National
Safety
Council

Coal Mining Newsletter

JULY 1978

Considerations for Coal Mine Roof and Rib Supports

Roof and Rib Reinforcements

Supports in U. S. underground coal mines are mainly applied to the roof by roof bolting, leaving the ribs and floor more or less unsupported. This practice appears to be adequate in most cases, but there are cases where rib falls and/or floor heave are severe and require supporting. The problems of rib spalling increase as the mining height increases.

Floor heave occurs when the floor rock is soft and the horizontal stress is relatively great. Small roof falls occasionally occur between roof bolts. This can be reduced or eliminated by placing a wooden header or a steel channel between roof bolts. Wire mesh can be used to hold the broken rock fragments.

Because of rapid load relief after coal removal, numerous vertical cracks are formed near the ribs. Tensile horizontal stresses are generally found near the ribs around the midsection of the pillars. The maximum tensile stress increases with the length/width, ratio; for a constant pillar width, the taller the pillar, the higher the maximum tensile stress development.

Once the maximum tensile stress exceeds the tensile strength of the pillar, the existing vertical cracks propagate, new vertical cracks develop, and rib spalls start. Rib spalls can be reduced by rib bolting using either conventional roof or resin bolts. However, the conventional tensioned bolts are not expected to be as effective as resin bolts.

Because coal is a friable material and contains numerous natural and induced fractures, the anchors have difficulty gripping firmly. The point anchored resin bolt is practical because the resin fills the fissures around the anchor point, ensuring the necessary anchorage. In either case, it is essential that the bolt be long enough to reach beyond the area where the tensile horizontal stress or vertical fractures occur.

To further reduce rib spallings between the bolts, steel bands or wire ropes can be used to wrap around the midsection of the pillars. The effectiveness of steel banding and wire roping will be greatly increased if it is kept in intimate contact with the ribs. Demonstrations in the laboratory indicate that wire roping around the midsection of the cylindrical specimen increases pillar strength up to 241%.

Mine sealants are available for spraying on the roof and rib. A thin coat of sealant not only strengthens the coated surface to some extent, but also seals the surfaces from the effect of wet-dry cycles of the ventilated air. In addition to the basic requirements of nontoxicity and incombustibility, a sealant must be low in permeability. Furthermore, it must adhere easily and firmly to coal, steel, wood, concrete, brickwork or other materials commonly encountered in the mines, without spalling and develop its full strength shortly after application.

There are several sealants currently on the market. Zonolite, for example, is a lightweight cementitious material which consists of processed vermiculite ore, cement and other elements combined to produce a firm, monolithic coating that can be sprayed from ¼-2½ in. thick in one application. Zonolite is packaged in bags that contain all the necessary ingredients. It can be placed by standard rock dusting equipment, mixing it with approximately 4 to 5 gallons of water per bag. Zonolite, once fully cured, has a compressive strength around 500 psi and a tensile strength of 100 psi.

Another commercial sealant, Airtrol, is a noncombustible gypsum cement. It can also be applied with conventional rock dusting equipment. The system combines air, water and binder at the nozzle. Glass fibers can be added to increase its flexural strength. This is achieved by an air-driven chopper at the nozzle. Airtrol can be sprayed from ¼-8 in. thick and sets in 15-20 minutes. It attains 50% ultimate dry strength (minimum 2000 psi) one hour after setting. Airtrol provides an excellent bond to rock surfaces or concrete blocks one hour after application.

Blocbond is a fiberglass sealant and therefore requires a special spraying machine. It is much stronger, capable of reaching a flexural strength of 985 psi and a compressive strength of 4720 psi after setting. Therefore, a minimum thickness of 1/8 in. is sufficient to provide superior crack resistance. Fiberglass is also highly impermeable to water and air, which is ideal for eliminating roof and rib weathering.

Dowel Reinforcement

Because of the existence of the

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from the mouth of the hole. The same operation is applied to the double-end-threaded bolt in the other hole. The turnbuckle and serrated extension are then added to the double-end-threaded bolt. Finally, the tapered collar is slipped in and a wedge driven to complete the installation.

A bolt tension of at least 1200 lbs. is applied by turning the turnbuckle. A roof truss like this can be installed in 15 minutes. A ¾-in. bolt can support a load of 10.5 tons, whereas a 1-in. bolt is capable of supporting 15 tons at each hole.

Roof trusses are most effective for areas where the suspension effect of roof bolting fails. This includes broken rock falls between roof bolts. Photoelastic model studies demonstrated that in a truss-supported roof, upward thrusts are generated at the mouths of the holes and wooden blocks. Consequently, the tensile stress in the midspan roof is reduced and the neutral axis of the strata moves downward.

