SUBSIDENCE PREDICTION REPORT

(THROUGH 3-D NUMERICAL MODEL)

BHATGAON UG PROJECT

SOUTH EASTERN COALFIELDS LIMITED

CHHATTISGARH(INDIA)

DEPARTMENT OF MINING ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY
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JUNE 2017

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1.0 INTRODUCTION

Bhatgaon Underground project of South Eastern Coal fields Ltd. Is situated in Bisampur coal field in Surajpur District of Chhattisgarh. Bord and pillar system of mining will be adopted to extract coal from underground mine.

1.1 LOCATION & COMMUNICATION

The Bhatgaon block is located towards the North-western corner of Bisrampur coal fields and is bounded by latitudes $23^0 21$'N to $23^0 23$'N and longitudes $82^0 58$'E to $83^0 02$'E. The colliery is situated about 23 kms to the north of the Bisrampur Colliery.

The nearest rail head is Karonji on Manendragarh-Bijuri-Bisramapur Branch line of South Eastern Railway, which is about 15 Km to southwest of the colliery. Ambikapur-Varnasi fair weather road passes at a distance of about 4 Km from the project.

1.2 TOPOGRAPHY

In common with the rest of Bisrampur Coalfield, the Bhatgaon area is an undulating plain with general elevation varying from 550 to 570 m above M.S.L. The general slope of the area is towards Masan nallah. Patpahari ridge in the western part and Bisahi hill in the north are two small elevation in the area.

1.3 DRAINAGE

Drainage of the area is controlled by Rehar river in the western part and Mahan river in the east. Streamlets know as Masan nala, Kudaria nala, chotagobri nala etc. drain the area into the above two rivers.

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1.4 FOREST COVER AND LAND FORM

The surface of the underground mine is partly covered with forest land. The remaining area is either private land or owned by the company. Some area of the mine is covered by loose strata ground where pot holes are likely to be formed.

1.5 CLIMATE

Based on the observation at Ambikapur for 10 years, the wind direction normally is from north and north-east to south and south-west. The wind speed normally is 6 to 10 km/hr. The total annual rainfall is about 1400 mm.

2.0 GEOLOGY

The area is mostly cover of variable thickness. The Barakar formation is generally composed of coarse grained sandstone with few lenticular pebble beds. The talcher is generally composed of greenish grey siltstone and shale and is exposed in the Gobrinala towards South and Babamara nallah towards west of Bhatgaon Colliery. The generalised stratigraphic sequence of the area is as follows:

Recent	Alluvium	
Cretaceous to Eocene	Intrusive	Basic dyken
Lower Premian	Barakars	Coarse grained to fine grained cross-bedded felspathic sandstone with sandy shale, shai and coal seams.
Upper Carboniferous	Talchirs	Dark grey to greenish grey shales and siltstones
-- Unconformity --		
Pre-Cambrian	Metamorphics	Grainte Gneisses and quartzites.

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The dip of the coal seams is towards East and North-East and the amount being 1 in 28 to 1 in 40. Rolling dips are quite common as has been observed in the underground workings of Upper Patpahri Seam. The block is comparatively free from major geological disturbances. A total of 8 faults have been interpolated in determining the structure of the area on the basis of sub-surface data and underground workings.

The most persistent coal seam i.e. Upper Patpahri Seam over the occurs as a pair with the lower Patpahri seam over the major part of the area, thus facilitating identification the Masan Seam where present, is of very good quality and maintains a parting of about 24 to 32 m with the upper patpahri seam

3.0 METHOD OF WORKING

Bord and pillar method of work was adopted by the project authorities after the earlier proposed method of longwall with caving did not work out to be feasible due to shallow depth cover.

4.0 PERIOD OF PREDICTION

The time period for the prediction of subsidence required is 12 years as given by the company.

Stage-I	5 years
Stage-II	10 years
Stage-III	End of Mining

4.1 SIMULATION FOR PREDICTION

The natural mining has to be simulated before it can lend itself to the numerical modeling. As the first step, Fig. 1 is a simulated grid map of the proposed mining area of Bhatgaon Project in terms of contours of the surface profile. Fig. 2 and Fig. 3 is the

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simulated grid map of the workings of the Upper Patpahri Seam and Lower Patpahri Seam. The simulated mine plan has a scale of 1:4000, same as that provided by the mining company.

Table 4.1 gives the co-ordinates of few boreholes on the simulated grid maps, which can be used for the studying, and analyzing of all the maps provided by us.

Table 4.1: Co-ordinates of some boreholes on the simulated grid map.

S.L. No.	Bore hole No.	X-Co-ordinate (m)	Y-Co-ordinate (m)
1	NCBM-25	796	860
2	NCBM-26	1390	870
3	CBBB-32	1878	1720
4	CBBB-44	344	2072
5	CGBH-8	2288	1048

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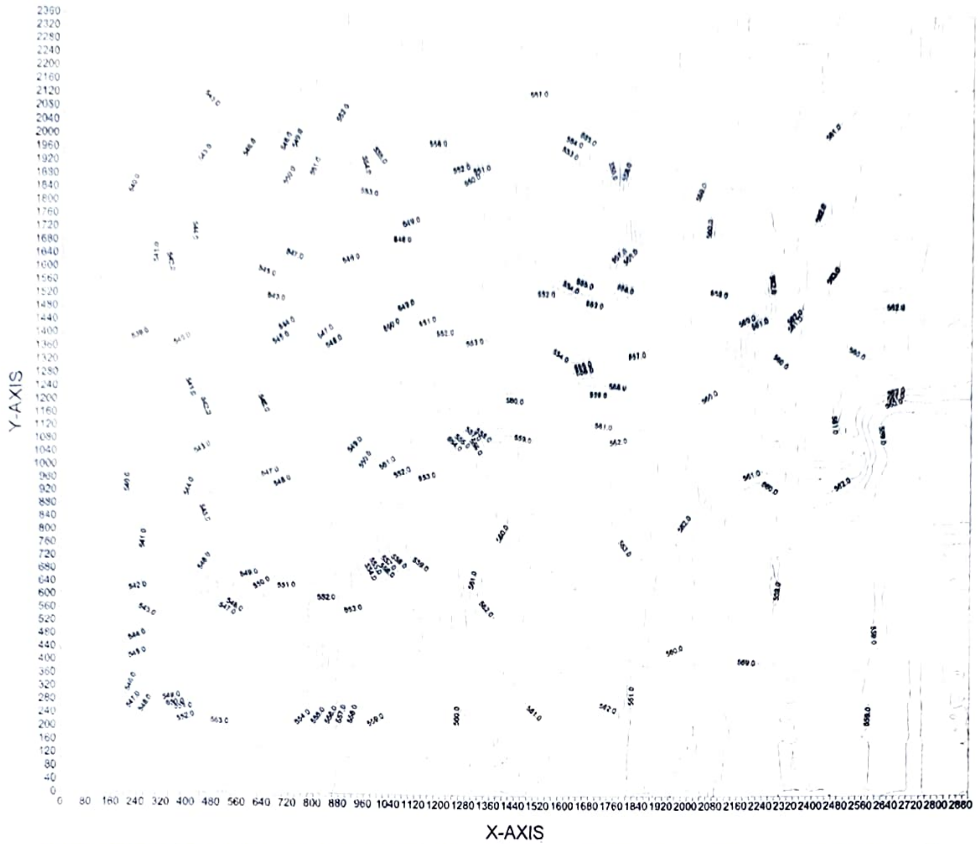

FIG.1 SURFACE CONTOURS BEFORE MINING (BHATGAON UNDERGROUND PROJECT)

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FIG. 2 SIMULATED GRID MAP OF UPPER PATPAHRI SEAM (BHATGAON UNDERGROUND PROJECT)

