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INTRODUCTION

Since 1947 mine roof support by means of roof bolts has been shown to be practical in coal mines both from the standpoint of safety and economy (1, 2, 5, 6, 8, 9). Most of the roof or rock bolts used are manufactured from steel, but in certain areas, particularly where corrosive water is a problem, wood pins are used.

The Rio Verde mine in western Kentucky, operated by the Norton Coal Company, has used wood pins (3). In this particular mine wooden pins resulted in greater safety and lower costs, when compared with conventional timbering. In various metal mines in the northwest, treated fir pins are used extensively, especially in faulted areas and in wet ground (7).

There is the possibility that in many other areas the use of wood pins would result in reduced costs and lead to the more profitable utilization of certain timber species, as well as to free for other uses at least part of the approximately 90,000 tons of steel now used annually for roof supports. It is therefore important that the value of wood pins as a means of mine roof support be determined and that the factors affecting the holding capacity of the pins be investigated so that the most suitable design can be developed.

It is believed that the critical factors involved in the holding ability of a mine pin are the tensile strength of the pin itself and the anchoring ability of the fastening device used. Although the strength properties of the wood of most native species have been determined (4), there is no information available on the relative efficiencies of different types of fastening devices. The object of this report is to describe a holding device and testing procedure for obtaining such data.

DEVELOPMENT OF HOLDING DEVICE

The holding device discussed here was designed to simulate a hole in the rock portion of a mine roof and to be applicable to laboratory use. It is recognized that the holding capacity values obtained with such a device will not necessarily be the same as they would be if the pins were pulled from an actual mine roof. However, standardization of the holding medium and testing procedure should provide results of sufficient comparative value to enable satisfactory evaluation of different types of fastenings and an analysis of factors affecting holding capacity.

The possibility of using blocks of natural rock, the material actually encountered in the roofs of coal mines, was considered. However, it was felt that this would be impractical because there is considerable variation in the properties of natural rock, and the high cost of getting blocks of the desired size quarried and drilled. It was decided that concrete be used as the holding medium and that the holes be cast rather than drilled. Experiments with different concrete mixes indicated that one part of Portland cement by weight to two parts of sand obtained from crushed sandstone, together with an amount of water equal to 15 per cent of the weight of the solid material, gave a concrete reasonably similar in texture to sandstone and with comparable compressive strength. The sieve analysis of the sand used was as follows:

Passing 3/8-inch sieve	– 100%
Passing No. 4 sieve	– 100%
Passing No. 8 sieve	– 99 - 100%
Passing No. 16 sieve	– 97 - 98%
Passing No. 50 sieve	– 5 - 10%
Passing No. 100 sieve	– 0 - 1%

The device as finally developed is shown in Figure 1. The form used to mold the concrete cylinder and encase it during testing is shown in Figure 2. It was made from a 14-inch length of steel pipe with an inside diameter of 8 inches and a wall thickness of 1/2 inch. The pipe was sawed lengthwise to form two equal sections. Steel flanges were welded 1/4 inch from the edge of each section. Complementary holes were drilled in the flanges of each section so that the sections could be bolted together with 1/2-inch bolts. Steel plate 1/4 inch thick, with a semi-circular piece removed, was welded to one end of each section so that when the two sections were bolted together, one end was closed except for a hole 2 1/2 inches in diameter in the center. In order to center the piece of pipe used to cast the hole in the concrete, a metal disc 2 1/2 inches in diameter was fitted in the hole. A small bolt protruded through the center of the metal disc about 1/2 inch. The pipe was filled with concrete and a hole placed in the concrete at one end to fit the protruding

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bolt. The other end of the pipe was centered by means of a piece of plywood with a hole drilled in the center equal in diameter to the outside diameter of the pipe. The piece of plywood was fitted over the end of the pipe and bolted to the form so that the longitudinal axes of the pipe and the form were parallel.

