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MODEL SIMULATION STUDY OF COAL MINING UNDER RIVER BEDS IN INDIA

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ABSTRACT

Over 80% coal reserve of Bihar coalfield and substantial portion of Ranigunj coalfield of India is within Damodar river basin. Mahanadi - brahmani basin is the coal resource of Orissa region. Total coal of Nagpur area is under the HFL of Kanhan river. The methods of mining thick seams under these water bodies and depth cover of 50 m to 500 m required planning such that thick strata band in between the subsiding mass and the floor of the water body remained free from tensile strain, cracks, bed separation or open joints. For these studies, the high flood level of rivers was taken as catastrophic danger in view of their perennial water resource.

With a view to evolving suitable mining geometry under Indian geo-mining conditions, an indirect technique - Equivalent Material Mine Modelling was used. The studies conducted under idealised laboratory condition covered the scope of mining 7 m thick seam under river Damodar at Sudamdih Incline mine, 2-4 m thick seam under Damodar at Chinakuri and Seetalpur mines, 3 m thick seam under HFL of river Brahmani at Deulbera, and 5 seams of 40 m total thickness under Kanhan river High Flood Level (HFL) at Kamptee colliery. The problem of mining different seams of Sudamdih, Chasnalla and Chapui Khas underneath subsurface water was also studied in models. Indian coal measure formation contained an average 60-80% medium grained calcareous/arenaceous brittle sandstone which developed open cracks when the strain exceeded 5 mm/m. It was, therefore, essential to devise mining methods/goaf treatment so that the surface subsidence and strain remained within the safe limit.

INTRODUCTION

Indian coal mining industry is sieged with flooding problems since last 50 years mainly because of accumulation of water in old abandoned or existing mines. The flooding disaster of Newton Chickli mine occurred in 1954 killing 62 persons while the toll of Chasnalla colliery crash of 1975 was 375. A similar accident followed at Hurrilladih, late in 1983, killing 19 persons. So far most of the accidental floodings occurred due to unknown position of abandoned or existing water bodies (Table 1) and that too when the workings reached within 4 m to the water bodies; within the same seam.

The flooding disaster of Chasnalla revealed the helplessness of the experts and inadequacy of the existing safety measures. This problem was under continuous observation for a period of 2 years before the crash, in addition, to boreholes in advance of development headings and laboratory model investigations. The back-analysis of Silewara mine and Hurrilladih mine disaster was also undertaken to identify the reason of the accidents.

Table 1 - Innundation Disaster in Indian Mines

Mine	Year	Source	Casualty
Underground accumulation of water			
1. Newton Chickli (M.P.)	1954	Old workings	62
2. Central Bhowrah (Jharia)	1958	Old workings	23
3. Damua mine (M.P.)	1960	Old workings	16
4. Karanpura mine (Bihar)	1970	Old workings	3
5. Silewara mine (Nagpur)	1975	Old workings	10
6. Chasnalla mine (Jharia)	1975	Old workings	375
7. Hurrilladih mine (Jharia)	1983	Old workings	19
Surface water bodies			
1. Buradhemo mine (Ranigunj)	1956	Rain water	28
2. Central Sounda mine (N. Karnapura)	1976	Rain water	10
3. Chasnalla 3/4 Incline (Jharia)	1976	Surface water	5

CHASNALLA DISASTER

The problem of Chasnalla water hazard was subjected to detailed underground and laboratory investigations on the basis of reported 68 m thick parting between the experimental panel LCE of the shaft mine and the deepest known developed waterlogged horizon L of inclined mine. The seam 20 m thick was worked by horizontal slicing in conjunction with stowing. Three slices were worked in ascending order, keeping the water seepage, seam sliding and movement of coal mass under continuous observation. Borehole extensometers were installed in the observation chimney along the fifth horizon with anchors 1.5, 3.0 and 4.5 m apart. At no stage en-masse active movement was noticed except local falls along the hanging wall and a stone dyke.

The model study revealed major roof fall after 4 slice workings in ascending order. A crack normal to bedding plane traversed the coal seam nearly up to 23 m height from the working horizon (Fig.1). It reached up to 25 m height under the influence of 70 m equivalent water head. The thickness of solid barrier in between the water body and the working slice was recommended to be 50 m with a safety factor of 2. As such it was decided to extract 18 m of the barrier coal in conjunction with stowing. The LCE panel of mine was under extraction on the basis of this finding with all possible precautions.

