Highwall Mining in India

S.K. Dixit[1] and Manoj Pradhan[2]

[1] South Eastern Coalfields Ltd., India
[2] National Institute of Technology, Raipur, India

Abstract. Coal has been recognized as the most important source of energy for electricity generation in India. Currently the country produces more than 550 million tonnes of coal per year, more than 80% of which comes from opencast mines. The demand of coal is increasing day by day. Despite of having the fourth largest coal reserve and being the third largest coal producing country in the world, India needs to import coal to meet its growing requirement. Most of the opencast coal mines were started in early eighties in India. Many of these opencast mines are reaching their pit limits. A significant amount of coal is blocked in non workable thin seams, in the highwalls, below surface dwellings in these opencast mines. Highwall mining is a proven technology in USA and Australia to extract the blocked coal in thin non-workable seams and the coal blocked in the highwall of opencast mines. In USA, highwall mining contributes about 4.0 % share of total coal production. In India, the highwall mining is in the nascent stage. So far only two highwall mining are being worked; one by Singreni Collieries Company Ltd at RG II opencast project and other by South Eastern Coalfields Ltd at Sharda opencast mine . Many projects have been identified by major coal producing companies like Coal India Ltd, Tata Steel and Singreni Collieries Company Ltd. for introduction of this technology. The future of highwall mining in India is keyed to the success of these projects. This paper gives an overview of the highwall mining technology deployed at Sharda opencast mine where two thin seams are being extracted by this technology.

Keywords: Highwall, Auger mining, CHM, Web pillar, Barrier pillar.

1 Introduction

Coal renders more than half of India's power generation. More than half of the country's 223.3 gigawatt installed capacity is produced from coal [1]. India is the world's third-largest producer of coal. It has produced 557.5 million tonnes of coal in 2012-13 [2]. Despite its abundant reserves of about 286 billion tonnes, the world's fourth-largest, coal production in India has failed to keep pace with demand. India imported 135 million tonnes of coal in the 2012-13[1] and is struggling to raise domestic supplies. Environmental and land acquisition constraints, the long drawn process in obtaining lease and clearances from the government are the main snag in opening and operations of the new mines.

C. Drebenstedt and R. Singhal (eds.), *Mine Planning and Equipment Selection*,
DOI: 10.1007/978-3-319-02678-7_18,

More than 80 % of coal produced in India comes from opencast mines. Most of the opencast coal mines were started in eighties and are reaching pit limits. A significant amount of coal is blocked in non workable thin seams in the highwalls, beneath the surface dwellings in these opencast mines. Highwall mining can extend the life of these opencast mines. Also the coal blocked in the highwalls of abandoned opencast mine can be extracted by this technology. In the current Indian scenario where the hope of operating new mines is distant, the demands need to be met through imports. Highwall mining offers a economic viability to the existing projects and can narrow down the demand-supply gap of coal. To explore the possibilities of introduction of highwall mining in India, this technology was recently introduced at Sharda opencast mine of M/s South Eastern Coalfields Ltd.

Around the world, highwall mining is a proven technology to mine coal from the high walls of opencast mines in USA and Australia. More than 55 million tonnes of coal is produced annually in USA using this technology [3]. About 100 highwall miners are working worldwide. In India, this technology is new and was first introduced in Dec 2010 at Ramagudam II opencast project of M/s Singereni Collieries Company Ltd. The second highwall miner was deployed in March 2011 at Sharda opencast mine of M/s South Eastern Coalfields Ltd.

2 Highwall Mining Systems

Highwall mining is a generic term for the mining of coals from the final highwall of an opencast mine. It is a hybrid method of opencast and underground method. Highwall is the final boundary of an opencast mine beyond which the economic extraction of coal by opencast mining is not possible. Sometimes the presence of some local surface constraints also restricts the further progress of opencast mine.

In highwall mining, a series of parallel rectangular, unsupported entries separated by a narrow web pillars are made in the exposed coal seam in the highwall of an opencast mine. The entries are made via a remote controlled operated unmanned cutter head and coal transport system placed in front of the highwall. Since all the personnel remain outside the entries, there is no need of ventilation and support.