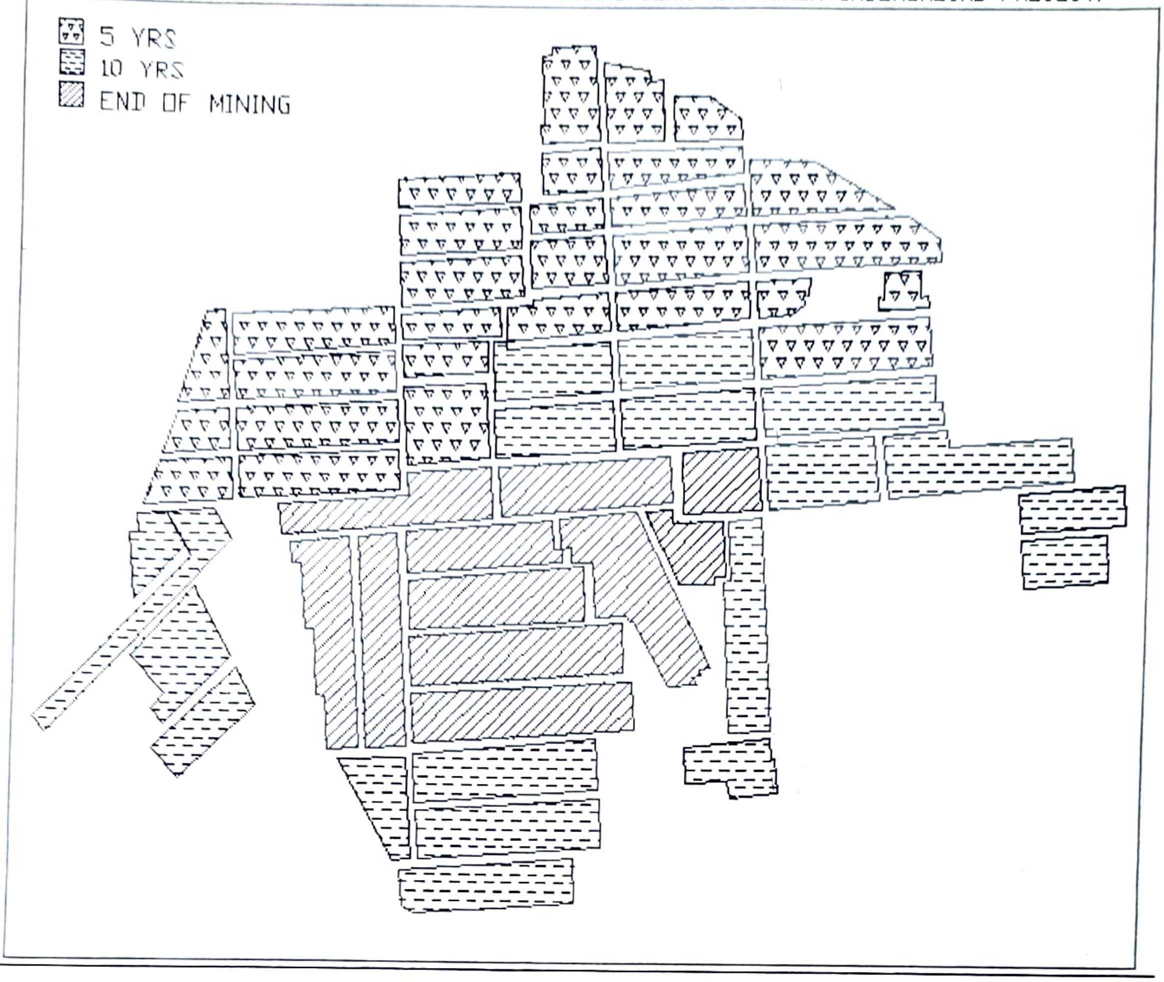

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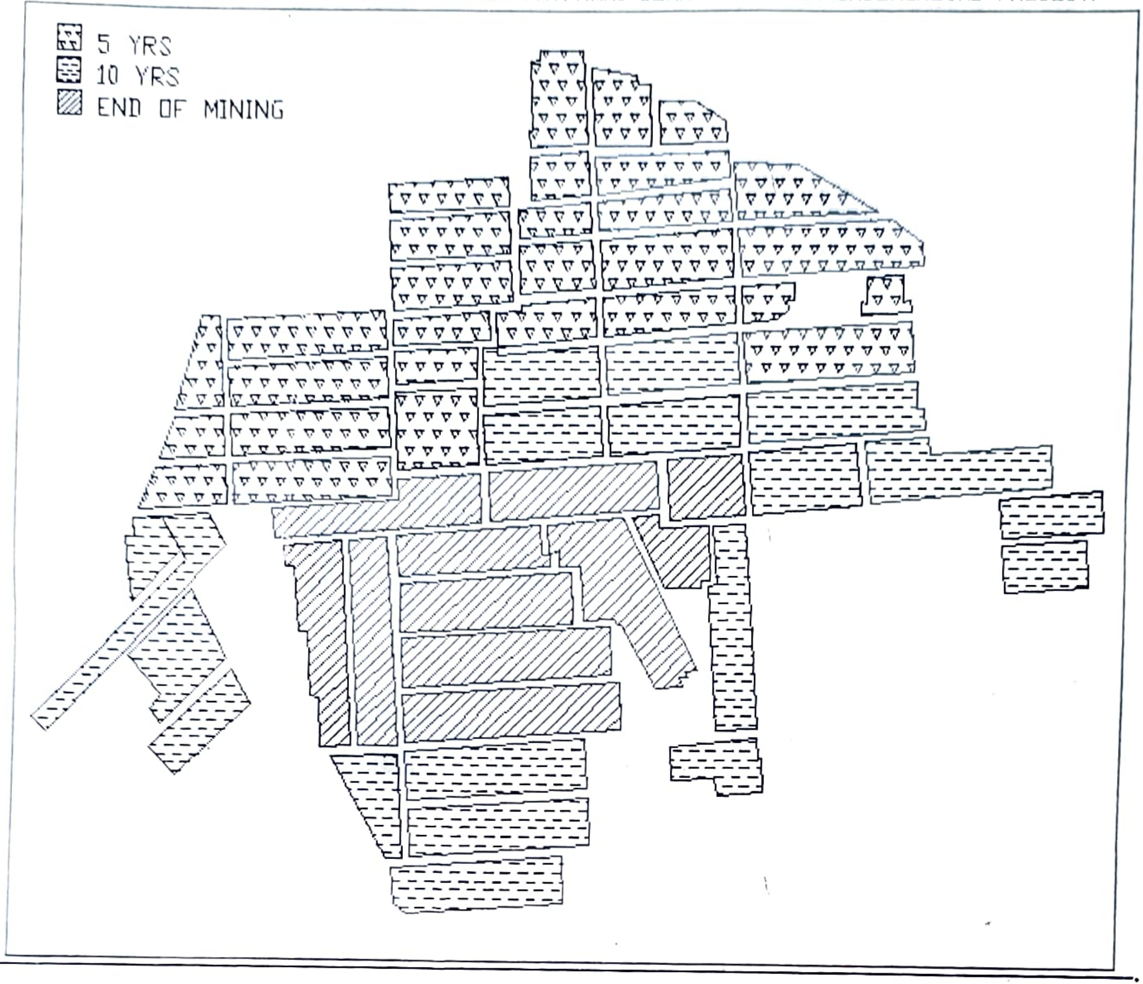
FIG. 3 SIMULATED GRID MAP OF LOWER PATPAHRI SEAM (BHATGAON UNDERGROUND PROJECT)



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4.2 REQUISITE GEOTECHNICAL PARAMETERS FOR THE PREDICTION

The numerical prediction of subsidence requires following basic data:

1) Geotechnical parameters of the seam and surrounding rock mass upto the surface,
2) Mathematical model and computer programs (software)
3) Major structural features of the strata,
4) Details of the mine excavation
5) Sequence of extraction and size of panels, and
6) Important features on the surface.

The information on the above mentioned parameters were provided by the company. The company also provided the data for the physico-mechanical properties used in the simulation. The above properties were taken for various panels as per their proximity to the above boreholes in the block. The boreholes nearest to the panels were considered to be representative one and hence selected for the simulation.

4.3 PREDICTION TECHNIQUE

The computer-simulated model was developed for the prediction of subsidence and alterations in the resulting profile of the surface, keeping in mind the total area, the mining sequence and geo-technical properties and above all, depth of each mining panel, which varies significantly from panel to panel. The grid map for simulation is based on 20 m grid on the surface having about 18000 points for calculation process using finite element method (FEM) – a numerical simulation technique. The computation for prediction of subsidence of the area is based on the grid pattern. The 3-D mathematical model, thus

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simulated was subjected to the finite element analysis. The model also takes care of the non-linear behaviour of the rock mass (if any), bed separation and its recontact.

5.0 RESULT

5.1 PREDICTED SUBSIDENCE CONTOURS

Fig. 4 shows the subsidence contours after 5 years of mining. Similarly, Fig. 5 and Fig. 6 give the subsidence contours at the end of 10 yerar and end of mining, respectively. The maximum values of the subsidence predicted at the end of each time blocks are given in Table 5.1.

Table 5.1: **Maximum values of predicted subsidence at the end of mining.**

Sl. No.	Year	Subsidence values, m
1.	5	1.414
2.	10	1.492
3.	End of mining	1.875

5.2 THREE DIMENSIONAL PROJECTIONS OF SUBSIDENCE

To give a 3-dimensional impact of the subsidence, the predicted subsidence has been projected on the surface for each of the mining period based on X and Y coordinate defining the horizontal plane and 'Z' coordinate, the depth of the surface. It may be noted that the 'Z' coordinate has been exaggerated (20 times) to have a better visual appreciation of the impact of subsidence.

