PACKING WITH INCOMBUSTIBLE MATERIAL IN COAL MINES.

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1. *Historical.*

The winning of underground coal seams is conducted by two main systems of working: (*a*) Bord and Pillar, and (*b*) Longwall.

The Bord and Pillar system has other names such as Room and Pillar, Stoop and Room, Pillar and Stall, etc.—all of which indicate the general idea of comparatively narrow drivages or galleries which block out the coal area into Pillars or Stoops which may be extracted subsequent to the driving of the galleries.

In the early days of English mining the pillars were left standing with a view to preventing accidents from falls of ground, economising in timber supports, and preventing surface subsidence, and under present-day conditions in the U.S.A., India and South Africa these considerations still apply, with resultant loss of the valuable coal pillars.

The Longwall system of working has now replaced the Bord and Pillar system in English and Continental mines; in this method of work the whole of the coal seam is worked by long faces, the strata above the seam being supported temporarily by props and permanently by packs. The roadways serving these long faces are formed out in the packed areas as the face advances, the roof or floor in these roadways being 'ripped' or excavated to give the necessary height and width for the working of tubs or conveyors and the passage of the ventilating air current.

The success of the Longwall system of working largely depends on the efficiency of the packing or stowing of the excavated areas. As the coal is extracted the immediate strata converge, tending to close the excavation; if this convergence of the roof and floor becomes excessive accidents from falls of ground frequently occur, the coal is worked with difficulty, roadways cannot be maintained and there is a danger of large bodies of inflammable gas being emitted and fouling the ventilation currents. Of such importance is 'Roof Control' or 'Strata Control' in Longwall mining that in 1929 the Safety in Mines Research Board appointed a highly qualified Chief Mining Engineer and a staff of coalfield engineers to study the problems of packing and strata control; the various reports issued by the Safety in Mines Research Board on the subject afford very valuable information to the mining engineer.

In India the subject of stowing has been prominent before the mining profession of recent years and the Coal Mining Committee in its report of 1937 dealt with many aspects of the problem.

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2. *Objects of Packing.*

It is generally agreed that efficient stowing of areas from which coal has been worked gives the following advantages:—

(1) The filling of the wastes or goaves prevents accumulations of inflammable gas and eliminates 'weights' and large collapses of roof which might expel large volumes of gas into the working areas with consequent increase in the risk of explosion.

(2) Spontaneous heating of coal or carbonaceous matter in goaves (gob fires) is eliminated.

(3) No pillars of coal need be left to support the surface and coal may be worked under the sea or riverbeds and under occupied areas or industrial works.

(4) The ventilation of the workings is improved.

(5) The maintenance of the strata in an unbroken condition reduces the risk of the miner being killed or injured by falls of ground.

(6) With intensive support intensive methods of working can be adopted, the number of roadways and haulages can be reduced, increased efficiency and economy result and supervision can be more effective due to the reduction in the area of workings to be inspected.

3. *Methods of Stowing.*

There are four main methods of packing: (*a*) Hand Packing, (*b*) Hydraulic Stowing, (*c*) Pneumatic Stowing, and (*d*) Mechanical Packing.

(*a*) *Hand Packing* may be done:—

(1) with imported materials alone;

(2) with materials obtained from rippings of dummy or main roads (brushings) or back rippings, with material obtained from controlled falls in the goaf, with materials rejected *in situ* whilst working the seam, with chocks or cogs;

(3) with a combination of materials obtained under (1) and (2).

System (1) is rarely practised in British or Continental mining as the seams are thin (generally below 6′ thick) and the roof or floor strata have to be ripped to make and maintain roadways of adequate dimensions. System (2) is the common practice, strip or partial packing being employed to give controlled convergence of roof and floor. In certain seams notably in S. Wales, material is imported to supplement materials obtained under system (2). In Germany, where the Mines Police at one time insisted on solid packing, there has been a notable change over to partial or strip packing.

Where the materials are weak, *i.e.*, where good stones for building the pack walls cannot be obtained, the pack walls are sometimes built of bags filled with small debris or the packs may be reinforced by wire mesh, or by wooden cogs.

Cost of Hand Packing.—With materials readily available close to the site of the pack being built, *i.e.*, within 6′ to 8′, a good workman (in England) can well pack 200 cu. ft. per 7-hour working shift. At a wage of 8 shillings per day this constitutes a charge of over 1*s*. per ton of coal won, if solid packing is done. If materials have to be imported the cost is increased by approximately 50%. With partial or strip packing, in which material is obtained from dummy road rippings or controlled goaf falls, the cost of packing varies according to the percentage area packed but generally in seams of moderate thickness with shale roofs is 9*d*. per ton; in exceptional cases, *i.e.*, a thin seam 3′ thick with strong sandstone roof with 4-yard gob packs and 16-yard wide gobs, the cost was from 4*d*. to 5*d*. for packing, excluding packs built by main road rippers.

The cost of solid packing by bags is excessive; a bag 32″ × 14″ wide, costing approximately 2*d*., gives when filled a builder 30″ long by 12″ wide by 6″ deep. The cost of bags alone approximates to 4 shillings per ton. In practice bags are used only as pack walls which confine hand-packed small debris and even then the cost of bags is high.