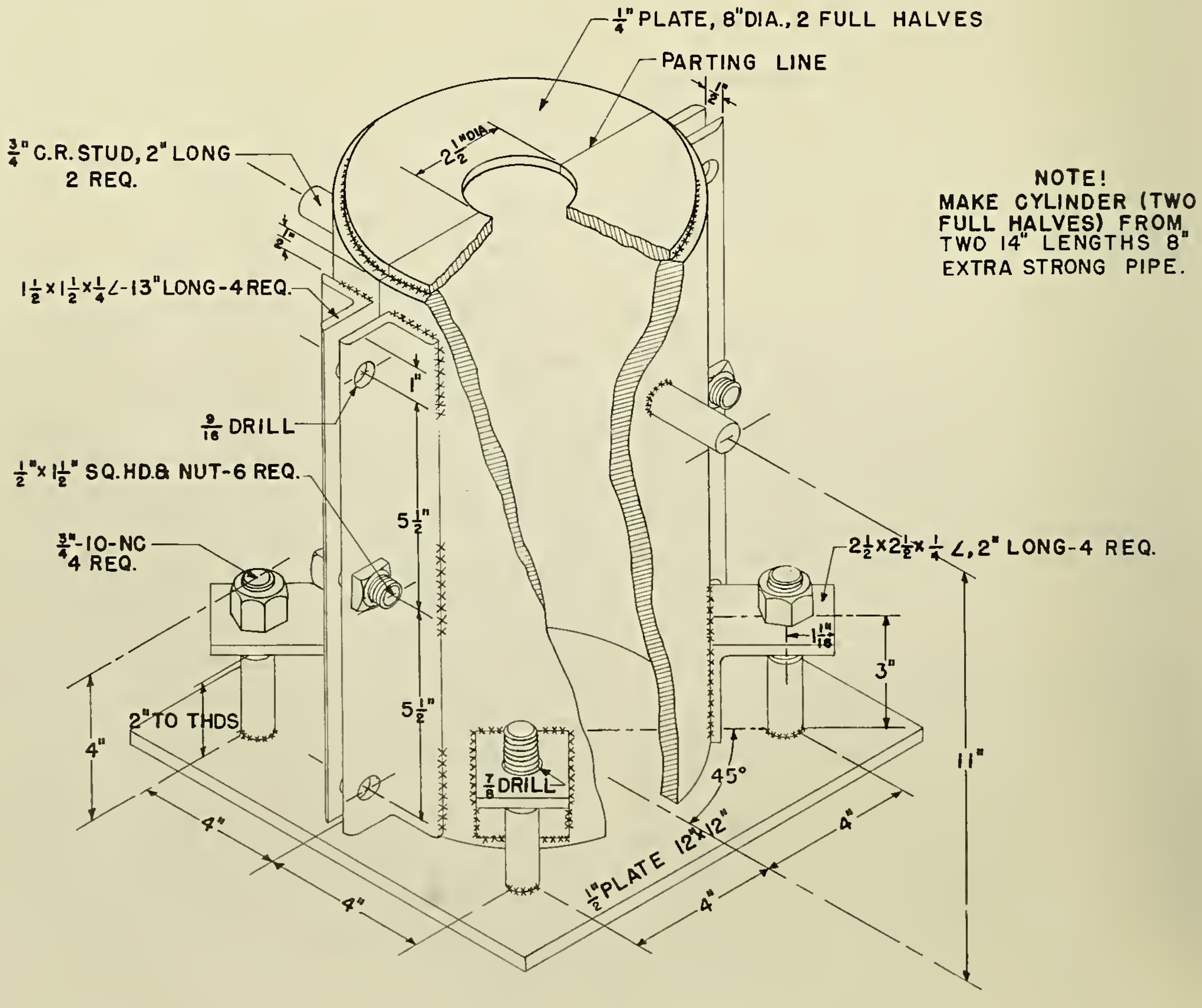
During pouring, the concrete was tamped to eliminate air bubbles. Four hours after prouring, the pipe was removed. After the form was removed, the concrete cylinder was submerged in water for 24 hours and then aged at least one week prior to use.

TESTING PROCEDURE

After placing the concrete cylinder in the form, a base plate consisting of a piece of 1/2-inch steel plate was attached to the open end of the form by means of bolts and flanges. The base plate served the same purpose as the upper end of the hole in an actual mine roof. Some attempts were made to eliminate the base

Figure 1. Holding device used in testing wood pins in tension.