As tension in the roof truss increases, the tensile stress continues to decrease until the neutral axis of the lowest roof strata is eliminated and the midspan is completely in compression. Therefore, a roof truss eliminates or reduces roof falls by creating a compressive stress zone at the midspan of the opening as opposed to a tensile stress area in an unsupported roof. Since rock is much weaker in tension than in compression, a tensile stress region poses the greatest potential for breaking down.

Most underground installations of roof trusses place the two inclined holes at 45° with a maximum spacing between the two holes at 12 ft and an interval of 4 ft between adjacent trusses. The hole mouth is usually 1 ft from the riblines while the hole end is at least 6 in. inside the ribline in the same roof. This design agrees with both theoretical and model analyses.

Truss efficiency is affected:

1. When the angle of the inclined holes measured from the horizontal roof line is increased to larger than 35°, the bolt tension decreases, but the supporting force at the collar of the roof-truss support hole increases rapidly while the supporting force at the block is insensitive to increases in the angle.

2. When the angle is larger than 60°, increases in block length will reduce the bolt tension with no change in the supporting force.

3. Bolt tension and supporting force decrease as the thickness of the wood block increases.

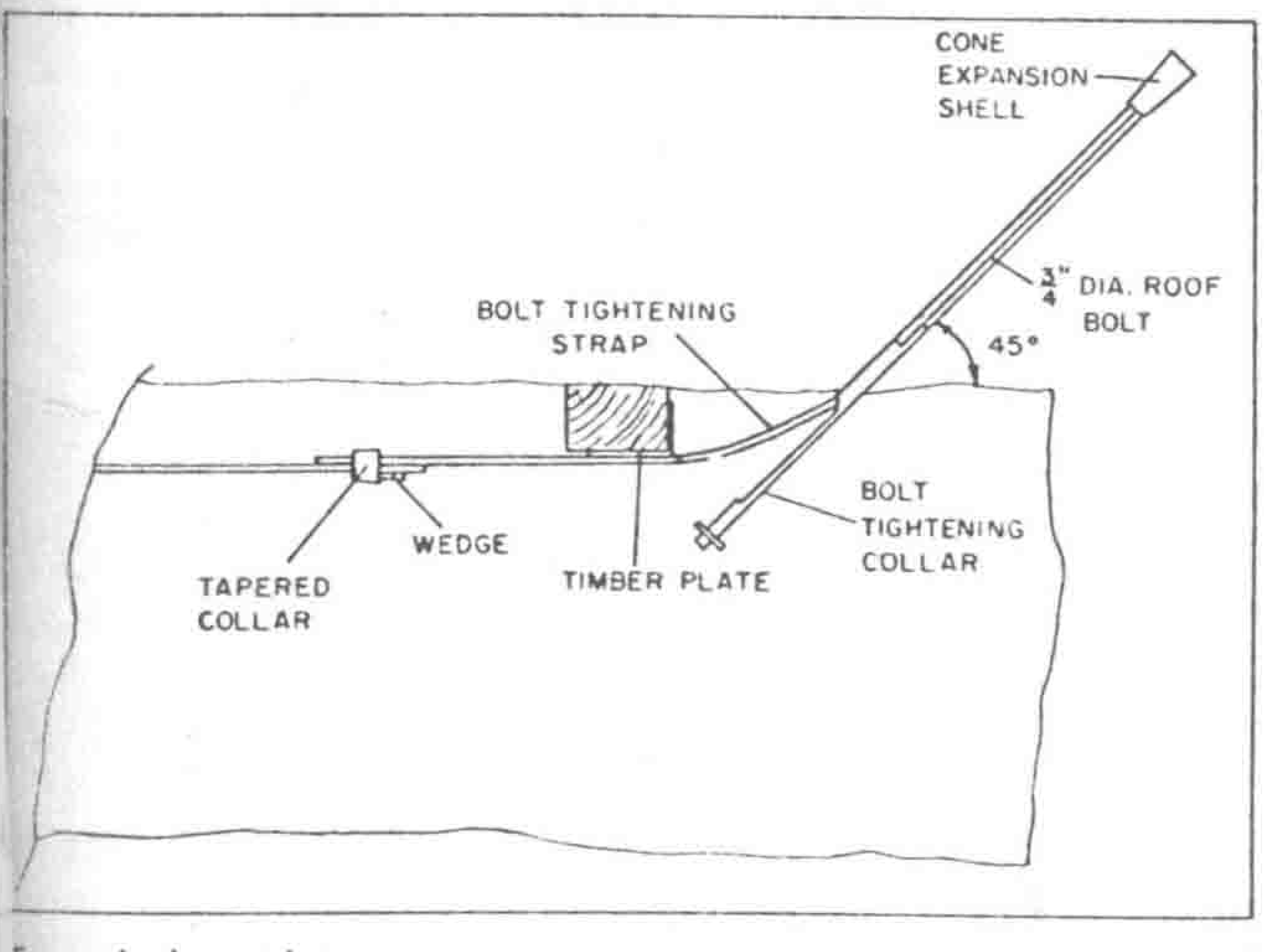
It is recommended that the angle of hole inclination should preferably be 60° and in no case less than 45° The best combination of hole span, block thickness and hole to block distance is shown in Table 1.