Limitations of Hand Packing.—In seams over 6′ high good hand packing is rarely practicable. In thick seams the cost of stowing increases rapidly for each foot of height over 6′.

Hand Packing in India.—Materials for packing are rarely available underground as rippings are not taken and the seams are fairly clean. The labour force underground is composed of men small in stature and in the main unaccustomed to shovelling. A rough estimate of the cost of hand packing in India, in a seam 12′ to 16′ thick, of which 25% has been taken in first workings, is 12 to 16 annas per ton plus capital charges and the underground labour force in a mine turning 1,000 tons per day would have to be augmented by from 750 to 1,000 extra underground workers.

In our present Indian mines the tramming grades would prove a great obstacle to taking materials for packing into working faces and it appears obvious that hand packing on a large scale in thick seams is impracticable in this country.

In thin seams 6′ thick or under, partial packing and controlled convergence may be accomplished by dummy road rippings or controlled goaf falls at a cost of 6 to 8 annas per ton of coal in virgin workings. Such seams are rarely worked, and the labour personnel is unsuited to such work as yet.

(*b*) *Pneumatic Stowage.*—Pneumatic stowage is a system whereby stowing material is conveyed through pipes by compressed air and delivered with some force to the place being packed. The material has to be graded and the length of pipes, and curves in them, limited.

In Great Britain the system was tried at a colliery near Manchester and was abandoned; and it is now in use at a colliery in Fifeshire.

In Germany various pneumatic stowage machines of the Torkret, Miag Konig and Biein types are being used, whilst at a colliery in Rumania experiments are being conducted in blowing material from the surface *via* pipes to the underground workings.

At a Ruhr Colliery visited by the writer a Biein machine was stowing 200 tons per day. Dirt up to 3″ mesh was taken in tubs in the upper level, tipped by a side tippler on to a short belt conveyor which delivered the material to the stowing machine. The material was fed through the machine into 6″ pipes, maximum length 300 yards, air pressure 55 lbs. per sq. inch, on to the face. With the special layout the number of men required per shift for stowing 200 tons maximum was 17. Compressed air consumption was heavy and cost of pipe renewals and bratticing likewise.

At a Scottish Colliery working a thick seam a pneumatic stowage installation is working and the following notes apply to it.

Wet sand was not delivered satisfactorily but dry sand proved suitable except that it was not jammed tight against the roof, and a considerable quantity of sand was blown on to the working face by the compressed air jet.

The maximum capacity was about 25 cu. yds. per hour and air consumption 2,500 cu. ft. per minute; some sparks were given off at the delivery end but it was stated these would not ignite gas. It is to be noted, however, that Audebest and Delmus in France must have had some grave doubts as to the danger from sparks from pneumatic stowing apparatus when they suggested that pneumatic stowage should be prohibited and 2 explosions, one in Lancashire and one in France, are attributed to such sparks. In gassy mines, therefore, the introduction of pneumatic stowage has to be viewed with suspicion.

Summary.—Pneumatic stowage does not appear suitable for general Indian mining conditions owing to:—

(*a*) High cost of compressed air.
(*b*) High initial outlay.
(*c*) Difficulties in adapting existing layouts for transport of material to site.
(*d*) In gassy seams the possibility of gas ignition by sparks.
(*e*) High cost per ton of material stowed.

In certain special cases it may be applicable, however.

(*c*) *Mechanical Stowing* is still in an experimental stage but at the Rheinpreusen Colliery, Ruhr Coalfield, turning out 3,000 tons per day, it has replaced hydraulic, pneumatic, and hand stowage.

In this system the material is delivered at the tail end of a face belt conveyor and is automatically dumped off the belt at any predetermined place on the face on to a high speed throwing belt which delivers the material to the goaf. Wet material can be handled up to 3″ cube in size. The machine can be electrically driven and has delivered 70 tons per hour. At Rheinpreusen Colliery the cost of stowing 100% solid with this system, including power, depreciation on machine (25% per annum), replacement of stowing belt (every

40 days or 16,000 tons), all underground labour for delivery material and stores was given as 0·4 marks per ton of coal (approximately 5 annas).

It appears the mechanical throwing belt has a future in this country in virgin areas where an intensive mining system can be laid out to suit it but it is not entirely suitable for collieries already laid out.

Hydraulic Stowage.—The objections to, and difficulties attendant on, hydraulic stowage in British and Continental mines are well understood and except in Silesia and the Myslowitz mine it has tended to be replaced by hand, pneumatic and mechanical stowing.

The main difficulties attending hydraulic stowage are:—

(1) The effects of water on weak floors and roofs; rapid floor heaving and deterioration of weak roofs rendered it unworkable in many cases.

(2) Difficulties in supplying suitable stowing material. Washed sand, which permits of ready drainage of clear water, is the ideal filler for this system.

(3) In thin seams, *i.e.*, under 4′ thick, with weak roofs, there is difficulty in packing close to the face, only small quantities can be packed per operation and there may be admixture of stowing material with the coal being wrought.