There are two variants of highwall mining systems- auger mining and continuous highwall mining. Auger mining has been used for contour mining since 1940. In auger mining, a circular cutter head much like a drill bit cuts the coal and the coal is scrolled to the surface by a series of open spiral flights driven from the launch vehicle. Continuous highwall miner (CHM) systems were introduced in 1980 [4]. In CHM system, modified underground continuous miner is used for cutting of coal and a material transfer mechanism using belt or screw conveyors is used to transport the cut coal to surface.

Highwall mining methods are useful to mine the:

- Coal blocked in the highwalls of open cast mines due to un-economic stripping ratio

- Coal blocked in the boundaries of opencast mines
- Coal blocked in thin seams for which no conventional mining method is available or economically viable
- Coal seams in hills and in forest area
- Coal blocked below roads, permanent surface structures and villages
- Coal where conventional extraction is constrained for various reasons

The following methods are generally practiced with highwall miner [5, 6].

1) Contour Mining: When the coal seams appears at outcrop in hilly area conventional method of mining i.e. opencast or underground may not be best economic choice. Highwall mining can be used economically and safely, since it follows the contour of the coal seam along the sides of the hill.
2) Trench Mining: Trench mining offers an economic option for mining thin reasonably flat coal seams which may not be amenable to opencast mining. In this method, an artificial highwall is created by making a trench at convenient place up to the coal seam. The miner is positioned on the floor of the seam within the trench and entries are driven on both sides of the purposely prepared trench.
3) Opencast: Highwall mining from opencast pit practiced when the opencast mine reaches its economic stripping ratio or mining is not possible because of some surface constraint like forest, villages and any permanent structures. In this method the highwall miner is positioned on the floor of the seam and in front of the highwall; from this location the galleries are driven in the highwall.

3 Highwall Mining at Sharda Opencast Mine

3.1 Introduction

Sharda opencast mine of M/s South Eastern Coalfields Ltd. a subsidiary of Coal India Ltd. is located in Shahdol district of Madhya Pradesh state of India between the latitudes 23º12´10" to 23º13´45" and longitudes 81º35´12" to 81º38´08". The mine was started in the year 1986. The area has gently undulating terrain with elevation ranging from 450 m to 480 m above MSL. The river Sone flows from the eastern and northern side of the mine. The sequence and important features of coal seams in the mine lease area are given in tab. 1. The total lease area of the mine is 1060 ha. Two pits had been developed in the mine namely Sharda opencast (Bakho patch) having an area of 175 ha to work Seam VI top and Sharda extension (Bakhi patch) having an area of 103 ha to work Seam IV. The working in both the pits was discontinued when uneconomical stripping ratio was reached.

While considering the availability of coal seams, it was observed that seams are available in three locations, viz., Sharda opencast, Sharda extension and in the unmined virgin area.

Table 1 Sequence and features of the coal seams at Sharda open cast mine

Sr no	Seam	Thickness, m	Depth of cover / parting, m	Nature of the rock parting	Status	Remarks
1	VI Top	0.40-5.64	up to 25.00	sandy soil, very course to fine grained sand stone	worked out by open cast method in Sharda opencast mine	unworkable thickness in northern part
2	VI Bottom	0.06-2.05	11.00-24.00	course grained sand stone intersected with thin layer of shale	virgin	attains workable thickness in south-western part
3	V	0.10-0.70	0.40-8.00	coarse grained sand stone	virgin	thin inconsistent non-workable
4	IV	0.37-1.78	20.00-25.00	coarse to very coarse grained sand stone intersected by thin layer of sandy shale	worked by opencast in Sharda extension	attains workable thickness in central and eastern part
5	III	0.08-1.79	11.00-20.00	medium to coarse grained sand stone	virgin	thin and inconsistent
6	II	0.47-1.89	6.00-9.00	sand stone	virgin	attains workable height near northern and south-eastern boundary
7	I	0.22-0.54	12.00-15.00	sand stone	virgin	thin and inconsistent

