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Research Article

Study on the Evaluation Scope of Resource Reserves for Underground Mining Overlaid by Construction Project

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Abstract: The aim of this study is to propose a method for determining the evaluation scope of mineral resources overlaid by construction projects. The determination principles for evaluation scope of underground mine overlaid by the construction project are introduced, the vertical section method is employed to design the boundaries of safety pillars based on the mine displacement angles which represent the allowable values of surface deformation and the evaluation scope of underground mine overlaid by the planar engineering and linear engineering are analyzed through cases. The research results can provide references for route optimization of project or mining right compensation.

Keywords: Construction project, evaluation scope, occupied mineral, resource reserves, underground mining

INTRODUCTION

Exploitation of mineral resources underneath or near construction projects will affect or destroy the buildings/structures and the equipment of the projects and pose a threat to the safety of personnel. To ensure the safety of construction projects, safety pillars should be established to prohibit the exploitation of mineral resource reserves within a certain spatial range, i.e., the occupied mineral resource reserves (Zhang, 2012). For the purpose of balancing the project construction and the protection of resource reserves, the rationality, economical efficiency and necessity of resources occupation by construction projects need to be fully demonstrated, on condition that the evaluation scope of resource reserves to be overlaid has been determined (Yue *et al*., 2013; Li *et al*., 2014).

In order to study the evaluation methods for mineral resource overlaid by constructed projects, some researchers actively carry out relevant research work. The calculation program for the coordinates of turning points of line of overlaid mineral resources has been developed with Visual C++ (Xu *et al*., 2013). The principle of solid analytic geometry has been adopted to calculate coordinate of the surrounding inflection point in the region below the construction (Ma, 2008). The error factors of coal resources/reserves estimation with different division methods have been analyzed and an improved division method has been put forward (Wang and Li, 2014). The nominal group technique and analytic hierarchy process method have been used to filter out the important influence factors of construction projects constructed over mineral resources and determine the weights of factors (Gao and Gao, 2015). The displacement angles have been selected to be used to compute distribution of the ore body beneath construction projects according to burial depth of ore body, dip and covered rock type (Zhang, 2014). An evaluation model for overlaid mineral resources mining is built, which takes maximum profit as the target and the standard parameter values are determined in such basic models as overlaid mineral resource value, mining cost and relocation cost (Zhang and Lan, 2014).

The evaluation of the occupied resource reserves involves many fields, including engineering geology, mining technology and mineral exploration, but the technical specifications for such evaluation are unavailable in China, so the techniques applied for practical works are confused. Some geological exploration units even define the resource reserves below the vertical portion of the construction project range as the occupied reserves. Therefore, the study on techniques for the evaluation scope of occupied resource reserves becomes particularly urgent.

MATERIALS AND METHODS

Determination principles for evaluation scope: In the process of investigation and assessment of occupied resources, first of all, the safety protection scope of construction projects should be determined in accordance with relevant regulations, including the land

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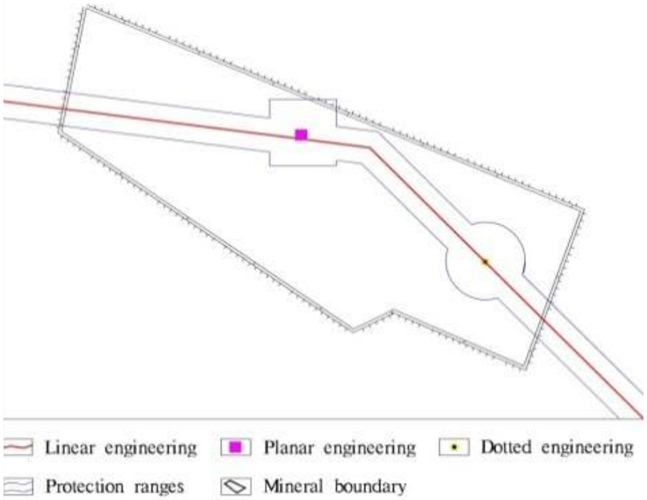


Fig. 1: The occupation area of mineral land overlaid by construction project

acquisition scope for construction, construction belt and safe distance for safeguarding project construction and operation. For dotted or planar engineering like storied building, factory, substation, dam, station valve chamber and industrial site, the building periphery is generally taken as the boundary and a certain distance extended from the polygon or circle is defined as the protection ranges; for linear engineering like railway, highway and long-distance oil/gas pipeline, a certain distance extended respectively from both sides of the engineering centerline is defined as the protection ranges; for dotted and linear engineering, the outermost connecting line is defined as the protection ranges (Fig. 1).

