NIOSH SAFETY PERFORMANCE TESTING PROTOCOLS FOR STANDING ROOF SUPPORTS AND LONGWALL SHIELDS

By Thomas M. Barczak[1]

ABSTRACT

The safety of mine workers depends on the proper installation of roof supports to prevent the ground from collapsing into the working areas of an underground mine. As new support systems are developed, they need to be properly evaluated to make sure that they are capable of providing adequate roof support before they are first used in a mine. In addition to making certain that the supports meet basic safety criteria, the limitations of the support need to be fully defined in order to avoid improper application of a particular support design. The National Institute for Occupational Safety and Health (NIOSH) operates a world-class facility called the Safety Structures Testing Laboratory. This laboratory contains a unique load frame, the Mine Roof Simulator, which is capable of simulating the ground behavior in underground mines for conducting full-scale evaluations of roof support systems. Safety performance testing protocols using the unique Mine Roof Simulator have been developed for both standing roof support systems and longwall shield supports. The purpose of this paper is to describe these test procedures. The protocol for standing roof supports incorporates seven test series: (1) uniform loading baseline tests, (2) height evaluations, (3) asymmetric loading, (4) biaxial loading, (5) load rate studies, (6) active loading determination, and (7) static loading evaluations. For longwall shields, a four-series test program that accurately simulates in-service conditions on a longwall face is proposed. This test program consists of (1) transfer of horizontal load to the caving shield-lemniscate assembly (zero-friction test), (2) point loading of shield joints due to lateral movement or rotation of the canopy, (3) evaluation of leg socket and leg cylinder integrity, and (4) face-to-waste racking of the shield. In addition, an evaluation of the shield's hydraulic components will be conducted prior to the performance testing. These protocols will provide state-of-the-art safety performance evaluations of emerging support technologies, as well as a means to assess the safety of both new and aging longwall shields. Hence, this effort will enhance the safety of mine workers by ensuring that critical support elements are properly designed and that aging supports are retired before their support capability is jeopardized.

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[1] Research physicist, Pittsburgh Research Laboratory, National Institute for Occupational Safety and Health, Pittsburgh, PA.

INTRODUCTION

Ground control is one of the most fundamental aspects of underground mining. Roof support systems are needed to stabilize exposed mine openings and prevent collapse of the mine roof. Without these critical support structures, the safety of the miners would continuously be in jeopardy. Therefore, it is essential that roof support systems be properly designed so that they can provide adequate ground control in all circumstances.

The National Institute for Occupational Safety and Health (NIOSH) is available to conduct safety performance testing of emerging roof support technologies as they are developed to assist manufacturers in meeting basic safety standards before the supports are ever used in an underground coal mine. These tests are also designed to ensure that the support is a viable roof support system. Hence, in addition to evaluating basic safety criteria, the safety performance tests are designed to determine the limitations of the support system by evaluating the support performance to failure under various loading conditions, so that performance characteristics can be matched to ground behavior in a particular mine in which the support system is installed. These tests are conducted at the Safety Structures Testing Laboratory in the unique Mine Roof Simulator load frame and simulate actual in-service conditions in a mine. The tests are conducted through cooperative agreements established with the various support manufacturers.

In the past 7 years, over 1,000 tests have been conducted on various secondary roof support systems. As a result of this effort,18 new support systems have been successfully adopted by the mining industry, making a significant impact on longwall tailgate support as alternatives to conventional wood and concrete cribbing. These include the following supports developed by Strata Products USA: Hercules crib, Link-N-Lock crib, Link-N-X crib, Propsetter support, Power Wedge, Rock Prop, and Star Prop. Heintzmann Corp. developed the Alternative Crib Support (ACS), the 55-Ton Prop, Quick Timber, and the Pumpable Crib. Burrell Mining Products conducted tests on The Can support. Fosroc Corp. developed the Tekcrib and Tekprop supports. American Commercial, Inc., developed the Tri-Log crib. Ferrocraft, Inc., developed the Stretch Prop and other yieldable timber posts systems. Safety performance tests were conducted on the YIPPI Prop (Western Support Systems) and the Coal Post (Dywidag Systems International, Inc.).

In addition to the development of innovative alternatives to conventional wood and concrete cribbing, safety performance testing protocols have been developed for longwall shield supports. The unique loading capabilities provided by the Mine Roof Simulator are especially suited to testing shield supports. The caving mechanics of strata in longwall mining, and in-service loading conditions can be simulated much more realistically than is possible in a static load frame. Cyclic testing procedures have also been developed to evaluate the remaining life of aging longwall shields.

The purpose of this paper is to describe the support testing protocols developed for the unique loading capabilities of the Mine Roof Simulator load frame, protocols that will improve the safety of mine workers by helping design support systems properly and by evaluating aging supports so they are not used beyond their useful life span.

NIOSH SAFETY STRUCTURES TESTING LABORATORY

The Mine Roof Simulator is a servo-controlled hydraulic press custom built by MTS Systems Corp. to U.S. Bureau of Mines (USBM) specifications. It was designed specifically to test longwall shields, and is the only active load frame in the United States that can accommodate full-size shields.

A functional diagram of the load frame is shown in figure 1. The load frame has several distinctive characteristics. The size of the platens are 20 ft x 20 ft. The upper platen can be moved up or down and hydraulically clamped into a fixed position on the directional columns to establish a height for tests. With a maximum vertical opening between the upper and lower platen of 16 ft, the load frame can accommodate the largest shields currently in use. Load application is provided by controlled movement of the lower platen. The load frame is a biaxial frame, capable of applying both vertical and horizontal loads. Load actuators are equipped with special hydrostatic slip bearings to permit simultaneous load and travel. This allows vertical and horizontal loads to be applied simultaneously. The capability to provide controlled loading simultaneously in two orthogonal directions is unique at this scale.

Vertical load is applied by a set of four actuators, one on each corner of the lower platen. Loads of up to 3 million pounds can be applied in the vertical direction by upward movement of the lower platen. Each actuator is capable of applying the full 3 million pounds of force, so that the specimen can be placed anywhere on the platen surface and the full 3 million capacity can be provided. The vertical (upward) range of motion of the lower platen is 24 in.

Horizontal loading is applied by four actuators, with two actuators located on both the left and right side of the load frame just below floor level. These actuators act in pairs to provide horizontal displacement of the lower platen in either a positive or negative (x) direction. The horizontal range of motion of the lower platen is 16 in.

There is no programmable control of the lower platen in the lateral horizontal axis (y-direction). The load frame has a reactive capacity of 1.6 million pounds in this direction, but loads can not be applied laterally. The range of motion of the lower platen in this direction is ± 0.5 in.

The lower platen is controlled within six degrees of freedom through the unstressed reference frame. This frame provides feedback on platen displacements and rotations to the closed-loop control system. Pitch, yaw, and roll of the lower platen are controlled to keep the lower and upper platens parallel during load application.

A shock absorber actuator is positioned on the left and right sides of the lower platen. These shock absorbers will control displacement of the lower platen to less than 0.1 in in the event of a sudden failure of the support specimen. The shock absorber action absorbs energy stored in the load frame so that it is not unintentionally released to the test specimen.

Two hydraulic pumps provide up to 3,000 psi of pressure to the vertical and horizontal actuators during load application. The rate of movement of the lower platen is limited by the 140-gal/min capacity of the hydraulic pumps. The maximum platen velocity is 5 in/min, assuming simultaneous vertical and horizontal displacement.

