Study. Movement Characteristics, "Re-stabilization" Conditions. Overlying Key Stratum Structure after Losing Stability

Nan Li

Deep Coal Resource Mining. Education; University. Mining & technology

Abstract: Engineering practices, phenomenon, step subsidence. roof caused.Sliding destabilisation. key stratum structures without support crushing frequently exists. hence a mechanical model. key stratum structure after sliding instability. established, movement characteristics, "re-stabilization" conditions. key stratum structure after losing stability. An-alyzed. .: Show, roof subsidence caused. instability. key stratum structure may not always exceed. threshold, crushes supports. alternatively, unstable block. key stratum may stop sliding. stability. rotation squeezing or touching. falling rocks be-fore crushing. support. two "re-stabilization" conditions. revealed. under certain conditions maintaining rational mining height within support capability or increasing support resistance. make. unstaBle block. rotation squeezing stability. put forward so as. prevent crushing. support.

Keywords: Key stratum;Sliding instability;Re-stabilization;Support crushing;Unstable Block

Cladding rock key layer structure of stability study is a support surrounding rock each other role relationship, carry out Roof Support Design and the roof Disaster Prevention and Control of foundation. Domestic and foreign scholars for key layer structure stability problem and support surrounding rock each other role relationship carried out a lot of useful of research: Literature[1-3]Study the fracture with the strata structure of possibility and structure of balance conditions proposed the masonry Beam balance structure mechanical model and established the masonry Beam Structure of"S-R"Stability theory; Literature[4-6]To masonry Beam Structure of"S-R"Stability Theory for guidance established the stope Surrounding Rock overall mechanical model. However due to coal mine mining conditions of difference and complexity in some special of geological conditions under the appear cladding rock structure abnormal instability and of stope pressure frame roof fall disaster. Literature[7]Think In addition to hard roof cause a large area of the Pressure frame roof fall accident[8]The Shallow Coal Seam Mining[9], Loose pressure aquifer under Mining[10-11], King of High Mining[12-14]And other conditions are the frequent conditions of Large Area Roof Caving accidents in Chinese coal mines in recent years. Such working faces often appear the phenomenon of roof cutting and falling along the coal wall, which leads to the roof bench sinking and even dead supports. This is mainly due to the failure to form a stable masonry beam structure after the broken key layers, the failure block of key stratum is caused by sliding and instability. But there are also some working faces that the roof steps are sinking due to the instability of the overlying strata structure and the supports are not crushed. The roof will stop moving to a certain extent and reach a new stable state. Qidong Coal Mine

7.1 30The mining height of the working face3.2 mHowever, the sliding instability of the roof structure caused the stent to be crushed.

Under the same conditions, the middle mining height of the working face is3.8 mHowever, the structural instability of the roof only caused400The sharp contraction,

Did not crush the stand[10]. Another example is living chicken rabbit Coal Mine in shendong Mining Area12304,12305And12306During the process of mining in the working face, the shrinkage under the maximum living column of the support reaches420,1 000And500Roof Structure Sliding instability resulted in the collapse of support live column, but the working face also only appears under the roof

The phenomenon of sinking and not dying the stent[7,9]. The above case fully shows that even if the broken block of the key layer has slipped and unstable, the resistance of the stent and the overlying load are not changed, it is not necessarily caused by the stent living column continued to shrink until the stent was crushed.

However, most of the current studies mainly focus on the analysis

If the structure will slide instability, slide instability should have

And how to take measures to prevent slip instability?[1-3]However, it is not reasonable to explain the phenomenon that the roof steps of the working face are sinking without killing the support after the failure of the key Layer Structure in engineering practice. In addition, the research on the Motion Characteristics of the key strata instability block after the collapse and instability of the key layer structure, as well as the ability to reach the stability state again are still lacking.

Motion Characteristics and "re-stability" conditions after instability are studied.

1. Motion Characteristics of key overlying strata after structural instability

1.1 Motion Analysis of key overlying strata after structural instability

According to the masonry Beam Structure"S-R"Stability theory, the conditions for failure of masonry Beam Structure[1]For:

Type:HFor the thickness of the key layer;H1.The thickness of the strata under load for the key layer;SigmaCFor the compressive strength of the key layer;ρGFor the volumetric force of rock mass;TanφIt is the friction coefficient between rocks;Theta1.It is the Return angle of the hanging exposed rock block in the masonry beam after fracture.

