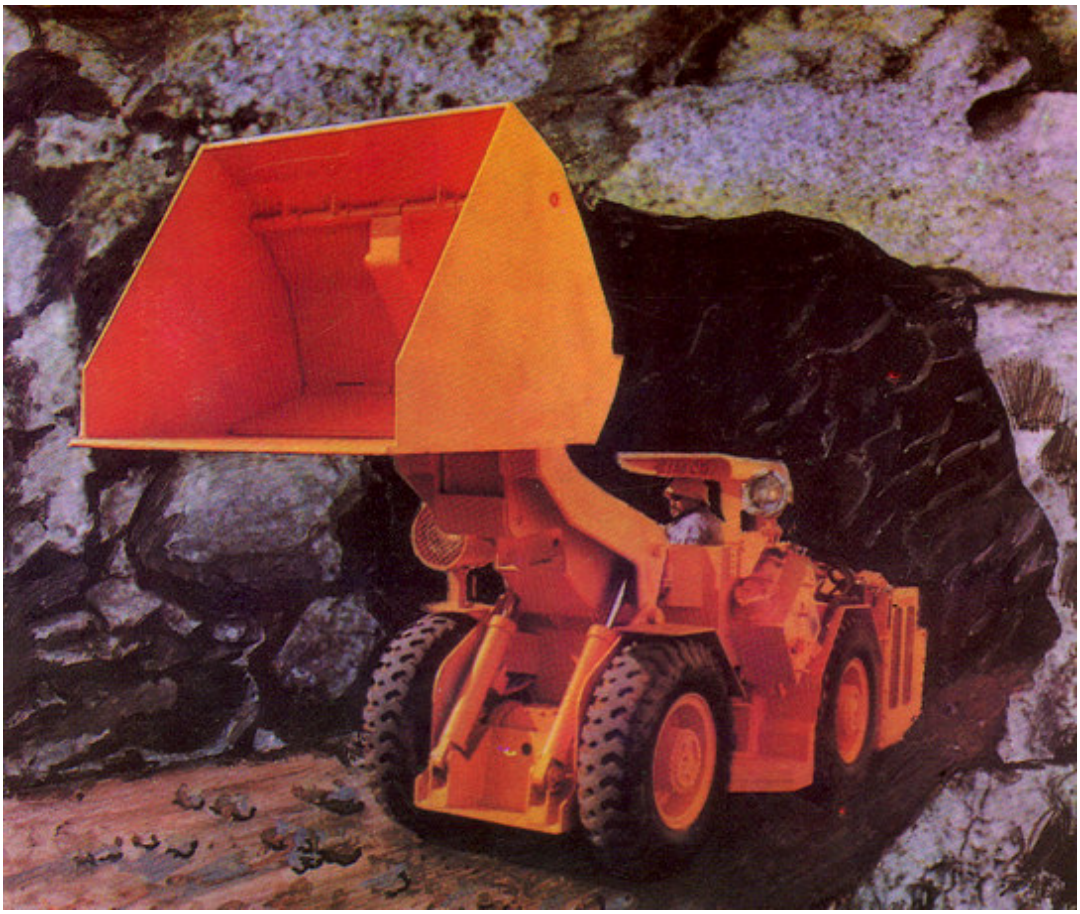
MINING METHODS

The phenomenal rise in coal production, nearly six-fold in the past three decades, necessitated rapid but judicious mechanization of mining methods. While opencast operations are now fully mechanized employing large capacity earth moving equipment, introduction of machinery in underground workings has been gradual. In conventional bord and pillar workings coal loading and transport have been mechanized, eliminating human labour and drudgery to a large extent. There have mostly been increasing use of Side Discharge Loaders [SDLs] and Load Haul Dumpers [LHDs] for loading of coal at the faces along with armoured face conveyors and belt conveyors for coal transport.