The requirements for safety distance as stipulated in standards and regulations vary with the type of construction projects. Taking the long-distance oil/gas pipeline engineering as an example, the Law on the Protection of Oil and Gas Pipelines of the People's Republic of China (No. 30 Presidential Decree) stipulates that the quarrying, mining and blasting shall be prohibited within 1,000 m from both sides of the centerline of special tunnels for pipelines and that blasting, seismic method exploration, engineering excavation, engineering drilling or mining shall be prohibited within 200 m from both sides of the centerline of pipeline route and within 500 m around pipeline subsidiary facilities. Such facilities mainly include the dotted or planar engineering like pipeline compressor station, metering station, oil gathering station, gas gathering station, oil transportation station, gas transmission station, gas distribution station, pigging station, valve chamber, oil depot, gas storage and cathodic protection station.

For the ore deposits outside the protection ranges and adjacent to the project, the effect of ore deposit mining on the engineering protection zones should be taken into consideration, together with the safety protection ranges beyond the project boundary, so as to further determine the width overlaid by the project (i.e., the overall width overlaid by the project beyond the boundary). After underground ore bodies are mined, caving zone, fractured zone and sagging zone will take shape in overlying strata of mine goaf and a subsidence basin or a caving range (Fig. 2) much larger than the mine goaf, will come into being in ground surface, which will affect or destroy surface buildings or their foundations. Indices of displacement and deformation within ground subsidence basin include subsidence, inclination, curvature, horizontal displacement and horizontal deformation. During evaluation of the occupied mineral resources, construction projects should be taken as the protected object and boundary of safety pillars which are established to prevent mining subsidence can be calculated after the rock displacement angle is extrapolated to the projected plan view of coal seam based on the enclosing belt. Then the boundary value is compared with the protection range as stipulated in standards and regulations and the larger value should prevail. Finally, evaluation scope of resource reserves for underground mining overlaid can be determined.

Width of enclosing belt: When safety pillars are designed to define the protection ranges, the belt area around surface buildings for the sake of safety is referred to as the enclosing belt. The belt width is associated with type and function of buildings. Taking coal mining as an example, the protection grade is divided into I~IV according to importance and application of buildings as well as consequences of mining. Each grade is provided with different belt width (Table 1).

Table 1: The width of enclosing belt of buildings with different grades (Jin and Mu, 2000)

Grade of safety pillars	Width of enclosing belt (m)
I	20
II	15
III	10
IV	5

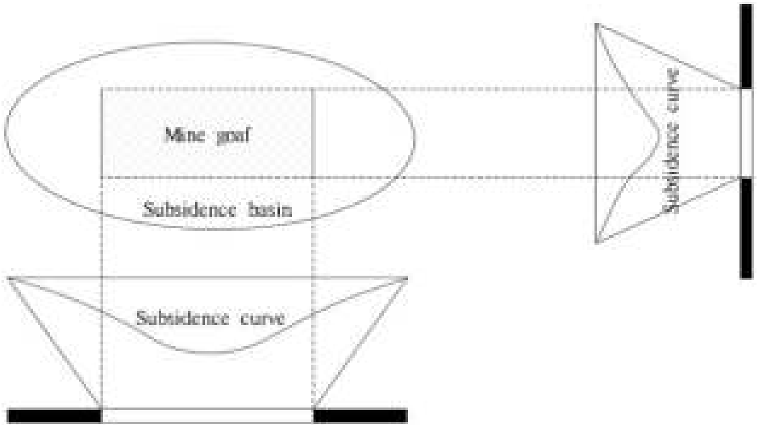


Fig. 2: The diagrammatic sketch of ground subsidence basin

Table 2: The range of displacement angle of loose bed (Jin and Mu, 2000)

