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A study of subsidence over a longwall panel – prediction and calibration

Mechanized longwall retreat mining with caving is a popular method for winning of coal at greater depths. It is associated with subsidence on surface. Subsidence results in vertical and horizontal displacements and horizontal strains. Subsidence over the longwall mine in Southern India was predicted with the help of three dimensional models generated by using ANSYS software. The results obtained from numerical model are compared to field data and validated.

Keywords: Subsidence – vertical displacement – horizontal displacement

1.0 Introduction

Surface subsidence is recognized as a problem in most countries particularly those with significant underground mining with caving. Subsidence is a consequence of all underground mining methods (Shorey, 2000). As shown in Fig.1 the subsidence associated with longwall mining is a bit complicated process because in this process damage caused to super incumbent strata and surface may lead to different environment problems which could affect the public safety.

As shown in the Fig.1, the strata immediately above the worked out panel tends to cave downwards, thereby causing the strata above the caved zone to fracture. The fractured zone extends till the surface forming cracks on the surface. The extent and intensity of these cracks depend on geological conditions of the strata. The zones vary from location to location (Peng, 1984).

The prediction and monitoring of subsidence has a long history of more than 100 years. Many researchers and investigators have postulated their findings on effects caused by single or multi seams. Salomon (1963), Brauner (1973), NCB method (1975) etc., have proposed various mathematical and empirical methods for predicting of subsidence. However, due

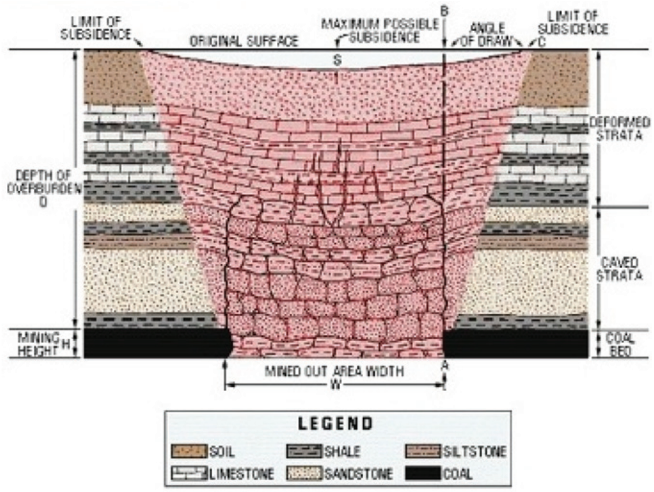

Fig.1: Legend of mine subsidence (After Peng 1984)

to complex geological conditions the mathematical and empirical equations to predict the subsidence have limitations (Chrzanowski, 1998). Due to advancement in technology, the numerical methods became more reliable. Among the Numerical methods finite difference method is mostly used for solving dynamic and static problems.

Finite element method is systematic computer programmeme that offers analysis to wide range of problems associated with mining and non-mining static and dynamic problems (Deb, 2006). In this study ANSYS APDL software is utilized.

2.0 Longwall mining

Longwall mining is the most favourable method employed in coal extraction. In this method coal is extracted by forming panels. The geometry of these panels varies with respect to geological condition. The length of panels range from 1-4km, its height varies from 1.8-4m and width of it ranges between 100-500m.

The longwall mining is classified into two types with reference to direction of extraction. If the extraction is from panel start position to end, it is termed as advancing longwall method. If extraction is in reverse direction then it is retreating longwall method as is shown in Fig.2.

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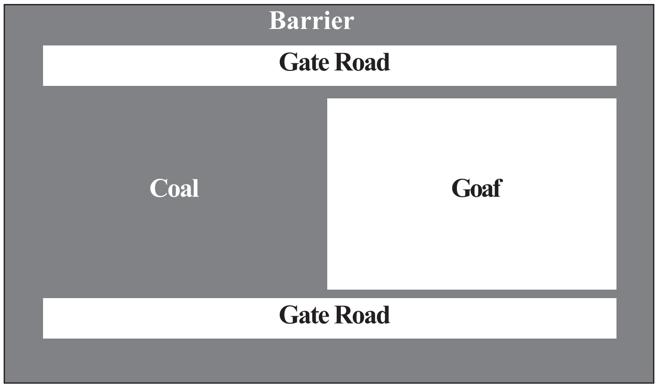

Fig.2: Longwall retreating method

Site discussion

The Adriyala longwall mine considered here is located in Telangana state of India. This mine is lying in between North Latitude of N 18°39'03" to 18°40'34" and East Longitude of E 79°34'28" to 79°35'55". The mining block covers an area of 3.4 sq.km. The distances along strike and along dip are 2.75 km and 1.25 km respectively. This mine is equipped with new generation longwall technology and it is the first of its kind to be introduced in Indian coal mines (Manohar Rao, 2015). The coal block is virgin deposit and consists of four workable seams. Presently workings are done in no.I seam as is shown in Fig.3.