These difficulties are not of grave import in India. The roofs and floors of the seams are strong and are little affected by water; in many cases there are ample supplies of clean river sand which can be delivered fairly cheaply at the pit head; and in thick seams it is possible to flush continuously up to 4,000 tons of sand in one place.

The cost of hydraulically stowing sand underground consists principally of

(*a*) cost of supplying sand to the pit head,
(*b*) renewal of pipes,
(*c*) pumping stowage water from the workings to the surface,
(*d*) barricade material to hold the stowage in place,
(*e*) labour for attending to pipes, flusher, pumps, etc.

As may be judged from a consideration of the above factors the cost of hydraulic stowing will vary at each pit where it is practised. One of the most important items, however, is the cost of delivering sand to the pit head; and in those cases where sand or other material is not available on or near site the cost of transporting the stowing material may be heavy.

4. *Research Work on Packing.*

The programme of researches carried out by the Safety in Mines Research Board may briefly be classified as—

(*a*) The physical properties of coal measure strata.
(*b*) Laboratory experiments to determine the resistances developed by packs, cogs and bag supports.

(c) Underground investigations. The effects of depth, nature of material, thickness of seam, quality and extent of packing, rate of face advance, depth of undercut, line of face, width of working, the working of sub-jacent or super-jacent seams, inclination of seams, etc. Associated with researches on packing are the studies connected with the resistances developed by face supports, the causes of weights, strata movements ahead of and behind Longwall faces and the development of suitable convergence recorders and dynamometers to measure height reduction and the resistances developed by various types of supports.

The results of some of the investigations on hand packing are summarised below:—

(1) Packs built close to the face and rammed tight to the roof, with intermediate crosswalls and face walls, gave the best results.

(2) Packs should be built before cutting of the face is commenced.

(3) Even in very well-built packs built by hand the percentage of voids was from 35 to 40.

(4) The quality of the packing is all-important and well-built packs, though of limited dimensions, provided more efficient roof control than continuous poorly built packing, *i.e.*, well-built strip packs are preferable to poor quality solid stowing.

(5) The rate of convergence associated with well-built packs was less than ½″ per foot of face advance, whether the face advanced quickly or slowly. Roof conditions are better on a slowly advancing well-packed face than on a quickly advancing badly packed face but where the packing was of equal quality the quickly advancing faces gave better conditions than the slowly advancing faces.

(6) Packs built of hard slabby sandstones developed greater resistances in the early stages of compression than packs built of rounded stones or of softer materials.

(7) Cogs built of round timber and well filled with stone developed up to 6 times the resistance of an unfilled similar cog for the same extent of compression. An unfilled cog of round timber is of little value as a roof support.

(8) 'Weights', phenomena characterised by a large increase in the convergence/advance ratio and often accompanied by widespread collapses of roof and emissions of gas, were the results of poor quality packing; in certain cases where the quality of the packing was improved 'weights' were eliminated.

(9) 'Bumps' are often associated with a lateral movement of the roof or floor in advance of the face by which stress is relieved but the inward movement of roof and floor was small.

There is not sufficient space in a short article to describe all the results so far obtained but some of the main features established by researches on packing are given above.

5. *Difficulties associated with Stowing.*

At British and Continental mines stowing has been practised for several decades and systems of working have been evolved to obtain the full benefits for the expenses incurred in stowing. As an example a case may be cited of a seam 7′ thick being worked on the Longwall system by conveyors and coal cutters; a double unit Longwall face 240 yards long is advanced 5′ per day and 850 tons of coal are loaded in 6 hours at one loading point. The mechanisation of the coal winning operations, the high output per man, the concentrated work resulting in few roadways to be maintained and efficient supervision and a high degree of safety, combined with a low cost per ton, are dependent entirely on the efficient system of stowing, or roof control which is adopted. In this case, although the cost of stowing is a high proportion of the total cost per ton of coal won, the advantages gained more than outweigh the disadvantages.

In Indian mines many of which are now fully developed for pillar extraction the mines were laid out and development proceeded before the necessity for stowing was obvious; and in these mines the full benefits of stowing, apart from conservation of coal and increased safety, cannot be realised. In new mines it may be possible to plan the workings so that some of the expense of stowing may be recovered by reducing other costs.

As seams in India are generally thick, it is not practicable to rip the roof or the floor to provide stowing materials; hence material for packing will have to be derived from the surface. Some collieries at which sand or other material can be excavated and transported cheaply to the pit head can obtain their material for stowing much more cheaply than other collieries, where the transport of the material may be so costly as to render the cost of stowing prohibitive, unless some assistance is rendered.

The method of stowing adopted depends on the conditions associated with each mine; no hard and fast rule can be laid down as to the best system of stowing. For Indian conditions in general, however, the system of hydraulic stowage appears the most suitable but there may be conditions where hand, pneumatic or mechanical stowage might be more cheaply applied.

6. *Conclusion.*

Efficient packing, whether solid or partial, ensures the extraction of the maximum quantity of coal with the greatest degree of safety and accordingly is to be recommended. Many difficulties have to be overcome, and much pioneering work done, before the system can be applied generally to Indian conditions but recent legislation should greatly facilitate the extension of stowing systems.