Figs. 7 though 9 give prediction of the subsidence at the end of 5, 10 and end of mining respectively, considering the surface to be horizontal, before mining. These figures give a real feel of the impact of subsidence as a result of the progression of mining with

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time. Two sets of subsidence figures are provided for each stage. These are having opposite viewing directions, *i.e.* 45° and 225°. It may be pointed out at this stage that the 3-dimensional projections shown in the Figures 7 through 9 should not be used to pin point the maximum subsidence area because all the points may not be visible on the map. However, these drawings provide fairly accurate idea about ground behavior after mining.

It is worth noting that the troughs shown in the figures should be viewed in the proper perspective as the scale in '*Z*' direction has been enlarged to 20 times to have appreciable viewing impact.

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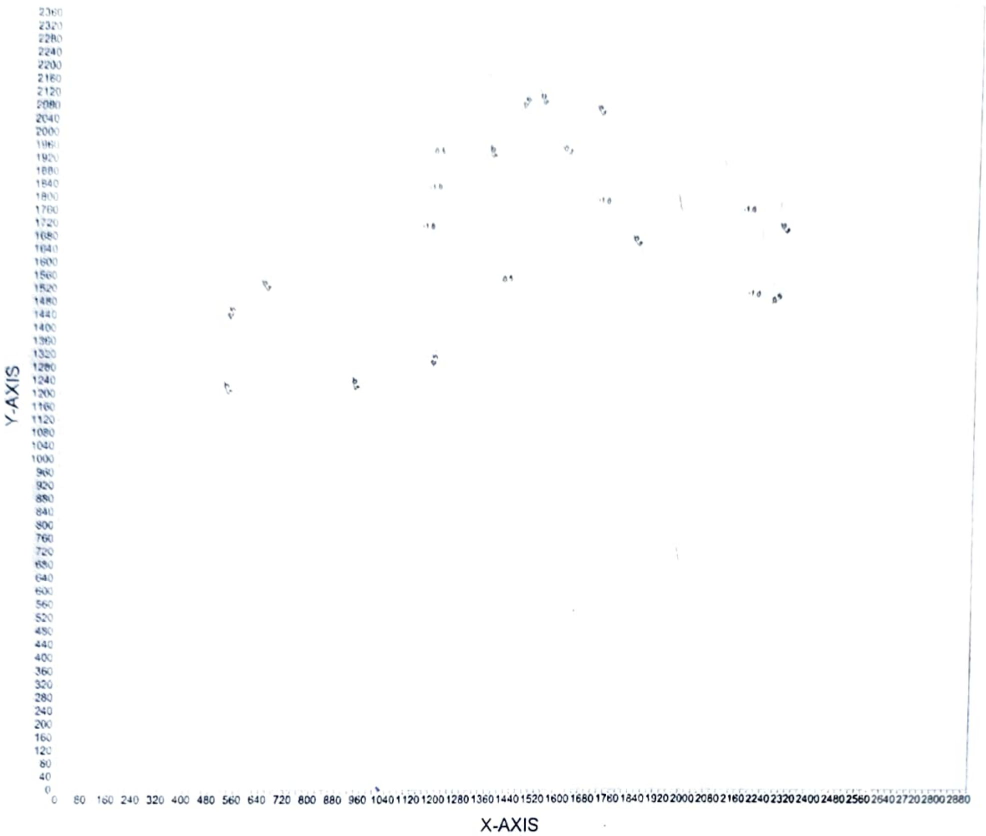

FIG.4 SUBSIDENCE CONTOURS AFTER 5 YRS OF MINING (BHATGAON UNDERGROUND PROJECT)

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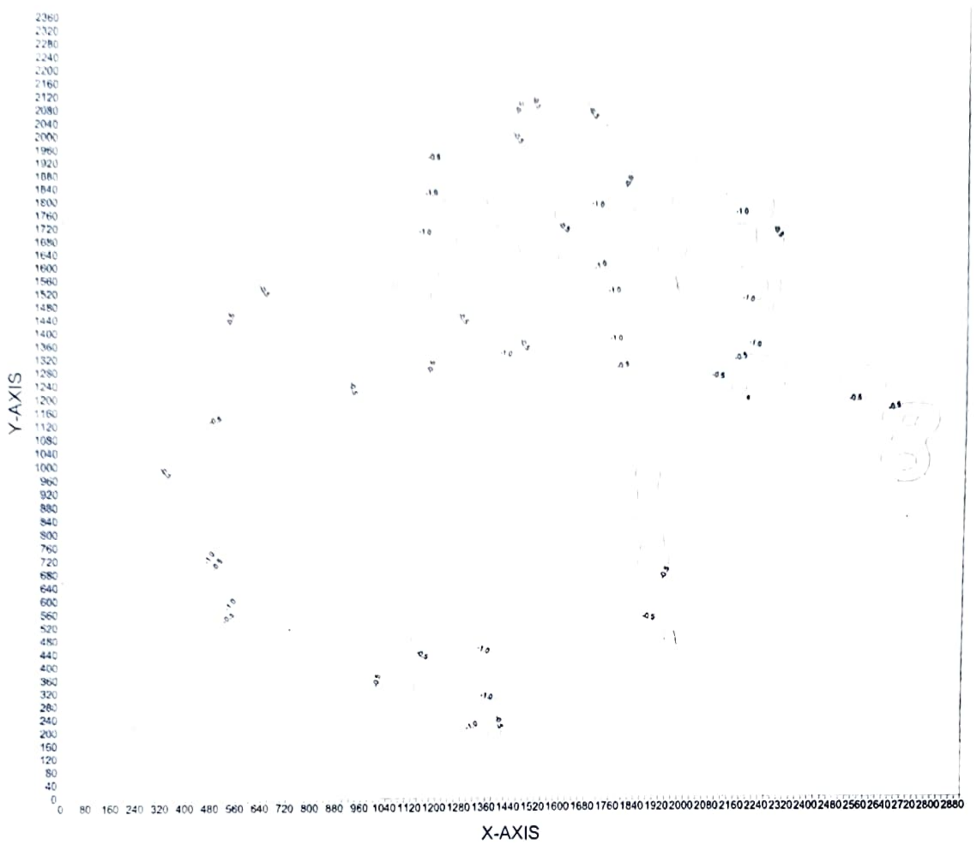

FIG.5 SUBSIDENCE CONTOURS AFTER 10 YRS OF MINING (BHATGAON UNDERGROUND PROJECT)

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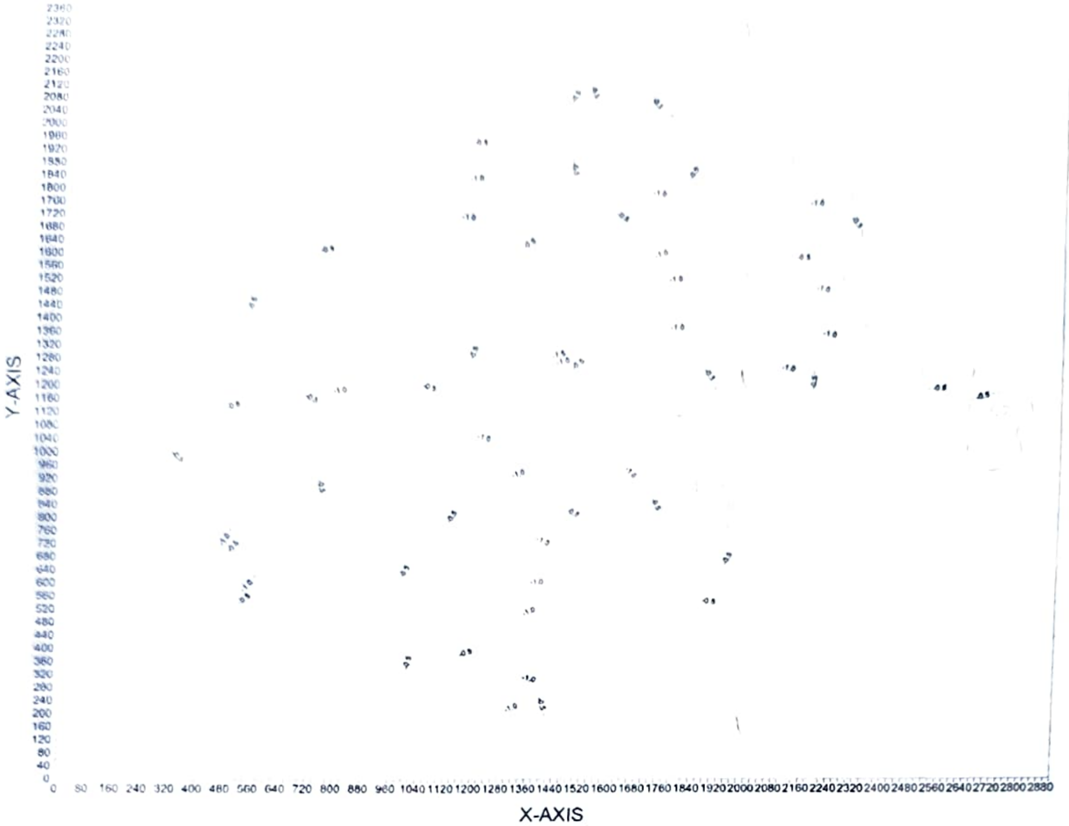

