A POSSIBLE ALTERNATIVE TO HARDWOOD CHOCK PIECES.

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ABSTRACT
The development of a softwood alternative to the hardwood chockpiece used to build the waste-edge breakers commonly incorporated in gateroad packs is described. The results of laboratory tests on softwood prototypes and two underground trials are presented. The results of the last trial suggest that a viable alternative chockpiece has been designed, offering advantages over availability of wood, weight and given reduced wood content, price.

INTRODUCTION
In a competitive economical climate, attention has been focused on mining costs. Provision of packing for gateroads protection can be a significant part of total mining costs, eg, for coal realising £42 per tonne the cost of packing materials for two gateroads can amount to £2 per tonne.

Hardwood chocks are a traditional pack component (1). There have been several attempts to produce an alternative to the hardwood chockpiece. Two currently in use are internally reinforced aerated concrete and coarse concrete and coarse concrete made with furnace bottom ash (2). The former product creates an excellent yielding support but is significantly more expensive than hardwood, while the latter is difficult to handle and must be built in a solid configuration to develop reasonable crushing strength.

Accordingly effort was directed to the development of a cheaper alternative to the hardwood chockpiece, with the following points in mind:

(i) Economic supplies of home grown softwood are more assured than supplies of hardwood.
(ii) The crushing strength of wood loaded along the grain is much greater than that of wood loaded across the grain as in a conventional chock.
(iii) Until a chock has undergone about 45% compaction, it is only the intersecting corners which carry load.
(iv) A fire proof glue with the NCB Non-Metallic Materials Approval was available, enabling laminated wooded constructions to be used underground.

PERMANENT SUPPORT REQUIREMENTS
The primary function of the permanent system is to control and possibly limit the amount of spuma movement, or convergence, around the gateroad, the convergence being a direct result of the extraction process.

The permanent support system usually combines steel arches in the gateroad itself with one or a number of the following components installed immediately adjacent to the gateroad on the waste and possible rib sides:

(i) Hand or mechanically stowed rock debris packs.
(ii) Monolithic packs created by the placing of cementitious slurries between shutters or into bags.
(iii) Hand built chock or crib-type constructions made from wooden or aerated concrete members.

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Whatever combination of components are used in the construction of the permanent support system, the authors believe that immediate provision of an efficient waste-edge breaker is important for the following reasons:-

(i) To offer early support to the face end area and provide protection from falling debris in the waste area while permanent support system construction proceeds.

(ii) To create a “clean” transition or break between the fully developed caving in the waste area behind the face line and the zone of controlled roof strata convergence over the gateroad and permanent support system.

(iii) In creating such a waste-edge break, the high seal formed also eliminates air which might encourage the migration of gas from the waste into the gateroad and/or spontaneous combustion.

In order to satisfy the above points, the waste-edge breaker should be relatively stiff, rapidly developing resistance to convergence, and also be of solid construction or collapse after promoting caving, so eliminating air space.

Hardwood chocks are commonly used as waste-edge breakers while in seams liable to spontaneous combustion, aerated concrete alternatives may be utilised. The aerated concrete alternative to wood exhibits the ideal load bearing characteristic, being initially stiff and subsequently yielding at a designed load to eliminate air space. The typical ultimate bearing capacity of 40 tonnes for two-per-layer chock is, however, low for waste breaker applications in strong roof conditions.

The hardwood chock is less stiff initially than aerated concrete but after yielding to give approximately 4% compaction, stiffens dramatically as the horizontal flaps of the cross members come into contact. The high ultimate load bearing capacity of the woodchock, the comparative ease with which it is handled and the relatively high cost of the aerated concrete alternates, has meant that hardwood chocks are still by far the most common type of waste-edge breaker used in British mining.

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**COMPARISON OF HARDWOOD AND SOFTWOOD PROPERTIES**

**COST AND AVAILABILITY**

It might be thought that softwood has a price advantage over hardwood but in practice there is some cross-over (1987 prices):

- Hardwood - £70 to £90 per m³
- Softwood - £60 to £80 per m³

The benchmark prices for the most commonly used timber do however show a more direct savings:

- Home Grown Scots Pine - £70 per m³
- Home Grown Oak - £75 - £77 per m³

The price of hardwood has, as with most timbers, been stagnant for some time. The most significant point however is not so much direct cost differences on present day terms but rather future availability. Lewis (2) directed considerable effort into finding a substitute for chock timber because of problems with supply. As the demand for prime agricultural land increases with demands for food swelling from a rapidly growing world population so land available to grow hardwood will become scarcer.

