new support technologies that can be used for longwall recovery operations and provides some insight into other new support technologies under development for western longwall operations.

Improving the Performance of the Can Support

The Can support remains a fundamentally sound support design with an excellent performance record. No other support currently on the market can match the stability and high yield performance of the Can support. It has performed well in both high mining heights and high deformation environments that include 2-3 feet (0.61-0.91 m) of floor heave that produces large lateral displacements of the base of the Can relative to the roof contact (figure 6). The Can is installed by a machine which eliminates much of the material handling required for the support installation, and thereby, has been shown to dramatically reduce material handling injuries compared to wood crib construction. From a design perspective, it has only one significant drawback, it has to be topped off to establish roof contact. Normally, this is done with conventional wood crib blocks.

Figure 6. The Can is the most stable support presently available. It can accommodate large roof-to-floor convergence as well as large lateral displacements.

Table 1. **Impact of wood cribbing on overall stiffness of the Can support system.**

Can diameter, inches (m)	Wood crib	Wood crib stiffness, tons/in (metric ton/cm)	Can stiffness, tons/in (metric ton/cm)	System stiffness, tons/in (metric ton/cm)
36 (0.91)	9 pt 8x8x24 - 2 layers	210 (75)	400 (143)	138 (49)
36 (0.91)	9 pt 8x8x24 - 3 layers	164 (59)	400 (143)	116 (41)
36 (0.91)	9 pt 8x8x24 - 4 layers	131 (47)	400 (143)	99 (35)
36 (0.91)	16 pt 8x8x24 - 2 layers	320 (114)	400 (143)	178 (64)
36 (0.91)	16 pt 8x8x24 - 3 layers	287 (103)	400 (143)	167 (60)
36 (0.91)	16 pt 8x8x24 - 4 layers	227 (81)	400 (143)	145 (52)

A closer examination of the impact of the crib blocks on the performance of the Can reveals just how important this material is to preserving the performance potential of the Can. The first point to understand is that the wood crib blocks will always reduce the stiffness of the support. The wood crib blocks stacked on top of the support act in series with the Can. The equivalent stiffness of the complete system can be theoretically determined from equation 1. Hence, if the wood cribbing on top of the Can had the same stiffness as the Can itself, then the overall stiffness of the support system would be reduced by 50 pct. In other words, the Can would be twice as stiff if it was not topped off with wood cribbing, assuming the two components had equal stiffness.

$$K_{System} = \frac{K_{Can} \times K_{WoodCrib}}{K_{Can} + K_{WoodCrib}} \qquad (1)$$

Table 1 shows the estimated initial stiffness of a 36-inch (0.91 m) diameter; 6-ft (1.83 m) tall, Can topped off with 2 to 4 layers of a 9-point or 16-point wood crib structure made from 8x8x36-inch (0.20x0.20x0.91-m) Lodgepole pine timbers. The stiffness values shown in this table have been derived from full-scale tests of these structures conducted in the NIOSH Mine Roof Simulator. As seen from this table, the initial stiffness of a 36-inch (0.91 m) diameter Can is reduced from 400 tons/inch (143 metric ton/cm) to 99 tons/inch (35 metric ton/cm) if the Can is topped off with a 9-point crib structure that is 4 layers tall (32 inches [0.81 m]).

A full wood timber contact layer should ***always*** be used on the top of the Can even if fewer timbers are used above the immediate layer. Without a full immediate contact layer, the crib blocks will punch into the Can and initial capacity of the Can will be reduced to that provided by the contact area of the timbers instead of the full contact area of the Can (figure 7). In addition, the yield capacity of the cribbing structure should always be greater than the yield capacity of the Can. The NIOSH Support Technology Optimization Program (STOP) software can be used to estimate the yield capacity of the wood crib structure used on top of the Can (Barczak, 2000). The yield capacities of the Can can also be determined from STOP, which will provide the following approximations: (1) 36-inch (0.91 m) diameter Can – 200 tons (181 metric tons), (2) 30-inch (0.76 m) diameter Can – 125 tons (113 metric tons), and (3) 24-inch (0.61 m) diameter Can – 100 tons (91 metric tons). For example, a 9-point lodgepole pine wood crib has a yield capacity of about 100 tons (91 metric tons). Therefore, if a 9-point crib would be constructed on top of a 36 inch (0.91 m) diameter Can, the 9-point crib would limit the capacity of the Can through the first 6+ inches (152+ mm) of convergence. Only after the wood crib has gone though several inches of plastic deformation (assuming it remains stable during this transformation) is it likely to gain sufficient stiffness to transfer load fully to the Can and cause the Can to yield. Another design consideration is the size of the Can for a particular seam height. The recommended height-to-diameter aspect ratio for application of the Can support is 5.0 to 1. For example, in a 10-ft (3.05 m) seam height, the minimum Can diameter would be 24 inches (0.61 m).

