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Application of Influence Function for calculation of Mining Subsidence and Displacement Prediction

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Abstract- **In the present world underground mining is carried out hundreds of meter deep from the surface and creating voids after mining out minerals and coal, these minerals were previously bearing the load of the surrounding strata, but due to the voids created after extractions, cracks are formed in the immediate roof, and these cracks travel to the surface causing the surface strata to come down and cause subsidence. This is a brief study on the estimated calculation of mine subsidence of a mine using mathematical influence function by which we divide the underground mining area into several annular rings and find out the effect of these area on the surface and plot a subsidence profile and hence the displacement calculation due to the void created in the mined-out spaces. From the subsidence profile of the mine area we can not only predict the extent of area which is going to subside but also with how much vertical displacement and thus saving life and livelihood.**

Keywords- **Subsidence profile, Influence function.**

I. INTRODUCTION

Subsidence management is the study for prediction and control of the surface subsidence which occurs due to extraction of mineral, or coal which is formed deep below the earth crust. It is basically the goaf area which creates the void and due to multiple roofs sagging including immediate roof and main roof, subsidence occurs during mining activities which can lead to risk of life and property in a devastating manner if not predicted and controlled properly. Through the paper we will go through the actual meaning and significance of Influence function, displacement calculation using focal point method, the method we use for calculation of subsidence and displacement and a detailed case study of Jitpur colliery in Jharia coalfield in Dhanbad region.

We in India practice underground coal extraction by board and pillar mining, although long wall and some special methods of thick seam extraction have in practice. We have used critical width of extraction, width-to-depth ratio of extraction subsidence profile and angle of draw in determining stress and strain conditions. But among this influence function is a powerful method of predicting ground subsidence for any type of extraction.

II.CASE STUDY OF JITPUR COLLIERY, DHANBAD (COAL CAPITAL OF INDIA)

Jitpur colliery is situated in Jharia area which is famous for the underground fire which is burning through decades and has created loss of lives and a livelihood in the area. The extraction of 17 and 18 seams from underneath was under process and was near a railway siding by board and pillar system with hydraulic stowing. The railway siding needed a good subsidence prediction to ensure any loss of life and capital.

1. Details of Jitpur Colliery Case Study-

- Coalfield : Jharia
- Colliery : Noonidih-Jitpur
- Company : Indian Iron & Steel Co. (IISCO)
- Coal seams : 17 & 18
- Seam thickness: 2.44 m & 3.37 m respectively
- Extraction thickness: 2.2 m & 3.3 m respectively
- Average size, depth and status of panels:
- Overlying strata: Interbedded sandstones and shales
- Method of working: Long wall and Board and pillar with hydraulic sand stowing
- Overlying workings: No overlying workings or the panels in 18 seams. However, the panels in 17 seam had graves and developed workings of 18 seam above them.
- Details of railway siding: Jointed construction with a long gradient of 1 in 335
- Extractable reserves : 10, 72,500 tons

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Table 1 List of panels and characteristics

Seam	Panel	Size(m*m)	Depth(m)	Status
17	P17A	290*145	130-173	Partially extracted with stowing and partially with B&P method
17	P17B	680*140	94-150	Developed on bord and pillar pattern
17	P17C	500*140	20-86	Developed on bord and pillar pattern
18	P1(A)	225*280	72-112	Extracted with Stowing
18	P2	92*125	16-34	Having developed pillars of various sizes
18	P3	70*360	60-93	Standing on developed pillars
18	P4	200*430	15-55	Standing on developed pillars

Table 2 Subsidence related parameters of the panels.

Seam	Panel	m'	h(avg)	w/h	M	e'	a'	h'
		(m)	(m)					
17	P17A	2.2	151.5	0.96	0.8	.95/.6	0.07-.1	1
17	P17B	2.2	122	1.15	0.8	.95/.6	0.07-.1	1
17	P17C	2.2	53	2.64	0.8	.95/.6	0.07-.1	1
18	P1(A)	3.3	93.5	2.41	0.8	.95/.6	0.07-.1	1
18	P2	3.3	25	3.68	0.8	.95/.6	0.07-.1	1
18	P3	3.3	76.5	0.91	0.8	.95/.6	0.07-.1	1
18	P4	3.3	35	5.71	0.8	.95/.6	0.07-.1	1

The panels in 17 seams can be extracted in the following manner.