Due to the small Return angle of broken block, the horizontal force between broken blocks is small, and the friction resistance to block slip is small, which may lead to sliding instability of roof structure.[1]. If the overlying strata structure cannot satisfy(1)The stability condition as shown in this paper is stable, and the support fails to provide enough supporting force for the roof unstable structure, roof slide reaches maximum value when the bracket is crushedMaxCan be expressed:

Type:MaxFor the maximum allowable roof slip of the bracket,M;MFor the mining height of the working face,M;HMinThe support height of the support when the support is crushed, that is, the support height of the support living column without stroke or when the shearer can not pass through, depends on the support and the shearer model,M.

It can be seen that if the key strata structure of Overlying Strata slide, the roof slide will reach the maximum allowable roof slide.Max, The stent was crushed to death. However, in engineering practice, the amount of roof sliding did not reachMaxThe stent was not crushed to death. As mentioned above, live chicken rabbit Coal Mine12304,12305And12306Working Face and Qidong Coal Mine7.1.30Working Face and other cases. It can be seen that after the collapse of the key strata structure of the overlying strata, the slip volume of the key strata will not reach the allowable level when the supporting force and the overlying load of the strata are not changed.

Xu's roof maximum slip is now "re stable" state.

1.2 Mechanical Model of key overburden strata after structural instability

In order to reveal the cause of the above "re-stability" State, according to the analysis method of key blocks of

masonry beam structure[1], Created a graph1.The mechanical model of the key Overlying Strata Structure After sliding instability is shown. In the figure,P1.,P2.Respectively, unstable BlocksIBroken BlockIIUnder the load,KN/m;RFor broken BlocksIIThe bearing reaction,KN/m;RSSupport for the support,KN/m;QA,QBFor respectivelyA,B

MaxWhen the bracket is not crushed to death, such(10)As shown:

The shear force on the contact hinge,KN/m;TFor horizontal force,KN/m;Theta1.,Theta2Respectively for instability BlockIBreaking BlockIIOf back to corner,(°);AFor contact surface height,M;DFor support of control top from,M;L1L2Respectively for instability BlockIBreaking BlockIIOf Length,M;HFor key layer of Thickness,M;SigmaHFor direct top of Total Thickness,M;MFor working face of Mining High,M;W1For instability BlockIIn Goaf of subsidence,M;W2For breaking BlockIIIn Goaf of subsidence,M; For instability BlockIThe fall of the roof of steps subsidence,

$$_{22}$$
M.

2. Cladding rock key layer structure instability after"Stable"State Classification and Formation Conditions

Cladding rock key layer structure instability due to sliding after whether will lead to support was killed and instability BlockIThe fall of size directly related. When instability BlockIThe fall of less than support allow of roof maximum slip

By type(12)It is known that the unstable blockIBack cornerTheta1.Larger, Type(12)The conditions shown are more easily satisfied, that is, the unstable blockIThe easier it is to stop falling further. Unstable BlockIThe corner we can reachTheta1.The size of the unstable block is affected by the height of caving gangue in goaf.IUltimate subsidence in Mined-out areasWLimTotal Thickness with direct topSigmaH, Mining HighM,

Because of the unstable blockIUltimate sinkWLimThe limit, by type(4),(13)Key layer slide unstable blockICan achieve

If the key layer structure is unstable after sliding, if the unstable blockIThe maximum corner we can reachThetaMaxAnd fall of respectively meet-(12)And Formula(10)Of conditions the instability BlockIOf back to cornerTheta1To the formation rotary extrusion stability state required of minimum back to cornerThetaMinAnd stop slide of the same time instability BlockIThe fall of less than support allow of roof maximum fallMaxSo can achieve rotary extrusion stability state prevent killed support. The cladding rock key layer structure instability due to sliding after to rotary extrusion stability state prevent killed support of conditions such

Touch gangue stable state as shown in Figure3Shown in.