Softwoods on the other hand are very successfully harvested from land of low fertility. hardwoods require prime land to be harvested successfully in large quantities.

**DENSITY**

The heavier and more bulky the chock piece, the more awkward it is to man-handle and the more labour intensive the provision of the support at the face end.

Mine hardwood has a density of 690 kg/m³, while softwood has a density of 430 kg/m³ (Peng (3)). From an underground utilisation point of view, softwood is therefore preferable to hardwood.

**LOAD BEARING CHARACTERISTICS**

Conventional chocks are built with timber grain oriented horizontally, hardwood being stronger than softwood as shown in Figure 1. Chocks built with two pieces of timber per layer have four immediate load-bearing contacts per layer. Similarly, three pieces of timber per layer produces nine immediate load-bearing contacts. Hence the designation “4pt” and “9pt”. In these cases the timber is loaded across the grain. When timber is loaded parallel to the grain however, its strength is...
Figure 1. Comparison of hardwood and softwood chock properties.

increased, typically by a factor of 5 to 10 times. In the extreme case this factor may increase to as much as 40.
Thus softwood load parallel to the grain can develop resistances equivalent to hardwood, with a stiffness which is also greater. Loaded parallel to the grain, timber usually displays little yield, failing completely at between 15 and 20% strain. This means that although a structure utilizing vertical grain shows very good early stiffness and load bearing properties, post failure resistance is likely to be minimal.

DEVELOPMENT OF A SOFTWOOD ALTERNATIVE TO HARDWOOD BREAKER-EDGE CHOCKS

PHASE 1

INTRODUCTION

Bearing in mind the potential cost savings, the availability and easier handling of softwood, it was decided to attempt to exploit the enhanced load bearing characteristics of wood loaded parallel to the grain, in the development of softwood alternative to the hardwood chock piece. It is the end pieces of a two-per-layer chock which are in contact and therefore develop load during the early and most critical part of the installation life.

The development exploited the availability of a fire-resistant wood glue, allowing the construction of laminated chock pieces, and proceeded from tests of individual load-bearing end-block tests to full scale chock tests.

BLOCK TESTS

The initial stages of testing involved establishing the exact properties of various designs of softwood blocks which would eventually form the load-bearing ends of the chock-piece. The blocks tested were as follows:-

(i) Softwood - a two layer block test loaded parallel to the grain
(ii) a two layer block test loaded perpendicular to the grain
(iii) a two-piece laminated two layer block test loaded perpendicular to the grain
(iv) a two layer block test with multiple laminations loaded perpendicular to the grain.

(ii) Hardwood - a two layer block test loaded perpendicular to the grain, used for comparison.
(iii) Stratabloc - a two layer block test of the popular aerated concrete chock material, again for comparison.

While the tests were carried out on the block configuration to give a guide to properties of the full scale structure, it subsequently became clear that the end effects induced by the steel platens of the testing machine were too great in this type of test to give a clear indication of full scale properties.

The most significant conclusion reached from these tests was that although using multiple laminations gave better post-yield properties, only the blocks loaded perpendicular to the grain had an initial stiffness and scale of failure load comparable to hardwood and aerated concrete.

FULL SCALE TESTS

Testing proceeded to full scale chocks, the initial chock pieces having stabilising strips or “coverboards” laid horizontally across the main loading surface as shown in Figure 2. To meet the requirements of the testing machine available within the University, the chock pieces had an overall length of 600 mm. Results of the compression test showed that there was a very soft early stage when the coverboards, loaded perpendicular to the grain, were compressed. In addition the chocks failed catastrophically showing very little stability at the point of
failure. Two modifications were incorporated in the coverboards of the chock pieces in subsequent full scale tests in an attempt to improve stability, i.e., an "overlap" at the coverboard ends to aid "locking-up" and "hinge" between the blocks to aid stability whilst the chock underwent eccentric deformation.

These modifications were not successful however, and consequently the major results coming from these tests was the re-positioning of the stabilising straps or coverboards, these finally being attached to the sides of the load bearing blocks as shown in Figure 3. This redesign eliminated much of the early soft phase and gave much improved stability, being more able to cope with eccentric loads. The load/compaction curves for the

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UNDERGROUND TRIAL NO. 1

The first site which became available for testing underground was that of Welbeck Colliery in the then North Nottinghamshire Area in October 1984. The face "863" in the East section of the mine was in the latter stages of its life. Extraction was hindered by faults and the face was used primarily as a back-up face.