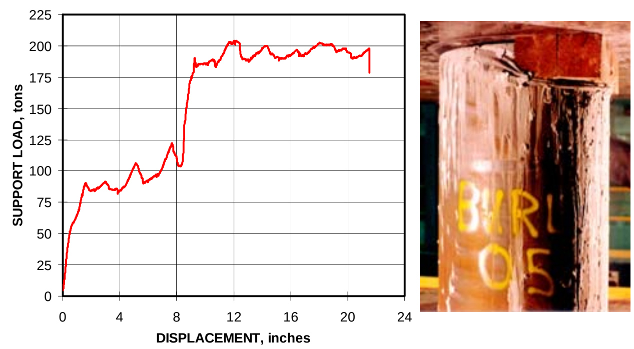


Figure 7. A full layer of timbers should be used for the first layer. The photo and graph shows the consequences of not using a full timber layer.

Recently, a new prestressing technology has been introduced that can eliminate a lot of these issues. Thin-walled steel diaphragms that can be inflated with water have been designed for prestressing a wide variety of roof support products including the Can (Barczak et. al., 2004). The prestressing units (PSU's) designed for the Can support are generally square in shape and can be fabricated in different sizes to accommodate different sized Can supports (figure 8). These units can be described as "flatjack" constructions where two, thin 0.039-0.079 inches (1-2 mm), sheets of cold-rolled steel are machine welded along the perimeter to form an encapsulated cell that can be pressurized. The PSU can be expanded up to about 6 inches (152 mm) after it is placed on top of the Can to close the gap between the Can and the mine roof. If the Can support can be sized to within 6 inches (152 mm) of the installation height, then wood cribbing can be eliminated. In this configuration (no wood cribbing), the PSU can be inflated with sufficient pressure to cause any size Can to yield. This eliminates all the stiffness reductions typically associated with wood cribbing on top of the Can and allows the full capacity of the Can to be applied immediately to the mine roof and floor upon installation. Since the Can has sufficient yield capability in itself, preloading the Can to its yield state will not have any negative impact on the subsequent support performance, and should enhance overall roof control by helping to build a more competent roof beam. If a moderate amount of timber is used in conjunction with the PSU, i.e., a full timber contact layer or header board, then the PSU will still have sufficient inflation expansion to generate yield loading in most applications. If the PSU is used without any timber, it should be placed on the closed end of the Can. Tests have shown that the welded seam sections on the open end of the Can will puncture the PSU on occasion when the Can deforms. The PSU can also be placed on the floor and the Can set on top of the PSU. There will still be plenty of pressure to lift the Can and preload the support in this configuration.

Figure 8. A water-filled prestressing unit (PSU) is now available for topping off the CAN and applying a substantial active loading to the mine roof and floor.

These PSU's can also be equipped with a hydraulic yield valve to control the load development on the Can or avoid over-pressurization of the PSU to prevent premature rupture. The yield valve is a simple spring-loaded system that is incorporated internally into the inlet check valve. Some older models may have a separate port for the yield valve. Different yield ratings can be obtained, but are typically 250 or 350 psi (1.7 or 2.4 MPa, respectfully) for the Can support applications, however, they can be customized if needed. If the PSU is not properly sized, the Can would yield before the PSU would yield. In this case, a yielding PSU may not be needed. For long-term applications of a year or more, it might be desirable to have the PSU yield prior to the Can yielding. This will help to reduce the risk of premature failure of the PSU due to corrosion.

If an oversized PSU is used as is illustrated in figure 8, which would be typical for Can applications, the PSU should be inflated with sufficient pressure to cause the PSU to fully balloon around the Can support. If this is not done, then the PSU will reduce the initial stiffness of the support as it is reshaped from the roof loading. The amount of pressure it takes to fully reshape the PSU during the inflation depends to some degree on the thickness and size of the PSU, but as a rule, a minimum setting pressure of 200 psi (1.4 MPa) will be adequate in most cases. The reshaping can be visually seen and the operator will not have a problem in knowing that the unit is properly inflated. The key point is that the unit should be used to preload the Can and not just to fill the gap between the Can and mine roof. The operator should also be aware that the preload is governed by the larger roof contact area and not the area of the Can. This may be important if the operator is trying to achieve a certain amount of preload on the support.