- Panel P17A - Bord and pillar with hydraulic stowing
- Panel P17B-Longwall/bord and pillar with hydraulic stowing
- Panel P17C-Longwall/bord and pillar with hydraulic stowing at depths more than 50 m, and partial extraction with hydraulic stowing at depths less than 50 m.

The panels in 18 seams can be extracted in the following manner.

- Panel P1(A)- The panel had already been extracted with hydraulic stowing
- Panel P2 - Partial extraction with hydraulic stowing
- Panel P3 - Bord and pillar with hydraulic stowing
- Panel P4 - Partial extraction with hydraulic stowing

The following precautions were suggested.

- The panels in the two seams are to be made approachable and their offset plans be made with a fresh survey.
- The partial extraction methodology with hydraulic stowing wherever applicable as per the recommendations will be decided after knowing the sizes of the pillars and galleries, i.e., after the offset plans are ready.
- During extraction of all the panels care will be taken that there is no lag in stowing and that practically no gap is left along the roof.
- Subsidence movements and their impacts on the surface properties shall be monitored panels during and after the extraction as necessary.
- Subsidence movements shall be monitored along the railway siding and if necessary, maintenance will be done, may request the railways to do maintenance of the siding tracks as the railway schedule.

III. INFLUENCE FUNCTION

The influence function measures the subsidence for an area dA in the bottom and the effect for this at the surface 'H' distance perpendicularly above and creating a trench at that point. The deepest point of the trench is the point just above the elemental area dA. Such all dA elements are considered in total and all the subsidence all added up due to these dA elements and trenches are calculated and the angle of draw.

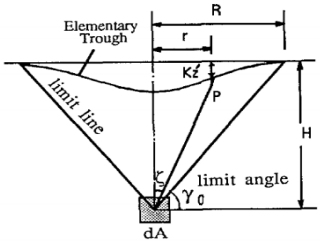

Fig. 1 Calculation of Influence function [5]

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Ren G, Reddish DJ, Whittaker BN. Mining subsidence and displacement prediction using influence function methods. Min Sci Tech 1987; 5:89–104.K_z' = f(r) or K= f(ζ). The magnitude of influence of dA on P (Kz') is dependent on ζ which is the zone angle which is 0≤ ζ ≤ θ, where θ is the angle of draw. The extraction of an infinitesimal element from within the influence area will result in an amount of subsidence ds at the surface point P, which can be given as

$$ds= S_oK_zdA \ [5] \quad (1)$$

where as S_0 = maximum possible subsidence. The net subsidence S can be calculated as

$$S = \int_A\int K_Z(r)\, dA \ [5] \quad (2)$$

The double integration is calculated to find the magnitude of Influence function over an area "a".

IV. CALCULATION OF SUBSIDENCE AND DISPLACEMENT

There are a lot of influence functions, but using the most commonly used is by the Polish investigators, Knothe(1957) and Litwiniszyn (1957, 1964).

$$K_z = (S/R^2)(e^{-\pi(r/R)\,\wedge 2}) \ [5] \quad (3)$$

Extraction of an annular area of radii r1 and r2 where r1 > r2 will produce subsidence(s) in that area as given by equation

$$s=S(e^{-\pi(r/R1)\,\wedge 2}- e^{-\pi(r/R2)\,\wedge 2}) \ [5] \quad (4)$$

Using these equations, the subsidence profile can be sketched in MATLAB, with the case study of a district in Jitpur colliery of P17 A seam having an average depth of 151.5 m and area of 290*145 m^2. By Taking the angle of draw as 35□. R= 0.35H and thus the radius is taken as 53.025m, erf () is the error function.

$$erf(X) = (2/\sqrt{\pi}) \int_0^x e^{-t\wedge 2} \ [5] \quad (5)$$

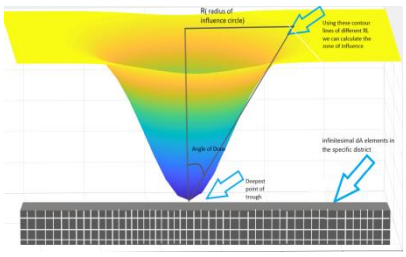

Fig 2 Zone Influence description.