FIG.6 SUBSIDENCE CONTOURS AFTER END OF MINING (BHATGAON UNDERGROUND PROJECT)

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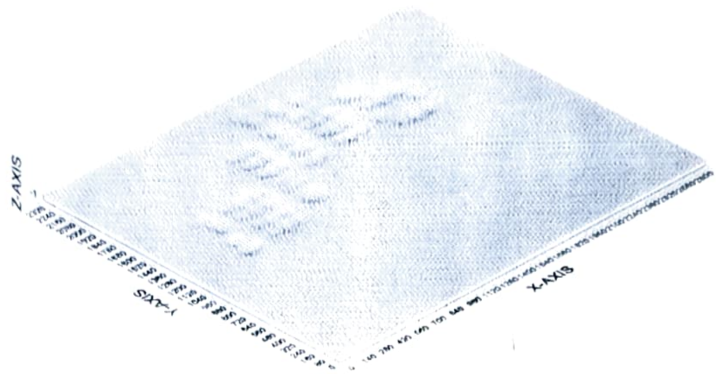

FIG.7a SUBSIDENCE PROFILE AFTER 5 YRS OF MINING (BHATGAON UNDERGROUND PROJECT)

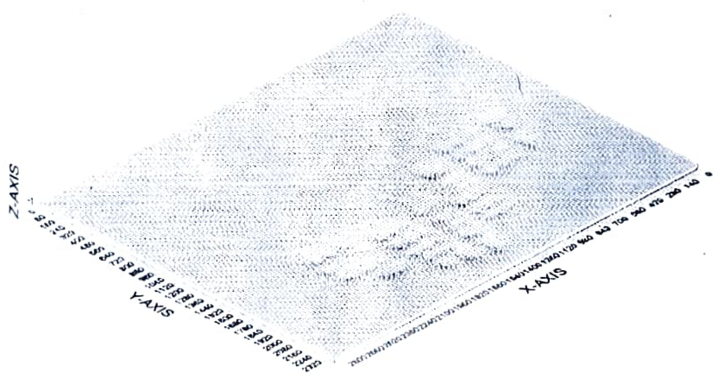

FIG.7b SUBSIDENCE PROFILE AFTER 5 YRS OF MINING (BHATGAON UNDERGROUND PROJECT)

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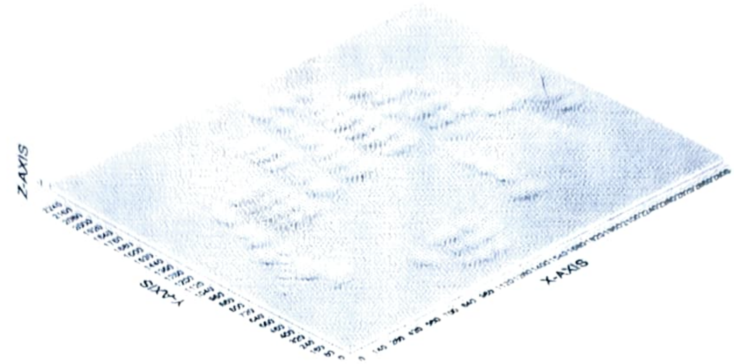

FIG.8a SUBSIDENCE PROFILE AFTER 10 YRS OF MINING (BHATGAON UNDERGROUND PROJECT).

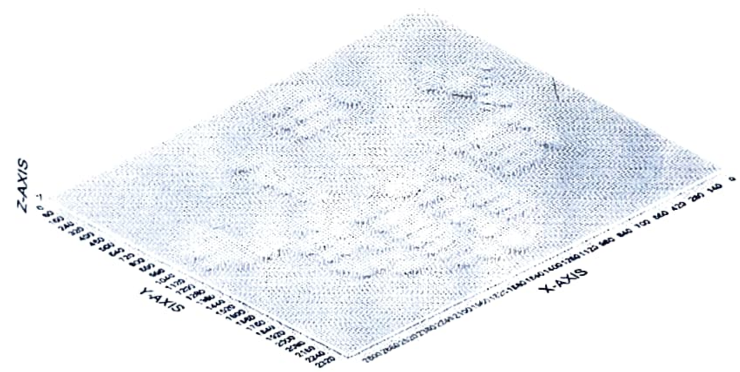

FIG.8b SUBSIDENCE PROFILE AFTER 10 YRS OF MINING (BHATGAON UNDERGROUND PROJECT).

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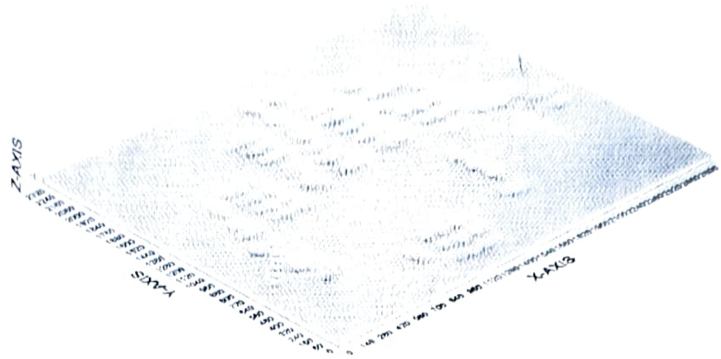

FIG.9a SUBSIDENCE PROFILE AFTER END OF MINING (BHATGAON UNDERGROUND PROJECT).

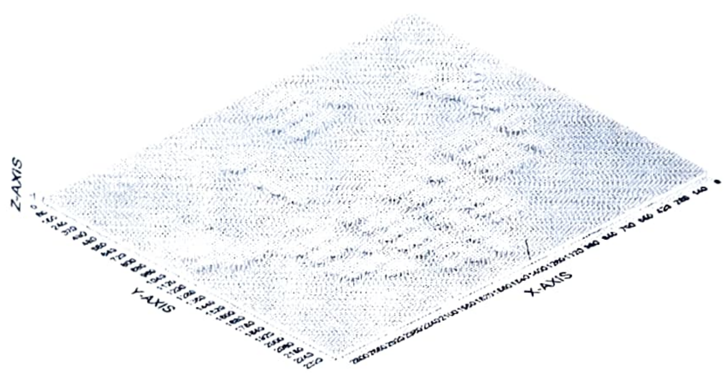

FIG.9b SUBSIDENCE PROFILE AFTER END OF MINING (BHATGAON UNDERGROUND PROJECT).

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5.3 SURFACE PROFILE

The surface profiles of the mining block after each stage of mining have also been predicted. These profiles have been obtained by superimposing subsidence with pre-mining surface profile after each mining sequence for different time blocks. Fig. 1 gives the surface profile of the mining block before mining. The contour maps which would finally emerge as a result of mining after 5, 10 and end of mining have been predicted and are shown in Fig. 10 through Fig. 12.

Fig. 13 shows the 3-dimensional prediction of surface profile before mining for the Bhatgaon Project. Figs. 14 though 16 give the 3-dimensional prediction of surface profile at the end of each mining sequence (the 'Z' axis has been exaggerated to 10 times for having better visual appearance of the impact of subsidence). A set of figures showing surface subsidence and surface profile at the end of each stage of mining is also being provided in larger sizes at a scale of 1:4000. The surface contours along with the panels of the seam are also being provided in larger sizes *i.e.,* at a scale of 1:4000.