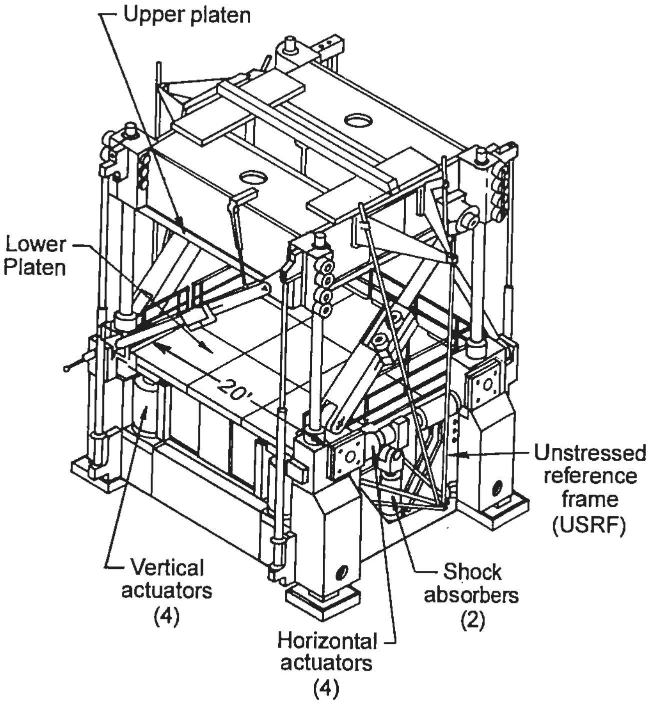

Figure 1.–Functional diagram of Mine Roof Simulator.

STANDING ROOF SUPPORT TESTING PROTOCOL

Standing roof supports are structures that are placed in a mine entry between the roof and the floor. Their performance can be described relative to three primary design factors: (1) strength, (2) stiffness, and (3) stability.

Strength – The strength of a roof support generally refers to its ultimate load capacity. Hence, all supports are tested to failure to determine the strength of the support.

Stiffness – Stiffness is a measure of how quickly a support develops its load-carrying capacity and determined by measuring support load capacity as a function of applied convergence.

Stability – Stability is a measure of how long a support can sustain its load-carrying capacity. The stability of a support structure is affected by several parameters. These include (1) aspect ratio of the support, (2) boundary conditions established with the load frame at the roof and floor contact, (3) direction of load application, (4) quality and properties of the specimen, and (5) rate of loading.

STANDARDIZED TESTS FOR STANDING SUPPORTS

TEST SERIES I - UNIFORM LOADING BASELINE TESTS

<u>Objective</u> – Establish baseline performance of a support under ideal loading conditions.

<u>Test Requirement</u> – Simulate roof-to-floor convergence by applying uniform loading to the support element. The response of the support structure is measured relative to its stiffness, strength, and stability.

<u>Test Procedure</u> – A representative support is placed in the Mine Roof Simulator with full roof and floor contact to establish uniform loading on the support. A controlled vertical displacement at a rate of 0.5 in/min is applied to the support system by the load frame to simulate convergence of the mine roof and floor. The applied load is measured as a function of vertical displacement to determine the stiffness of the support. Convergence continues until the support (1) becomes unstable, (2) sheds load to the point where the support provided is inadequate, or (3) until the full 24-in stroke of the load frame is

reached. Ultimate strength and complete performance profiles are determined by plotting support load versus applied displacement.

TEST SERIES II - IMPACT OF SUPPORT SIZE ON STABILITY AND CAPACITY

Objective – Determine the impact of the size of the support on its capacity and define proper support sizes that will ensure stability through a useful convergence.

Test Requirements – Vary support sizes and provide uniform loading through controlled roof-to-floor convergence. The capacity of the support as a function of the support area will be determined from this suite of tests. The stability of some support systems is largely governed by the aspect ratio or the height-to-width ratio of the support. When this is a design parameter, the support will be evaluated at several heights representing various aspect ratios to determine the limits of the support is stability. Standard heights are 4, 6, 8, 10, and 12 ft. Typically, the support is widened to maintain stability at higher operating heights. The goal of the test is to determine an acceptable aspect ratio range over which the support will maintain stability at all recommended operating heights. For example, tests on conventional wood crib supports have determined that the aspect ratio should be maintained between 2.5 and 5.0, with 4.3 considered an optimum for uniform load conditions.

Test Procedure – The test procedure is basically the same as in the first test series. A representative support is placed in the Mine Roof Simulator with full roof and floor contact to establish uniform load on the support. A controlled vertical displacement is applied to the support system to simulate convergence. Convergence continues until the support (1) becomes unstable, (2) sheds load to the point where the support provided is inadequate, or (3) until the full 24-in stroke of the load frame is reached. The ultimate strength and capability of the support needed to sustain load resistance while yielding will be determined by analysis of the load-displacement profile.

TEST SERIES III - ASYMMETRIC LOADING

Objective – Determine the impact of asymmetric loading on the stability and overall support capability of the support.

Test Requirements – Simulate asymmetric loading conditions that occur with uneven roof and floor contact or because of wedging the support in place. Figure 2 illustrates four asymmetric loading configurations that can be applied to standing roof supports. Figure 3 shows some examples of actual supports being subjected to these asymmetric loading conditions.

Another condition that creates asymmetric loading is floor heave. Floor heave is simulated by creating a foundation that rotates as support load is developed. This is accomplished by

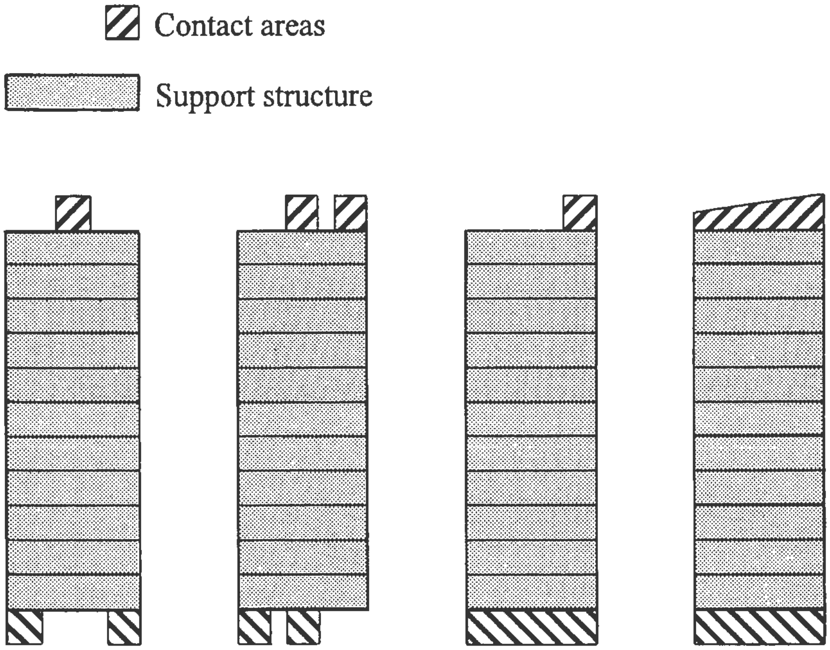

Figure 2.–Asymmetric loading configurations.