Using the following part of the sample code ,Fig3. Is generated inMATLAB(Case I)

```
x=[-290:40:290];
y=[-145:40:145];
[X,Y]=meshgrid(x,y);
Z=-53.025.*(erf(0.0033.*X)-erf(0.0066.*(X-170))).*exp(-3.14.*((Y)./150).^2);
Surf (X,Y,Z);
Shading interp
```

Using the following part of sample code, Fig4. Is generated in MATLAB (Case II):

```
x=[-290:40:290];
y=[-150:40:150];
[X,Y]=meshgrid(x,y);
Z=-53.025*(exp(-3.14.*(X/290).^2).*exp(-3.14.*((X-150)/290).^2)).*exp(-3.14.*((Y)./145).^2);
surf(X,Y,Z);
shading interp
```

V. CONCLUSION

The use of MATLAB for determining the displacement and zone of influence of Panel 17A can be used and in similar way the zone of influence can be calculated for other panels simultaneously and hence the net subsidence can be calculated. The subsidence profiles are shown below using MATLAB software and using the functions defined above. FLAC 3D can also be used parallelly.

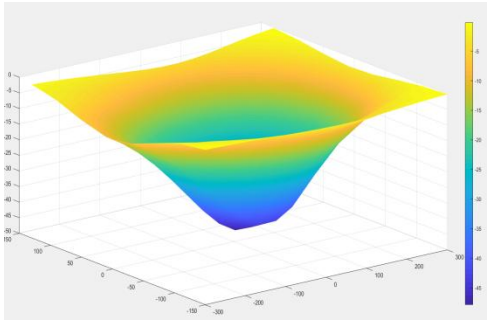

Fig 3 Subsidence profile (a).

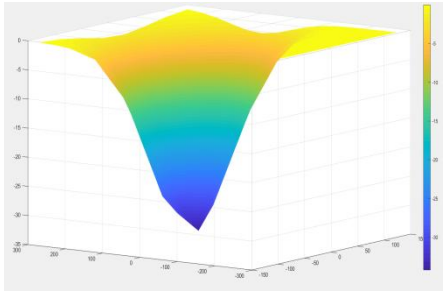

Fig. 4 Subsidence profile (b).

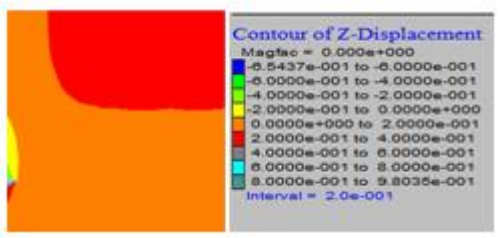

Fig 5 Displacement in z direction for a 40m advancement shown using FLAC 3D for a different longwall panel.

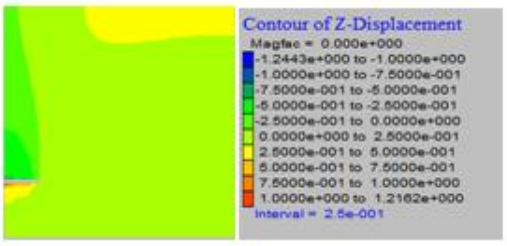

Fig 6 Displacement in z direction for a 120m advancement shown using FLAC 3D.

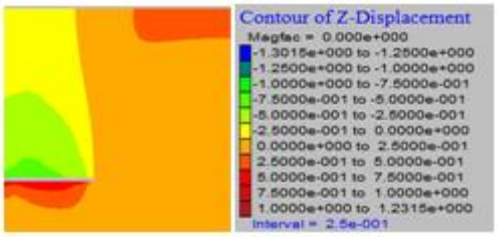

Fig 7 Displacement in z direction for a 320m advancement shown using FLAC 3D for a different longwall panel.

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