φ h	Dry and water-free	Highly watery	Containing quick sand bed
<40 m	50°	45°	30°
40~60 m	55°	50°	35°
>60 m	60°	55°	40°

φ is displacement angle; *h* is thickness of loose bed

Table 3: The general parameters of surface movement which is distinguished by nature of overlying strata (Liu *et al*., 2010)

Nature of overlying strata	Unidirectional compressive strength/ MPa	Subsidence factor	Displacement angle in strike direction *δ*
Hard	>60	0.27~0.54	75~80°
Medium hard	30~60	0.55~0.84	70~75°
Weak	<30	0.85~1.0	60~70°
Nature of overlying strata	Displacement angle in downhill direction *γ*	Displacement angle in uphill direction *β*	
Hard	75~80°	*δ*-(0.7~0.8)*α*	
Medium hard	70~75°	*δ*-(0.6~0.7)*α*	
Weak	60~70°	*δ*-(0.3~0.5)*α*	

Range of displacement angle: For the underground mining overlaid by construction projects, the allowable values of surface deformation which represent the building safety pillars is used to determine the occupation range. Generally, safety ranges are determined according to displacement angle of ore body overlying rocks. The displacement angle refers to an included angle, at one side of wall, between the horizontal line and the connecting line of the outermost critical deformation point and the boundary point of mining area on principle sections of subsidence basin at full or near-full subsidence and includes displacement angle of loose bed *φ*, displacement angle in strike direction *δ*, displacement angle in downhill direction *γ* and displacement angle in uphill direction *β*. The displacement angle is determined according to rock characteristics and local practical empirical observations. Table 2 and 3 for the range of displacement angle *φ* of loose bed and surface displacement angle which can be distinguished by nature of overlying strata. The additional deformation effect of mining landslide and movement shall be taken into account in mountainous areas. If surface dip angle is larger than 15°, the displacement angle in mountainous areas should be taken. When the displacement angle in flat land is used, the displacement angle in uphill direction and in downhill direction of buildings should be reduced by 5°~10° and 2°~3° respectively.

Vertical section method: The boundary of safety pillars can be determined by vertical section method, vertical line method or digital elevation projection method etc. according to the displacement angle (Jin and Mu, 2000), of which the vertical section method is most common. The coal mine is taken as an example. Firstly, the cutting section line perpendicular respectively to strike and dip is drawn from center point of the protected boundary on the plan of coal seam and the boundary point of safety pillars is determined on sectional drawing according to the topography, geologic column and the selected sectional drawing of displacement angle and then transferred to the plan. The connecting line is the range of safety pillars. As for other mine types, many typical sections are drawn directly according to the displacement angle, topography, stratum and ore body characteristics to obtain boundary point of many feature points and then lines are connected to get protection ranges.

RESULTS AND DISCUSSION

Planar engineering and linear engineering are taken as examples respectively to introduce calculation of safety pillar boundaries according to the vertical section method.

Planar engineering: Firstly, the vertical section A-A' (Fig. 3a) is drawn along the coal seam strike to get A-A' sectional drawing in Z-axis direction (Fig. 3b).

In Fig. 3b, the occupation ranges d_{A1} and d_{A2} in uphill direction and downhill direction of coal seam are calculated according to the following equation:

$$d_{A1} = w + s + m_{A1} = w + h\cot\varphi + (H_1 - h)/(tan\beta + tan\alpha) \tag{1}$$

$$d_{A2} = w + s + m_{A2} = w + h\cot\varphi + (H_2 - h)/(tan\gamma - tan\alpha) \tag{2}$$