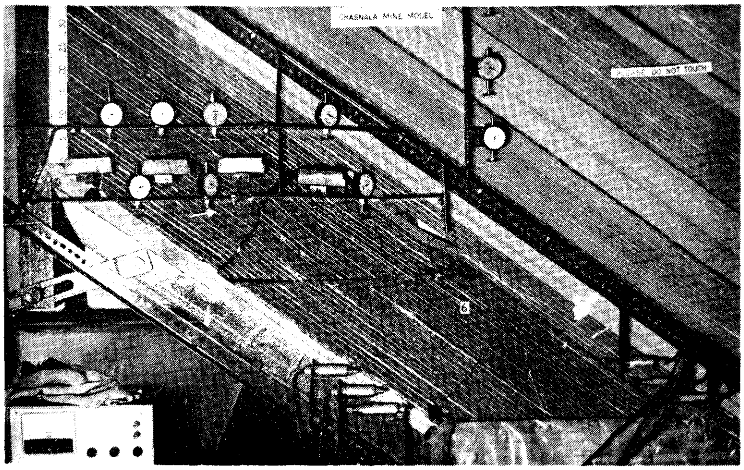

Fig.1. Strata movement due to horizontal slicing at Chasnalla

The crash occurred in unexpected western part of the mine during drivage of a connection between hanging wall and foot wall laterals. On the crash site, the extent of old development heading reached as close as 4 m which failed with a round of blasting to cause disaster.

The record of other accidents were not much different when many of the recent past developments were allowed to contain water and the subsequent developments reached as close as 1 metre. The thickness of rib in case of Silewara mine between the drainage gallery of longwall face and its lower development was only 0.60 m which failed to cause innundation of dip galleries. The mine workings were started past 10 years back, remained under the same management and only 6.5×10^6 l of water inrushed to kill 10 persons.

MINING UNDER SURFACE WATER

With the depletion of safe leasehold, the workings are being extended underneath HFL of rivers in all coalfields (Fig.2). Extraction of lower seams under river Damodar was done in Ranigunj coalfield in the past, mainly with stowing and subsequently efforts were made to cave lower or upper seams. Extensive coal reserve of North Karanpura, West Bokaro, Ramgarh and Jharia coalfields was sterilised under the same river Damodar, comparatively under shallow depth cover. Huge coal reserve of Maharashtra and Andhra Pradesh was locked under Pranhita, Godavari rivers and tributaries. Madhya Pradesh coalfields faced the water problem due to Hansdeo, Narmada rivers and tributaries. Brahmani river contained substantial portion of Orissa coal reserve under shallow depth cover.

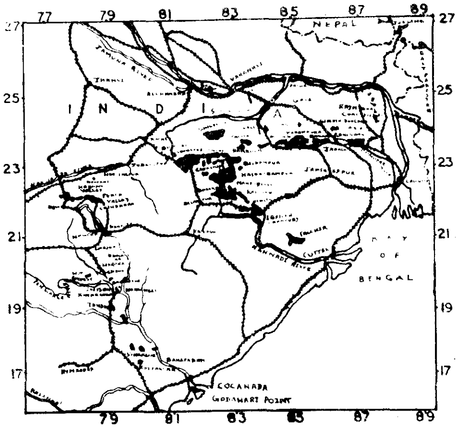

Fig.2. Part map of India showing river coal basins

RESEARCH FOR MINING NEAR WATER HAZARDS

Investigations were undertaken during the last 15 years to develop methods of mining and safety norms against water hazards of different nature. In these researches the geo-mechanical properties of the formation, geometry of the workings and equivalent material model studies were undertaken. The details of these studies are summarised in Table 2. The danger from surface water bodies while mining underneath was comparatively better defined with minimum uncertainties. In view of definite working horizon and physico-mechanical property of the intervening formation it was possible to define norms for underwinning water bodies. The investigation covered mining of coal underneath rivers, HFL of rivers and rivulets within 60-200 m thick partings. Depending upon the rock mass properties, scope of goaf treatment and thickness of parting; partial extraction, narrow panel to longwall caving and harmonic mining were recommended.

