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Index Function Analysis Method. Interlayer Thickness. Transition Time from Open Pit. Underground Mining Considering Slope Stability

Zhixin Liu

Resource, environmental EngineeringWuhan University. Science, technology

Abstract: Slope stability, Open Pit. one. important factors. determine. interlayerThickness. transition from open pit into underground mining. taking Miyun Iron Mine as an exam-ple,. relationship ~. interlayer thickness, slope stability. Open Pit. analyzed using. method. reduction FEM. transition time from Open Pit. underground mining. it shows, safety factor. Open Pit top slope increases. interlayer thickness.. Slope Safety Factor interlayer safety factor ore recovery ratio, interlayer Bearing Capacity. taken as eval indexes. determine. interlayer thickness. based. ideal point method, index function analysis method. proposed. calculate. interlayer thickness.. interlayer Thickness. Miyun Iron Mine. calculated. this method. .: Show, interlayer thickness.

Mine calculated with this method is in the accord with the results derived by other method when the slope stability is not considered. the relaxing interlayer thickness could be calculated with this method ac-winding to the priority of each index of the mine.

Keywords: Interlayer Thickness;Index Function Analysis Method;Slope Stability;Open Pit to under-ground mining;Safety Factor

If the shallow orebody reaches a certain depth by open-pit mining, it must be transferred to the underground mining due to the restriction of mining technology, economy and safety conditions.[1-2]. In order to ensure the smooth transition from open pit to underground mining, it is necessary to reserve a certain thickness of orebody as the isolation layer between the bottom of the Open Pit and the first stage of the underground. The isolation layer is too thin, which is easy to cause the collapse of the surrounding rock in the goaf, which is not conducive to the safety production of the first stage of the underground. The isolation layer is too thick, which will cause the loss of mineral resources. The mined-out area formed by the first stage of underground mining is prone to cause surrounding rock deformation, and extends to the open-pit slope through isolation layer, which affects the stability of the existing open-pit slope.[3-5]. Therefore, a reasonable isolation layer thickness must not only ensure the safety production of the first stage of underground mining, but also avoid the waste of mineral resources, and also consider the stability of the existing open-pit slope.

The calculation methods of isolation layer thickness are mainly divided into theoretical estimation method and numerical simulation method. The theoretical estimation method generally takes into account single or multiple factors, such as the span of Mined-out areas, characteristics of rock strata and external loads. The main methods are thick span ratio method, simplified beam method of structural mechanics, and puch' s ARCH theory estimation method, etc.[6-7].

The numerical simulation method can be used to calculate multi-working conditions according to the engineering situation.[8]. Because of the complex calculation conditions of isolation layer thickness, scholars mostly determine the final value of isolation layer thickness by combining numerical simulation and theoretical estimation. Li diyuan, Yan Xiaoming, etc. Isolation of various methods under Different Conditions

The corresponding relationship between the minimum safety thickness of roof and the span of goaf is established. Zhang qinli[11]The isolation layer thickness calculation results of different theoretical and numerical simulation methods were compared and analyzed. The numerical simulation results were corrected, and the isolation layer thickness of different goaf span was recommended. Lu Guang[12]Through the comparison and analysis of the theoretical estimation method and numerical simulation method, the isolation layer thickness of the mine is determined. Liu xieling[13]The stability of goaf with different span and thickness of roof was calculated by numerical simulation method, and the safety thickness of isolation layer under open-pit steps was obtained. The above research has solved some practical engineering problems, and it has a good effect on determining the isolation layer thickness of Open-pit to underground mining.

However, the relationship between the thickness of isolation layer and the stability of Open-pit slope is neglected in related researches.

Miyun iron mine is a typical open-pit to underground mining mine, the safety factor of Open-pit slope is regarded as one of the main evaluation indexes to determine the isolation layer thickness. A Functional Analysis Method of isolation layer thickness index considering slope stability is proposed in order to provide a new idea for the determination of isolation layer thickness.

1. Engineering Overview

The shallow orebody of Miyun Iron Mine adopts open-pit and deep orebody adopts underground mining. Open-pit mining is now basically over, forming a height greater100 mThe final slope angle of the top and bottom47 °,49 °The foundation of the pit is high0 mThe scope of the forthcoming underground mining is0 ~ 0 ~ -240 m, The inclination of the orebody60 ° ~ 65 °The average thickness of the orebody is about40 mMining is carried out by the method of sequential filling in the stage of rock drilling.70 m. To ensure the safety of the first stage of underground mining, it is necessary to reserve a certain thickness of isolation layer between the bottom of the Open Pit and the first stage of the underground. Overview of the first stage underground mining project in Miyun Iron Mine1.As shown in the table, the physical and mechanical parameters of the main rock1.Listed.