wherein,

w : Width of enclosing belt

h : Thickness of loose bed

φ : Displacement angle of loose bed

β : Displacement angle in uphill direction

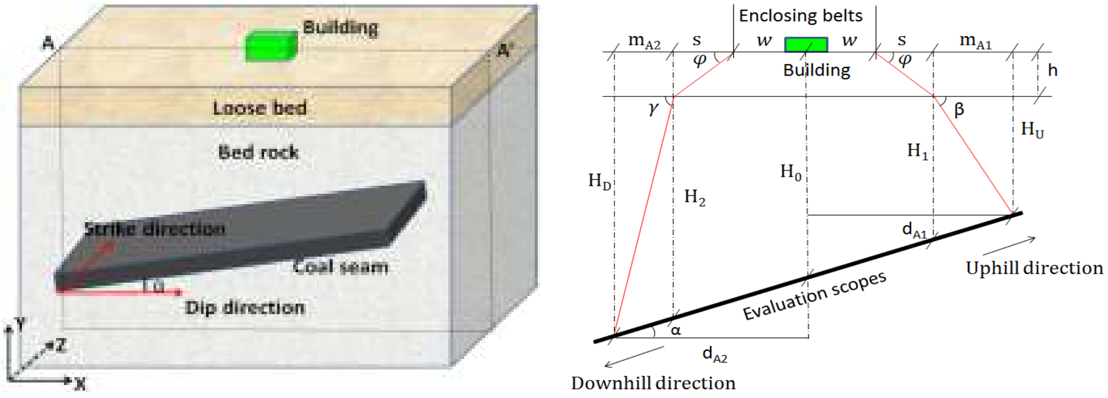
γ : Displacement angle in downhill direction

α : Dip angle of coal seam

H_0, H_1, H_2, H_U and H_D : Vertical depth from coal seam to ground surface at different points and the relational expression is shown as follows:

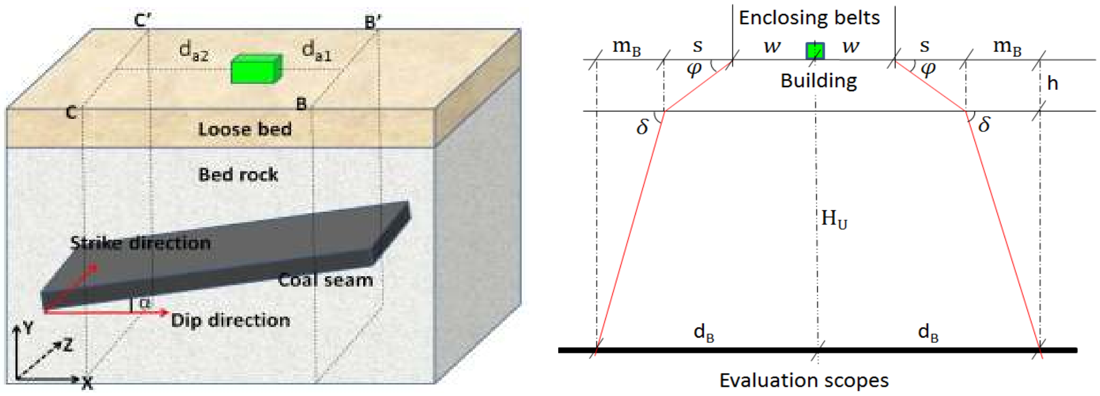
$$\begin{aligned} H_1 &= H_0 - (w+s)\tan\alpha \\ H_2 &= H_0 + (w+s)\tan\alpha \\ H_U &= \mathrm{h} + m_{A1}\tan\beta \\ H_D &= \mathrm{h} + m_{A2}\tan\gamma \end{aligned}$$

The vertical sections B-B' and C-C' (Fig. 4a) are drawn respectively at d_{A1} and d_{A2} from both sides of building boundary along coal seam dip (X-axis direction) to get B-B' sectional drawing (Fig. 4b) and C-C' sectional drawing in X-axis direction.



(a) (b)

Fig. 3: The Z-direction view of coal seam overlaid by a single building



(a) (b)

Fig. 4: The X-direction view of coal seam overlaid by a single building

In Fig. 4b, the occupation range d_B at B-B' section is calculated according to the following equation:

$$d_B = w + s + m_B = w + h\cot\varphi + (H_U - h)\cot\delta \tag{3}$$

Similarly, the occupation range d_C at C-C' section is calculated as follows:

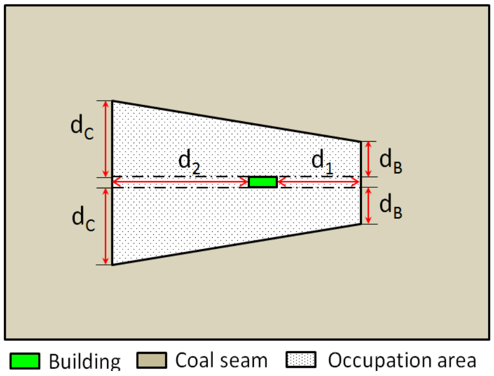
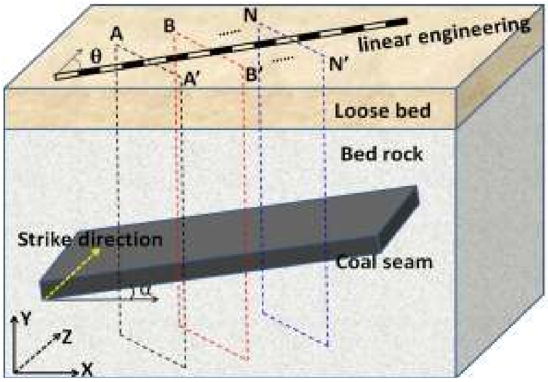
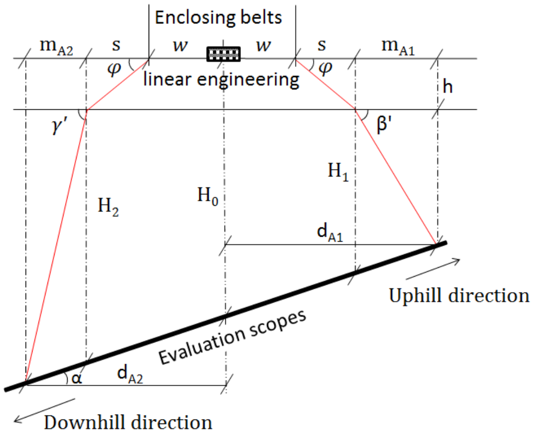


Fig. 5: The evaluation scope of coal seam overlaid by dotted engineering



(a)



(b)

Fig. 6: The schematic diagram of coal seam overlaid by linear engineering

$$d_C = w + s + m_C = w + h\cot\varphi + (H_D - h)\cot\delta \tag{4}$$

Building boundary size is obtained by means of taking (d_1+d_2) as height, $2d_B$ as upper line and $2d_C$ as lower line. An isosceles trapezoid is plotted around building and projected on coal seam plan (Fig. 5). The overlap area is the evaluation scope of coal seam resource reserves overlaid by dotted engineering.

Linear engineering: For linear engineering like highway, railway and long-distance pipeline, several vertical sections are drawn axially along linear engineering (Fig. 6a). Occupation range is calculated for each vertical section respectively according to the method similar to that for dotted engineering. However, linear engineering has a unique characteristic of the axial extension and calculation of its occupation range is also affected by engineering axial position and coal seam strike, so the included angle θ should be used to modify the original displacement angle in uphill direction β and in downhill direction γ (Jin and Mu, 2000). Taking A-A' section as an example (Fig. 6b), the occupation range is calculated according to the following equation:

$$d_{A1} = w + s + m_{A1} = w + h\cot\varphi + (H_1 - h)/(tan\beta' + tan\alpha) \tag{5}$$

$$d_{A2} = w + s + m_{A2} = w + h\cot\varphi + (H_2 - h)/(tan\gamma' - tan\alpha) \tag{6}$$

wherein,

$\beta' = \cot^{-1}\sqrt{\cot^2\beta\cos^2\theta + \cot^2\delta\sin^2\theta}$, modified displacement angle in uphill direction

$\gamma' = \cot^{-1}\sqrt{\cot^2\gamma\cos^2\theta + \cot^2\delta\sin^2\theta}$, modified displacement angle in downhill direction

θ, included angle between linear engineering and strike direction of coal seam

δ, displacement angle in strike direction

Occupation range of other vertical sections (d_{B1}, d_{B2}), ……, (d_{N1}, d_{N2}) are obtained respectively and then projected on the coal seam plan. End points at both sides of each occupation range are connected and the overlap area is evaluation scope of the coal seam overlaid by linear engineering (Fig. 7).