Key layer structure instability due to sliding after by goaf falling gangue height of influence instability BlockIMay in killed support before contact goaf gangue and stop further down if at this time instability BlockIThe fall of less than support allow of roof maximum fallMaxInstability Block

IWill in killed support before stop slide and to "stable" state this state that for touch gangue stable state. The cladding rock key Layer Structure

Instability due to sliding after to touch gangue stable state of conditions such-(16)Shown in:

Visible cladding rock key layer structure instability due to sliding after key layer instability due to sliding block of slide of not certain will to support allow of roof maximum slide of and killed support, but may be in killed support before to "stable" state. If key layer instability block physical meet-(15)Conditions to rotary extrusion stability state or-(16)Conditions to touch gangue stable state can prevent support was killed; on the other hand key layer instability block will continue to fall until killed support.

3. Mining High regulation to prevent killed support of role mechanism

points

Mining High is can human regulation of, can the roof support surrounding rock relations influence of important factors one. Working Face Mining Process in killed support accident when if don't take measures working face follow-up of mining process easy again happened killed support accident, through the use of high-Resistance support can effective to prevent roof structure of instability due to sliding[15]But temporary replacement High Resistance support will serious influence working face mining take over and high yield and high efficiency makes feasibility low. Working Face support model number certain of situation under certain conditions under still can be in don't haVe to replacement support of situation under by in support height range in Regulation of high prevent killed support.

3.1 Mining High on instability block"Stable"State of influence

Literature[13-14]In reference to more a working face Mining Process in killed support accident when there are coal seam thickness thinning caused by mining high significantly reduce the phenomenon. In addition Qidong Coal Mine7/130Working Face middle and the Section Mining Process in selectionZY6000/18.5/38Cover-support middle of high3.8 mRoof Structure instability support live column under Shrinkage0.4 mNot killed support[10]; And Working Face the section of high3.2 mSupport Resistance and roof lithology were same conditions under roof structure instability but caused by Shearer was down lead to support is crushed to support live column shrinkage reached0.8 m[7,10]. Visible working face support model number certain of situation under in support height range in by Mining High change can influence key layer instability block to "stable" State to prevent killed support.

Will-(16)Shown in the touch gangue stable state formation conditions the simplification available:

By-(17)The key layer structure instability due to sliding after can to touch gangue stable state to prevent killed support depends on direct top Total ThicknessSigmaHRock of broken Expansion CoefficientKPAnd support was killed when support high HMinAnd and of highMAnd support Support ForceRSNot.

Working Face support model number certain of situation under if key Layer Structure

Instability due to sliding after can meet-(17)To touch gangue stable state of conditions even if don't take measures support also will not be killed; on the other hand key layer structure instability due to sliding after working face there killed support of risk because-(17)Shown in the touch gangue stable state formation conditions and of highMNot the can't in support height range in by regulation of high meet-(17)Shown in conditions to prevent killed support. And by the section-(15)Shown in the to rotary extrusion stability state conditions shows that-(15)Shown in conditions and of highMRelated. For has killed support risk of working face still can be in don't haVe to replacement support of situation under by in support height range in security reasonable of Mining High, control instability block to rotary extrusion stability state prevent killed support but instability block can achieve the maximum cornerThetaMaxAnd fall of must respectively meet-(15)Listed in conditions.

Working Face support model number certain of situation under-(15)Of conditions the available of high change not change instability block to rotary extrusion stability state required of minimum back to cornerThetaMinChange of high essence is change instability block rotary of increase of high can increase instability block can achieve the maximum cornerThetaMax. So can be in not replacement support situation under by in support height range in security reasonable of Mining High the instability block has enough of rotary Space Control instability block can achieve the maximum cornerThetaMaxGreaterThetaMinMeet-(15)Of conditions.

Working Face support model number certain of situation under support was killed when the support heightHMinA value. By-(15)Of Conditions ② available increase of high can increase support of live column trip to increase support allow of roof maximum fallMaxSo can be in not replacement support situation under by in support height range in security reasonable of Mining High the instability block has enough of allow fallMaxControl instability block slide of lessMaxMeet-(15)Of Conditions II.