2. Relationship between isolation layer thickness and Slope Stability

2.1 Slope Failure Process in open-pit to Underground Mining

At the end of open-pit mining, the final side slope instability is mostly a gradual process which is accumulated by local deformation and failure and gradually expanded to the overall failure.[14-15]. The slope firstly produces plastic shear yield near the foot of the slope to form shear cracks, and gradually extends from the outside to the inside, from the bottom to the top of the plastic zone, resulting in overall instability, the underlying slip surface of the open roof and bottom slope gradually extends from the foot of the slope to the top of the slope, as shown in Fig.2 ()Shown.

The mined-out areas formed in the first stage of underground mining generally exist under the slope foot of the open roof top, and there is a certain thickness of isolation layer in the upper part of the mined-out areas, it is easy to cause local cracks in the surrounding rock of mined-out area, which extends further to the top of the slope and forms transacted slip surface Finally, resulting in the overall instability of the open-pit slope. As shown in Fig.2 (B)As shown, the potential slip surface of the open-top slope is generally gradually extended from the side wall of the goaf to the top of the slope when the goaf is not filled in the first stage of the underground. The potential slip surface of the open-top slope is similar to that at the end of the open-pit mining.

Isolation layer is located in open-pit slope and underground first order goaf between isolation layer the thick

isolation layer of slope of support stronger goaf from slope as far away, dew Zenith help slope of goaf-top potential slip surface of slip path the long the more conducive to the open-air slope of stability.

2.2 Numerical Simulation

According to figure1And table1Established Miyun iron ore numerical model on both sides of the Surface Boundary0Level Displacement constraint bottom boundary for the orientation0Displacement constraint on the surface and Goaf for free boundary.

Open-air mining ended when on numerical model the overall strength reduction of elastic-plastic calculation dew Zenith, the end of help slope of security coefficient strength to finite element calculation don't convergence when termination, at this time only

Get open-air the end of help security coefficient1.72Can't at the same time get dew Zenith help slope of security coefficient as shown in Figure3 ()Shown in. For this by Local Strength Reduction Method[16]Only of the ore body hanging wall surrounding rock the local strength reduction available dew Zenith help slope of security coefficient1.87As shown in figure3 (B)Shown in. By figure3The open-air mining ended when Finite Element Strength Reduction Method plastic zone in open-air the end of help and top help slope are from slope gradually extended to top formation slope overall damage of slip surface.

Underground first stage goaf not filling when select different isolation layer thickness respectively of the ore body of the, footwall rocks the local strength reduction of elastic-plastic calculation isolation layer approximate as support structure by elastic calculation, calculation different isolation layer thickness under to the zenith, the end of help slope of security coefficient calculation results such as table2Listed in. Which isolation layer thickness25 mOf numerical model plastic equivalent stress distribution as shown in Figure4Shown in figure4 ()For underground first stage goaf not filling, not the strength reduction calculation of strain distribution figure4 (B)For the hanging wall surrounding rock the local strength reduction calculation of strain distribution.

By figure4 ()The underground first stage mining goaf not filling hanging wall surrounding rock strength wei zhe reduction when dew Zenith help slope plastic zone range is small goaf hanging wall surrounding rock there is big range plastic deformation area; by figure4 (B)The with the hanging wall surrounding rock strength of reduction dew Zenith help slope of plastic zone and no obvious of extended and goaf hanging wall side wall surrounding rock of plastic zone up extended zhi ding help top.

By table2The underground first stage goaf not filling when with the isolation layer thickness from15 mIncrease45 mTop help security coefficient

0.87Increase1.37. Therefore isolation layer can effective to limit goaf caused of Slope Displacement share goaf hanging wall surrounding rock under the pressure is favourable to the stability of side slopes.

According to the above analysis transition from open-pit to underground mining isolation layer and slope stability between there are relationship:1)Local under the first stage mining goaf not filling when open-air slope top help of potential slip surface for goaf side wall to top;2)With the isolation layer thickness of increase top help Slope Safety Coefficient gradually increase the end of help Slope Safety Coefficient constant. So slope stability is transition from open-pit to underground mining isolation layer thickness must be consider the factors one.