The use of such equipment for underground operations required elimination of conventional timber support or other roof-to-floor type of supports to allow movement of machines in confined spaces. Extensive studies have been made under Coal S&T Grant for determination of physico-mechanical properties of coal measure rocks and observation of roof behaviour in bord and pillar workings with SDL/LHDs. As a result of these studies it has been possible to introduce roof bolting on a wide scale, reducing dependence on scarce timber. Adoption of roof bolting even in depillaring areas has allowed the use of loading machines during extraction of pillars and not in development galleries alone.

Coal loading is mechanized in most of the underground mines of CIL and SCCL with over 900 SDLs and 50 LHDs in operation, contributing over 40 million tonnes of production per year.

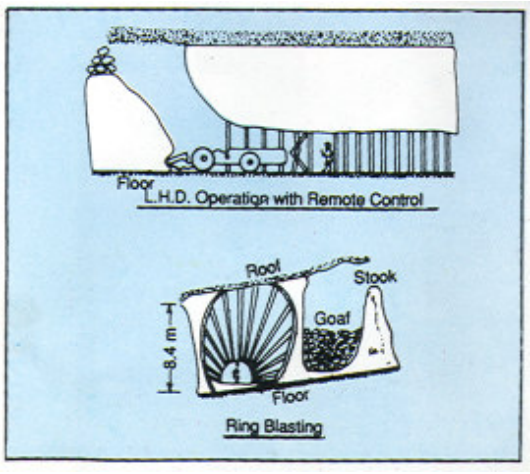
Side Discharge Loader [SDL]



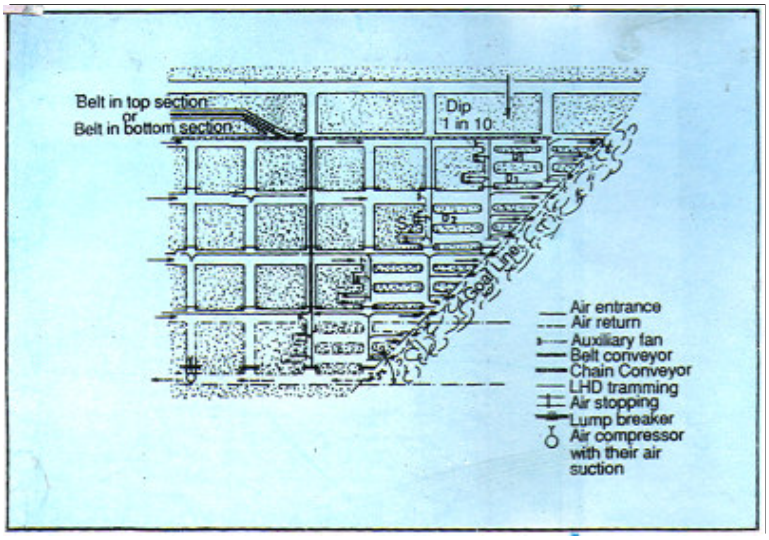
Load Haul Dumper [LHD]

Blasting Gallery Method

Conventional bord and pillar mining in thick seams is associated with very low percentage of extraction [around 30% in a panel] even under favourable conditions. Extensive development of pillars carried out earlier in thick seams had also resulted in large reserves of good quality coal locked up in developed bord and pillar workings [over 2,500 million tonnes]. Scientific investigations were initiated under Coal S&T Grant for safe and speedy liquidation of such developed pillars with maximum possible percentage of recovery.