The coal seam I of this mine is worked at a depth of 413m having a thickness of 6.74m. Two longwall panels are extracted with 250m width, 2350m long and having a working height of 3.2m from bottom of seam. The area above the working seam is composed of coal, shale and clay. The roof and floor of the coal seam is sandstone. Lithological details the mine is as shown in the Fig.3. The mechanical properties of the rocks are as given in Table.1

2.3 Model preparation

In this study a 3 dimensional element model has been developed having length and width of 3000m and 1000m each and a depth 500m. The dimension of the longwall panel is considered to be having a length of 2350m and width of 250m. The working height of the longwall panel is 3.2m. The mechanical properties of the material are taken from Table 2. The model is generated using Drucker Prager Criteria with solid brick Brick 185, CONTACT 174 and Target 170 elements.

The Y axis direction is considered for depth, X and Z axis directions are considered length along the panel length and length along width of the panel as shown in the figure. The volumetric model generated with the dimensions mentioned as above is as shown in the Fig.4 and then mechanical properties are given in Table 1 have to be assigned to the volumes before meshing.

After model is meshed as is shown in Fig.5, contact and

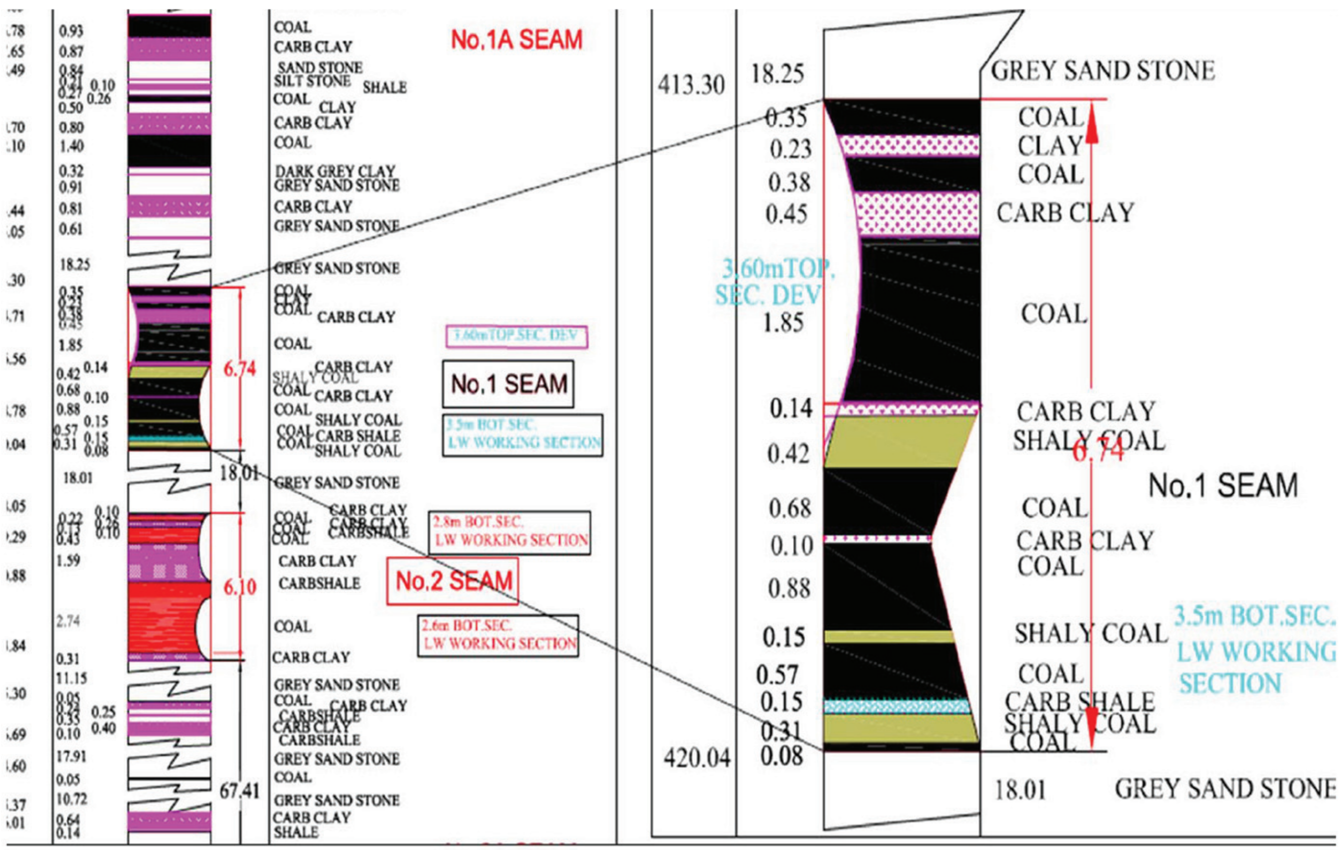

Fig 3. Lithology of the mine

TABLE 1: MECHANICAL PROPERTIES OF ROCK USED IN MODELLING (AFTER SREENIVASA RAO ET. AL, 2016)

Rock strata	Density	ρ(kg/m^3)	Elastic modulus $E\ cm$ (GPa)	Poisson's ratio	Cohesion C (MPa)	Friction angle Φ	Dilation angle Δ
Clay		1100	1.278	0.35	0.811	27°	18^0
Coal		1500	1.535	0.35	1.00	31°	21^0
Sandstone		2147	5.132	0.28	1.461	38°	19^0