Some caution should be exercised in selecting the size of the PSU. If the PSU is too large, folds may occur in the ballooned areas around the Can. These folds can reduce the rigidity of the PSU and substantially reduce its stiffness to the point where the PSU and not the Can is controlling the stiffness. The folds will also increase the probability of premature failure of the PSU. A new development is underway to prevent this problem. The PSU has been reshaped in this new design to fit as a cap over the end of the Can. Figure 9 shows a drawing of this new design. Prototype testing is expected to begin soon.

Figure 9. Diagram of a new PSU design for Can supports. This unit fits over the top of the Can like a cap and avoids issues caused by an oversized square PSU.

Although the Can has considerable capacity to absorb lateral displacements induced by floor heave, a study of this performance conducted by NIOSH through full-scale testing in the Mine Roof Simulator showed that this capability can be enhanced by proper fabrication of the Can. Cans in excess of 6 ft (1.83 m) in height are constructed in two or more sections that are welded together at horizontal seams. The welds tend to create a stress concentration due to the annealing that occurs during the welding. The stress concentration can cause a fold to occur near the weld during the early phases of the loading cycle. When this occurs and horizontal displacements are applied during testing to simulate floor heave conditions, the deformed area near the welded joint may act as a hinge allowing one section of the Can to tilt, while the other section remains more vertically oriented (figure 10). This hinge action will cause the Can to shed load throughout the loading cycle once the joint forms and horizontal displacements occur. The amount of load shedding can vary depending on how much rotation is occurring at the joint. In the example shown in figure 11, about 80 kips (40 tons

[36 metric tons]) of load was lost through the 21 inches (0.53 m) of convergence and 14 inches (0.36 m) of lateral movement which occurred after the peak loading was reached. The load shedding is much less likely to occur if the deformation is confined to the top and bottom areas of the Can (figure 12).

Figure 10. Buckling of Can caused by welding of sections together can create a hinge point during lateral displacement that may cause load shedding during yielding.

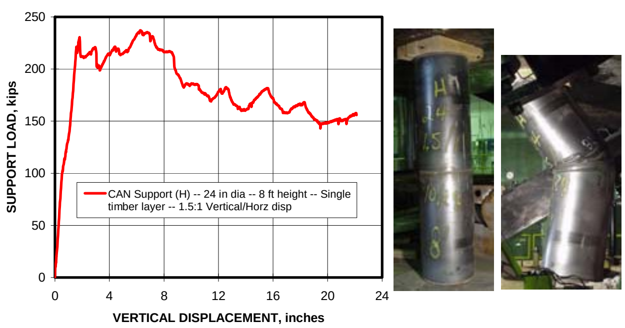


Figure 11. Load shedding during yield is caused by the welded joint as shown in this full-scale performance test in the NIOSH Mine Roof Simulator.

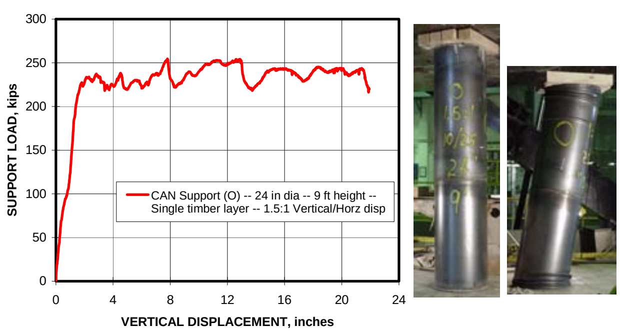


Figure 12. Load shedding is less likely to occur if the folding can be confined to the top and bottom sections as shown in this test.

Based on this observation, Can constructions where pieces are added onto both ends of a center, main body, section will provide optimum performance. Figures 13 shows a 24-inch Can that has gone through 25 inches (0.64 m) of both vertical and horizontal displacement without failure or instability that results in significant load shedding. Testing showed that 25 inches (0.64 m) of lateral displacement was the limit in this test configuration. Lateral displacements larger than that caused the Can to rip open.

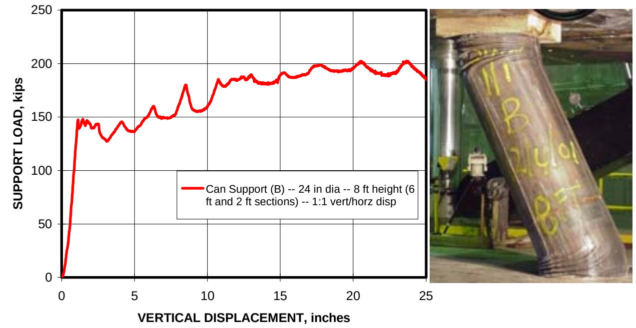


Figure 13. The limit of lateral displacement is shown where 25 inches of lateral displacement occurred prior to the Can ripping open.