Blasting gallery method



Dipillaring layout and LHD tramming in Blasting Gallery Method

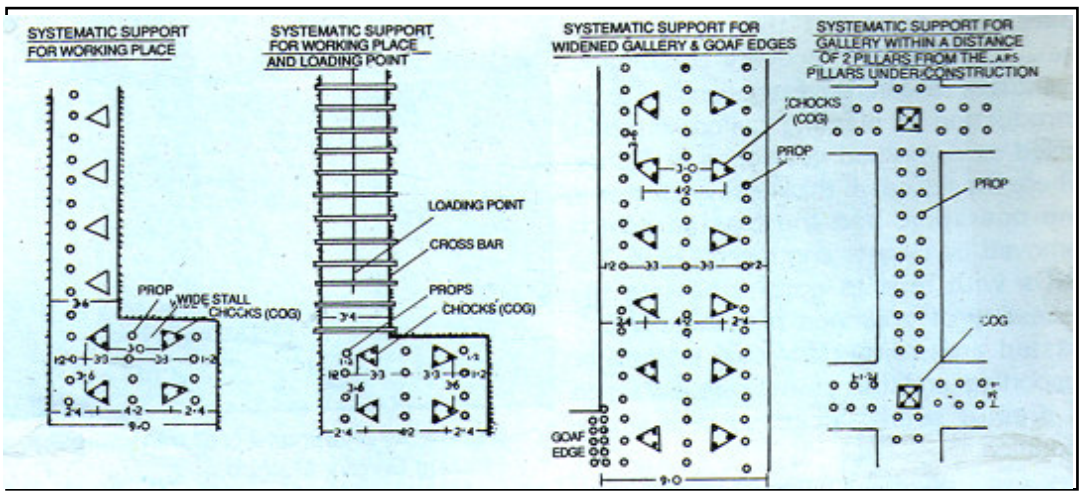
Blasting gallery method was introduced as an R&D project in technical collaboration with CdF, France, in 7.5m thick X seam of East Katras Colliery, BCCL. The method was a derivative of an earlier procedure adopted in France, which involved blasting of the full seam thickness in one operation. The system as adopted in India involves blasting of a series of holes drilled into the sides and roof of galleries in a single operation. After the ring-hole blasting, as it is commonly called, remote controlled LHDs are employed for loading of the blasted coal and transporting to conveyors.

After successful extraction in three panels the new method was replicated in Chora Colliery of ECL. Coal recovery was found to be about 70% in the panels, which was substantially higher than what was possible through conventional means. The output per man-shift [OMS] was also substantially higher at 2 tonnes. The method has been repeatedly employed in GDK-8 and GDK-10 mines of SCCL for working medium-thick seams with a high degree of success. A production level of 900 tonnes per day on a sustained basis with an OMS of over 5 tonnes could be achieved with as high as 85% recovery of coal.

Wide Stall Method

Of the large reserves of coal locked in developed pillars a substantial portion is sterilized due to the presence of structures and inhabited localities on the surface. In such cases only partial extraction from these pillars can be considered in view of the need to avoid subsidence and damage to the surface. The prevailing method under such conditions is splitting of the coal pillars, without further extraction of the resultant stooks, followed by stowing with sand. The drawback of this method, however, is that the percentage of recovery is low and comes down sharply to as low as 30 with increasing seam thickness due to adverse slenderness ratio of the pillars.

Wide stall mining at East Bhuggatdih Colliery

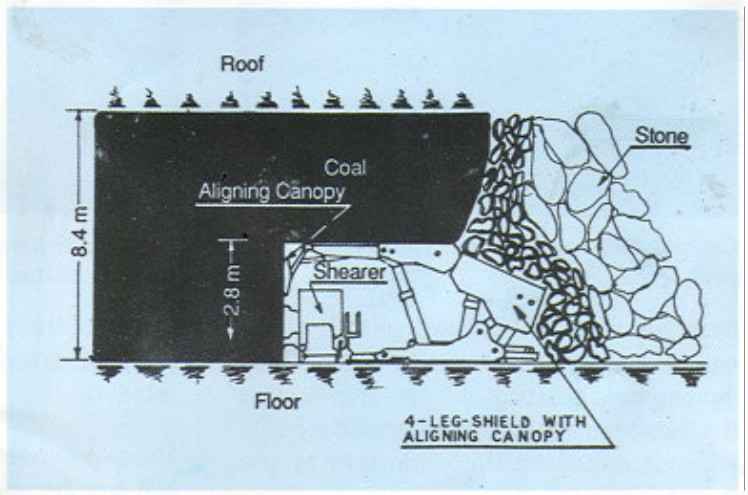


Support plan of wide stall method

Wide stall method was conceived to improve coal recovery under such conditions. The method was tried on a laboratory scale with the help of equivalent materiel modeling and then experimented by a field trial at East Bhuggatdih Colliery of BCCL in a 16.5m thick seam lying below built-up areas on the surface. The extraction procedure involved formation of 7 to 9m wide stalls, which were extended to full working height, leaving the pillar core as a natural support to the roof. Over 45% overall recovery could be achieved with a safety factor of more than one for remnant pillar cores left for long-term stability. A comparison of extraction percentage and safety factors of pillars between conventional bord and pillar system and wide stall method of working is given in table 3.