Figure 2. Steel form used to encose concrete test cylinder.



plate, but this resulted in the holding device tending to "climb" the pin during driving. The device used for driving the pin consisted of a piece of pipe 24 inches long with an inside diameter of 2 1/4 inches. One end was capped and filled with lead so that the total assembly weighed 17 pounds. After the end of the pin containing the holding device was started in the hole, the pipe was slipped over the other end. Two men pounded simultaneously until ten successive blows failed to increase penetration more than 1/16 inch or until the end of the pin reached the base plate.

Figure 3 shows the assembly in the universal type testing machine which was used to apply the tensile load. It should be noted that the holding device is attached to the underside of the lower head so that it does not drop when the pin is removed. The same procedure could be used with other universal testing machines. The upper end of the pin is held in Vee wedge grips like those used in conducting tension tests of metal rods. It was found that the slippage in grips of this type was negligible up to loads of around 20,000 pounds when hickory pins were tested. The load is applied by the lower head which moves downward at a constant speed, thus removing the pin from the hole in the concrete.

Displacement of the pin in the hole was measured by means of a bracket attached to the pin about 12 inches from the top of the holding device and an adjustable dial gauge assembly as shown in Figure 4. An initial load of 700 pounds was applied at which time the gauge was set at zero. Readings were then taken to the nearest 0.001 inch at a load of 1,000 pounds, and for additional load increments of 500 pounds until the maximum load was reached. The machine head speed was 0.167 inch per minute until the maximum load was reached, after which it was increased for more rapid removal.

The use of the holding device and testing procedure discussed above requires control of a number of factors if uniformity and comparability of results are to be obtained. Manufacturers of wood dowels of the sizes required for mine pins ordinarily turn them to a specified diameter in the green condition. If it is desired to test pins of a definite diameter at a moisture content such that shrinkage will have occurred, the amount of expected shrinkage must be estimated so that the proper green dimension can be specified. The effect of moisture content on both strength and dimension of wood is critical and its value will undoubtedly influence the holding capacity of wood pins. However, at this stage it seems advisable to standardize the moisture content since the principle use of the tests will probably be for comparing relative efficiencies of pins and fastening devices of different design.

Figure 3. Assembly for determining holding capacity of pin.

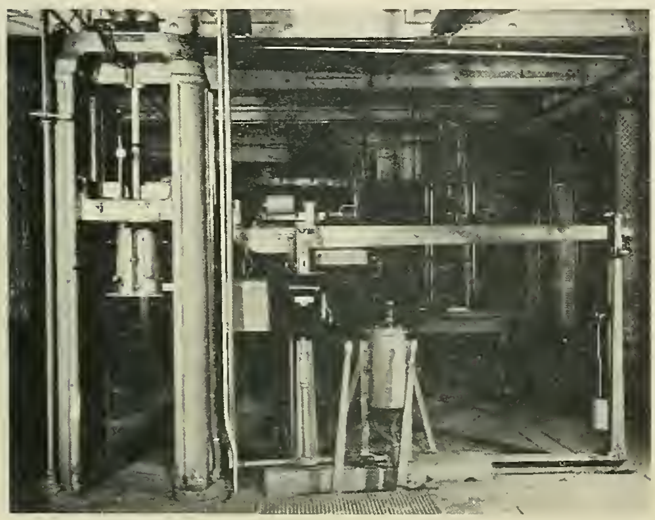
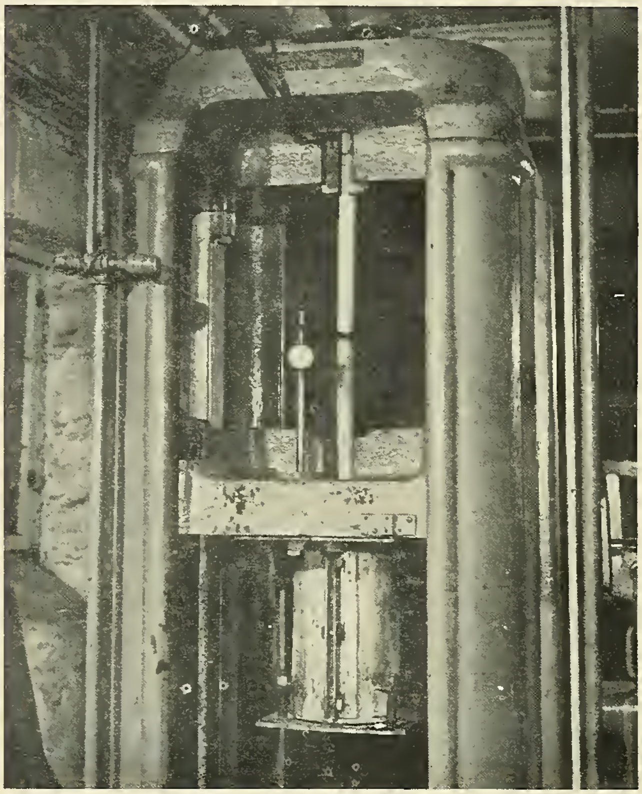