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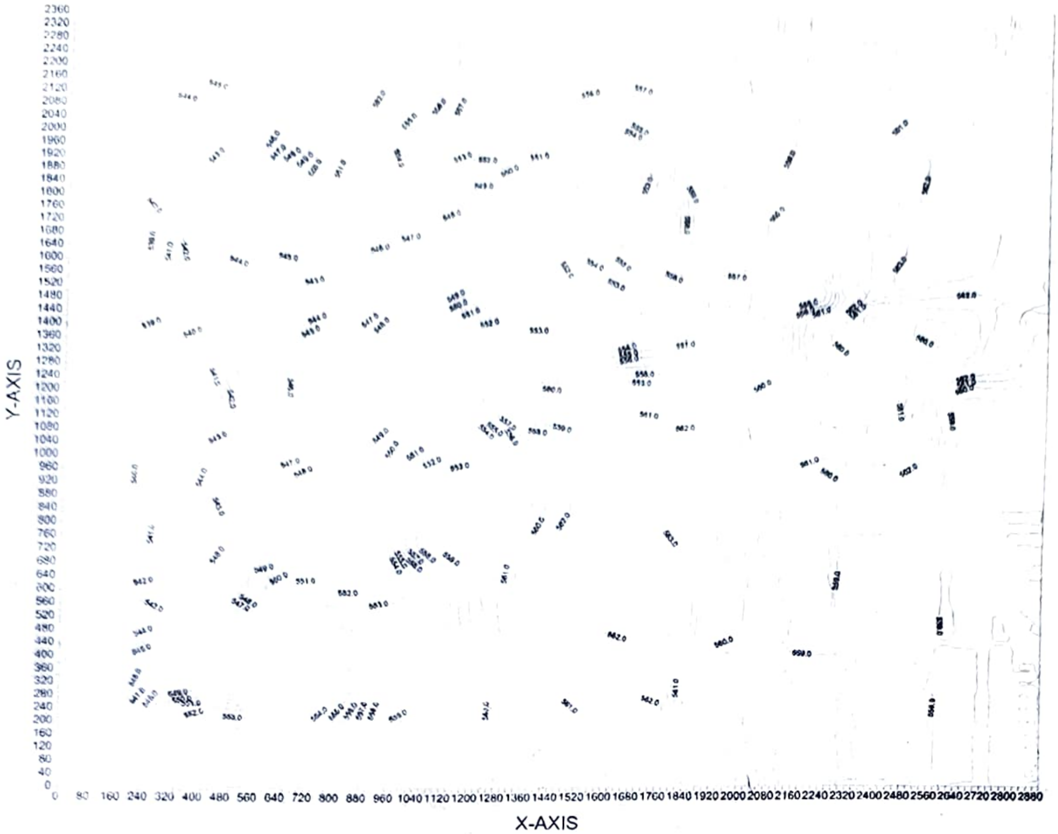

FIG.10 SURFACE CONTOURS AFTER 5 YRS OFMINING (BHATGAON UNDERGROUND PROJECT).

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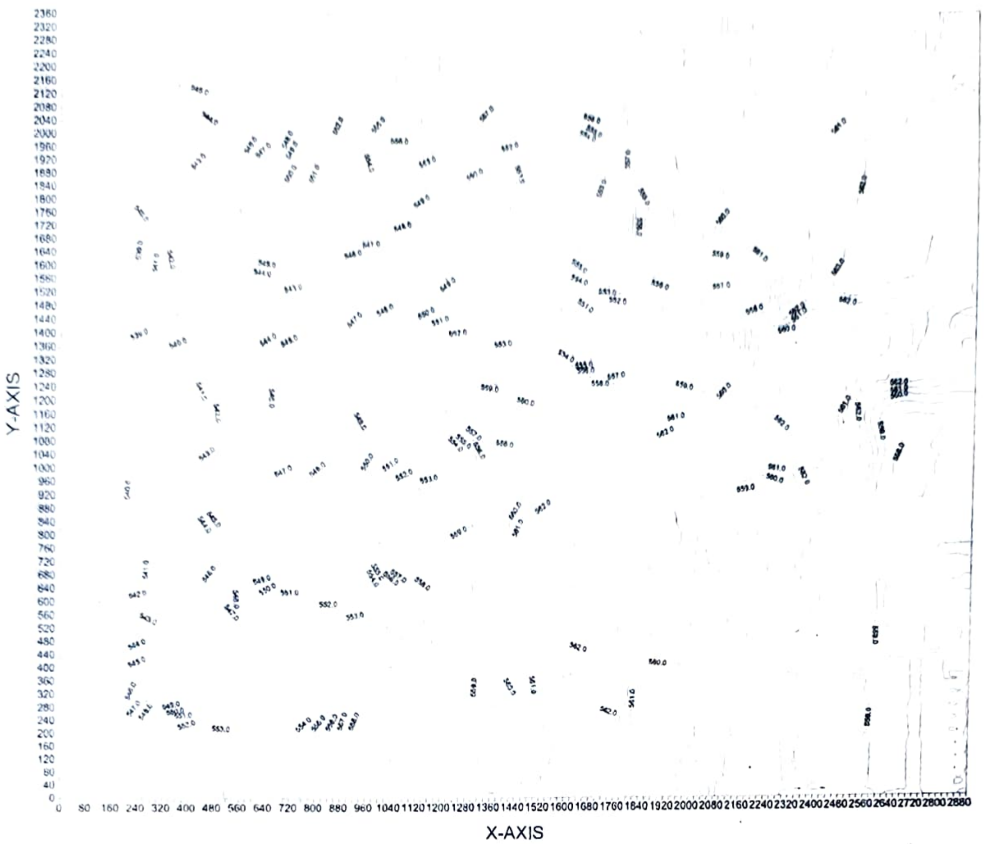

FIG.11 SURFACE CONTOURS AFTER 10 YRS OF MINING (BHATGAON UNDERGROUND PROJECT)

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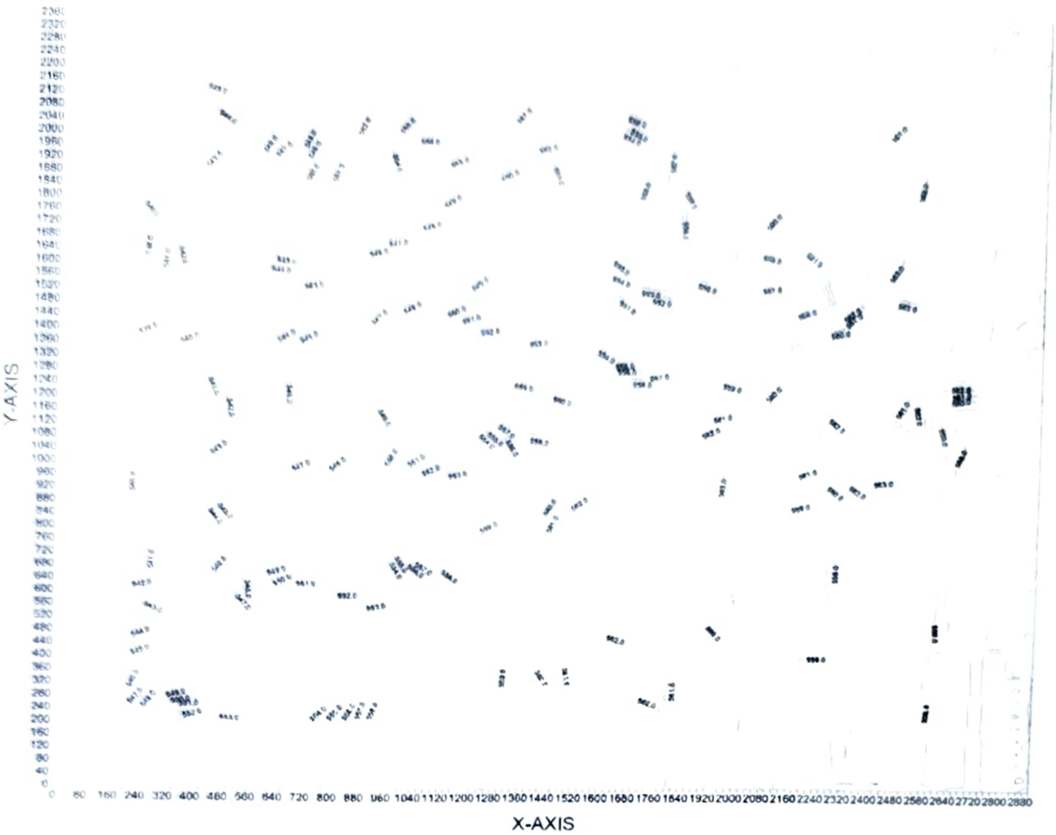

FIG.11 SURFACE CONTOURS AFTER 10 YRS OF MINING (BHATGAON UNDERGROUND PROJECT)