Sub-level Caving

In addition to the development of a suitable method for extraction of developed coal seams R&D effort was also directed towards optimum extraction of virgin thick seams, which constitutes a large percentage of the total coal reserves in India. The prevailing method of bord and pillar mining was inadequate as recovery was low and required stowing with sand not easily available in many areas. The feasibility of applying sub-level caving was examined with respect to two variants: sub-level caving and total under-winning, also known as soutirage. The first sub-level caving face was opened at East Katras Colliery of BCCL. It was possible to achieve a production level of about 850 tonnes per day in a 7.5m thick seam with over 60% coal recovery.



Sub-level caving [Soutirage]

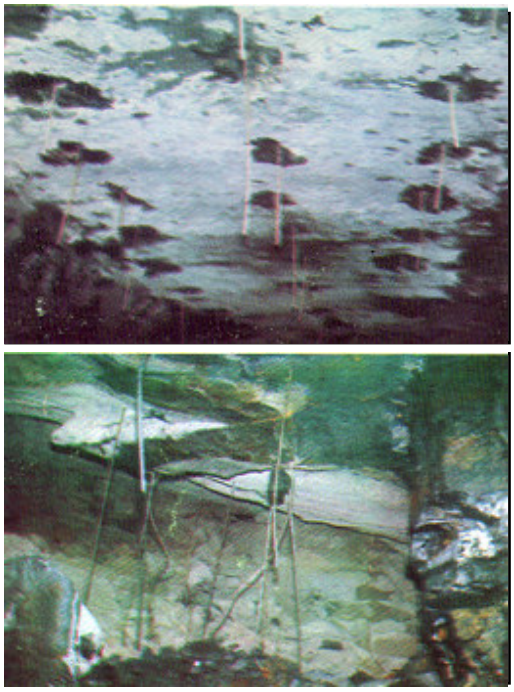
Table 3 : Coal recovery and safety factor of pillars for wide stall method

		Gallery Size (m)				
		3.6	4.0	4.5	5.0	5.5
1.	**Conventional stooking and splitting method**					
A.	**Development in two sections of 2.4m height**					
	Recovery %	6.5	7.2	8.1	8.9	9.6
	Safety Factor	4.6	4.5	4.4	4.3	4.2
B.	**Final extraction in two sections of 7.2m + 6.4m and pillar 15 x 15m size 3m parting**					
	Recovery %	34.6	37.8	41.7	45.5	49.1
	Safety Factor	1.05	0.98	0.90	0.82	0.75
2.	**Wide stall method with 2 sections of 7.2m + 6.4m and 3m parting**					
	Gallery size, m	6	7	8	9	10
	Solid pillar, m	24	23	22	21	20
	Recovery, %	29.5	33.7	37.8	41.7	45.5
	Safety Factor	1.56	1.44	1.32	1.21	1.11

Thick Seam Extraction by Cable Bolting

In order to obviate the high capital investment required for operating sub-level caving faces, which require powered-support longwall equipment, a new mining method, commonly referred to as thick seam mining by cable bolts, was developed under an S&T project mainly for extraction of thick seams with developed pillars. The method was successfully tried in 6m thick Seam III at Chirimiri Colliery of SECL. Wire ropes of 19 to 22mm diameter and 6 to 8m length with safe bearing load of over 20 tonnes under tension were grouted into the roof to avoid roof coal from sagging and bed separation. A part of the cables so grouted went into the immediate roof strata up to a height of about 1.5m above the coal seam and provided support even after blasting of roof coal, which allowed coal loading under the supported strata.