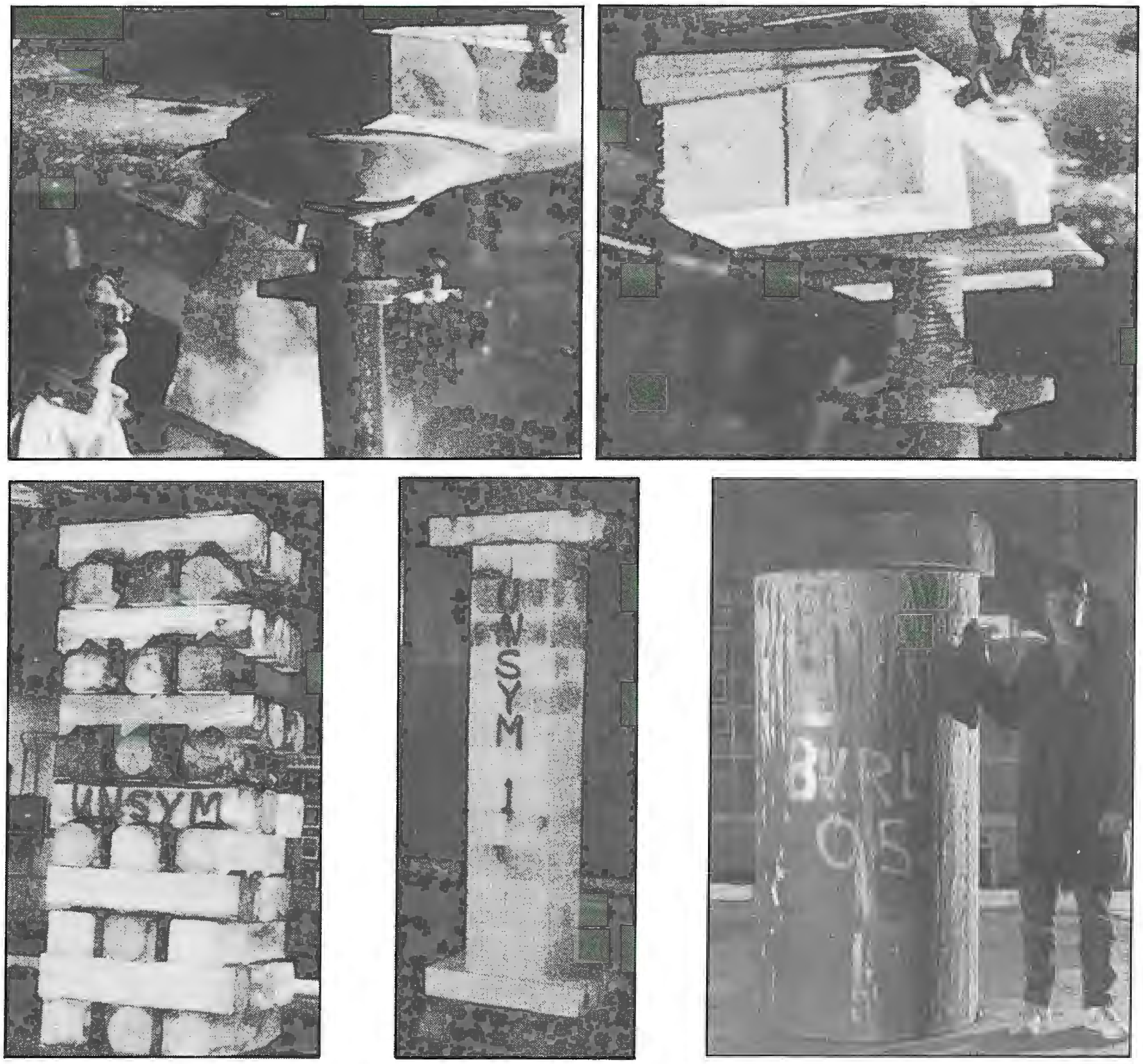

Figure 3.–Examples of asymmetric loading conditions.

placing the roof support structure on a rigid steel plate that is supported on one side by a soft (crushable) support and a stiff (rigid) support on the opposite side. Figure 4 illustrates this arrangement and an example of a test conducted in the Mine Roof Simulator.

Test Procedure – A support is placed in the load frame. A specific roof and floor contact is established in accordance with the diagrams shown above by strategically placing contact blocks at the roof and floor interface. A controlled vertical displacement is applied to the support. Convergence continues until the support (1) becomes unstable, (2) sheds load to the point where inadequate support is provided, or (3) until the full 24-in stroke of the load frame is reached. The ultimate strength and capability of the support to sustain load resistance while yielding will be determined by analysis of the load-displacement profile. Upon completion of this test, another support is installed and another contact configuration is established to evaluate a different asymmetric loading condition. The test procedure is then repeated for this and any other asymmetric loading configuration.

TEST SERIES IV - BIAXIAL LOADING

Objective – Determine the impact of horizontal loading on support capability.

Test Requirements – Simulate both vertical (roof-to-floor) convergence as well as lateral movements associated with bending or buckling of laminated roof or floor structures as a result of horizontal stress. This is accomplished by moving the floor of the load frame simultaneously in both vertical and horizontal directions creating a load vector in which the base of the support is moved laterally with respect to the top of the roof support at the same time the support is being squeezed by roof-to-floor convergence (see figure 5).

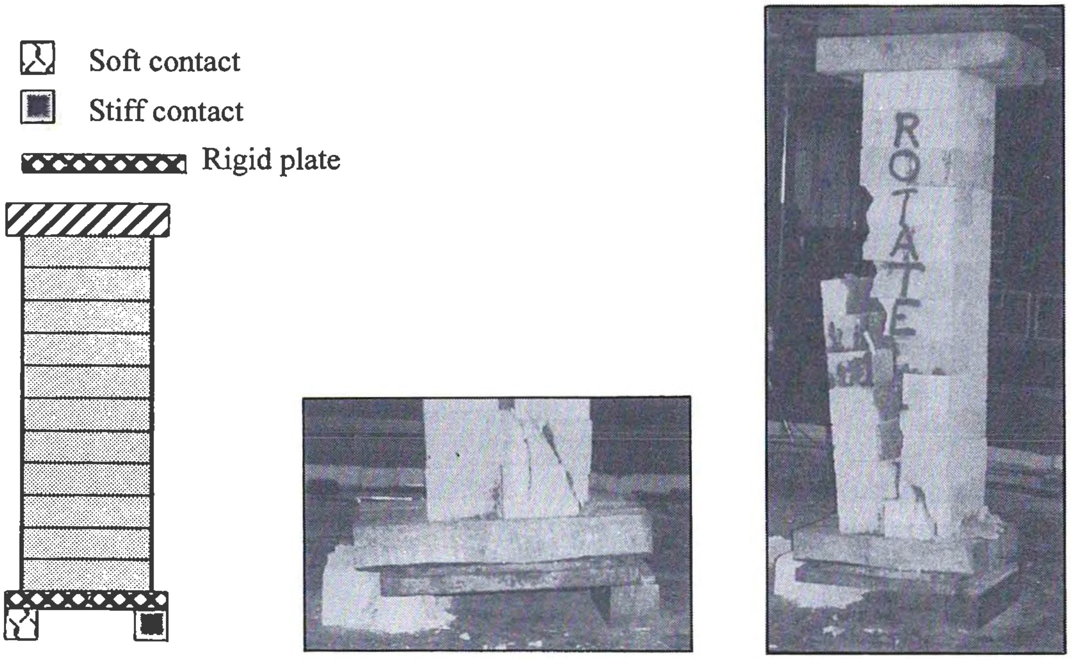

Figure 4 - Floor heave simulation and examples of support testing.

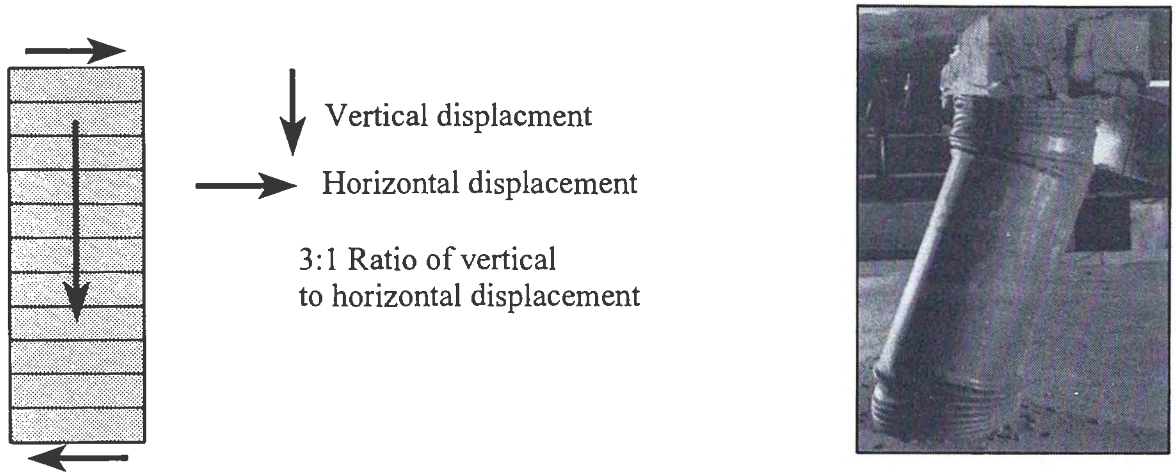

Figure 5.-Biaxial load conditions and example of support being subjected to biaxial loading.