The block pieces were installed as a direct replacement for the previously used hardwood waste-edge breaker in the tailgate. The blocks were 1.85 m high and 1 m square with the top layer loaded across-grain to modify the stiffness of the block. This allowed for the properties of the immediate strata viz. a strong floor but soft roof. The trial ran for a period of 6.5 months, but due to a combination of the effects of very bad face conditions, and to some degree the effects of an industrial dispute, the face moved on only 35 m. A run of some 24 m of Modblocks were installed with pack closure being monitored in the centre of the run. Unfortunately it became necessary to close the face in late March of 1985 because of heating.

CONCLUSIONS FROM THE WELBECK TRIAL

Ideally it was felt the capacity of the Modblock unit a longer trial run would have been necessary. However, a good deal was learned from the trial, the main points being as follows:

(i) While the Modblock generated a good cave line and subsequent disintegration within 10m of the face, thus preventing the formation of air channels at the waste-side of the pack, the disintegration appeared to be too rapid in relation to face position.

(ii) Some losses in Modblocks occurred during transport, due to coverboards being broken or parted from the end blocks.

(iii) While a 1 m long Modblock offers the optimum saving over an equivalent length of hardwood, a 1 m long chockpiece was difficult to accommodate between the handset bars of the tailgate face end.

(iv) Notwithstanding (i) and (ii) above, the replacement of the hardwood chock by the Modblock had no discernible effect on roadway closure. Increased closure localised near the instrumentation site was attributed to the combination of an inferior pack and the effects of water from the drilling of a methane drainage hole.

(v) The ease with which the Modblocks could be transported into the construction site was appreciated. Actual building had however to be done with greater care than used with conventional hardwood chock.

DEVELOPMENT PHASE 2
INTRODUCTION OF STEEL BANDING

BANDING TECHNIQUE

In an attempt to extend the load-bearing range of the Modbloc, mechanical bands were introduced around the coverboards, tests being conducted on a number of different configurations. The technique involved the fastening of a number of bands of binder strapping, of type used in packaging, around the loading blocks, thus preventing the coverboards from falling away on the failure of the glue line, and restraining the block itself.

In this configuration a 900 mm long Modblock with 150 mm rise contains 0.0083 m³ of softwood and weighs 3.4 kg, compared to 14 kg for a 900 mm long, 150 mm square conventional hardwood chockpiece with volume 0.02025 m³.

FULL SCALE TESTING

The testing of the Phase 2 design began with a nylon banded version of the Modblock used in the Welbeck trial. This proved to be quite successful but was rejected since there would naturally be some degree of concern over the use of an inflammable material such as nylon underground.

The next test utilised a single steel band and also gave enhanced load bearing characteristics. At the same time however, the National Coal Board had stipulated that home grown timber be used. Changing from foreign timber reduced the load bearing capacity of the chock but had little effect on the stability and post-yield properties.

The next step in the development was to incorporate two steel straps around the end blocks as shown in Figure 6, to see if stability could be further improved. The results can be seen in Figure 7. The resulting yield characteristic is much more controlled producing greater stability and much less violent release of yield. Post failure properties are much the same although
Figure 6. Design of steel-banded modblock.

Figure 7. Effect of loading chock with one layer “cross-grain”.

The graph would indicate a reduced final supported load.

To meet the demands of the first trial site at Comrie, in the Scottish Area, a chock was tested with one layer loaded across-grain. The effect may also be seen in Figure 7. The gradient of the curve is lower in its initial stages, but load is built-up steadily to the same level as previously. Good controlled failure and post-failure properties were recorded. In January 1985 a Breyer test was successfully completed and permission then sought for an underground trial.

UNDERGROUND TRIAL NO. 2

The site chosen for a trial was that of the C08 maingate of the panel at Comrie, in Fife, located within the National Coal Board’s Scottish Area. The Modblock was substituted for the hardwood in the waste-edge breakers of the permanent support system as shown in Figure 8. The trial ran in July 1985, and an observation site was installed in the middle of the proposed run of some 65 m. The extracted height was 1.3 m and the choocks were constructed 7 layers high, 6 loaded normally and 1 loaded across the grain to increase prefracture yield. The observation site comprised three roof to floor convergence monitoring strata, one test to monitor loads in the dirt pack, and a pack dynamometer installed in one column of the Modblock chock to monitor loads within it.