In Sharda opencast, two thin seams, namely Seam VI bottom and Seam IV, non-workable by conventional opencast method but workable by highwall mining exists below the floor of the already worked out Seam VI top. Whereas at Sharda extension pit, thin Seam II workable by highwall mining is available below the floor of the already worked out Seam IV. Some coal of Seam IV minable by highwall mining is also blocked in the highwall of Sharda extension. In the virgin area of the Sharda opencast mine, three seams workable by highwall mining exists namely Seam VI B, Seam IV and Seam II. The total coal available for highwall mining at Sharda opencast mine in all the three seams is 15.7 million tonnes. The details of the seams workable by highwall mining at Sharda open cast mine are summarized in tab. 2.

Table 2 Details of the seams workable by highwall mining at Sharda open cast mining

Seam	Workable thickness, m	Depth, m min	max	Roof rock up to 5.0 m	Floor rock up to 3.0 m	Emission of inflammable gas, m^3/ ton of coal produced	Incubation period, months	Reserve minable by HW mining, million tonnes
Seam VI B	0.80-2.05	10.06	40.80	sand stone of varying grain size/ carb shale overlain by shale	sand stone of varying grain size/ alternate shale & sand stone/shale	0.12	9	3.135
Seam IV	0.80-1.78	36.05	68.43	stone of varying grain size/ sandy shale, carb shale overlain by sand stone	sand stone of varying grain size/ alternate shale sand stone/shale	0.17	NA	9.657
Seam II	0.80-1.89	59.18	75.50	sand stone of varying grain size/sandy shale, carb shale overlain by sand stone	sand stone of different grain size	NA	NA	3.183

3.2 Highwall Miner at Sharda Opencast Mine

The highwall mining at Sharda opencast was outsourced by South Eastern Coalfields Ltd to M/s Cuprum Bargodia Ltd, Kolkata. M/s CBL deployed Bucyrus SHM machine (Fig.1). The machine consists of a launch vehicle, on which most of the drives and all controls are positioned, a coal cutting head, which cuts the coal and a material transfer mechanism, which transfers the cut coal to the launch vehicle and on to a stock pile. The launcher is placed at the surface in front of the highwall. All the main operations are controlled from a closed operator's cabin situated on the top of the launcher. The launcher also houses hydraulic power pack to feed power to push-beams and cutter head. The machine is capable of exerting a push in and pull out force of 170 t and 350 t respectively. The dimensions (L x W x H) of the launcher are 17 m, 10 m and 8.5 m respectively. A steel-armoured hose chain stores and protects power cable for cutter head, control cable for cutter head, methane sensor cable, hydraulic pressure hose for cutter and cooling water hose etc. The hose chain automatically unwinds and winds during mining. The material transfer mechanism consists of a string of push beams. The string of the push beams pushes and pulls the cutter unit in and out of the seam and also conveys the mined coal to the surface through two contra-rotating augers. Push beams are 6 m long rectangular reinforced steel box structures joined together to form a string, which connects the cutter unit to the launcher. Push beams are the back bone of the system. The cutter unit that goes inside the coal seam is basically the cutter head of continuous miner. Depending upon the thickness of coal seam, there are three types of cutter modules i.e. thin seam, medium seam and thick seam. The cutter module used at Sharda opencast is thin seam cutter module capable of cutting seams having thickness in the range of 0.8 to 1.7 m.

Fig. 1 Highwall face installation showing highwall miner machine at Sharda project

The highwall system is equipped with a number of monitoring and control systems. To ensure the parallelism of the galleries automatically to maintain adequate pillar thickness throughout the gallery, the machine is fitted with Fiber Optic Gyro navigation system. The machine is provided with continuous methane monitoring system. When the percentage of methane exceeds 0.75 %, it gives warning to the operator. If the methane percentage exceeds 1.25 %, the power supply gets shut off automatically. To keep the temperature down and to dilute the concentration of methane, air is circulated to the face by the augers used to transport the coal in the push beams. The augers are capable of circulating 48 m^3 /min of air. The machine is also equipped with the provision of compressed air circulation inside the galleries to flush the methane. Coal dust at the face is suppressed by effective water mist spray system.