Test Procedure – A support is placed in the load frame. Typically, full roof and floor contact is utilized for this test series. The Mine Roof Simulator is commanded to apply a ratio of vertical to horizontal displacement. The standard ratio (vertical to horizontal displacement) is 3:1, although the ratio can be varied if desired. The applied biaxial convergence continues until the support (1) becomes unstable, (2) sheds load to the point where inadequate support is provided, or (3) until the full 24-in vertical stroke of the load frame is reached. The ultimate strength and capability of the support to sustain load resistance while yielding will be determined by analysis of the load-displacement profile. If the support stability is sensitive to changes in the aspect ratio as determined in test series II, then support height will also be varied.

TEST SERIES V - LOAD RATE STUDIES

Objective – Some supports have a tendency to provide greater load resistance as the loading rate is increased. The objective of this test series is to determine the impact of loading rate on the support's behavior.

Test Requirements – Vary loading rate by controlling the applied roof-to-floor convergence. The Mine Roof Simulator can control the rate of roof-to-floor from 0.1 to 5.0 in/min.

Test Procedure – Baseline test data were established in test series I at the standard loading rate of 0.5 in/min. To establish a load rate profile, supports are tested to failure at least two additional rates. Typically, rates of 0.1 and 5.0 in/min are utilized. Support load as a function of convergence is then compared for the different loading rates, and the impact of loading rate on the stability of the support and the nature of the failure are documented. Figure 6 illustrates a concrete crib exploding during a high rate of loading.

TEST SERIES VI -ACTIVE LOADING DETERMINATION

Objective – Some roof supports are capable of providing an active roof load during installation of the support. The objective of this test series is to determine the active loading capability of those supports.

Test Requirements – Measure the active roof loading generated by a support during its installation.

Test Procedure – A load cell is placed on top of the support to obtain a more accurate measure of applied roof loading, particularly when the measured active roof loads are expected to be less than 20 kips. The load frame platens remain stationary during the test. An effort is also made to determine whether active loading remains constant or is shed over time once the support is installed. Hence, a plot of active roof loading as a function of time is made, and a decay rate is determined. The amount of time can depend on type of support, but the initial period is 30 min.

TEST SERIES VII - STATIC LOADING EVALUATIONS

Objective – Static loads are used to assess creep and relaxation in support material construction. The objective of this test series is to determine the creep and relaxation properties of a support.

Test Requirements – Creep is the continuation of deformation after a static load has been applied. To measure creep, a constant force must be applied to the support. Relaxation is the opposite of creep. Relaxation is the reduction in stress or load after an applied displacement. Hence, the test requirement to measure creep is maintaining constant displacement.

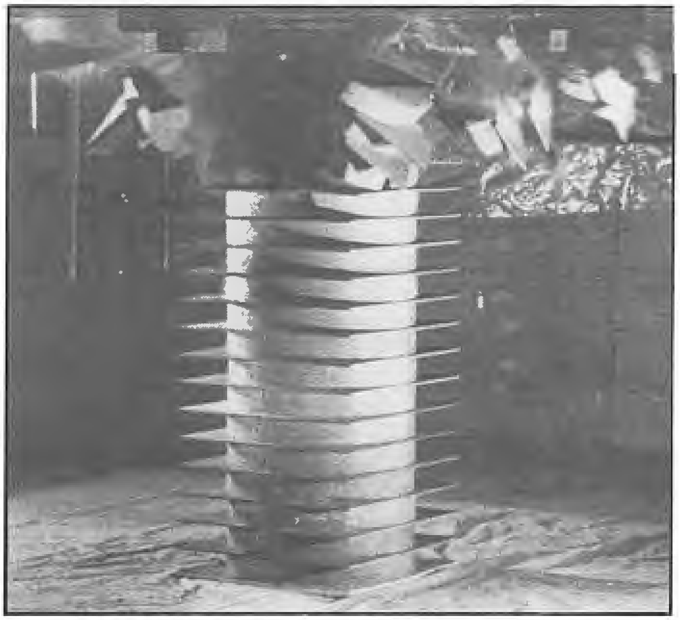

Figure 6.–Violent failure of concrete crib at 5 in/min applied convergence.

Test Procedure – For the creep study, a support is placed in the load frame. The load frame is operated in force-control, and a load is applied and held constant for an extended period. The change in displacement is then measured to determine the rate of creep.

For the relaxation study, the load frame is operated in displacement control, and the support is loaded through a designated convergence, that is held constant by the load frame. The change in support load is then measured as a function of time to determine the relaxation properties of the support.

NIOSH SAFETY PERFORMANCE TESTING PROTOCOL FOR LONGWALL SHIELDS

NIOSH also conducted shield performance tests in the Safety Structures Testing facility (figure 7). The Mine Roof Simulator can simulate in-service loading conditions on shields more accurately than static load frames. It is the only active load frame in the United States with sufficient size and load capacity to accommodate shield testing and allows realistic and cost-effective shield evaluations by combining both vertical and horizontal (racking) loads into a single load cycle.

The ultimate goal of the NIOSH shield testing program is to ensure the safety of mine workers by ensuring that new shields are adequately designed and that aging or damaged shields retain adequate structural integrity for continued use. This section describes the shield testing protocols, developed through extensive studies of shield mechanics and performance tests.

SIMULATION OF IN-MINE SERVICE CONDITIONS

There are two basic aspects to shield loading. The initial load condition is determined by actively setting the shield against the mine roof and floor. Subsequent loading is produced by the movement of the surrounding strata during the caving process and the associated internal forces developed within the support structure.

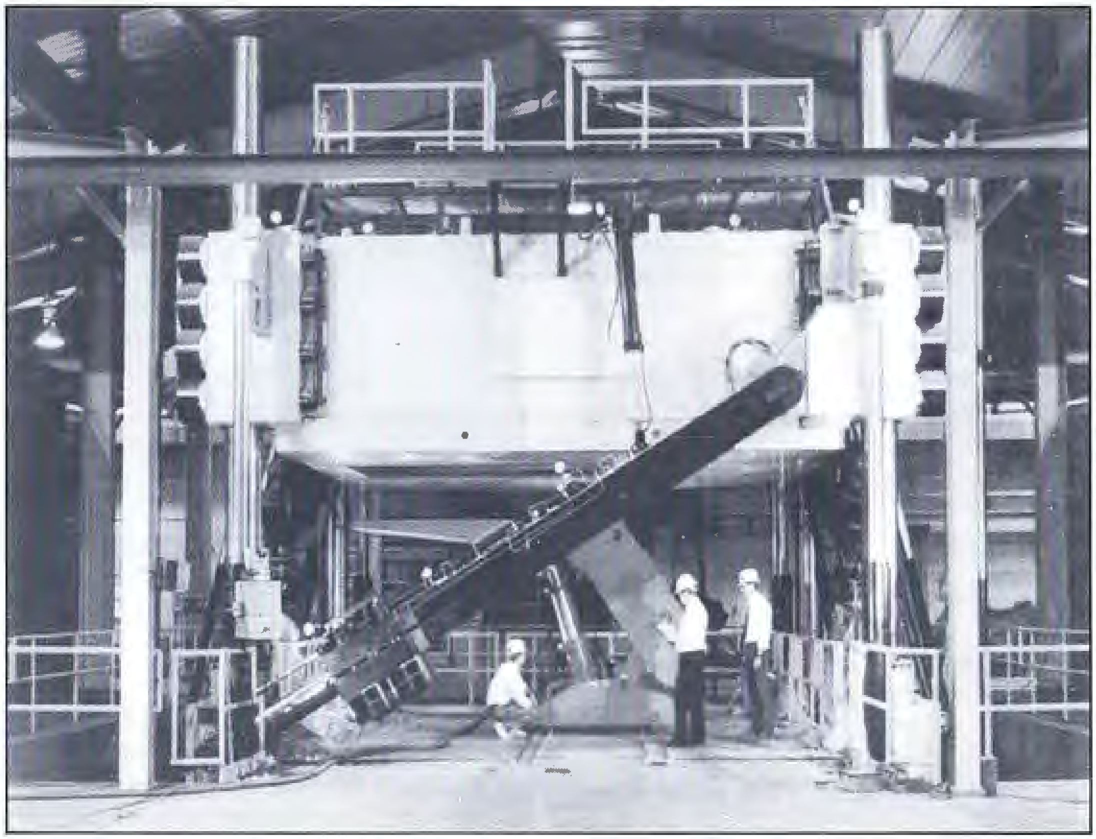

Figure 7.-NIOSH Mine Roof Simulator.