RESULTS OF UNDERGROUND TRIAL NO. 2

Figure 9 shows the development of closure between roof and floor as the face advanced away from the instrumentation site. In Figure 10 the same closure measurements are drawn as a vertical section, illustrating the “sliding” action of the roof, which is now thought to be characteristic of closure behind a longwall coalface. Also shown in the figure are the results obtained from a previous instrumentation site installed when a double row of hardwood choocks were used as waste breakers.

Comparison of the two sets of results suggest that the tilting action at the Modblock site occurs more rapidly, especially over the waste-edge of the pack, and then slows down to a comparable rate. Thus after approximately 50 m of face advance the Modblock site had undergone marginally greater (25 mm) compaction than the earlier hardwood site.

The results obtained for pressure development under the pack and one corner of the Modblock waste breaker are shown in Figure 11. These results reflect the relative stiffnesses of the components, the flaxjack under the stone built pack recording a slow, steady pressure development as compaction proceeded, the pack dynamometer under the much stiffer Modblock chock showing a rapid rise followed by failure.

A comparison of laboratory determined and in-situ load/deformation characteristics was produced from spot-readings and hence a higher peak may have been missed. However, the results were reasonably similar.

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Figure 8. Pack design and installation for Conmie C08 Mainage.

A comparison of roadway closure at the two sites, as measured by movement of the legs of the steel arch supports into the yielding stilts, showed that approximately 40 mm less closure had been recorded at the Modbloc site. At both sites roadway closure was minimal and the difference may not be significant.

A photograph of the waste-breaking action of the Modbloc chocks is shown in Figure 12.

CONCLUSIONS AND RECOMMENDATIONS
FROM TRIAL NO. 2

Conclusions

From visual observations, instrumentation results and discussions with management and workforce the following conclusions were made:

(i) Wastage of Modbloc due to storage on the surface and subsequent transport underground was negligible.
Figure 9. Strut closure v. face advance for Conrrie C08 Maingate installation.

Figure 10. Comparison of roof beam tiles for Sites 1 and 2 at Conrrie C08 Maingate installation.

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Figure 11. Pack pressure v. face advance for Conrie C08 Maingate installation.

Figure 12. View along waste-breaker edge showing caving.

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SMART, BROCK, THOMPSON & SOMERVILLE

(i) The workforce on the three shifts required an initial familiarisation period with the Modblock chock, to master installation and also to develop confidence in the load-bearing capabilities of the product.

(ii) After an initial introductory phase, (equivalent to about 15 m face advance) the caving pattern was effectively controlled by the Modblock chocks, which remained stable until reaching their maximum design load of at least 55 tonnes. The stiffness of the chock was matched by turning over the bottom layer of Modblocks, the design load being reached about 12 m behind the face.

(iii) Replacement of the double row of hardwood chocks with the Modblock chock as a waste-breaker appeared to have resulted in a period of increased convergence rate within the pack after failure of the chock 12 m behind the face, followed by stabilisation of the pack area.

(iv) Roadway closure at the Modblock site as recorded by stope closure was no greater and may even be less than that at the original site.

(v) If allowance is made for the frequency of readings taken underground, the in-situ load/deformation characteristics of the Modblock chock were similar to that determined in the laboratory.

(vi) The trial can be considered to have been successful, paving the way for continued use of the Modblock at Comrie and also further trials in more arduous conditions.

Recommendations

(i) Introduction of the Modblock for waste-breaker construction should proceed with a trial application in an extracted section nearer 2 m.

(ii) If the Modblock is to be developed to widen the scope beyond waste-breaker then the main priority is the design of a mechanism for introducing controlled yield without detracting from the stability of the chock.

GENERAL CONCLUSIONS
AND RECOMMENDATIONS

(i) The Modblocks applied at Comrie Colliery successfully supported the waste-edge of the face end and induced regular caving.

(ii) The replacement of 900 mm long by 150 mm square hardwood chock pieces with softwood Modblocks of the same length and height resulted in a weight saving of 10 kg per chock piece, improving handling and construction.

(iii) The load deformation characteristic of the Modblock can be controlled by adjusting the dimensions of the chock piece during manufacture and by selecting the number of layers of chock pieces, loaded with the grain horizontal during chock construction, up to a maximum of three layers.

(iv) The standard softwood Modblock is a potential replacement for hardwood waste-edge breakers in seams not liable to spontaneous combustion, with a fire proofed resin having the potential for application in all seams. This offers the advantages of availability of materials and, given reduced constructed volume, price.

(v) Further development of the Modblock should continue with the introduction of an extended yield chock design enabling more general application of the product.

REFERENCES


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