3.3 Mining Method at Sharda Opencast Mine

Planning Stage

The Sharda project with an estimated 15.7 million tonnes suited well for the introduction of highwall mining. Seam thickness, gradient, overburden depths, non-contiguous seams provided favourable factors in implementation. However, Sharda opencast has its seams overlain by either virgin rock or by the previously cast over burden. Hence, certain precautions are a must while handling the earlier formed dumps which form the overburden of the planned highwall seams.

An advantage of non-contiguous formations was that it aided in avoiding the difficulties which arose in the planning, development and mining of seam by creating superimposed galleries and pillars. In both the pits, the parting between the seams at all the places was more than 10 m; hence, columnization of the pillars was not necessary.

The coal seams in the Sharda opencast mine are competent. The uniaxial compressive strength of the coal varies from 17.75 MPa to 43.43 MPa and tensile strength ranges from 0.36 to 4.58 MPa. The uniaxial compressive strength of roof and floor rock varies from 9.02 to 24.16 MPa; tensile strength varies from 1.19 to 3.53 MPa, Young's modulus from 2.92 to 3.81 GPa, Poisson's ratio from 0.15 to 3.82, Bulk modulus from 1.63 to 2.09 GPa. The ground water inflow per tonne of coal produced is 0.11 m^3. The estimated gas emission per tonne of coal produced for coal seam VI and IV is 0.12 m^3 and 0.17 m^3 respectively.

While planning for the highwall mining sequence for seams, lower to upper or otherwise, the safety was considered as the prime concern. Having the backfill as overlying strata, the conditions remain tentative so as to provide reliable scientific understanding and judgment. Besides this certain adverse eventualities are anticipated when considering the sequence of mining the seam from bottom upwards; in ascending order of extraction, if the pillar in the already worked lower seam fails, it may damage or deter the workings of the upper seam. Hence, on a conservative front the sequence of seam extraction was chosen in descending order from top to bottom.

One of the visible unfavourable conditions that the seams showed was varying thickness. In the extension pit the Seam VI top and VI bottom has been found unfit for mining, though the same has been mined or is mineable in the old pit. Seam VI top presents an unworkable thickness in northern part of the leasehold area; this has been mined in old pit. Seam VI bottom is workable in south-west portion. Seam V, III and I are classified as inconsistent. Seam II is amenable near north and south-eastern portions. This seam variability and inconsistency is visualized as a hindrance to mining operations and in meeting the targets in production.Amongst the workable seams, the Seam VI bottom possessing workable thickness of up to 2 m can provide 3 million tonnes of coal, Seam IV with a thickness up to 1.78 m can provide 10 million tonnes of coal, Seam II with thickness of up to 1.89 m can provide 3 million tonnes of coal.

Thus, favourable gradients of up to 4°, seam thickness of up to 2 m, overburden depths of 40 to 75 m, and a well developed accessible seam reserve provides the most well-disposed mining environment for introducing the highwall mining system.

The following mining variants were decided for implementation at Sharda opencast project –

- Adopting highwall mining for extraction of the coal blocked in the highwall of Seam VI top at Sharda opencast and Seam IV at Sharda extension.
- Trench mining for working Seam VI bottom and Seam IV at Sharda opencast and Seam II at Sharda extension .
- Trench Mining for working Seam VI bottom, Seam IV and Seam II in the virgin area on the northern and north-eastern part.

For the three locations, viz., Sharda old mine, Sharda extension and the virgin unmined area, it was decided to dig four trenches namely T1, T2, T3 and T4 (Fig. 2). From these trenches the highwall faces shall be formed so as to extract the coal blocked in the highwall of Sharda opencast and Sharda extension.

- In the Sharda opencast, trench T1 and T3 are planned. T1 run in the centre of the mine, trench T3 is proposed in the northern part of the Sharda opencast mine in E-W direction. The trench T3 consists of two parts one in the virgin area and another in the worked out area. Highwall face 1 and highwall face 2 are proposed to work the Seam VI top from the highwall of Sharda opencast. The total length of the highwall face in Sharda opencast is 1720 m
- In the Sharda extension opencast trench T2 is planned in NE-SW direction. Highwall face 3 and 4 are proposed in Sharda extension to extract the blocked coal of Seam IV in the highwall. The length of highwall face 3 and 4 is 984 m and 650 m respectively.
- In the virgin area of northern to north eastern side of the property, the trench T4 is proposed in the E-W direction.