Visible for has killed support risk of working face support model number certain of situation under in support height range in reduce of High is not conducive to key layer instability block to rotary extrusion stability state avoid

killed support. Adjustment of high essence is security instability block has enough of allow slide of and rotary space. Even if in don't replacement support of situation under still can be by in support height range in security reasonable of mining high control key layer structure instability after instability block can achieve the maximum cornerThetaMaxAnd fall of meet-(15)To rotary extrusion stability state of conditions prevent killed support.

3.2 To prevent killed support reasonable mining high critical value of determine

Support Model Number certain of working face conditions under for make key layer structure instability due to sliding can be achieved after the rotary extrusion stability state instability block can achieve the maximum cornerThetaMaxAnd fall of must respectively meet-(15)Of conditions-(15)Can transformation:

Type:M1.To satisfy(15)The Minimum Mining Height of the conditions,M;M2.To satisfy(15)Conditions ② minimum mining height,M.

In order to make the key layer structure slide instability can achieve rotary extrusion stable state, Working Face mining height must meet(18)Medium Conditions (1) and conditions (2), the minimum reasonable mining heightMMinIf style(19)As shown:

For working face with dangerous dead supports, the minimum reasonable mining height required for working face with stable rotary extrusion state after the collapse of key layer structure is reached under certain support type.MMinIf the maximum support height of the bracket is larger than that of the bracket, the height of the bracket can not be controlled to prevent the compression of the bracket without replacing the bracket, can control the mining height in the range of the height of the support to prevent the pressure of the support, but should ensure that the mining height of the working face is not less than(19)Control the key layer structure sliding instability to reach the rotary extrusion stable state, to ensure that the working face roof sliding instability, even if caused by the roof step sinking but not die bracket, the working face can continue to mining.

4. Determination of reasonable support resistance threshold to prevent death

In addition to the control of mining height to prevent the pressure of the stent, improve the resistance of the stent can also prevent the slide instability block pressure to die. Type(17)Formation Conditions of gangue contact stable state and Support ForceRSHowever, we cannot control the supporting forceRSMeet the contact gangue stable state forming conditions to prevent the death bracket. But style(15)The condition of reaching the stable state of rotary extrusion and Support ForceRSRelated, can be controlled through the SupportRSMeet the forming conditions of rotary extrusion stability to prevent the pressure of the stent. General(15)The Forming Conditions of the stable state of the rotary extrusion are transformed, and the requirements of the supporting force of the support supporting support for the critical layer sliding and unstable block reaching the stable state of the rotary extrusion can be obtained:

Improve support resistance can promote key layer structure instability due to sliding after instability block to rotary extrusion stability state and made new of flat

Balance to avoid support was killed. For has killed support risk of working face if key layer instability due to sliding block killed support Front Bracket support force can meet-(20)Of requirements key layer instability due to sliding block will reach rotary extrusion stability state and avoid killed support.

5. Engineering instance analysis

5.1 Working Face basic mining conditions

Qidong Coal Mine7/130Working Face for hotels near loose pressure aquifer conditions under mining loose pressure aquifer effect of load transfer of easy to cause key layer of composite breaking lead to masonry beam structure instability due to sliding[11]. Working Face to long about1 604 mIs divided into in the section, the middle and the segment3A different of block. Working Face middle and the Section Mining Process in

selectionZY6000/18.5/38Cover-support control top from

4.5 mSupport width1.5 mMeasured cycle to pressure step

15 m. Middle and the Section Mining Process CPC happened.4Times roof structure instability due to sliding as shown in Figure4Shown in the first3Times roof structure instability working face of high3.8 mNot killed support live

Column under Shrinkage0.4 m[10]. But the first4Times roof structure instability when working face of high3.2 mSupport Resistance same situation under but caused

Shearer was down lead to support is crushed to support live column shrinkage0.8 m[7,10]By-(2)Available support was killed when the support height

HMinFor2.4 m.