A full-scale trial was also undertaken at NCPH Colliery of SECL, where Seam III had earlier been extensively developed and depillaring could not be carried out due to the absence of a suitable method. The use of cable bolts yielded excellent results in coal recovery, production and productivity. The trial was successfully repeated in seam thicknesses of 6.5m, 7m and 8m and at depths of 70m, 103m and 256m in panels of size varying from 38 to 55 pillars.



Cable bolted roof before and after blasting

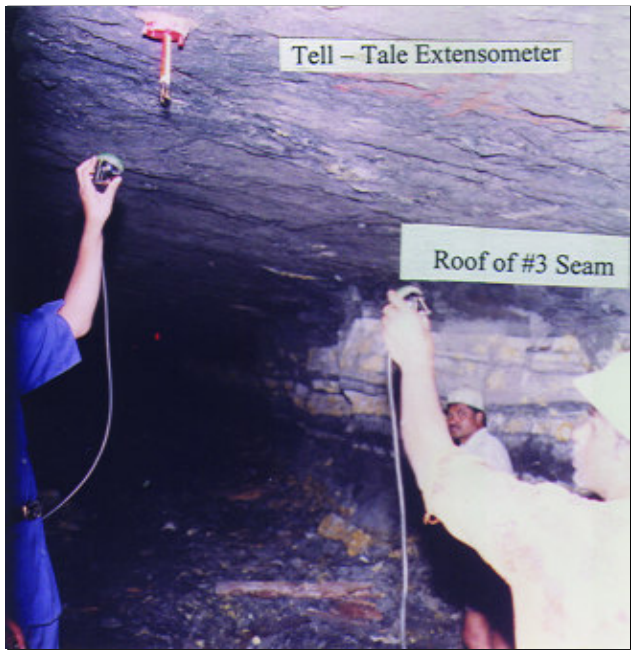
Extraction of Coal Locked in Pillars of Multiple and Thick Seams

In India large reserves of coal are locked in pillars developed in multiple and thick seams, which are not amenable to normal depillaring operation as the percentage of extraction achieved is very low and unsafe operating conditions are also likely to occur.

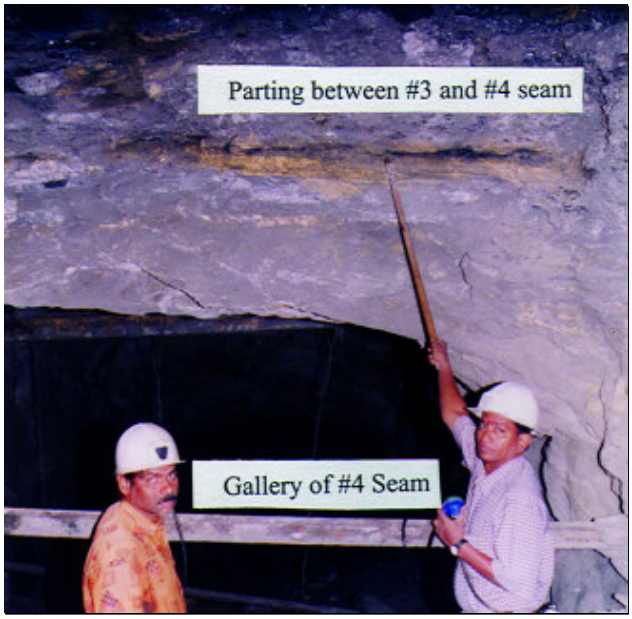
To overcome such problems a trial has recently been conducted by National Institute of Rock Mechanics at RK-8 Incline, SCCL for simultaneous extraction of pillars in three seams, each of about 2.5 m thickness with partings of about 7-9 m between the seams. To assess the stability of partings and to design a suitable support system, observations of strata behaviour were made during simultaneous extraction of the pillars in the experimental panel, which included the three seams.