In summary, the key to using the Can support successfully is to preserve the stiffness capability of the Can by avoiding too much wood cribbing on top. Since the wood acts in series with the Can, any amount of wood will degrade the initial stiffness of the Can, but the softer the crib structure used on top of the Can, the softer the Can response prior to yield will become. The hydraulic PSU technology can overcome this problem by preloading the Can to its yield rating so that this load is immediately applied to the mine roof and floor upon installation of the support.

Figure 14. The Cluster Prop is three Wedge Props bundled together as shown in this longwall gateroad application.

Cluster Props as Alternative Tailgate Support

An alternative to the Can support is the Cluster Prop. The Cluster Prop, as shown in figure 14, is based on the Propsetter support, which relies on the wedges cut into the bottom section of the timber post to control yielding of the prop. Three Wedge Props are bound together with three strong steel bands positioned at the top, middle, and bottom section of the props. This allows the three props to perform in unison and provide a stiff, high capacity, yet yielding support system. Currently, two Wedge Prop sizes, 8.5-inch (0.22 m) diameter and 10-inch (0.25 m) diameter, are used in the Cluster Prop design in western mines. The maximum recommended operating ranges for the 8.5-inch (0.22 m) Cluster Prop is 6 to 9 feet (1.83 to 2.74 m) and 6 to 12 feet (1.83 to 3.66 m) is the recommended operating range for the 10-inch (0.25 m) Cluster Prop. Each size is available from the manufacturer, Strata Products USA, in 6-inch (0.15 m) length increments.

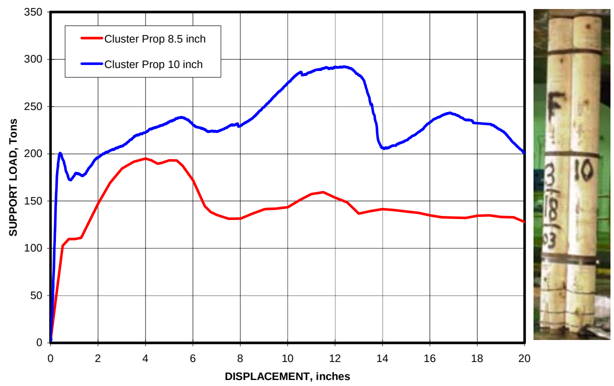


Figure 15. Full-scale performance test data for the Cluster Prop illustrating a load-displacement performance for 8.5-inch and 10-inch models.

The performance curves for the 8.5-inch (0.22 m) and 10-inch (0.25 m) Cluster Props as measured during full-scale testing in the NIOSH Mine Roof Simulator are shown in figure 15. Figure 16 includes the 24, 30, and 36-inch (0.61, 0.76, and 0.91 m, respectfully) diameter Can performance. These conclusions are drawn from these performance curves.

1. The 8.5-inch (0.22 m) Cluster Prop is rated at an average yield capacity of 150 tons (136 metric tons) and the 10-inch (0.25 m) Cluster Prop at an average yield capacity of 225 tons (204 metric tons). Overall, the equivalent Cluster Prop provides support capability similar to that of the Can support. The equivalent support would be a 10-inch (0.25 m) Cluster Prop in comparison to a 36-inch (0.91 m) diameter Can and a 8.5-inch (0.22 m) Cluster Prop in comparison to a 30-inch (0.76 m) diameter Can.
2. The Cluster Prop will be slightly stiffer than the Can as a passive support, particularly when a lot of wood cribbing is used in conjunction with the Can. The 10-inch (0.25 m) Cluster Prop is stiffer than the 8.5-inch (0.22 m) Cluster Prop due to its larger cross sectional area.
3. The yield behavior of the Can is more controlled with less load shedding and more consistent than that of the Cluster Prop. This is because the Cluster Prop relies on deformation of wood that can be erratic, while the Can relies on the confinement and folding of the steel container to control the post yield load.
4. The Can has larger yield capability than the Cluster Prop. Although not shown in figure 16, full-scale tests have confirmed that for vertical loading only, the Can can yield through 50 pct strain. The Cluster Prop has been shown through full-scale testing to yield up to 20 inches (0.51 m) without headboards or footboards, provided the wedge props are yielding in unison. The yield capability of the Cluster Prop is less consistent and can be impacted by the loading conditions. It will be maximized when the props yield in unison and will be minimized if the props act independently. Hence, the steel strapping must maintain sufficient confinement to provide uniform behavior.