3. Isolation layer thickness index function analysis

3.1 Index function analysis an overview

Transition from open-pit to underground mining isolation layer thickness and slope stability relationship close consider Slope Stability of isolation layer thickness is a more complex of more factors problem. Commonly used of more factors comprehensive analysis methods is more such as level analysis, multi-attribute comprehensive evaluation method, fuzzy mathematics and gray system evaluation method and, but the methods more is in limited of feasible programme in select a optimal programme[17]. This paper in Ideal Point Method[18]Of Based on is presented function

analysis and this methods calculation isolation layer thickness. The methods not only can solve more factors Problem,

And can avoid feasible programme quantity limited of limitations.

Index function analysis is a kind of through the establishment of a elements with its evaluation index between the function relationship and then get total evaluation function to determine elements optimal solution of more factors comprehensive analysis methods. If elements

Of evaluation index$Y_1Y_2,...,Y_N$The Application Index Function Analysis of basic conditions:1)Elements$A$Can abstract for unknown$X$;

$Y_1Y_2,...,Y_N$Can abstract for index value$Y_1Y_2,...,Y_N$;

Can Construction$Y_1Y_2,...,Y_N$And$X$Between the function relationship.

Determine Elements$A$Of Value$X$Of basic solving steps are as follows:

Determine Elements$A$Of Evaluation Index$Y_1Y_2,...,Y_N$Points

WillY_IThe in the world-dimension

-In Max {$|F_I(X)|$}Said$|F_I(X)|$In value range in the maximum. If a A factors of index on Value$G_I(X)$Relative other factors

X Change of amplitude is large the in order to avoid the factors become total evaluation

Establish total evaluation index value$Y$And$X$The function relationship between

$Y=F(X)$. The Delphi Method$G_I(X)$Give weightW_IThe

If a index on value .-(3)Of processing-(4)In$G_I(X)$With$G_I'(X)$Replace.

Solving Elements$A$The optimal value$X$. Okay$F(X)$The a-order

Please-that

$F(X)$And take the maximum when the obtained$X$That is for optimal solution.

3.2 Isolation layer thickness index function analysis

Slope stability is the transition from open-pit to underground mining isolation layer thickness must be consider the factors one according to transition from open-pit to underground mining isolation layer thickness when need to consider the factors model of the Slope Stability

Of the isolation layer thickness index function analysis when determine main evaluation index for isolation layer security coefficientY_1, Slope Safety CoefficientY_2, Ore recovery rateY_3And isolation layer Bearing CapacityY_4.

3.2.1 Isolation layer thickness of Evaluation Index Function Relationship Analysis

According to underground goaf of span and actual engineering preliminary

Estimation reasonable of isolation layer thickness$X$The value range[AB]In value interval in such as step$H$Select some a isolation layer thickness value:$X_1X_1H,...,X_1(N-1)H$. Use numerical simulation method calculation different thickness

Usually for isolation layer of ore body difficult to mining according to Figure5Shown in the space geometry relationship the underground mining leave isolation layer when ore of recovery rateY_3Can be said

Isolation layer bearing capacity is refers to isolation layer of bending ability according to isolation layer of force conditions will thickness$X$Of isolation layer simplified into on both sides

Surface by dew Zenith, the end of help slope extrusion of is cross section for rectangular of Bending Beam Structure[19-21]As shown in figure6Shown in. Isolation layer by load including self-

G, On the surface were cloth Load$Q$, Vertical in on both sides of surrounding rock extrusion Role Stress $_{N1}$And $_{N2}$And parallel in on both sides of the shear Role Stress $_{N1}$And $_{N2}$.

4. Miyun iron ore isolation layer thickness calculation

4.1 Isolation layer thickness index function analysis calculation

According to geological data and engineering experience preliminary estimation Miyun iron ore isolation layer thickness$X$Of value interval[1545]In interval in such as step select7/A isolation layer thickness value

respectively15Natural 202530354045 m. Use finite element Strength Reduction Method7/Of isolation layer thickness value of elastic-plastic Numerical Calculation get Miyun iron ore first stage mining at the end of the isolation layer and open-air slope of stress distribution state isolation layer thickness respectively153545 mOf Big principal stress distribution cloud as shown in Figure8Shown in.

Extraction each thickness isolation layer of maximum pressure stress($_1$Of absolute value for elastic-plastic theory and rock mechanical symbol provisions of difference)And the most

The increase,Y_1.But lower.