As the shield is set against the mine roof and floor, there is a tendency for the canopy to be displaced horizontally relative to the base (figure 8). This is due to the resultant horizontal component of the leg forces, which causes either slippage of the canopy along the roof interface or displacement (compaction) of fractured strata or debris immediately above or below the shield. The Mine Roof Simulator accurately simulates this behavior by allowing the floor of the load frame to move horizontally and transfer horizontal load from the horizontal component of the leg forces to the caving shield-lemniscate assembly. When a shield is tested against a rigid frame, the canopy and base are restrained from moving horizontally. This restraint eliminates load development in the caving shield-lemniscate assembly and therefore does not properly simulate in-mine service conditions.

Once the shield is set against the mine roof and floor, load development within the shield is controlled by—

(1) Contact configuration established with the mine roof and floor,

(2) Vertical displacement of the canopy relative to the base induced by deflection of the main roof beam and the weight of the fractured immediate roof strata being supported by the shield (figure 9),

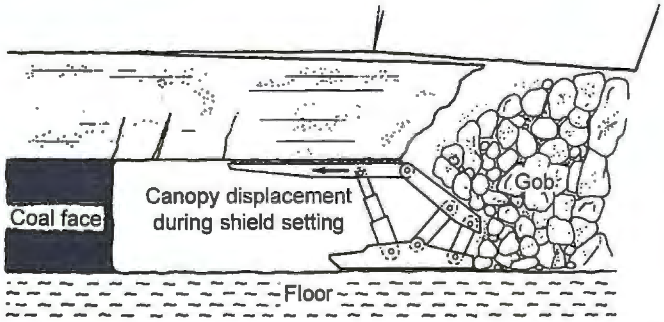

Figure 8.-Horizontal movement of canopy toward longwall face as the shield is set against the mine roof.

(3) Face-to-waste movement of the immediate roof as the strata break into disjointed blocks because of face abutment loading and loss of confinement (figure 10), and

(4) Waste-to-face loading induced by gob material acting on the caving shield and/or the internal forces developed within the shield resulting from leg forces and component reactions (figure 11) and lateral loading due to skewing of the canopy caused by setting against adjacent shields, inclination of the face, or rotation of the canopy due to uneven roof and/or floor conditions (figure 12).

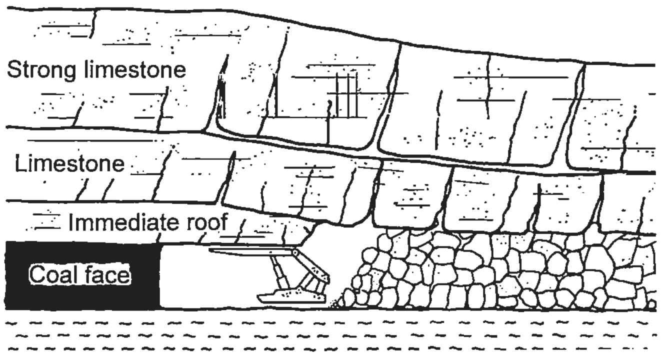

Figure 9.-Vertical shield loading induced by deflection of main roof and weight of damaged immediate roof.

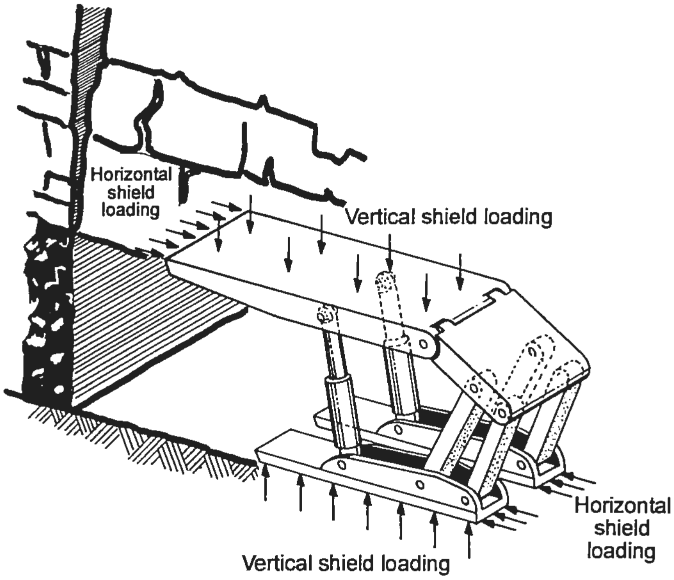

Figure 10.-Horizontal shield loading induced by face-to-waste movement of immediate roof.

NIOSH STANDARDIZED SHIELD TEST PROCEDURES

Standard tests consist of an evaluation of hydraulic components under static loading conditions followed by a series of cyclic tests to evaluate the structural integrity of the shield. For each test, the shield is positioned in the load frame in an orientation consistent with the objectives of the test. Prior to cyclic loading, the shield is actively set against the load frame platens by pressurization of the leg cylinders to some nominal load, typically 50 to 75 bar. Cyclic loading is provided by controlled displacement of the Mine Roof Simulator load frame floor against a stationary roof. Each load cycle consists of ramping the load, a hold, an unloading ramp, and a hold. A combination of vertical and horizontal displacements are applied, often simultaneously, to produce the required load conditions. The loading rate is dependent on the shield stiffness and capabilities of the load frame. Two load cycles per minute are a typical loading rate. The loading profile in each test series is designed to maximize total shield loading. Hence, load profiles are typically chosen that provide load equal to the yield load rating for the shield. Since the Mine Roof Simulator is an active load frame, there is no need to exceed the rated capacity of the shield to account for friction effects within the support structure. A minimum of 5,000 cycles for each test series is recommended, but this number may be varied depending on the customer's needs.

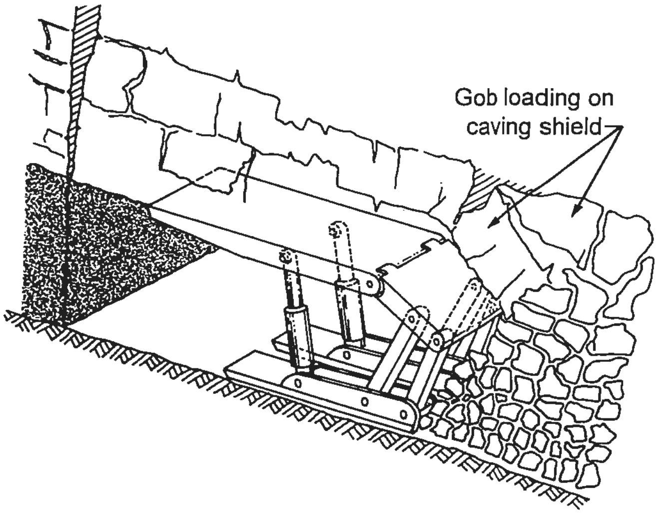

Figure 11.-Horizontal loading toward coal face induced by gob loading on caving shield.

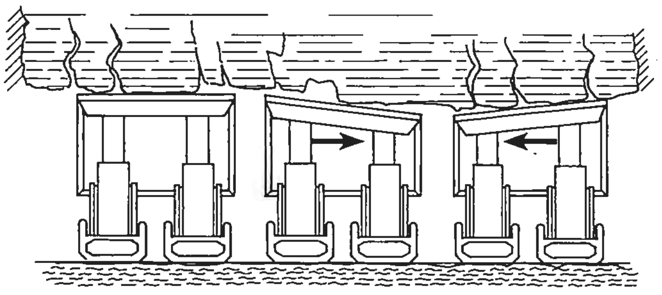

Figure 12.-Lateral loading induced by uneven roof contact.