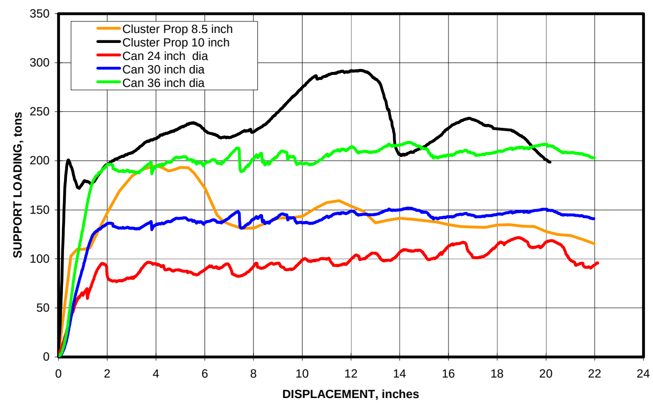


Figure 16. Comparison of Cluster Prop to the Can support performance.

Installation issues can also be critical to optimizing the performance of the Cluster Prop. The Cluster Prop will perform best when used with no more than a rugged, 4-inch (102 mm) thick foot board or headboard, and can be used without any headboard or footboard. Like the Can support, any additional material in series with the prop will soften the overall response of the support. Its yield range is limited to the yielding of the Wedge Props. Attempting to extend the yield range by adding soft crib block timbers on top of the support (figure 17) is not recommended. The wood crib timbers, in addition to softening the support response, create a hinge point that can severely degrade the stability of the support, particularly in floor heave conditions where the base of the prop is moved laterally from the roof contact. The Cluster Prop can be installed with either end up. Traditionally, the prop is installed with the wedged end of the props down, but from a performance perspective this orientation does not matter. If used without a footboard or headboard, it may make more sense to install the wedged end against the roof if the floor is too soft to handle the bearing load when installed with the wedged end on the floor. Since the prop performance will be optimized when the wedge formation and crushing of the individual props act in unison, the orientation of the props with respect to the lateral movement or any condition that is likely to cause uneven loading of the individual props may help to determine how the prop is installed. As a rule, the Cluster Prop should be installed as vertically as is practically possible, although a 5-degree tilt was determined not to have a dramatic effect on the prop performance during full-scale laboratory testing.

The Cluster Prop, like the Can support, is installed with a mechanical aid. Unlike the Can system that utilizes a hydraulically powered clamp, the Prophandler is simply a mechanical clamp and a static tray from which the Cluster Props are slid into position. One advantage of Cluster Prop over the Can support is an improvement in haulage productivity since more units of equivalent capacity can be transported on the same supply car due to their smaller size and physical shape. Up to 100 of the 10-inch (0.25 m) Cluster Props can be transported in the same load compared to 35 Cans that are 36-inches (0.91 m) in diameter.

Figure 17. Adding crib timbers to the top of a Cluster Prop is not advisable. As shown in this figure, this can create a hinge point that can severely degrade the stability of the support in high deformation environments.

Pumpable Roof Support Technologies

Pumpable roof support technologies have advanced with new developments in the late 1990's. Heitech (part of Heintzmann Corporation) has led the development of a two-component, quick setting, grout system that can be pumped over 3 miles (4.83 km) through a surface borehole, into a fabric bag hung from the mine roof (figure 18). The bag not only provides a structure to form the support, but also provides confinement to the fractured grout once its peak capacity is exceeded. The support can be sized to satisfy specific loading conditions, a 24-inch (0.61 m) and 30-inch (0.76 m) diameter are the two standard sizes used in eastern tailgates. The performance curves for these two supports are shown in figure 19. As seen in these figures, the pumpable support provides a very stiff response, considerably stiffer than the Can support. But unlike the Can which utilizes an air-entrained material that can be volumetrically crushed and a steel container that can sustain its peak support capacity during yielding, the pumpable support sheds considerable load during its post peak behavior. This is because the fabric bag does not have the rigidity of the steel Can container, and cannot provide sufficient confinement to prevent this load shedding. A residual load of about 100 tons (91 metric tons) can be maintained through several inches, but the pumpable crib is never going to have the yield capability of a Can support. These supports have been successfully employed in a few eastern longwall tailgates and have performed very well for these applications. Successful trials of this support technology have also been conducted in bleeder entries in at least one western longwall with nearly a foot of floor heave, but the floor material moved around the support and did not induce much (probably less than 2 inches [51 mm]) deformation within the support. It is still unknown as to whether this technology can perform well in a high deformation environment where the convergence cannot be controlled by the support capacity. Hence, its application potential in yield pillar tailgates or areas of excessive floor heave remain unknown.

Figure 18. Pumpable roof supports offer an alternative support system whereby the support material can be pumped from the surface or a remote underground location.