It was observed that maximum roof to floor cumulative convergence was about 8mm in the panel. The maximum rate of convergence was 2 mm / day prior roof falls in the goaf. Vertical supports near the goaf edge experienced a maximum cumulative load of 6T. The maximum load on the support in the galleries remained within 4T. The average rate of change of load near goaf edge was 1.5T/day prior to the roof fall. It was found that estimation of support requirement based on "Q" classification tended to overestimate the actual requirement for lower seams. The intensity of abutment load in the experimental panel was not high. The maximum change in stress over the pillars was only about 0.8 MPa, 0.7 MPa and 0.6 MPa in No. 3, 4 and 5 seams respectively, which were attributed to the destressing due to regular roof falls in the overlying seams. The results of the numerical model using FLAC-2D were in close agreement with the observed field behaviour. In the model, the stability factor for the partings in the development workings was estimated to be greater than 1.0 for parting thicknesses more than 6m. The extraction of three rows of pillars in No. 3 seam was also simulated using numerical modeling. In the model, the safety factor of the partings between No. 3, 4 and 5 seams was less than 1.0 in the goaved out area.

This was in accordance with the actual conditions as observed from the collapse of parting after extraction of three rows of pillars in No. 3 seam. As compared with the conventional system of single and double seam extraction, the recovery of coal in the experimental panel with simultaneous extraction of three seams was more by about 10%.



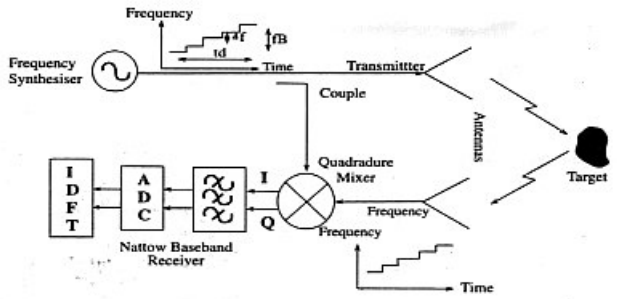
Study of roof behaviour at RK-8 mine, SCCL



Parting rocks between simultaneous extraction in two seams at RK-8 mine , SCCL

Ground Penetrating Radar

One of the major causes of disaster in underground mines is inundation due to accidental connection with old waterlogged workings. Old workings are usually not approachable and often the old mine plans available for such workings are not accurate enough to indicate the exact thickness of barrier existing between the earlier and present workings. There have been several instances of inrush of water due to old galleries getting connected by new development headings, resulting in disasters involving heavy toll of life.

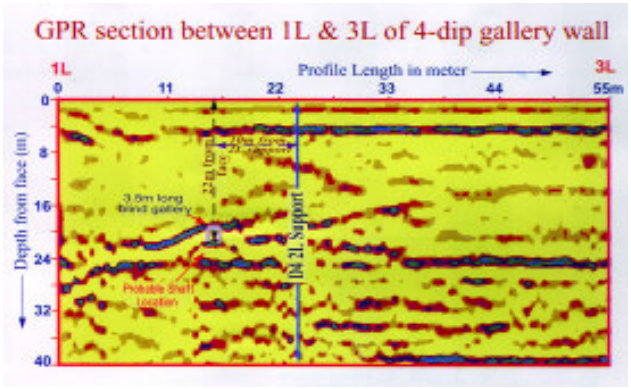


Block diagram of the stepped-frequency radar

To safeguard present workings against such occurrences an S&T project has recently been concluded in which the application of ground penetrating radar (GPR) has been established for detection of old galleries in the vicinity of present workings. The project has been carried out by the National Institute of Rock Mechanics (NIRM) in collaboration with CMPDI.

Under the project GPR survey was conducted both from surface and in underground workings in a number of collieries of ECL, BCCL, WCL and SCCL. At one of the mines pillar thickness between successive longwall panels was measured and in two other collieries mapping of pillar thickness in bord and pillar workings was done to detect blind galleries.