Hole Span ft.	Block Thickness, b in.	Hole to Block Distance, ℓ in.
8.53	3.15	7.87--8.66
9.84	3.15	7.87--8.66
11.81	3.94	9.84-11.81

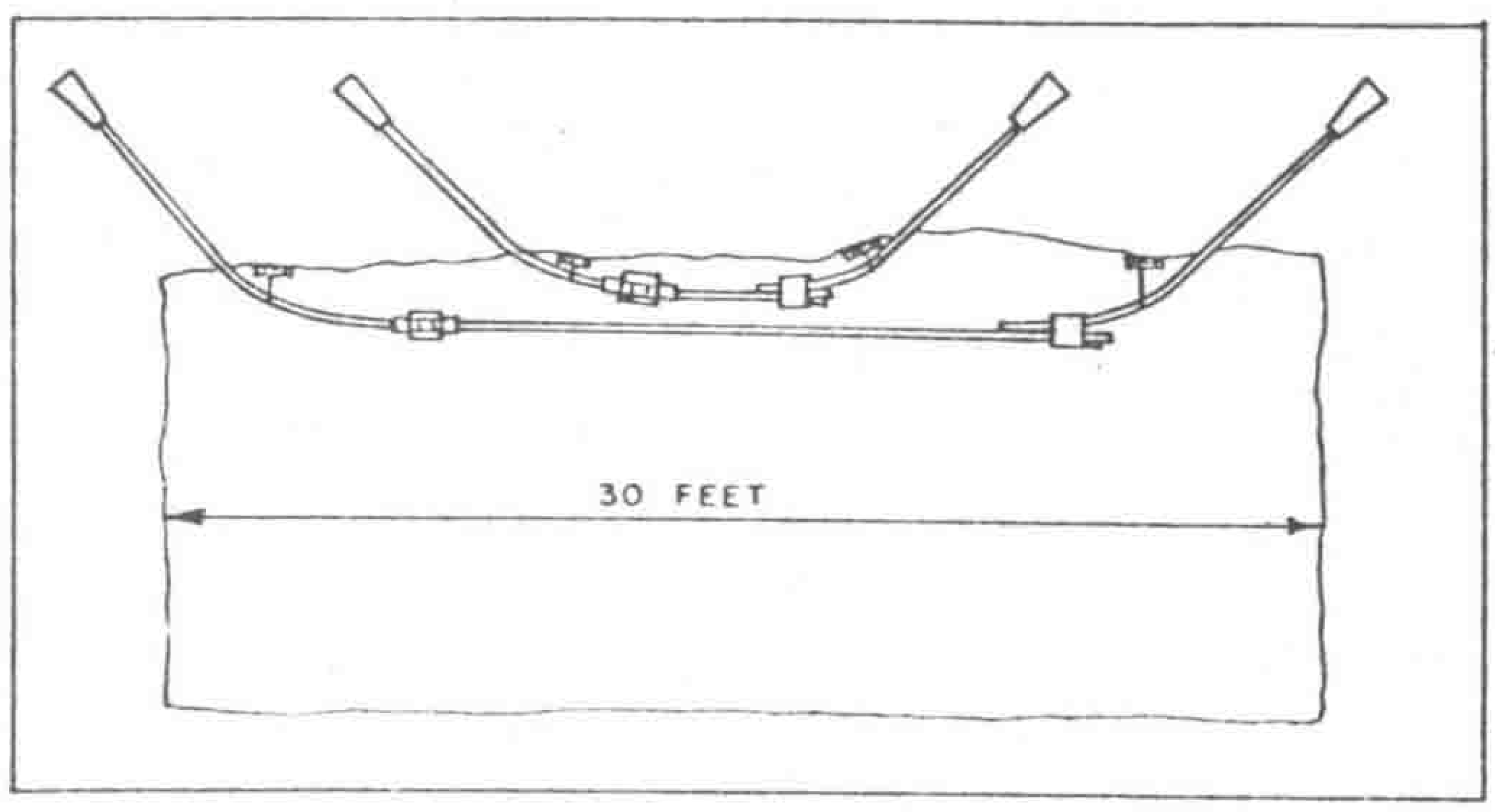
Table 1. Recommended hole span for various combinations of block thicknesses and hole-to-block distances.