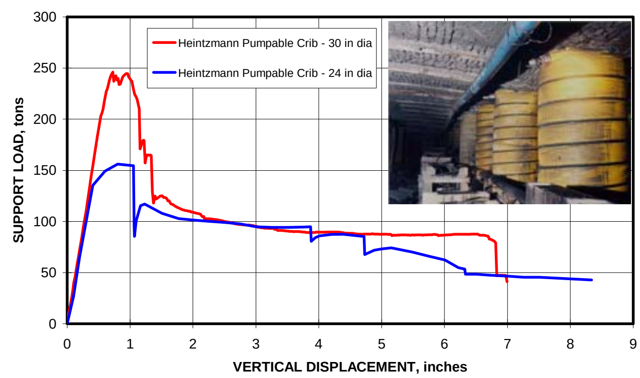


Figure 19. Performance assessment of Pumpable Roof Supports from Heitech showing load-displacement curves for 24 and 30 inch diameter supports typically used in longwall tailgate applications.

New Support Technologies for Longwall Moves

Longwall moves have always been a critical element in longwall operations. When shields are removed from a completed longwall panel, some form of standing support is usually installed to provide a stable environment to protect workers. Historically, this has been done with conventional wood cribbing. However, transporting heavy, bulky crib blocks along a longwall face can be difficult and time consuming. Further, constructing the crib takes considerable time and exposes miners to hazard during support construction. Some western longwall operations have also used the Can for support in these longwall recovery operations. Although the Can is still bulky, it can be transported as a unit and installed quickly with a machine. At least one western longwall operator is also using the hydraulic PSU's discussed in the previous section to preload the Can and actively transfer load to the mine roof for longwall recovery operations. In this application, the PSU with a yield valve installed, is placed underneath the Can on a layer of wood cribbing and inflated to the yield pressure. Once the adjacent shield is removed, the PSU yields fluid as the additional roof weighting occurs. The controlled yielding provided by the yield valve ensures a controlled transfer of load from the mine roof to the standing support to maintain a stable roof condition during the shield removal process.

Other mines have moved towards smaller standing support units in order to alleviate the transportation requirements for the bulkier Can support. Various forms of steel and timber props have been used in this capacity in the past including engineered supports such as the Propsetter, but recently two new products have shown promise in this application. These are the Rocprop and the Omni Prop.

The Rocprop, marketed by Strata Products USA, is a hydraulic cylinder that is extended against the mine roof and floor by pumping water or some other hydraulic fluid into the cylinder. Once the cylinder is set, a locking collar transforms the cylinder into a mechanical prop where the steel tubing is deformed in a controlled manner. A 35 and 50 metric ton unit (yield load rating) is available for 10-ft (3.05 m) mining heights. As a mechanical prop, Rocprop provides a very controlled yield capability which is beneficial, but its main advantage in the longwall recovery operation is that it can be set to various heights very easily and can provide an active load to the mine roof during installation. The performance curves as a passive support (no preloading) for the 35 and 50 metric ton unit are shown in figure 20.

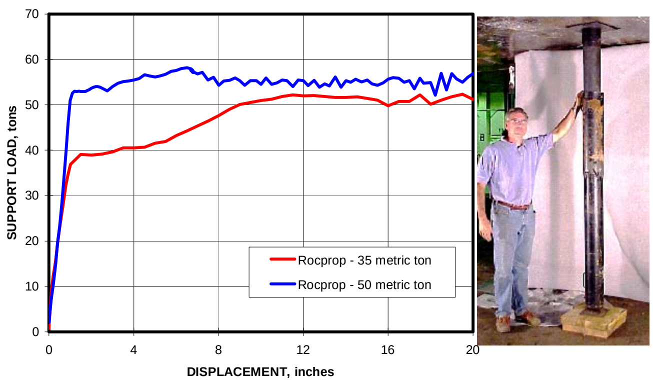


Figure 20. Performance assessment of the Rocprop support showing 35 and 50 metric ton designs.

The Omni Prop is a South African product that has recently been introduced into the American market by Heintzmann Corporation of Cedar Bluff, VA. The Omni Prop is essentially a single stage hydraulic cylinder. Water is pumped into the prop using shield emulsion or water. The fluid causes the end of the prop to extend to the roof line. As pressurized fluid continues to enter the prop, an active roof load up to the yield load rating of the prop can be applied to the mine roof. Up to this point, the Onmi Prop functions basically the same way as the Rocprop. However, unlike the Rocprop, the Omni Prop remains a hydraulic prop. Once the setting phase is completed and the hose is removed from the inlet port, a check valve in the bottom of the prop maintains the setting load. As the roof loading increases and overcomes the setting force, the captured water in the prop increases in pressure, functioning just like a hydraulic cylinder. The piston in the cylinder includes a yield valve, which controls the pressure in the cylinder. Once the yield pressure is reached, water is relieved though the piston and into the hollow section of pipe on the opposite end of the prop. If the prop is installed with the pressurized cylinder against the mine roof, the relieved water will flow into the bottom section and out a small slit in the base of the prop. This is a visual sign that the support is yielding. The performance curve for the Omni Prop is shown in figure 21. As seen in the figure, the support provides a consistent yield load of slightly more than 50 tons (45 metric tons).