HYDRAULIC COMPONENT EVALUATIONS

A series of tests are conducted to determine the performance and condition of the leg cylinders and shield hydraulics.

Yield setting – The shield is loaded until each yield valve on all leg cylinders opens. The recorded pressure and maximum shield rating for the designated operating height are determined.

Leakage Test –The leg cylinders are pressurized to some nominal load and held for 30 min. During the hold, the pressures are monitored. Leakages are evaluated to determine the source of the leakage.

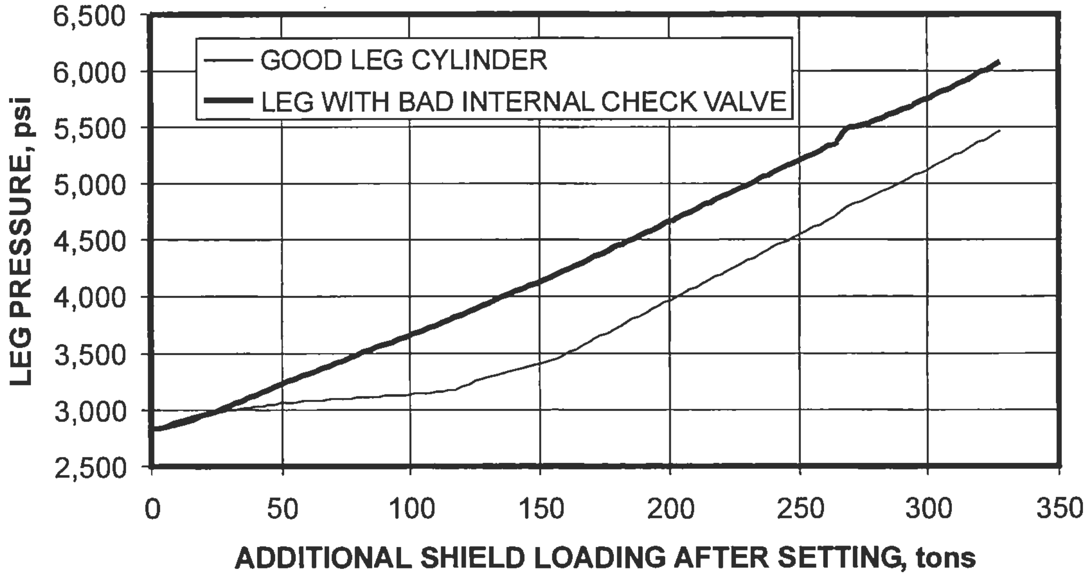

Figure 13.–Test to determine defective staging valve.

Staging Valve Test – The bottom stage on all leg cylinders is fully extended, and the shield is actively set against the load frame platens. Additional load is then applied to the shield while hydraulic pressure is monitored. If the staging valve is working properly, the pressure in the bottom stage should not increase until the force in the upper stage equals the setting force developed in the bottom stage (figure 13).

TEST SERIES I - TRANSFER OF HORIZONTAL LOAD TO THE CAVING SHIELD-LEMNISCATE ASSEMBLY

Objective – Minimize external horizontal load acting on the shield to ensure that horizontal components of the leg forces are transferred to the lemniscate links, thereby maximizing load development in the caving shield-lemniscate assembly.

Test Requirements – The canopy must be free to displace horizontally with respect to the base to allow the caving shield-lemniscate assembly to participate to a degree consistent with underground shield behavior. This is accomplished by commanding the floor of the load frame to move horizontally with respect to the roof in a direction and magnitude consistent with the resultant leg force. Main roof loading and deflection of the immediate roof beam are simulated by controlled vertical displacements. The applied displacement and associated shield response are shown in figures 14 and 15.

Canopy and Base Contacts – A four-point contact on the corners of the canopy is used to maximize bending produced by the increase in leg pressure. A three-point canopy contact where one of the rear contacts is removed can also be used to further intensify stress development in the canopy. Base contacts are located at the ends of each base section to maximize bending in the base.

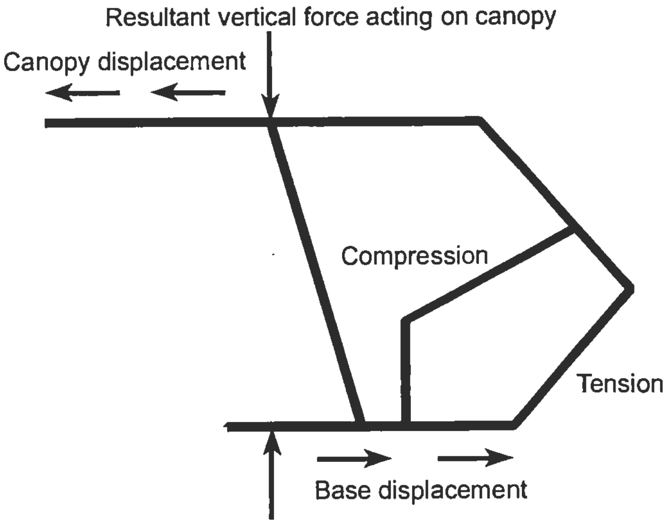

Figure 14.–Applied loading for test series I.

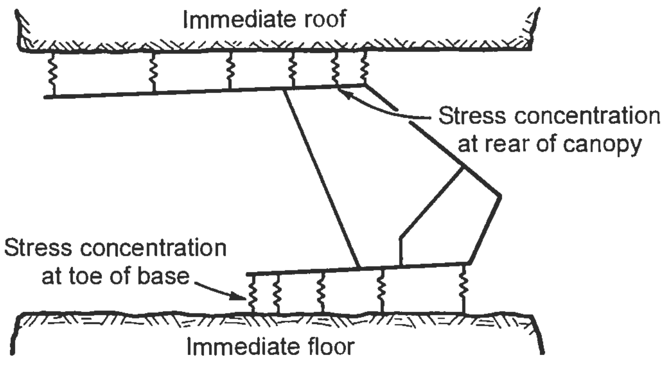

Figure 15.–Shield response to test series I loading.

Test Procedure

1. The shield is set against the load frame roof and floor at 50- to 75-bar leg pressure using an external hydraulic power supply.

2. The floor of the load frame is moved horizontally in a direction that eliminates the horizontal load applied by the load frame during the setting operation, which causes this horizontal load to be transferred to the shield components. The elimination of the external horizontal restraint moves the resultant force acting on the base forward, which intensifies toe loading, a critical load condition for two-leg shields.

3. Cyclic loading is initiated by a controlled vertical and horizontal movement of the lower platen of the load frame, inducing a combined vertical and waste-to-face displacement of the canopy relative to the base. The horizontal platen movement is calibrated to minimize horizontal load restraint provided by the load frame throughout the loading cycle. For two-leg shields, this requires the canopy to be displaced in a faceward direction at a rate that is proportional to the increasing horizontal component of the leg force developed from vertical closure. The result of these actions is that the caving shield-lemniscate assembly is fully loaded to provide internal equilibrium within the shield.

TEST SERIES II - POINT LOADING OF SHIELD JOINTS DUE TO LATERAL MOVEMENT OR ROTATION OF CANOPY

Objective – To maximize loading in the various shield joints and component clevises by causing point load conditions due to tilting of the lemniscate links caused by lateral movement of the canopy relative to the base.

Test Requirements – Joint wear is the most common problem causing premature shield retirement. The requirement for this test is to induce a resultant load vector that skews the canopy laterally with respect to the base (see figure 16). The shield joints have a single degree of rotation, much like a person's knee functions. Stress on the connecting pins is intensified when the canopy is skewed laterally, causing partial contact of the connecting pins within the clevis (figure 17).

Canopy and Base Contacts – A three-point canopy contact with one contact omitted from the rear canopy corner is used to further maximize twisting of the canopy and connecting joints (figure 18A). The outside base, away from the direction of the tilt is supported at the ends, while the inside base in the direction of the tilt has full contact (figure 18B).