TABLE 2: VERTICAL DISPLACEMENT PREDICTED AND FIELD DATA AFTER EXTRACTION OF PANEL I

	Panel/seam	Vertical displacement	Type
1	Panel I Seam I	1.32	Predicted
2	Panel I Seam I	1.306	Field data

Fig.4. Volumes generated in modelling

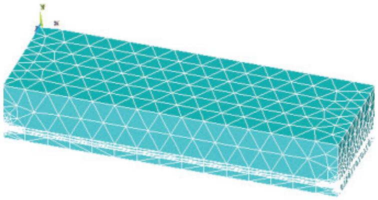

Fig.5: Meshing of the model

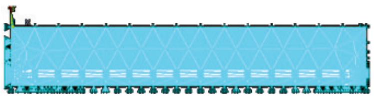

Fig.6: Loads applied on the model

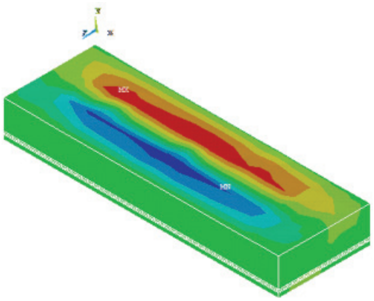

Fig.7: Horizontal displacement predicted in the model

target element command are applied and then loads are applied. The loads applied on the model as following: (a) the bottom of the model is constrained for vertical displacement (U_y), (b) The sides along the panel length are constrained in Z direction, (c) The sides along the width of the panel are constrained in X direction and (d) the acceleration due to gravity is applied in Y direction as shown in figure. Then model is solved.

3.0 Result and discussion

The result obtained from numerical modelling consists of vertical displacement, horizontal displacement etc., is as shown in Fig.7. In this study vertical displacement and horizontal displacements are considered.

The horizontal displacement generally tends to become zero at the middle of width, while it is expected to be maximum towards the edge of barriers. In the above Fig.7, the horizontal

TABLE 3: ANGLE OF DRAW OBSERVED ON FIELD AND MODEL AFTER EXTRACTION OF PANEL I

	Panel/seam	Angle of draw		Type
		Main gate	Tail gate	
1	Panel I Seam I	23°35'59.25"	21°5'1.52"	Predicted
2	Panel I Seam I	24°26'53.03"	22°35'59.25"	Field

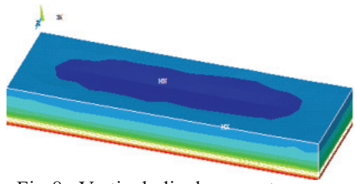

Fig.8: Vertical displacement predicted in the model

displacement predicted after the extraction of panel I was given, this displacement further increased after extraction of panel II.