Table 2. Method of mining underneath water bodies

Mine	Area	Seam depth/ parting	Constraint	Method recommended/ adopted
Surface Water bodies				
Silewara	Nagpur	100 m	HFL of Kanhan	Longwall with stowing
Sudamdih	Jharia	65 m	HFL of Damodar	Wide stall with stowing
Chinakuri	Ranigunj	140 m	River Damodar	Narrow panel caving
Surakachar	Korba	135 m	HFL of Ahiram	Narrow panel caving
Kamptee	Nagpur	60 m*	HFL of Kanhan	Harmonic mining - stowing
Inder	Nagpur	60 m*	HFL of Brahmani	Harmonic mining
Deulbera	Orissa	60-90 m	HFL of Brahmani	Bord and pillar
		40-60 m	HFL of Brahmani	Bord and pillar (controlled size)
		40 m	HFL of Brahmani	No mining
Seetalpur	Ranigunj	170 m	River Damodar	Narrow panel caving
Bhamori	Pench Valley	80 m	HFL of Pench	Splitting of pillars
Sub-surface Water bodies				
Chapui Khas	Ranigunj	140 m	Upper seam old workings	Narrow panel - caving
Chasnalla	Jharia	68 m	Same seam old workings	-

* Depth of topmost workable seam

LINE OF APPROACH

Coal measure formation :- The coal measure formation underneath river Damodar, Godavari-Pranhita, Narmada-Kanhan, Pench etc. was Barakar or Ranigunj of Gondwana Series. Over 70% of the formation was sandstone, the share of which sometimes increased to 90%. The shale percentage varied from 10-30%, the higher being in Kamptee's of Maharashtra coal-field. The matrix in sandstone was quartz/ feldspar grain with calcareous or arenaceous binder. It showed low softening effect on saturation, high brittleness (with σ_c/σ_t ratio up to 20) and coarse grain size. The clays of Kamptee and Karharbari formation showed softening effect, high fluidity and plastic behaviour on saturation.

For mine planning under rivers or HFL of rivers, the nature of formation, extent of its weathering and thickness were considered. Subsidence of brittle sandstone formation was always associated with open fractures. In the absence of fine clay particles, wall swelling and subsequent sealing tendency, the cracks were likely to offer channel for water inflow or even connect water bodies in case of thick/multiple seam caving (Fig.3).

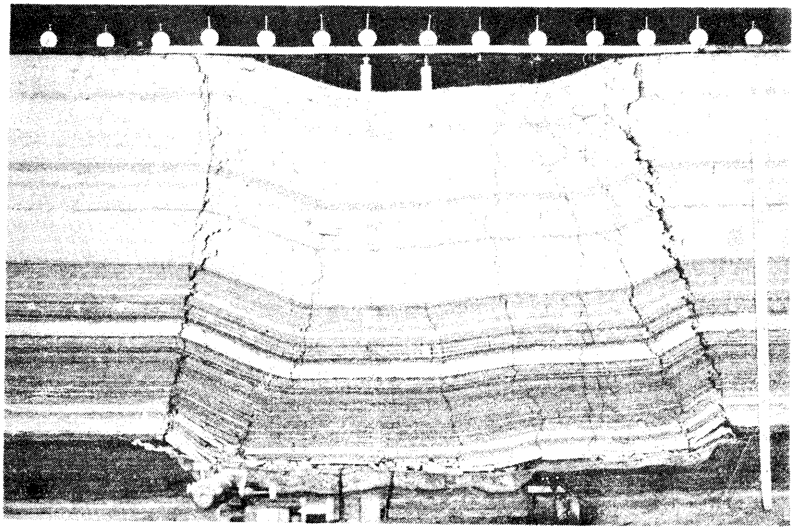

Fig.3. Cracks across formation due to thick seam mining

Strain control across formation : Cracks in sandstone formation appeared when the maximum tensile strain reached 5 mm/m across poorly jointed formation. In case of well jointed formation 3 mm/m caused such cracks while in the presence of fault planes, the strain tended to accumulate along the same and lower tensile strain might activate the openings. Cracks due to subsidence induced secondary permeability to otherwise impervious formation. Depending upon seam and strata thickness, the strain could be just enough to impart permeability or offer ready channel for free flow. Depending upon the nature of formation, water body and goaf treatment, strain up to 2 mm/m in the bed of river/HFL was permitted with necessary pumping preparation of enhanced seepage and withdrawal of persons was recommended. In other cases, no strain was allowed to reach up to river beds due to thinner parting and perennial nature of water body. For controlling the magnitude of strain either of the following approaches were adopted :