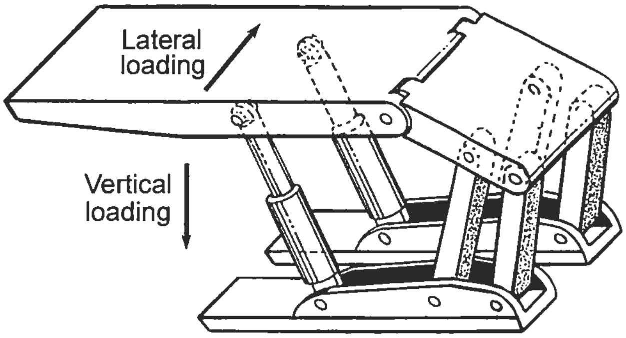

Figure 16.–Lateral loading caused tilting of leg cylinders and lemniscate links during test series II.

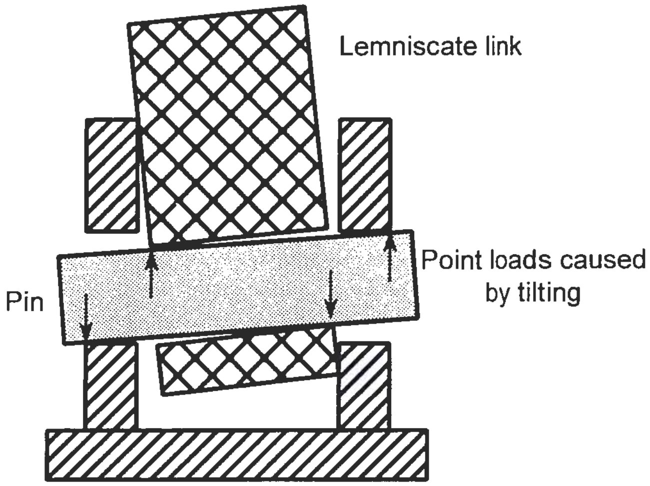

Figure 17.–Illustration of point loading in lemniscate link joints due to tilting of lemniscate link in test series II.

Test Procedure

1. The shield is positioned in the load frame so that the direction of applied horizontal displacement (loading) is across the canopy, as shown in figure 16.

2. The shield is set against the load frame roof and floor at 50 to 75 bar of leg pressure.

3. The canopy is displaced laterally with respect to the base, causing the leg cylinders and lemniscate links to tilt toward the direction of applied lateral loading.

4. Cyclic loading is initiated by the active load frame applying vertical displacement while maintaining the lateral displacement of the canopy with respect to the base. If necessary, the internal load can be increased during the vertical load application.

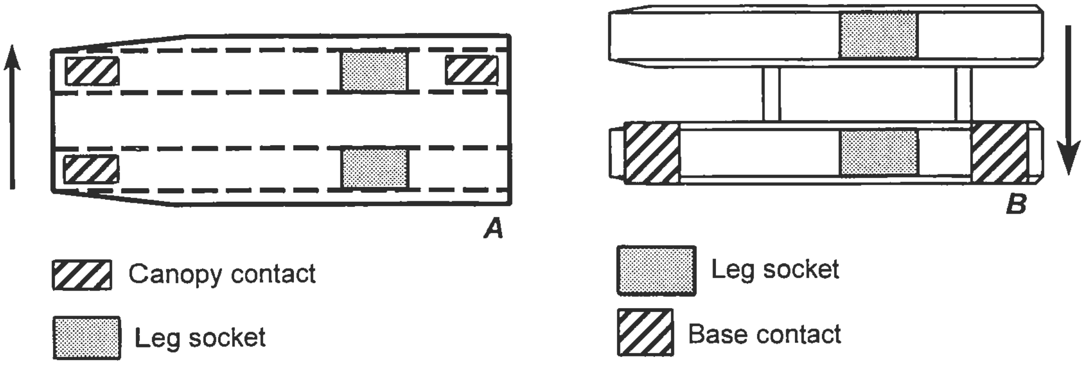

Figure 18.-Setup for test series II. A, Canopy contact; B, base contact.

TEST SERIES III - EVALUATION OF LEG SOCKET AND LEG CYLINDER INTEGRITY

Objective – Maximize stress development in the leg socket welds and expose the leg cylinder seal and piston to maximum side loading at full-stage extension.

Test Requirements – Failure of the leg sockets is a common shield problem. The leg socket is a casting that is welded along the top four sides to the side rib plates of the base and to horizontal stiffening plates in the base construction. The canopy construction is similar, except that unlike the base, the canopy is a single unit with additional stiffening plates built into the structure. The test requirement is to induce maximum loading into the welds.

Canopy and Base Contacts – For the base structure, plates are cut so that their width is approximately 50 mm less than the inside dimension of the side rib plates (figure 19A). This contact arrangement requires that the full load be supported by the bottom plate without being carried directly through the side rib plates. Therefore, the plates are designed to maximize stress development in the rib socket welds. The base contact plates are spaced 1 m apart during loading to simulate steps in the floor caused by shearer cuts. A centerline canopy contact is established as shown in figure 19B. The contact is positioned between the leg sockets to induce transverse bending of the canopy structure and focus loading on the leg socket welds.

Test Procedure

1. The shield is configured so that the upper stage of the leg cylinders are at full extension (figure 20). The transverse bending of the canopy with full extension of the upper leg cylinder staging will cause maximum side loading of the piston and seals.
2. The shield will be set against the load frame with 50 to 75 bar of leg pressure.
3. Cyclic loads are applied by controlled vertical displacement of the load frame platens. Horizontal positioning of the canopy and base will be restrained by the load frame during load application. The shield is cycled between the setting load and yield load.

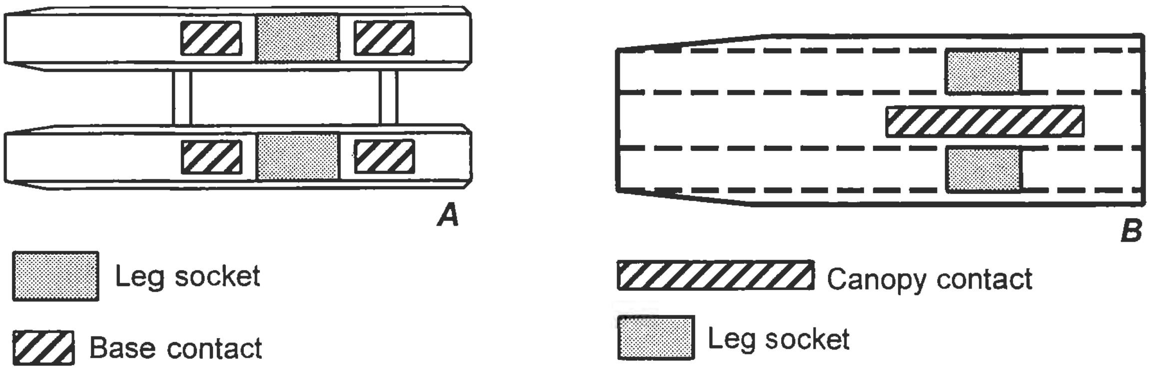

Figure 19.-Setup for test series III. A, Base contact B, canopy contact.

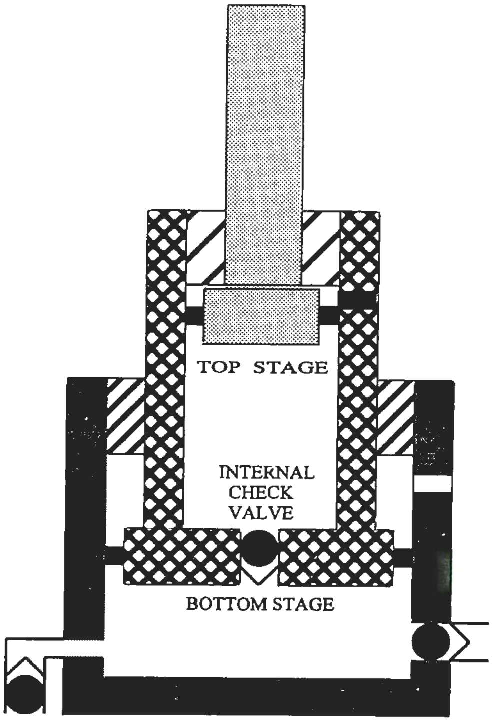

Figure 20.–Upper stage of leg cylinders is fully extended during test series III.