Figure 4. Apparatus used to determine displacement of wood pin in holding device during testing.



It is recommended that, particularly where the results of tests are to be used for comparative purposes, uniformity in density be maintained as closely as possible. Within any species there exists a relatively small range in the strength of wood of like density.

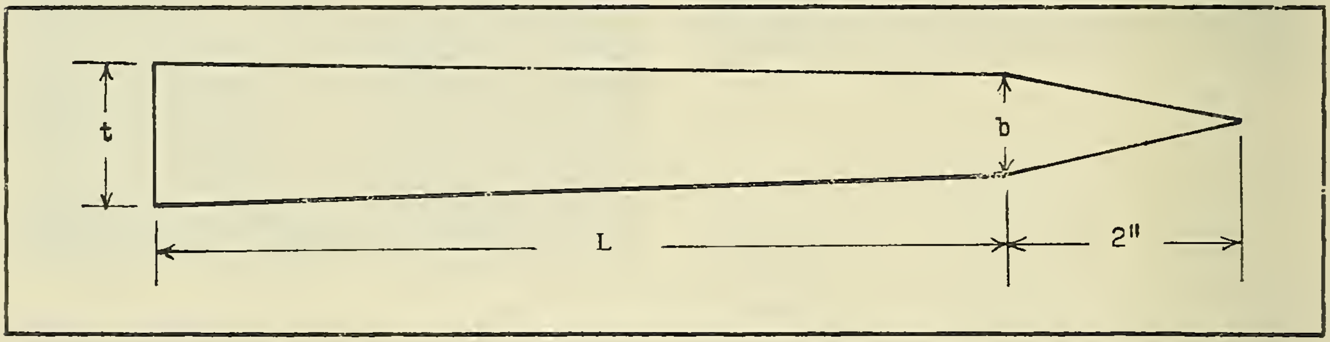
The testing procedure discussed above has been used to test several hundred hickory pins with slot and wedge type fastening devices. Results to date indicate that the variation in holding capacity values obtained for a given pin size and fastening device is no greater than would be expected from standard tests of strength properties of clear wood. The use of a single test cylinder for as many as five tests does not appear to affect the results significantly.

SUMMARY OF TESTS

At the present time the holding device and testing procedure described are being used to investigate factors affecting the holding capacity of hickory pins using slot and wedge type fastening devices. Although a number of types of fastening devices have been advocated for use with wood pins, the slot and wedge seems to be the most common and the most easily manufactured. Hickory was selected for several reasons — mainly because of its high strength and because there is a considerable quantity of the species available which apparently has little utility for other uses.

The pins used in the experiment are turned on a dowel machine in the green condition and dried to a moisture content of about 12 per cent prior to testing.

The wedges used conform to the sketch shown below, the slope of such a wedge being $\frac{t-b}{2(L)}$:



The slots, which are 3/16 inch wide, are sawed perpendicular to the growth rings to a depth of 3 inches more than the length of the wedges used.