CONCLUSION

The vertical section method is used to determine the evaluation scope of the occupied mineral resources by means of vertical projection of displacement angle on ground. Compared with the method of taking the resource reserves vertically below the range of construction projects as the occupied reserves, the vertical section method can obtain more accurate and reliable results of the occupied reserves, which can be easy to scientifically demonstrate the route rationality.

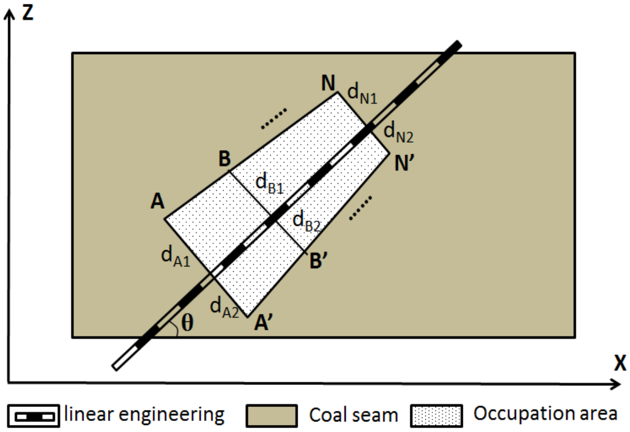


Fig. 7: The evaluation scope of coal seam overlaid by linear engineering

The case analysis mentioned in this study aims at the mining in single coal seam. For multi-seam mining, as the safety pillar boundaries of each seam expand continuously along with the extension of mine displacement angle, both sides of boundary for the bottom coal seam should be taken as the maximum occupation range for evaluation of the occupied reserves. As a result, in addition to the calculation of direct occupation of pipelines on each coal seam, the mining effect of the bottom coal seam on other overlying seams, i.e., indirect occupation, should also be taken into consideration.

As for the special types of occupied mineral, including filling mining, underground salt solution mining, groundwater mining and underground ultra-deep mining, the effect of the factors (such as mining depth and methods) on ground surface should be taken into account and the above techniques cannot be simply relied on.

REFERENCES

Gao, Z.Q. and W.M. Gao, 2015. Influence factors of construction projects constructed over mineral resources. Resour. Environ. Eng., 29(4): 499-502.

Jin, L.S. and J.S. Mu, 2000. Specifications for Coal Pillar Preservation and Compressed Coal Mining for Buildings, Water Bodies, Railways and Main Shafts. China Coal Industry Publishing House, Beijing.

Li, Z.X., W. Xu, N. Peng, S.Y. Luo and J.B. Qi, 2014. Study on reserve estimation of the overlaid mineral resource—A case study on overlaid mineral resource on the Sanmenxia-Xichuan highway. Ground Water, 36(3): 148-160.

Liu, D.H., Y.Q. Xing and D.D. Zhai, 2010. Study on technical methods of mineral resources reserves below constructed projects-taking the main channel of middle line of south-to-north water transfer project for example. Henan Sci., 28(9): 1182-1188.

Ma, X.G., 2008. The method of map the mineral resources reserve zone below constructed projects. Xinjiang Geol., 26(2): 212-213.

Wang, W.D. and Y.P. Li, 2014. Error and correction of coal resources/reserves estimation by geological block methods. Coal Geol. Explor., 42(5): 1-3.

Xu, P., X.M. Wang and Z.W. Song, 2013. Main calculating points of reserves for overlaid mineral resources and the program design. Min. Res. Dev., 33(1): 106-109.

Yue, X.B., Z.P. Shuai and J.X. Wang, 2013. Discussion of estimation method of mineral resources below construction projects. Yangtze River, 44(6): 44-46.

Zhang, S.H., 2012. Discussion on investigation and evaluation method for mineral resource below constructed projects. Resour. Environ. Eng., 26(3): 278-280.

Zhang, S.H., 2014. Application of displacement angle in assessment of mineral resources below constructed projects. Resour. Environ. Eng., 28(3): 326-331.

Zhang, W.J. and S.D. Lan, 2014. Sensitivity analysis of mining economic parameters of overlaid mineral resources. Gold, 9(5): 35-39.