The vertical displacement is generally observed to be more in the centre of the workings, but in some cases due to different geological conditions it may vary. Fig.8 shows the maximum vertical displacement predicted after extraction of panel I was 1.32m at 1720m retreat length and the

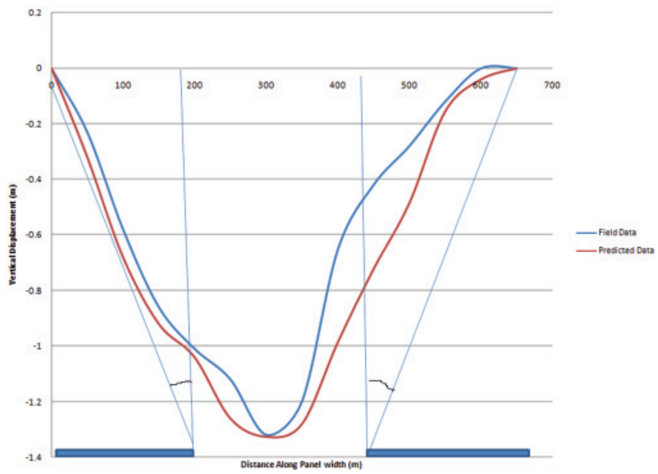

Fig.9 Vertical displacement predicted and field data after extraction of panel I

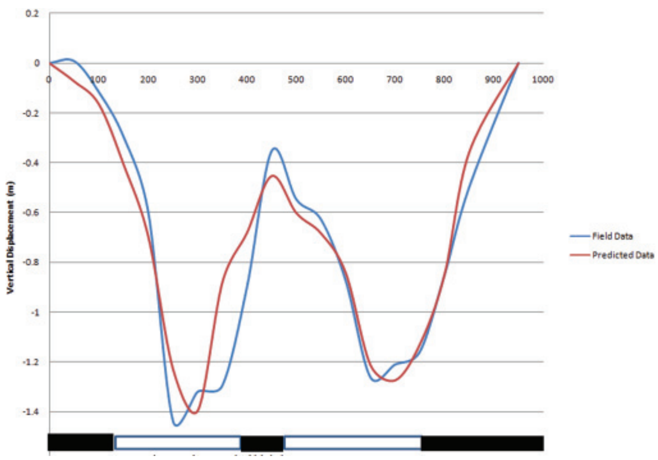

Fig.10 Vertical displacement predicted and field data after extraction of Panel II

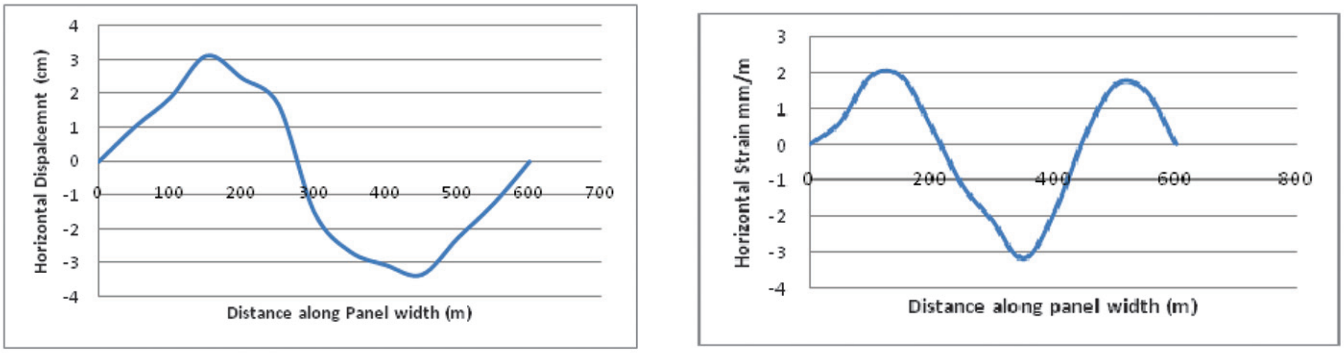

Fig.11 Horizontal displacement and horizontal strain predicted from the model after extraction of panel I.