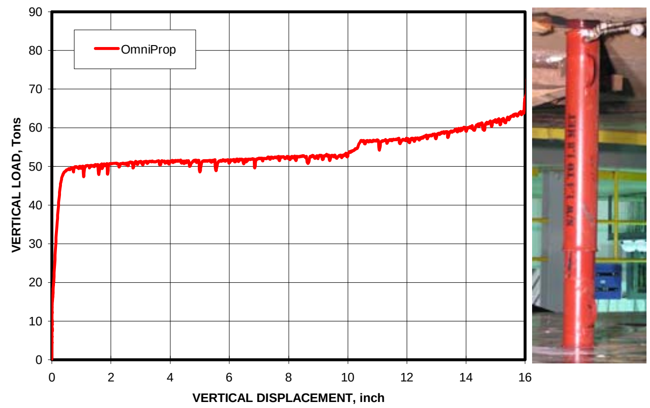


Figure 21. Performance assessment of the Omni Prop, a water filled hydraulic cylinder that provides active roof loading with controlled yielding.

Other Support Technologies

The Sand Prop, marketed by Strata Products USA, incorporates a novel approach to developing an extendable support. The support consists of two telescopic sections of pipe. It is preassembled and shipped in a collapsed state. The top section is pre-filled with a "sand-like" or granular material. As the upper section is lifted into place, the granular material flows from the top section into the bottom section to form a column of granular material upon which the upper section rests. Figure 22 shows the performance curve for the Sand Prop and an underground installation. It has a load rating of 50 tons (45 metric tons). A yielding version of the Sand Prop is called the Bolt Prop. The Bolt Prop includes a collar that is threaded with bolts which are inserted to a specified torque and shear into the face of the inner pipe as yielding occurs. The yield rating of the Bolt Prop is 40-50 tons (36-45 metric tons), respectfully, but can be inconsistent during yielding, especially in the presence of eccentric loading.

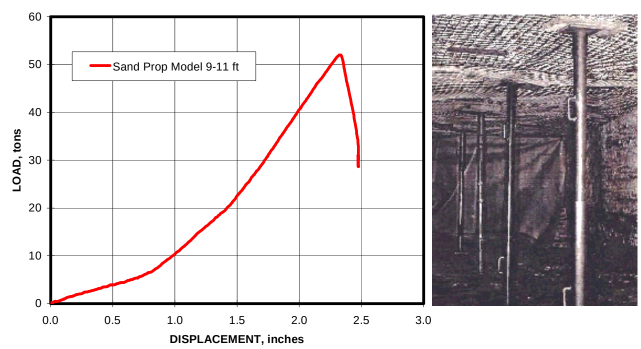


Figure 22. Performance curve for the Sand Prop from full-scale testing in the NIOSH Mine Roof Simulator and an underground installation.

Another support that has recently been introduced into western longwall operations is the Spider Prop, marketed by Heintzmann Corporation. The Spider Prop has a unique design that provides extension capability to a conventional timber post or steel prop. A photo of the Spider Prop is shown in figure 23. In this version, a steel cap is fitted over a conventional timber post. A specially designed steel endplate is secured to the end of the timber post. Cutters are included in this end piece as shown in the figure. A wire spring holds the cutters in place as the metal cap is lifted to the roof height. Then the cutters engage the inside of the metal cap and shear through it as the roof loading begins. The cutters then peel open 1/4-inch (6.25 mm) slots in the metal cap to provide controlled yielding. The performance curve is shown in figure 24.

Summary and Conclusions

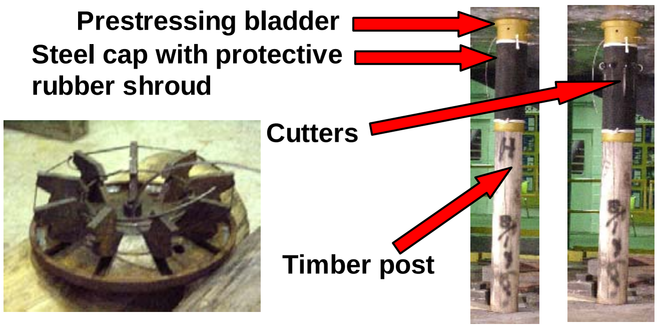


Figure 23. Photo of the Spider Prop, a unique approach to developing an extendable and yielding timber prop.