Part plan of 1&2 Incline/Jhanjra mine, ECL



GPR section between 1L&3L of 4-dip gallery wall

The technique was found to have a range of 35m for detecting blind galleries. Coal barrier thickness up to 25m against waterlogged workings could be mapped with an accuracy of ±10%. This technique could detect old workings up to a distance of 40m from the current workings. The method could also be applied for mapping old workings 25-35m below the surface, thus providing an estimate of the rock parting between opencast benches presently being worked and old underground workings existing below the benches. Thus, this new technology provides a major tool for enhancing safety in underground mines close to water logged workings. The technique also has the potential to safeguard opencast workings being carried out over past underground mines by ensuring adequate thickness of cover so as to avoid accidental collapse of rock strata

Coal Bed Methane

One of the on-going S&T projects relates to a hitherto unexplored area in the Indian coal industry. Recovery of coal bed methane (CBM), being taken up under the project, is likely to add a new dimension to harnessing the energy resources of the country.

This demonstration project involving CBM recovery and commercial utilization has multilateral funding involving S&T Grant, UNDP/GEF and ONGC. It is being implemented jointly by CMPDI and BCCL at Moonidih and Sudamdih coal mines in Jharia coalfield where adequate CBM reserves are expected. The project intends not only to bring state-of-the-art methodology for resource assessment and recovery techniques but also demonstrate utilization of the exploited methane. Recovery of CBM will provide a clean source of energy and also prevent methane, a highly potent green house gas, from being released into the atmosphere.

Table 4 : S&T projects on mining methods

Sl. No.	*Title of the Project*	*Project Code*	*Imple-menting Agency*	*Year of completion*	*Total Approved Cost (Rs. in lakh)*
1	Scientific investigation on shearer longwal faces	MT/1	CMPDIL/ECL	1981	3.00
2	Stability of slopes in Opencast Mines	MT/10.3a	ISM	1981	13.18
3	Study of adoption of sublevel caving at East Katras and Kendwadih collieries	MT/18	BCCL/ Sofre-mine(F)	1983	11.50
4	Evaluation of workability indices of Indian coal seams and coal measure rocks	MT/8.3	ISM	1983	4.30
5	Slope stability in pit walls, dumps stability ground monitoring in and around pit with Geo-technique studies	MT/40	CMRS	1986	11.0
6	Optimisation of extraction of coal from pillars below surface structure using technique of partial stowing	MT/43	CMRS	1987	17.60
7	Evaluation of new mechanised system performance using SDL, LHD and roof bolting	MT/49	CMRS	1989	33.74
8	Hydraulic mining	MT/11	CMPDI/ BCCL	1989	818.67
9	Workability indices of coal seams	MT/8.3	CMRS	1989	24.11
10	Tests of sub-level ca ving from galleries in developed area in East Katras Colliery	MT/37	BCCL	1990	141.00
11	Mine Accident analysis and control a sociopsychological approach in coal mines	MT/57	BHU	1990	5.00
12	Computerized mine planning for opencast coal mines	MT/50	ISM	1990	11.59
13	Field trial of wide stall method	MT/44	CMRS	1991	19.45
14	Analysis of some time and cost over run projects	MT/75	IIM, Ahmedabad	1992	8.54
15	Induced caving of sub-level coal numerical evaluation of some geological and mining parameters	MT/71	BHU	1993	2.00
16	Assessment of status of coal mining in the state of Meghalaya	MT/79	CMPDIL	1994	15.00
17	Mechanised depillaring of 6m thick seam III of Chirimiri with cable bolted support	MT/77	SECL/ CMRI	1995	213.25

Sl. No.	*Title of the Project*	*Project Code*	*Imple-menting Agency*	*Year of completion*	*Total Approved Cost (Rs. in lakh)*
18	Underground coal g asification	MT/62	CMPDI	1995	322.0
19	Development of method of mining for extraction of thick and steep seams of NEC	MT/78	NEC	2000	120.00
20	Extration of coal locked in pillars of multiple and thick seams	MT/107	NIRM/SCCL	2003	26.20
21	Application of ground penetrating radar (GPR) technique to locate coal water logged workings in coal mines	MT/110	NIRM/CMPDI	2003	47.00