By table2.The thickness of isolation layer has no effect on the safety coefficient of Open-pit bottom slope.Y_2.And isolation layer thicknessXAs shown in the fitting curve11Shown.

XWang Yi[15,45]Slope Safety FactorY_2.And isolation layer thickness

The functional relationship between them is closer to the quadratic polynomial, that is

Y_2.Wang YiF$_2$.(X)Wang YiWang YiWang Yi60X^2.Wang Yi5530XWang Yi18620Wang YiWang Yi10 ^{5}. (15)

Yutu1.Therefore, the scope of underground mining is0 ~ 0 ~ -240 mMining range the ore-body in the thickness basic equal willH= 240 mInto-(9)Ore recovery rateY_3And isolation layer thicknessXOf relationship

This paper using the Delphi Method to Determine the evaluation index function of weight. Please9A engaged in mining, teaching, research of Experts Root

4A Evaluation Index (isolation layer security coefficient, slope safety coefficient, ore recovery rate and isolation layer bearing capacity) of isolation layer determine when the heavy

To the degree of scoring. Each expert4A Index Scoring of and10.0Points experts scoring results such as table3Listed in. According to all experts

Of every A Index Scoring of average and the total score of the ratio get in this paper

Of weight respectively:W_1=W_2=W_3= 0.3W_4= 0.1.

-Push(4)Establish total evaluation index valueF(X)And isolation layer thicknessXThe function relationship between whichG4(X)WithG_4'(X)Replace

$$F(X) \quad (\quad 0.97X^3 \quad 48.33X^2 \quad 317.94X \quad 60694.80) \quad 10 \quad ^5 \tag{23}$$

In-(23)Of based on,X [1545]When that$F'(X)$ 0ObtainedX_1.= 36.2Time,F(X)Get the maximum value, that is, the reasonable isolation thickness is36.2 m.

4.2 Comparative Analysis of calculation results with Different Methods

Platts arch and$K.B$Rupegny[8,10-11]It is widely used in engineering2.According to the engineering conditions of Miyun Iron Mine, this paper uses2.Isolation layer thickness is calculated by using the method of index function analysis.4.Listed. The safety factor of all calculation methods is unified1.2, Isolation layer Span40 m.

Table 4 interlayer services with Different Methods

4. The thickness of isolation layer is equal2.Double the pressure arch height(H= 2H); Use$K.B.$ Rupe

When calculating according to law, because there is no open-air operationQ= 0. Using the index function analysis method, when the slope stability is not considered(W_2.= 0)Without considering the influence of external load(W_4.= 0)The calculated thickness of the separation layer is32 m,$K.B.$ Rupenei

Law(Q= 0)Calculation results32.2 mWhen the slope stability is not considered(W_2.= 0)But considering the influence of external load,34.8 mAnd the calculation results of putt's arch Method35.1 mCloser. With Platts arch and$K.B.$ Compared with law, when calculating the isolation thickness by index function analysis method proposed in this paper, the weight of each evaluation index can be adjusted reasonably according to the mining technology, economic conditions and safety requirements of each mine, get the isolation layer thickness for each unit.

5. Knot On

The Finite Element Strength reduction method is used to simulate the engineering conditions at the end and the first stage of the open-pit mining in Miyun Iron Mine. The relationship between the thickness of the isolation layer and the stability of the open-pit slope is obtained: in the first stage of underground goaf without filling, the potential slip path of the open roof slope changes from slope foot-slope top to goaf-slope top, the safety factor of the open roof slope gradually increases, which indicates that the slope stability is one of the factors that need to be considered to determine the thickness of the isolation layer in the open pit to underground mining.

Based on the ideal point method, the safety factor of isolation layer, slope safety factor, ore recovery rate and isolation layer bearing capacity are considered.4.The safety factor of Open-pit slope is considered as one of the Evaluation Indicators of isolation layer thickness, the optimal thickness value is calculated by establishing the functional relationship between the isolation layer thickness and Its Evaluation Index, which provides a new idea for the separation layer thickness calculation in open-pit to underground mining.

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If the slope stability is not taken into consideration when the isolation layer thickness is calculated by numerical analysis, the calculation results are consistent with those of the existing methods; at the same time, the method can also adjust the weight of each evaluation index according to the mining technology, economic conditions and safety requirements, and obtain the isolation layer thickness suitable for the specific situation of each unit.

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