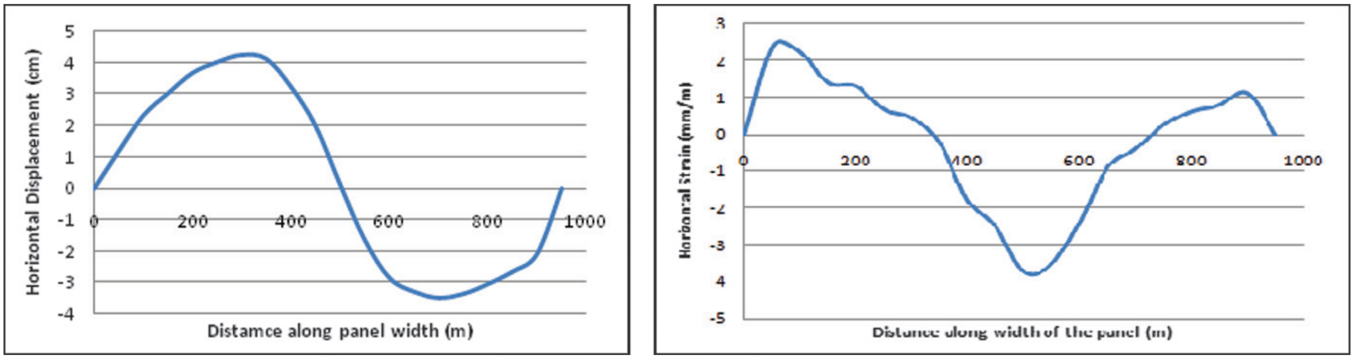

Fig.12 Horizontal displacement and horizontal strain predicted from the model after extraction of panel II.

TABLE 4: VERTICAL DISPLACEMENT PREDICTED AND FIELD DATA AFTER EXTRACTION OF PANEL II

	Panel/seam	Vertical displacement	Type
1	Panel I seam I	1.438	Predicted
2	Panel I seam I	1.402	Field data
3	Panel II seam I	1.262	Predicted
4	Panel II seam I	1.296	Field data

vertical displacement increased from 1.32m to 1.438m in panel I after extraction of Panel II, The vertical displacement observed in panel II was 1.262m.

As is shown in the Fig.9, the vertical displacement measured on field was about 1.306m at 1720m retreat length but the predicted value after extraction of panel I was 1.32m. The variation between the field data to the predicted data is about 98% (A Nurnic, 2012)

The angle draw observed on field at maximum subsidence point i.e., at 1720m in panel retreat length is 24^{o}26'53.03" towards main gate and 22^{o}35'59.25" and the angle of draw predicted from the model is 23^{o}35'59.25" and 21^{o}5'1.52" towards main gate and tail gate respectively.

As shown in the Fig.10 the maximum vertical displacement predicted after extraction of panel II is 1.438m. The displacement observed on panel I after the extraction of panel II was increased from 1.32 to 1.438m. As per the field data the increment in vertical displacement of panel I after extraction of panel II was 1.402m, the variation between the field data to the predicted data is about 97% (A Nurnic, 2012). The vertical displacement observed on panel II was 1.262m and the field data of the corresponding panel was 1.296m. Therefore the variation is about 97% (A Nurnic, 2012)

The horizontal displacement predicted after extraction of panel I was 3.1cm on the initial edge point of the width and 3.2cm at the other edge point of the width as shown in the Fig.11. The displacement values are predicted to be zero at the centre of panel. The horizontal strain is predicted after the extraction of panel I, the maximum tensile (+ve) strain is around 2mm/m and the maximum compressive strain (-ve) is 3mm/m. The compressive strain is observed within the excavation zone while the tensile strain is on both sides of the excavation.

The horizontal displacement after extraction of panel II was the crest of profile is 4.2cm and the trough of the profile is 3.53cm on the other edge of the width. The horizontal strain predicted after extraction of panel I and panel II is as follows. The maximum tensile strain (+ve) is 2.8mm/m, while the maximum compressive strain is 3.8 mm/m. The strains values predicted were within normal level as per MOEF and CC guidelines,

Conclusions

(a) This study proposes the subsidence prediction technique using ANSYS APDL software.

(b) The accuracy of the vertical displacement predicted from the model is compared to the field data and accuracy around 97-98% is achieved, thus the results generated are validated.

(c) The maximum horizontal displacement predicted around 3.2-4cm, which will cause negligible cracks on the surface.

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