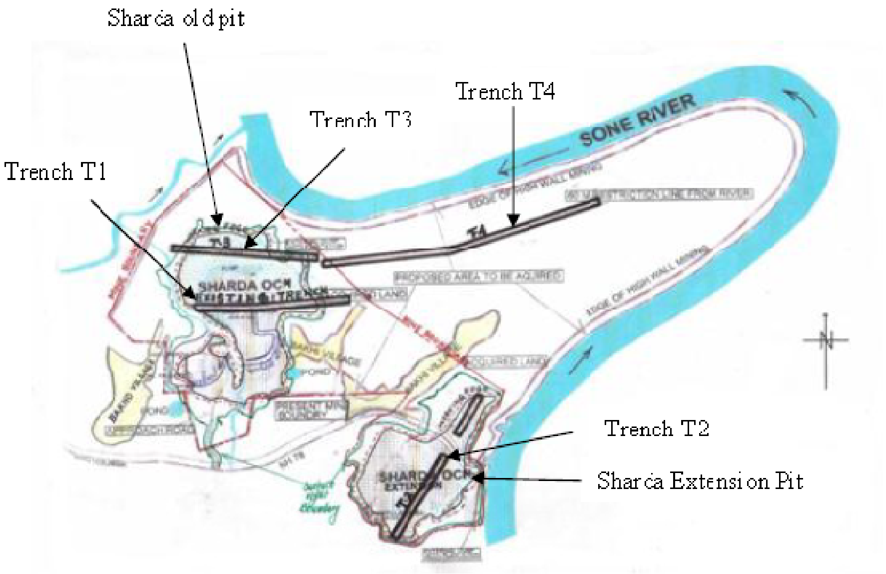

Fig. 2 Mine plan showing location of trenches in Sharda opencast

Operations Stage

Having traversed through time from its conception to execution, to development and hence towards actual mining operations, the Sharda opencast today stands fully operational. The highwall mining at Sharda opencast was started in March 2011 in trench T1. The length of T1 is 1421 m. The trench has been divided into 4 panels, P1x, P2x, P1y and P2y (Fig. 3).The trench T1 is located in Sharda opencast, where about 30 m of overburden was backfilled after extracting the seam VI top.

For construction of T1, the loose over burden has been removed to expose the floor of the Seam VI top. The width of the trench on the surface has been kept more than 120 m. From the floor of the Seam VI top, the trench has been cut by drilling and blasting the parting between the Seam VI top and VI bottom in benches of 6 m wide 6 m high and maintaining a slope of 45º. After extracting the seam VI bottom, the trench T1 has been extended to Seam IV. The minimum width of the trench at the floor of the Seam IV was kept 30 m.

Using the Bucyrus SHM machine, highwall mining has been done on both sides of the trench T1 in Seam VI bottom by driving 2.9 m wide galleries by the highwall miner to an extraction height of 1.35 to 1.42 m. A web pillar of thickness ranging from 1 to 1.2 m has been left between the two adjacent galleries. A barrier pillar of thickness 2 to 3 m has also been left after every 10 galleries. The salient features of the highwall mining design in Seam VI bottom for the trench 1 are presented in tab. 3.

Fig. 3 Proposed panel layout in the Sharda opencast

All the four panels in Seam VI bottom have been extracted successfully. No ground instabilities occurred. The web pillar and barrier pillar were designed after thorough geotechnical investigations and with a very conservative stability factor of over 2.

The trench T1 was cut along the strike of the coal seams and highwall galleries were driven in dip and rise direction perpendicular to highwall. Full depth penetration could not be achieved with this system due to undulation nature of Seam VI bottom. To overcome this problem, orientation of galleries was changed later and galleries were driven in apparent dip rise direction. This resulted in improved penetration depth. An exception was recorded in the form of restrictions imposed on blasting in trench T1 because of close proximity of a village at some portions of T1; this largely delayed the availability of panel faces and coal production.