The primary objectives of the experiment are:

1. To determine the relationship between pin, wedge, and hole size, displacement and holding capacity.

2. To investigate the relationship between pin diameter and holding capacity using the wedge determined most suitable in the first objective.

3. To investigate the effect of preservative treatment on holding capacity.

4. To determine the holding capacity of lower fastenings using a slot and wedge with and without a bearing plate.

To date, data has been collected on all objectives. Although the results have not been completely analyzed, the following information may be of interest.

In objective 1 tests were made using pins with diameters of 1 5/8 inches in holes with diameters of 1 3/4 inches and 1 7/8 inches. The wedges used were made of soft maple. The (t) dimension was varied from 3/8 inch to 5/8 inch, the difference between (t) and (b) being 1/16 inch in each case. Slope was varied by using wedge lengths of 6, 8, and 10 inches. The use of the hole with a diameter of 1 7/8 inches was discontinued because it was found impossible to insert the wedges without splitting the pins. For holes with diameters of 1 3/4 inches the average holding capacity values increased from 4,000 pounds, using a wedge with a (t) dimension of 3/8 inch, to 8,000 pounds when the (t) dimension was 1/2 inch. Wedges with (t) dimensions in excess of 1/2 inch were considered unsatisfactory since their use resulted in considerable damage to the wood during driving. The effect of wedge thickness on holding capacity appears to be highly significant, the allowable thickness being between rather clearly defined limits.

Increasing the length of the wedges appeared to have little effect on holding capacity. The use of 8- and 10-inch wedges resulted in about the same penetration as with the 6-inch wedges, the result being that a considerable portion of the longer wedges was not utilized. The maximum average holding capacity value of 8,200 pounds was obtained using wedges 6 inches long with a (t) dimension of 1/2 inch. The average displacement for this load was 0.130 inch.

Further tests were made in which the (b) dimension was held constant at 5/16 inch (an amount calculated to allow 1/16 inch compression) and the (t) dimension was varied from 3/8 inch to 1/2 inch. As in the previous tests, the holding capacity values increased with increases in the (t) dimension; however, holding capacity values for a given length and (t) dimension were somewhat less. The increases in holding capacity were the result of increases in thickness and slope. However, statistical analysis indicates that the effect of thickness is the more significant.

In the second objective, pins with diameters of 1 3/8 inches, 1 1/2 inches, and 1 5/8 inches were used. Hole diameters were 1/8 inch greater than pin diameters and hickory wedges were used. It was found that higher holding capacity values could be obtained with hickory wedges by reducing the (t) and (b) dimensions found most suitable with maple wedges. This was due to the fact that the hickory did not compress as easily, and the larger wedges could not be driven satisfactorily. The (t) and (b) dimensions found most suitable were 7/16 inch and 3/8 inch, respectively. Holding capacity values ranged from 8,800 pounds for pins with diameters of 1 3/8 inches to 9,400 pounds for pins with diameters of 1 5/8 inches. While the differences were not statistically significant, they were approximately proportional to differences in contact area as would be expected.

Initial tests of pins and wedges pressure treated with approximately 15 pounds of creosote per cubic foot indicate that holding capacity values comparable to those obtained with untreated pins can be obtained. With pins having a diameter of 1 5/8 inches and wedges 6 inches long with (t) and (b) dimensions of 1/2 inch and 7/16 inch, respectively, an average holding capacity value of 11,100 pounds was obtained with an average displacement of 0.078 inch.

While the results of the tests discussed above have not been analyzed to the point where definite conclusions can be made, it appears that the holding capacity of wood pins with the conventional slot and wedge type fastening device is considerably lower than can be obtained from steel bolts. Tests indicate that steel bolts installed in mines frequently require loads of from 15 to 20 tons to cause failure (8).

To date it has been impossible to obtain loads which approximate the tensile strength of the wood except in cases where a tapered hole was used. Preliminary tests using the slot and wedge in a tapered hole indicate total loads of approximately 20,000 pounds can be developed, although the displacement occurring at such loads is excessive. Further tests using the tapered hole are planned.

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