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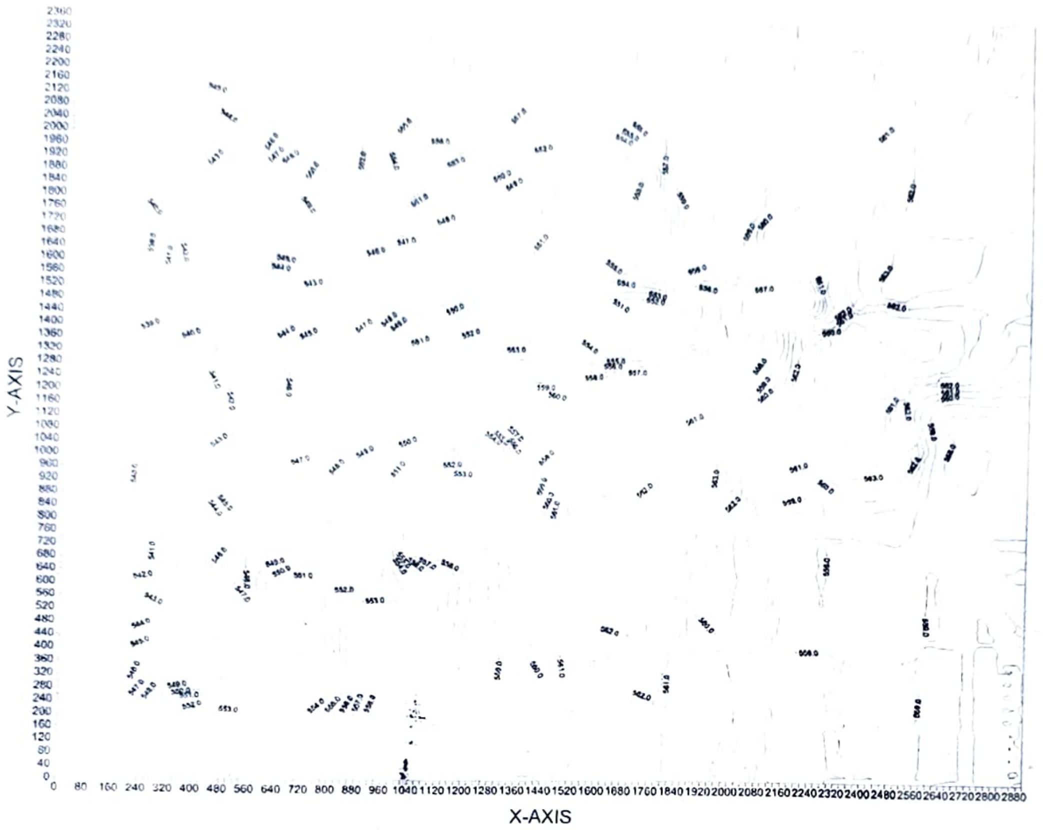

FIG.12 SURFACE CONTOURS AFTER END OF MINING (BHATGAON UNDERGROUND PROJECT)

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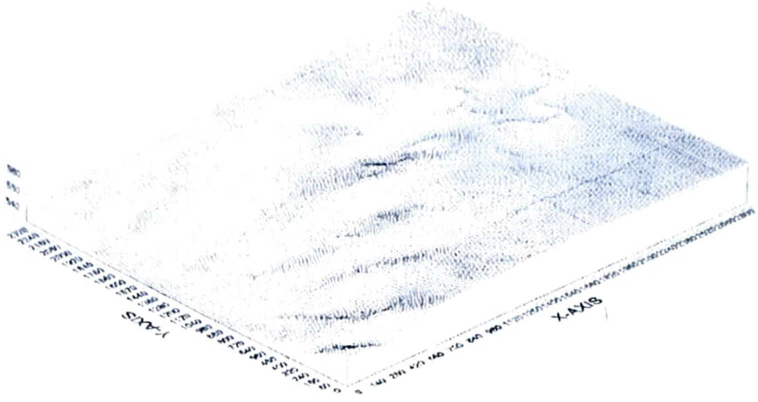

FIG.13a SURFACE PROFILE BEFORE MINING (BHATGAON UNDERGROUND PROJECT)

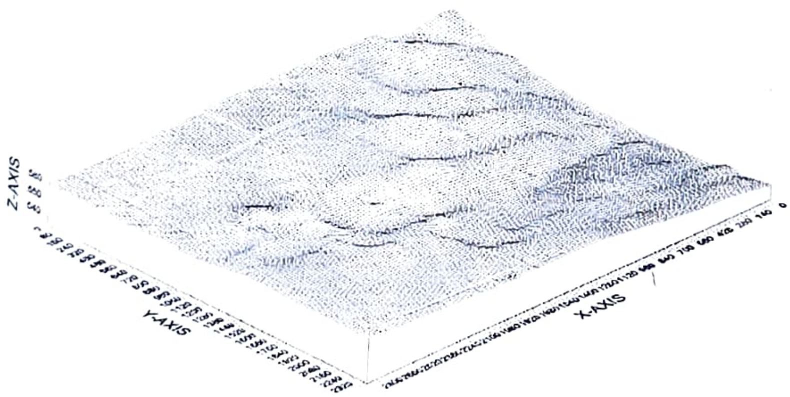

FIG.13b SURFACE PROFILE BEFORE MINING (BHATGAON UNDERGROUND PROJECT).

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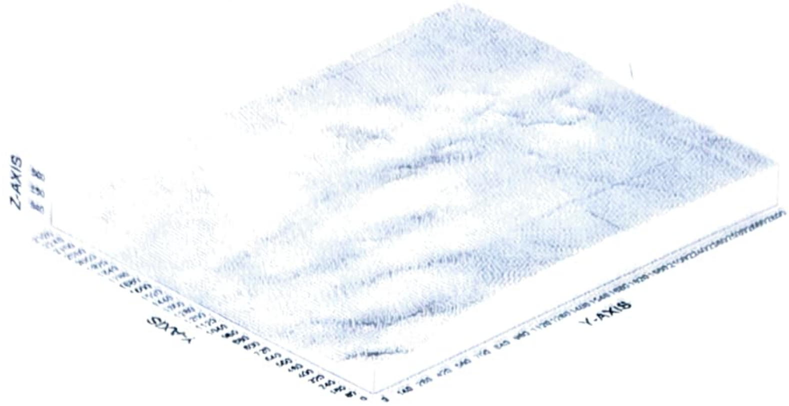

FIG.14a SURFACE PROFILE AFTER 5 YRS OF MINING (BHATGAON UNDERGROUND PROJECT)

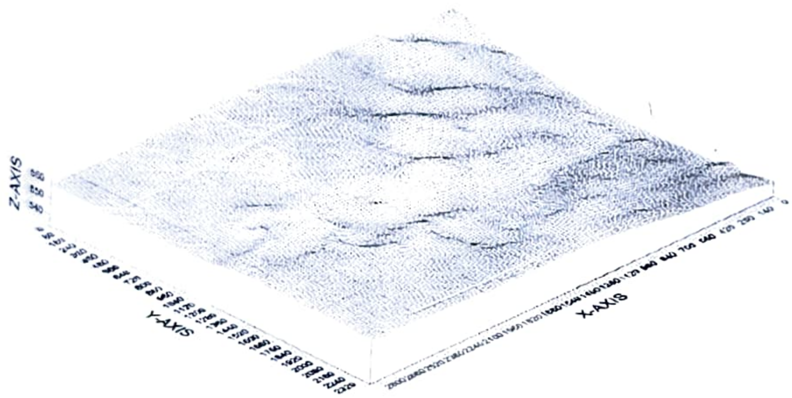

FIG.14b SURFACE PROFILE AFTER 5 YRS OF MINING (BHATGAON UNDERGROUND PROJECT).

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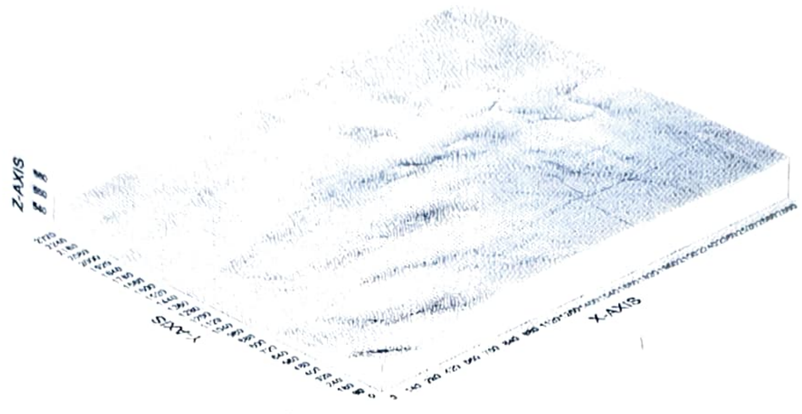

FIG.15a SURFACE PROFILE AFTER 10 YRS OF MINING (BHATGAON UNDERGROUND PROJECT)

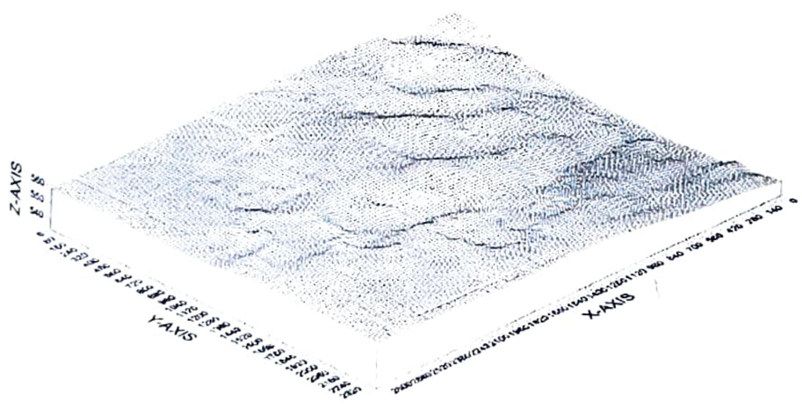

FIG.15b SURFACE PROFILE AFTER 10 YRS OF MINING (BHATGAON UNDERGROUND PROJECT).