TEST SERIES IV - FACE-TO-WASTE RACKING OF SHIELD (OPTIONAL)

Objective – Simulate the effects of roof strata pushing toward the gob.

Test Requirements – Induce a load vector that produces face-to-waste racking of the canopy with respect to the base. The caving shield-lemniscate assembly is designed to alleviate bending moments on the hydraulic leg cylinders by absorbing all horizontal loads acting on the shield. This condition is unlikely to occur in two-leg shields except at high operating heights where the leg and lemniscate link orientation is closer to vertical. Hence, this test requirement is considered optional depending on shield design and kinematics of the shield.

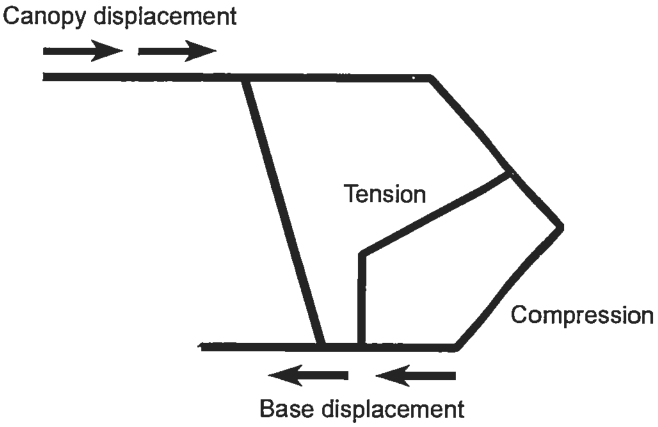

Figure 21.–Canopy is displaced toward the gob in test series IV to cause face-to-waste racking of shield.

Canopy and Base Contacts – Full canopy and base contact is utilized to facilitate frictional contact along the canopy and base.

Test Procedure

1. The shield is positioned in the load frame so that the direction of applied horizontal displacement of the canopy is toward the gob (figure 21).
2. The shield is set against the load frame roof and floor at approximately 50 to 75 bar of leg pressure.
3. Cyclic loading is initiated by the active load frame applying a combined face-to-waste and vertical displacement of the canopy relative to the base. Vertical displacement is applied to the degree necessary to sustain horizontal loading. Horizontal displacement is applied until the legs reach yield load. Since the horizontal displacement is in the opposite direction to that in test series I, the lemniscate link force is also opposite, with the front link acting in tension and the rear link acting in compression. This change in state of stress produces maximum wear and fatigue loading.

SHIELD INSTRUMENTATION AND DATA ACQUISITION

To monitor load development through each of the shield components, strain gages are installed at selected locations on the various shield components, as described below. The primary purpose of the strain gages is to monitor load transfer through each of the shield components. The gages are not necessarily installed in areas where stress concentration is greatest. Signal conditioning and data acquisition are provided by a data acquisition system. Typically, each sensor is sampled once a second to provide a reasonably complete load profile. Sampling rates up to 10 kHz are available if needed to assess failure developments. Both historical and real-time observations of the data are possible through the data acquisition system. The shield is inspected after every 1,000 load cycles for structural damage. A dye penetrant can be used to assess crack developments. The utilization of magnetic flux, x-ray, or ultrasonic technologies is beyond the scope of the standard test program and will require additional funds.

Canopy – Two to four gages are installed on the main vertical ribs of the canopy structure to assess bending strains. One gage is typically installed near the leg connection where the bending moment is the largest. The other gage is typically installed forward of the leg connection. Strain gages are generally installed on both the left and right side of the canopy.

Caving shield – A strain gage is installed near the canopy clevises and/or the lemniscate link clevis on the main load-transferring members of the caving shield.

Lemniscate links – One or two strain gages are installed on each of the lemnscate links to measure load development in the lemniscate links. Both axial and bending-induced strains are measured. Gages on both the top and bottom surface are used in link designs that promote bending of the link structure.

Base – A series of two or three strain gages are installed on the inside and outside ribs of each base fabrication to measure bending in the base sections. Gages are also applied to the bridge connecting the two base sections in split-base designs.

Leg Sockets – Gages are installed on the plate sections that support the leg socket in both the canopy and base.

Hydraulic – Pressure transducer is installed in each hydraulic cylinder to measure pressure development during loading.

Cycle count – The number of cycles is counted automatically by tracking leg pressure development.

DATA PRESENTATION

The applied loading and strain developments are monitored during each load cycle. A full profile of strain development during the loading cycle will be recorded at 100-cycle increments. Ten strain profiles collected during 1,000 loading cycles will be plotted on a single graph for comparison. Maximum and minimum strains will be recorded for each loading cycle. The maximum and minimum strain values will be plotted in groups of 5,000 loading cycles to examine trends over a sustained loading period. NIOSH reserves the right to modify this standard data presentation plan when extenuating circumstances dictate that other data presentations would be adequate or more appropriate.

SHIELD PERFORMANCE TESTING REPORT

A performance test report is provided as shown below. The report describes how the tests were conducted and the results of the tests. A failure assessment is made documenting time of the failure and the component(s) involved.

SHIELD SAFETY PERFORMANCE TESTING FINAL REPORT

1. Scope of Work
2. Testing Objectives and Simulation Methods
    - Objectives
    - Simulation of the In-Mine Service Conditions
    - Standardized Shield Tests and Exceptions
3. Shield Instrumentation and Data Acquisition
4. Test Results
    - Hydraulic Component Evaluation
    - Cyclic Tests
        - Test Series I
        - Test Series II
        - Test Series III
        - Test Series IV
4. Failure Assessment and Problem Report
5. Conclusions and Recommendations

CONCLUSIONS

The safety of mine workers depends heavily on roof support systems that prevent the unintentional collapse of ground in both working and access areas of the mine. Support manufacturers continually strive to develop new support technologies that provide more effective roof support at less cost and with less effort to install. It is imperative that these prototype support technologies be thoroughly evaluated to make sure that they meet required design criteria for use in various underground mine conditions.

The availability of the NIOSH Safety Structures Testing Laboratory with the unique Mine Roof Simulator load frame provides support manufacturers and mine operators with the most precise simulation of underground conditions to ensure the safety of their products prior to installing prototype systems. The safety performance testing protocols developed by NIOSH for application in this world-class facility are based on years of research into support design and testing requirements. As such, they are believed to provide the best possible evaluation of support technology.

In recent years, numerous roof support technologies have been successfully developed and evaluated at the NIOSH Safety Structures Testing Laboratory utilizing the protocols described in this paper. In the past 7 years, over 1,000 tests have been conducted on various secondary roof support systems. As a result of this effort,18 new support systems have been successfully introduced to the mining industry, making a significant impact on longwall tailgate support as alternatives to conventional wood and concrete cribbing.

The NIOSH Safety Structures Testing Laboratory provides an opportunity for coal operators andsupport manufacturers to have shields tested domestically. The Mine Roof Simulator is unique in its capabilities to apply active vertical and horizontal loads simultaneously, providing realistic simulations of underground load conditions. Since the Mine Roof Simulator more accurately simulates in-mine service conditions than static frames, testing at the Safety Structures Testing Laboratory reduces the risk of premature failures due to poor design. In addition to performance-testing new shields, the remaining life of aging shields can be determined with more confidence and can provide an engineering basis for shield retirement and new shield procurement.

In summary, the benefits of shield performance testing using the unique capabilities of the Safety Structures Testing Laboratory include—

- Unbiased assessment of support performance.
- A location in the United States that improves access to mine operators.
- Freedom of control over the test program.
- NIOSH knowledge of shield mechanics and design issues.
- Capability for active loading as opposed to static-frame testing.
- Controlled loading that simulates in-mine service conditions accurately.
- Participation in research programs to improve shield design and operation.

Further information concerning utilization of the Safety Structures Testing Laboratory can be obtained by contacting Tom Barczak at (412) 386-6557, by fax at (412)386-6891, or by email at thb0@CDC.gov.

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U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
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