Currently, mining in Seam IV in trench 1 is in progress. The extraction of Seam IV is being undertaken in the panels P1x, P2x, P1y and P2y (Fig. 3). The salient features of the highwall mining design in Seam IV for the trench 1 are presented in tab. 4. No problem was encountered in Seam IV regarding extraction of galleries to full depth.

Presently, T2 is proposed at Sharda extension opencast to work Seam II having a thickness of 1.25 m. The depth of the Seam II varies from 39 to 46 m from the surface. Here also, the over burden is backfilled during extraction of Seam IV by conventional opencast. It is proposed to work this trench in two panels P3 having length 1180 m and width 214 m and P4 having length 1254 m and width 235 m. The proposed gallery width, web pillar width and barrier pillar width in both the panels is 2.9 m, 1.30-1.35 m, 3.40-3.50 m respectively.

Table 3 Main features of highwall design for Seam VI bottom, Trench 1

Parameters		Panel P1x, m	Panel P2x, m	Panel P1y, m	Panel P2y, m
Panel length		545.00	544.00	877.00	874.00
Panel width		186.00	250.00	228.00	250.00
Cover	Min.	22.28	22.28	26.30	26.3
	Max.	28.51	28.51	40.80	40.80
Seam thickness		1.42	1.42	1.35	1.35
Extraction height		1.42	1.42	1.35	1.35
Gallery width		2.90	2.90	2.90	2.90
Web pillar		1.00	1.00	1.20	1.20
Barrier pillar		2.00	2.00	2.80	3.00
Factor of safety, Web pillar		2.36	2.36	2.35	2.35
Factor of safety, Barrier pillar		2.05	2.05	2.23	2.47
Factor of safety, over all		2.54	2.54	2.62	2.66

Table 4 Main features of highwall design for Seam IV, Trench 1

Parameters		Panel P1x, m	Panel P2x, m	Panel P1y, m	Panel P2y, m
Panel length		545.00	544.00	877.00	874.00
Panel width		196.00	250.00	238.00	250.00
Cover	Min.	47.47	47.47	55.40	55.40
	Max.	56.43	56.43	68.43	68.43
Seam thickness		1.00	1.00	1.15	1.15
Extraction height		1.00	1.00	1.15	1.15
Gallery width		2.90	2.90	2.90	2.90
Web pillar		1.50	1.50	1.80	2.00
Barrier pillar		4.00	4.00	5.00	5.00
Factor of safety, Web pillar		2.32	2.32	2.28	2.58
Factor of safety, Barrier pillar		2.19	2.19	2.11	2.10
Factor of safety, over all		2.72	2.72	2.71	2.97

Also, T3 is proposed on the northern part of the Sharda open cast in E-W direction. It partially falls in the worked out area of Sharda open cast and partially in the virgin area. Two seams, Seam VI bottom having thickness 1.25 m and Seam IV having thickness 1.20 m are available for highwall mining. The depth of the Seam VI bottom from the surface varies from 25.72 to 35.52 m and that of Seam IV varies from 39.35 to 60.29 m. It is proposed to work the patch by two panels, P5 having length 1348 m and width 228 m and P6 having length 1348 m and width 200 m. It is proposed to work Seam VI bottom in both the panels by driving 2.90 m wide gallery and leaving a web pillar of 1 m between two consecutive galleries and a barrier pillar 2.30 m wide after every 10 galleries. The proposed dimension of gallery width, web pillar and barrier pillar width in Seam IV in both the panels are 2.90 m, 1.50 m and 4.50 m respectively.