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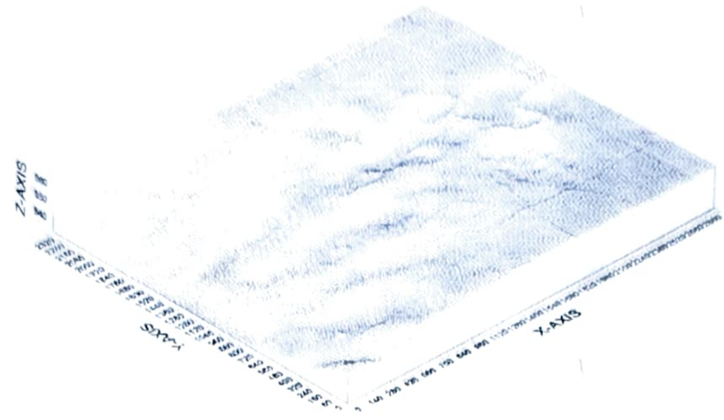

FIG.16a SURFACE PROFILE AFTER END OF MINING (BHATGAON UNDERGROUND PROJECT)

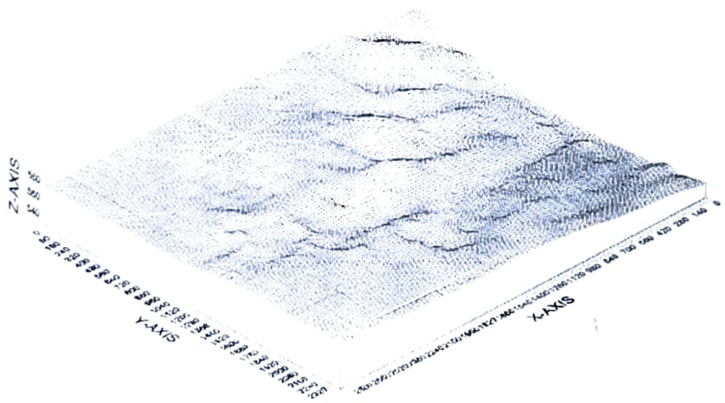

FIG.16b SURFACE PROFILE AFTER END OF MINING (BHATGAON UNDERGROUND PROJECT)

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6.0 TENSILE STRAIN AND CRACK WIDTH

6.1 MAXIMUM TENSILE STRAIN

The maximum predicted tensile strain for Bhatgaon Project for various time blocks has been given below in table 6.1.

Table 6.1: Predicted maximum tensile strain for Bhatgaon Project at various time blocks

l. No.	Time Block (in years)	Tensile Strain (mm/m)
1.	5	24.46
2.	10	28.56
3.	End of mining	30.58

The maximum predicted tensile strain has been predicted for each time block separately and is 30.58 mm/m at the end of mining.

6.2 CRACK

It is well established from the field experience that the cracks may occur under the condition of high tension and weak rock. The prediction of cracks width is associated with high degree of uncertainty. Zones of possible cracks will be in the vicinity of weak rocks and near fault planes under high tensile strain. To have accurate prediction, the strain maps should be superimposed over the detailed geological plan with geotechnical data. Cracks of width more than 300 mm/m are likely to be formed due to extraction of the panels in this project.

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7.0 DISCUSSION

The extraction of coal is likely to result in subsidence on the surface. The strata condition in part of the mine is also having very weak and loose formation. The peak subsidence is likely to be 1.414 m at the end of 5 years of mining, 1.492 m at the end of 10 years of mining and 1.875 at the end of mining. The peak horizontal strain is likely to be 24.46 mm/m at the end of 5 years of mining, 28.56 mm/m at the end of 10 years of mining and 30.56 mm/m at the of mining. Wide cracks are also likely to be formed on the surface. Therefore, it needs a subsidence management plan to tackle the subsidence in forest area, area having loose strata and remaining land. Keeping above discussion in mind, the surface land has been divided into three category i.e., forest area land, weak strata land and remaing land.

Fig. 17 shows the forest cover on the surface. This map has been superimposed with the working panel plan. It is shown in the Fig. 18 the panels coming under forest can be identified. The surface of the mine is likely to experience subsidence resulting into horizontal tensile strain and crack width more than the permissible limits. It is suggested that the panels coming under forest cover should not be depillared completely. Either it should be developed and left as such or it should be partially depillared (with permission from DGMS).

Fig. 19 also shows the panels having weak strata. The panels coming having weak strata will result into pot holes. Therefore, these panels should not be depillared. The development work should also be done with caution.

Cracks are likely to be formed on the surface of remaining land. The surface should be inspected daily beneath which underground depillaring is being carried out. The cracks should be regularly filled so that underground workings do not breathe air.

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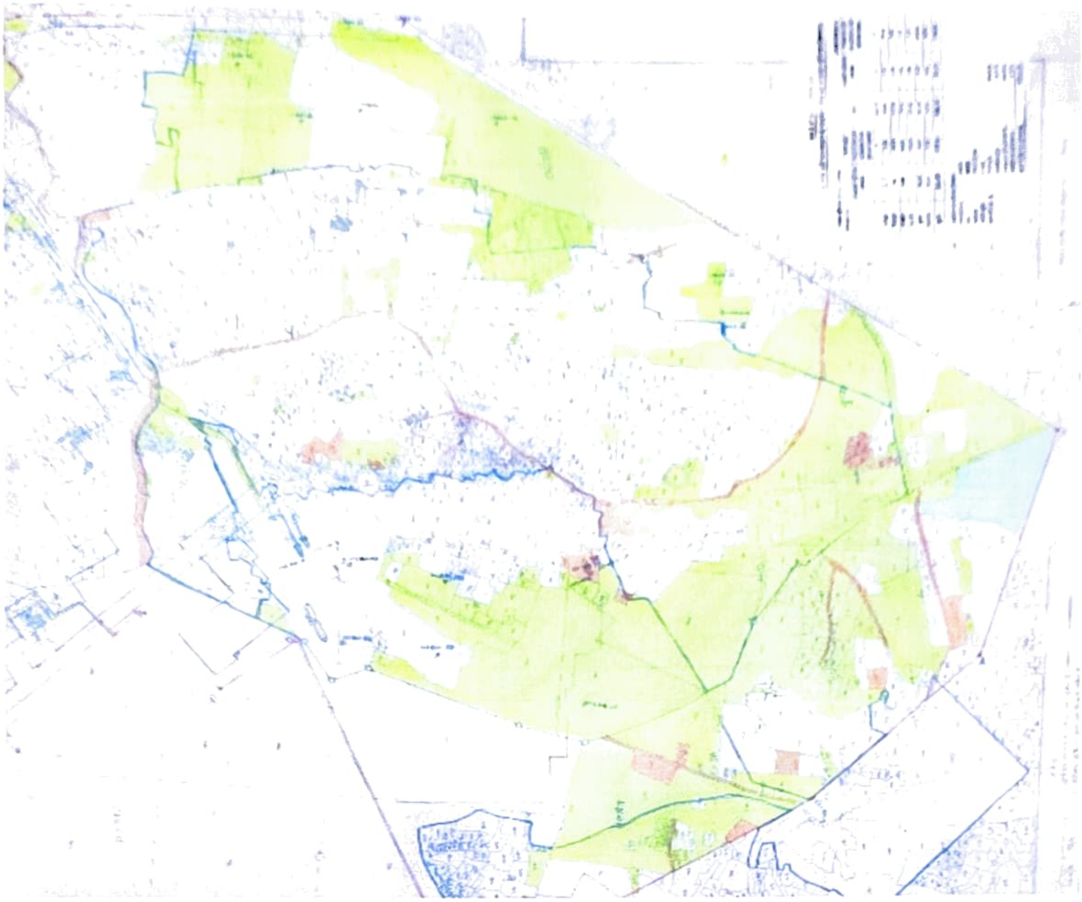

Fig. 17 : Forest cover on the surface.