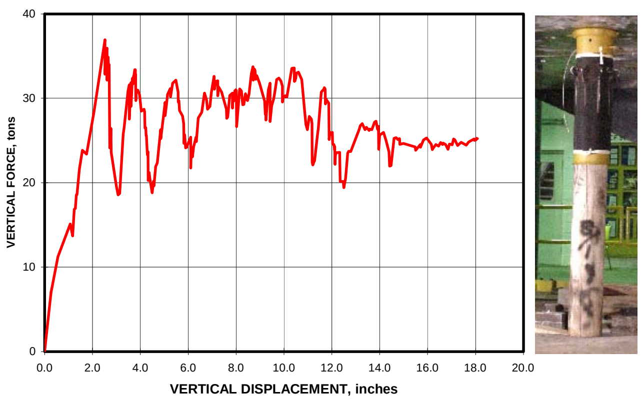


Figure 24. Performance curve for the Spider Prop based on full-scale testing in the NIOSH Mine Roof Simulator.

Secondary support in western U.S. mines has evolved as Can supports replaced conventional wood cribbing. The Can continues to be an effective design with a very successful performance record. The key is to maintain the performance capability of the Can by proper capping practice, which historically has been done with crib timbers. Poor practice in this regard can significantly soften the support response and degrade its stability as well. Recently, a water-filled diaphragm has been developed as a prestressing unit (PSU) for Can applications. The PSU can eliminate the need for wood cribbing if the Can is sized to within 6 inches (0.15 m) of the installation height. The PSU can also preload the Can to its yield capacity and provide a substantial active load to the mine roof and floor. Prestressing secures the Can in place and prevents it from being dislodged, unintentionally by pillar sloughage or other events, once it is set in place. The PSU can also be used to control load development by utilizing a yield valve in the PSU.

Other support concepts have been introduced in the past 2 or 3 years that can provide an alternative to the Can. These include the Cluster Prop and the pumpable roof support. The Cluster Prop is a timber support that utilizes three Wedge Props to provide a support system with equivalent capacity to the Can. It is slightly stiffer than the Can prior to yielding and can yield through about 20 inches (0.51 m) of convergence, but its yield load is less controlled than that provided by the Can support. Its primary advantage is improved haulage productivity since more units of equivalent capacity can be transported on the same supply car due to their smaller size and shape. Pumpable roof supports continue to perform well in eastern longwall tailgates and at least one successful trial has been achieved in a western longwall bleeder entry application. The pumpable roof support is significantly stiffer than the Can prior to yielding, but the fabric bag does not have sufficient rigidity to sustain the peak loading, and this is the primary performance difference between the pumpable roof support and the Can. The pumpable roof support's capability to perform in a high deformation environment, where the convergence cannot be controlled by the support capacity, is doubtful but extensive trials in such applications have not yet been done.

Other advancements have been made in support applications for longwall support recovery. Here too, the Can in combination with the hydraulic PSU's, have been successfully employed. Other supports that show promise include the Rocprop and Omni Prop. The Rocprop has some proven history in this area in U.S. mines both in the East and West, while the Omni Prop has just recently been introduced to the U.S. market. Although the Onmi Prop has a successful history in South African mines, it has not been installed underground in the U.S. to date. Both of these products provide a relatively small, easily transported, support that can be quickly set and provide a substantial active roof load. They also provide very controlled yielding. These performance characteristics make them well suited for longwall recovery operations, and are often used in conjunction with roof beams to help control the span in the immediate working area during shield recovery.

Finally, specialty products now exist in standing supports much like they do in roof bolts. Two such products are the Sand Prop and Spider Prop. The primary features of both products are their extendibility, and therefore, ease of installation. The Sand Prop transfers granular material from one end to the other to provide easy height adjustment during installation. The Sand Prop is considered a "non-yielding" support with only 1-2 inches (25-50 mm) of yield capability. A variation of this design, called the Bolt Prop provides a yielding support product. The Spider Prop, on the other hand, uses a rather sophisticated mechanical cutter assembly to allow height adjustment of a timber post or steel prop. These products have limited capacities and stability, and therefore are more likely to be used in areas along belt lines or other applications where space is limited and is a primary factor in support selection.

In summary, because of these innovations in support technology, there are now a wide variety of support systems to assist in gateroad and shield recovery ground control. Each system has its advantages and disadvantages. There is not an ideal roof support for all conditions. However, these new support systems provide mine operators with several alternatives to the conventional wood cribs that have historically been used for secondary roof support and the more recent Can support applications. Performance data for these support systems, presented in this paper, will help to ensure their safe utilization.

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