Single trusses have been used for rooms or entries up to 24 ft. wide, while two multiple trusses have been used successfully for rooms or entries up to 30 ft. It is possible that three multiple trusses can be used for rooms up to 40 ft. Multiple trusses can be installed one within the other or with one overlapping the other. The principle behind multiple trusses for wide openings is that the upward thrusts at the hole mouths and the wooden blocks produced by the truss next to the rib, serve to solidify the anchorage point of the next truss and so forth.

For supporting room or entry intersections, several methods have been proposed. The simplest one is an "X" type in a four-way intersection where two trusses are installed. Each truss is anchored at the diagonal corners of the intersection over the pillars. Another type involves driving entry



Truss-bolt anchorage.



Four panel truss.

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Considerations

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beyond the projected intersection and installing cross trusses as usual. Carrying trusses are installed parallel to the riblines and anchored at the corners of the pillars across the projected cross-cuts. Carrying trusses must be installed before driving cross-cuts.

A split set is a long steel tube with a slot cut through its entire length. The tube is usually 1½ in. in diameter but varies in length up to 6 ft. The wall thickness of the tube is 9/100 in. and the slot width is 1/2 in. When the split set is forced into a hole with a smaller diameter, it closes inside the hole and creates a radial stress distribution between the split set and the wall of the hole. The radial stress creates a compressive stress field and reinforces the surrounding rocks. The split set is usually impact-driven or hydraulically thrust into the hole.

To facilitate the insertion, the top end of the split set is tapered and frequently a starter bit with a larger diameter is used for drilling the hole. The bottom end of the split set is upset so that a bearing plate (or roof plate) can be inserted immediately beneath the roofline. The split set can be installed with or without a top anchor. This is better than most mechanical roof bolts, but it also requires similar force to drive them into the borehole during installation. Consequently, a special machine capable of delivering high-impact force is needed, because the conventional roof bolters are not designed for this purpose.

The split set makes an extremely firm grip between the wall rock and the tube. The cyclic pullout tests indicated that a repeated pullout and pushing of up to 1/2 in. in cyclic amplitude will not weaken its anchorage capacity, and that, in some cases, the anchorage capacity is increased after the cyclic test.

The most significant characteristic of the split set is that its anchorage capacity increases with time after installation. For example, the anchorage capacity of a 4-ft long split set installed in a hard shale is 2.7 tons immediately after installation. It increases to 8.4 in 19 days and 10 tons in 100 days.

Field tests conducted at the underground entry intersections indicated that the split set was superior to the resin bolt because, everything being equal, the roof-to-floor convergences in the split-set supported intersection were smaller than those in the intersection supported by the resin bolts.

—Syd Peng
West Virginia University

Combat Complacency: Make Planned Safety Inspections

There is a constant need to update accident-prevention programs, even in the most safety-conscious manufacturing organizations. Special emphasis should be given to changed conditions which result from new facilities, as well as changes in workforce characteristics and attitudes.

An important part of a safety program is an emphasis on planned safety observations by supervision.

We believe that the basic safety training of our employees is the responsibility of the individual supervisor. After he has instructed the worker in how to do his job, there is no better way to be sure that he is doing his job safely than to watch him perform. Only through planned and repeated observation of both inexperienced and experienced workers can a supervisor be assured that his people are working safely.

It seems strange that having made the initial effort to establish good work habits and adherence to established safety rules among new employees, our accident reports so frequently illustrate their low retention of safety knowledge.

We think the problem is associated with the generally desirable innovative characteristic of the American worker in combination with simple human complacency.

We have learned the hard way that when workers grow complacent they are most vulnerable to error. When human errors occur we become more vulnerable to accidents and injuries.

We believe the best way to combat complacency is for supervisors to make planned safety observations of people, equipment and work areas at regular intervals. But before the supervisor takes on this assignment, he must be trained to know the difference between a casual observation and a planned observation.

A casual observation is when a supervisor with many problems on his mind, walks through his work area and casually glances at the workers, materials and equipment until he reaches his destination.

In contrast, a planned safety observation is one in which a supervisor concentrates on the activities in his area of responsibility, with specific reference to its hazard index. He looks for unsafe work performances and unsafe conditions and takes the necessary corrective action.

This is the same procedure we follow to solve quality and production problems. Since we know that planned observations are effective in maintaining high performance standards in these manufacturing variables, it is logical to apply the same techniques to accident prevention.

—F.G. Jaicks
Inland Steel Co.

New MSHA Aids

MSHA announces two new health and safety training aids: *Safety in Surface Coal Mining* which is available as 16 mm movie film for loan or purchase and *The Care and Use of a Permissible Flame Safety Lamp* which is available on 3/4-in. video-cassettes or 1/2-in. black and white reels for purchase only.

Requests should be addressed to: Chief, Audio Visual Office—Educational and Training, Mine Safety and Health Administration, 4800 Forbes Ave., Pittsburgh, Pa. 15213. ■

Printed in U.S.A. Stock No. 112.03-06