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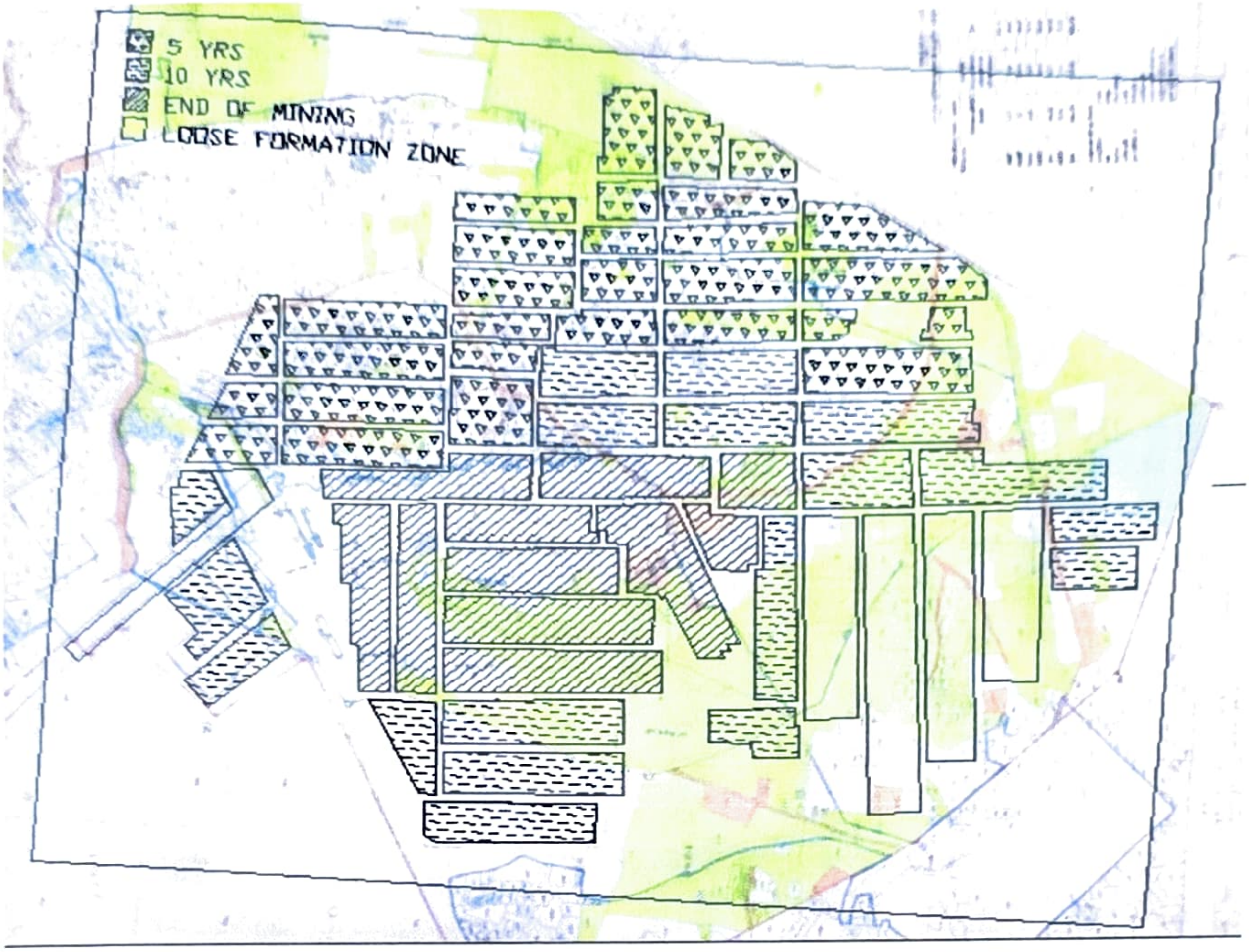

Fig. 18 : The panels coming under forest

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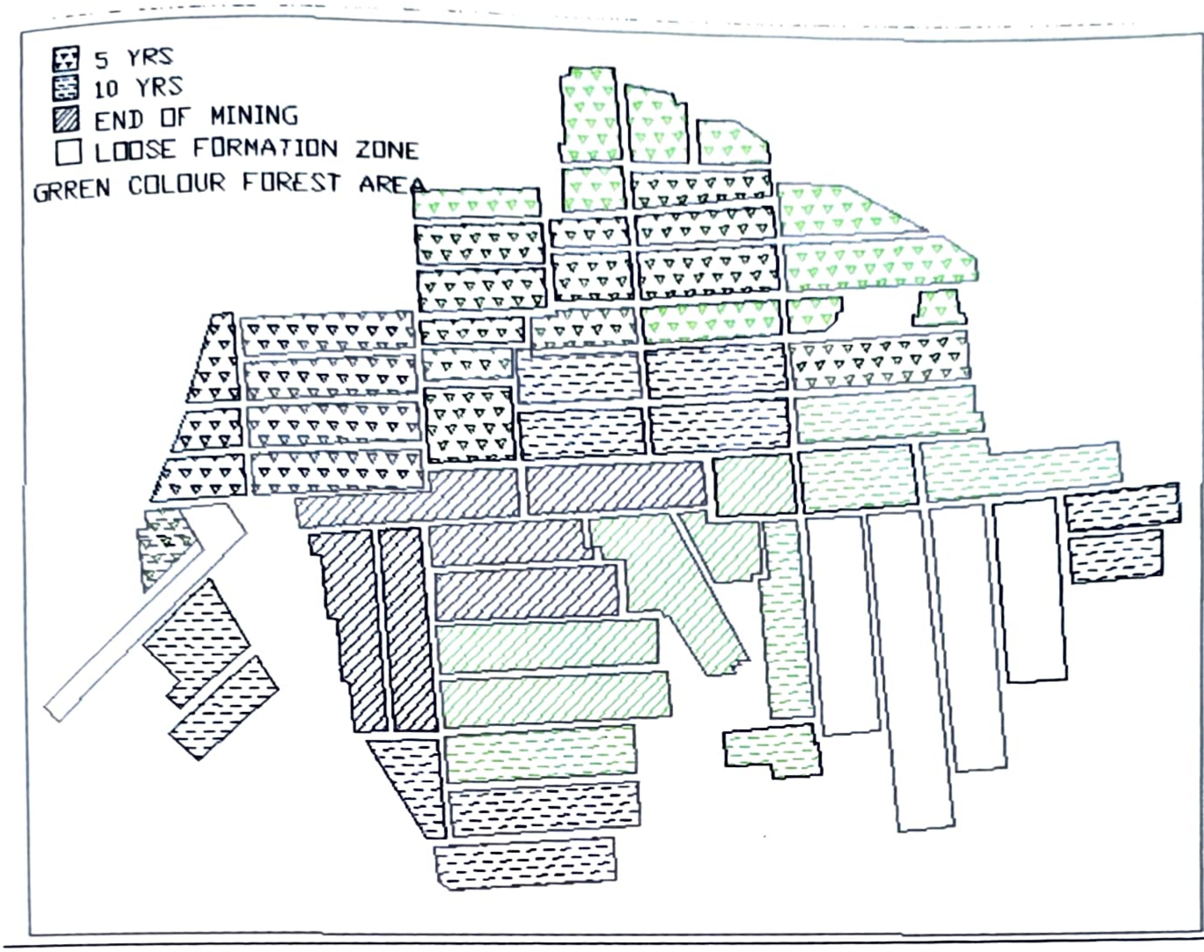

Fig. 19 : The panels having weak strata

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8.0 SUBSIDENCE MANAGEMENT PLAN

The surface land over underground mine has been divided into three category i.e., forest area land, weak strata land and reaming land. Fig. 18 shows the panels above the underground working.

It is suggested that the panels coming under forest cover should not be depillared completely. Either it should be developed and left as such or it should be partially depillared (with permission from DGMS).

Fig. 19 also shows the panels having weak strata. The panels coming having weak strata will result into pot holes. Therefore, these panels should not be depillared. The development work should also be done with caution.

Cracks are likely to be formed on the surface of remaining land. The surface should be inspected daily beneath which underground depillaring is being carried out. The cracks should be regularly filled so that underground workings do not breathe air.

9.0 CONCLUSION

Bhatgaon Underground project of South Eastern Coal fields Ltd. It is situated in Bistampur coal field in Korea District of Chhattisgarh. Bord and pillar system of mining will be adopted to extract coal from underground mine.

The extraction of coal is likely to result in subsidence on the surface. The strata condition in part of the mine is also having very weak and loose formation. The peak subsidence is likely to be 1.414m at the end of 5 years of mining, 1.492 m at the end of 10 years of mining and 1.875 at the end of mining.

The peak horizontal strain is likely to be 24.46 mm/m at the end of 5 years of mining, 28.56 mm/m at the end of 10 years of mining and 30.56 mm/m at the of mining. Wide

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cracks are also likely to be formed on the surface. Therefore, it needs a subsidence management plan to tackle the subsidence in forest area, area having loose strata and remaining land.

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