(i) Control the geometry of the panel or development headings such that the fracture planes remained below the water body, leaving at least 60 m thick formation as impermeable mass.

(ii) Reduce the effective working height of the seam by way of goaf stowing and thereby subsidence factor.

(iii) Adopt harmonic system of mining in conjunction with hydraulic stowing for mining of multiple seams under shallow depth cover.

HARMLESS PANEL MINING

Depending upon the nature of strata vis a vis thickness, competency and bending strength, the harmless width of panel was defined by model studies which depicted the panel geometry likely to cause no subsidence and strain in the river beds. The harmless width/depth ratio for Jharia, Ranigunj and Bilashpur areas varied within 0.4 to 0.9 (Table 3).

Table 3. Harmless width/depth for narrow panel mining

Case	Seam/working height	Depth	Harmless w/h
Chapui Khas	Sripur seam - 2.4 m	170 m	0.5
Silewara	IV Top seam - 2.6 m	100 m	0.4
Chinakuri	IV Top seam - 2.0 m	140 m	0.4
Sudamdih	XI/XII seam - 6.0 m	65 m*	0.5
Jhagrakhand	A seam - 2.0 m	234 m	0.9
Surakachar	G-III seam - 2.0 m	135 m	0.5
Ninghah	Sripur seam - 2.0 m	153 m	0.6

* No mining without stowing recommended

Accordingly, narrow panel longwall/depillaring system was suggested for different areas. For mining of Bharatchak seam underneath river Damodar, caving of 60 m wide panel of 3 pillars, leaving a row of pillars in between for 140-200 m depth cover was envisaged; while for XI/XII seam mining at Sudamdih, even safe narrow panel of 30 m was not recommended without tight stowing. The effect of 5 panel working of Bharatchak seam at Chinakuri mine was also studied to ensure safety of workings (Fig.4). The cumulative subsidence factor due to these workings increased from 0.5% for individual panel to 1.3% for 5 panels.

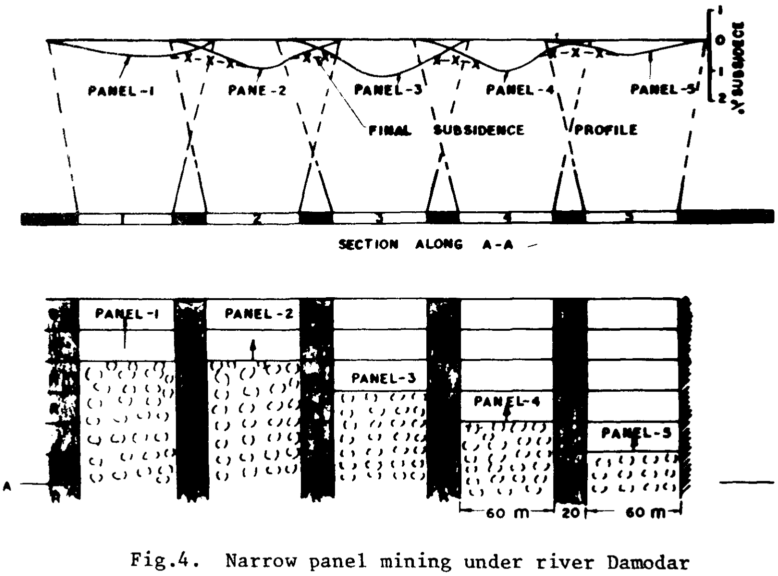

Fig.4. Narrow panel mining under river Damodar

The narrow panel caving was recommended where the intervening competent strata thickness exceeded 60 x t with the panel width from 0.4 to 0.6 times the parting. Where the thickness of strata in between the working horizon and water body was 30 t to 60 t, narrow panel with hydraulic stowing was recommended to ensure long term safety against delayed subsidence. In case the parting thickness was 10 t to 30 t, wide stall mining with stowing and precaution for withdrawal of persons from underground during flood period was recommended even in the presence of very competent formation.