In the future, T4 is proposed in the virgin area of northern to north eastern side of the property in E-W direction. Three workable seams namely Seam VI bottom having thickness 1 m, Seam IV having thickness 1.30 m and Seam II having thickness 1.50 m are available in the northern side of the trench in panel P7. On the southern side of the trench in panel P8, only two seams namely Seam IV and Seam II are available for highwall mining. The Seam VI B is less than 0.80 m thick in panel P8 and therefore not workable. Two panels, P7 having length 1963 m and width 250 m and P8 having length 1914 m and width 235 m are proposed in this trench. The depth of the Seam VI bottom, Seam IV and Seam II varies from 10.36 to 30.00 m, from 36.05 to 56.05 m and from 59.18 to 75.50 m respectively. The proposed gallery width in both the panels in all the three seams is 2.90 m. The proposed width of the web pillar for Seam VI B is 0.80 m, for Seam IV is 1.3 m and for Seam II is 2.00 m. The proposed barrier pillar widths for Seam VI bottom, IV and II are 1.20 m, 3.59 m and 6.50 m respectively.

Highwall mining in T1 has been a learning experience of Indian engineers. The mining environment has provided unfailing and most amenable governing parameters to deploy the highwall technology and achieve safe production of around 0.6 million tonnes of coal in the initial stage.

4 Conclusions

Sharda project offers a duel advantage to the mining community while having being considered as a model installation of highwall mining in India. Firstly, it has its already retired pits comprising of seams which exhibit amenable characteristics for highwall deployment. Secondly, the virgin area provides the possibility of adopting the highwall mining technique at the end of the planned opencast mining operations. This entails to visualizing at the mine planning stage the post-opencast operations, wherein the possibility of deploying highwall technique as an end-measure can be considered. Thus, such consideration of pre-planned highwall deployment in a new mining project allows the mining engineer to design and plan all the facilities in accordance with safety, implementation of the highwall operations, better utilization of resources and also attempting to maximize the recovery of the coal.

The Sharda highwall mining project with estimated coal reserves of 15.7 million tonnes has provided an impetus to the Indian coal mining industry. This project is characterized with most of the favourable characteristics in the introduction of highwall technology. In its highwall operations, with an exception, there have been affirmative signals of project execution, production, implementation and safety. The numerical modelling coupled with thorough structural analysis has provided a secure mining design, although at a higher safety factor. There have been no occurrences of roof stress signals, failures, or other deterrent indications. Sharda highwall mining project thus presents the most encouraging scenario of introducing this technology extensively and reliably throughout India.

It is in succession to this Sharda project that major coal producing companies like Coal India Ltd, Singreni Collieries Company Ltd. and Tata Steel have steadfastly identified some projects where this technology can be deployed. The SCCL also has the highwall venture in operational stage at Ramagundam II opencast project. Initial results have indicated success alongside admirable productivity. The highwall mining finds an intrinsic benefit of being deployed for the thin seams which are rated as unminable. India has a significant amount of coal blocked in thin seams and in the highwalls of abandoned existing coal mines. With highwall mining such precious resource can be best recovered.

Acknowledgements. The views expressed in this paper are that of authors and not necessarily of the organisation they belong to. Thanks are due to management of M/s SECL and NIT Raipur for their valuable cooperation in preparation of this paper.

References

[1] Official Website of Reuters (U.K.), RPT-India coal imports hit record high on slow domestic output-sources (May 8, 2013), `http://uk.reuters.com/article/2013/05/08/india-coal-imports-idUKL3N0DP4NL20130508` (August 25, 2013)

[2] Official Website of Reuters (U.K.), India's thermal coal output up 3.3 pct y/y in 2012/13-source (April 22, 2013), `http://www.reuters.com/article/2013/04/22/india-coal-output-idUSL3N0D92RH20130422` (August 25, 2013)

[3] Highwall Mining in India: Challenging Opportunities, `http://www.miningengineeringhub.com/presentationhighwallmining.pptx` (August 25, 2013)

[4] Carr, I., Hari Prasad, P.: Highwall Mining-Current Technology Trends– Opportunity in India (unpublished)

[5] Prasanta, C.: Highwall Mining- A Mass Production Technology for Safe Extraction of Blocked Coal. In: Mine Tech 2007: National Seminar on Mining Technology-Present and Future, Bhubaneswar, India (2007)

[6] Dixit, S.: An Innovative Approach - Highwall Mining in India. In: International Seminar on Advances in Management, Technology and Engineering Science, Bangkok, Indonesia (2012)