BORD AND PILLAR MINING

Partial extraction by way of bord and pillar mining was recommended where the competent strata thickness over coal seam varied from 10 to 30 times the working height. The extraction of seam I of Deulbera (Orissa region) covered mining depth from incrop to 200 m. The zone between 30 t to 60 t was earmarked for bord and pillar mining with no restriction on working height and development galleries. The zone in between 20 t to 30 t was isolated for bord and pillar development, delimiting the height and width of the development galleries to 2 m and 4 m respectively. No mining was recommended in zones where the thickness of strata was below 20 t. The bed was presumed to be competent in between the top-most coal horizon to the working horizon. The coal being impervious prevented water dependant weathering/leaching of lower formation and hence was considered as marker horizon. This became important in view of 20-30 m deep weathering in coal measure formation and occurrences of pot holes of 20 m depth.

HARMONIC MINING

Extraction of 5 coal seams with cumulative thickness of 40 m within 120 m depth cover inclusive of top 20 m subsoil or loose sand underneath HFL of Kanhan river (Pranhita tributory) was a real problem for Nagpur area. Caving of only four coal seams with superimposed panel caused wide open cracks to serve as channels for water inflow. The formation was extremely weak flowing type clay, sand stone and shale. The cumulative parting/working height ratio was 3-5 only. As such partial extraction of some of the coal horizons in conjunction with stowing was adopted with 30-40% recovery.

With a view to maximising recovery and reduce surface tensile strain it was decided to adopt longwall mining and stagger the panels of different seams in a harmonic fashion so as to cancel tensile strain of one panel with the compressive strain ot the other one. This was physically seen in a set of model experiments (Fig.5).

The moderately dipping seams of this area was proposed to be extracted in harmonic fashion with tight stowing. The total 40 m working height could thus be reduced to effective height of 2 m only in view of 5% subsidence factor with stowing. As a result, the parting ratio could be increased to 60-100 t and make the working safe. Adaptation of harmonic mining methods further reduced the magnitude of tensile strain and minimised formation of macro-micro cracks across the weak formation.

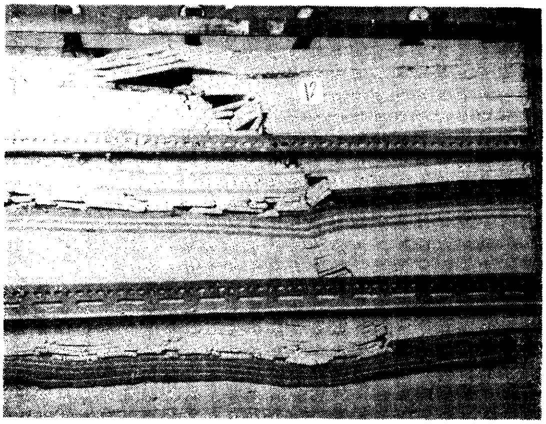

Fig.5. Harmonic mining studies for mining under HFL

The topmost 11 m thick seam I of this area immediately below subsoil, running sand and clay was recommended to be retained as an umbrella in view of its impervious nature. The seam along with overlying plastic clay was likely to serve as good water sealant during lower seam workings by harmonic method in conjunction with stowing. As a preamble to this proposal, field trial was undertaken to ascertain subsidence factor and travelling strain due to lower seam extraction by longwall with stowing.

CONCLUSIONS

The development or extraction operations of seams below water logged old workings or abandoned workings in the same seams, accounted for 95% of the total accidental flooding and innundation casualties. These accidents occurred in spite of safety precautions taken when approaching old mine workings of unknown extent. In such cases, it was therefore essential to make the rise side area free of water before working in its vicinity.

The extraction underneath surface water bodies was under comparatively well defined geo-mining and spatial domain. It was, therefore, possible to plan harmonic mining of multiple seams, narrow panel mining or controlled bord and pillar development with or without stowing within parting ratio of 10 t to 75 t with calculated risk of additional seepage and pumping.