Working Face the first3Times roof structure instability from the first4Times roof structure instability only about56 mVisual its lithology same support was killed location near the high91Drilling cladding rock key Layer Structure[10]Such as table1Shown in. According to on-site actual mining conditions corresponding parameters desirable: support of Support ForceRSFor4 000 kN/mSupport width take1.5 m; Support control top fromDFor4.5 m; Support was killed when the support heightHMinFor2.4 m; Key layer instability block LengthLDesirable15 m; By table1The thickness of the key layersHFor9.36 mTotal Thickness of the direct topSigmaHKiyo3.79 mFriction Coefficient between rocksTanφKiyo0.4[2]The crushing coefficient of rockKPKiyo1.3[16]; Length isLThe unstable block

5.2 After structural instability of working face"Re-stabilization"Conditional Verification

According7.1.30Working Face mining parameters willHMin,SigmaH,KPSubstitution of specific parameters(16)Available, unsatisfying(16)To achieve the stable state of the gangue7.1.30Under the working face mining conditions, the key layer structure can not reach the stability state of the Gangue to prevent the pressure of the stent, which is dangerous.

Considerations(15)The conditions for achieving the stability state of rotary extrusion After sliding and buckling of the listed key layers. For7.1.30Working Face no.3.Sub-roof structure instability, Working Face Mining HeightMFor3.8 m, Will(15)The required parameters can be substituted into the roof slide0.4 mThe maximum return angle of the unstable block after the collapse of the key Layer StructureThetaMaxFor8.7°, Greater than the minimum return angle required for the unstable block to reach the stable state of rotary extrusionThetaMinFor7.6 °Meet(15)1. The conditions(15)Conditions (2) the required parameters can be substituted into the maximum amount of roof slip allowed by the stent.MaxFor1.4 m, Greater than the first3.Roof slip during sub-Roof Structural Instability0.4 mMeet(15)The conditions. Therefore,3.After the sub-roof structure became unstable, it reached a stable state of rotary extrusion.

For7.1.30Working Face no.4.Sub-roof structure instability, Working Face Mining HeightMFor3.2 m, Will(15)Conditions (1) the required parameters can be substituted, when the roof slide, the same0.4 mThe maximum return angle of the key layer instability block can be reached.ThetaMaxFor6.4°, Less than the minimum return angle required for the unstable block to reach the stable state of rotary extrusionThetaMinFor7.6 °, Dissatisfied(15)The conditions

4.After the sub-roof structure is unstable, it cannot reach the stable state of rotary extrusion, and the unstable block will continue to slide until the scaffold is crushed.

5.3Determination of reasonable mining height of working face

To prevent7.1.30Pressure again in subsequent mining process of working face

At the same time, to avoid the impact of replacing high resistance support on mining replacement, other measures should be taken to ensure the normal mining of working face. Due to the first3.The rotary extrusion stable state is formed after the sub-roof structure is unstable.(18)Medium roof slide0.4 m, Will(18)Kazushi(19)The required parameters are available,7.1.30Minimum reasonable mining height required to achieve rotary extrusion stability after Working Face Roof Structural InstabilityMMinFor3.5 m, Less than the maximum support height of the bracket3.8M.

Therefore, in the case of not having to replace the bracket, the working face mining height can be ensured3.5 mSo that the key layer structure sliding instability after reaching the rotary extrusion stable State to prevent the dead bracket, to ensure the normal mining face follow-up.

5.4 Determination of reasonable working resistance of working face Bracket

For7.1.30Working Face no.3.Mining conditions of sub-Roof Structural Instability area, mining heightMFor3.8 mRoof slide0.4 m, Will(20)The required parameters can be substituted into3.Support Force required for achieving rotary extrusion stability after sub-Roof Structural Instability3 635 kN/m, That is, the required support working resistance is5 452 kN, Less than the working face bracket rated working resistance6 000 kNTherefore,3.After sub-roof structural instability, the sliding unstable block reached a stable state of rotary extrusion, And the stent was not crushed.

For7.1.30Working Face no.4.Mining conditions of sub-Roof Structural Instability area, mining heightMFor3.2 mDue to the first3.The rotary extrusion stable state is formed after the sub-roof structure is unstable.(20)Medium roof slide0.4 m, Will(20)Required of parameters into available the first4Times roof structure instability after to rotary extrusion stability state required of Support Force4 377 kN/mThe required of support work resistance6 566 kNGreater than working face support rated Work Resistance6 000 kNSo the first4Times roof structure instability after instability due to sliding block failed to achieve rotary extrusion stability state instability block experience continuous slide until killed support. Visible,7/130Working Face the first4Times roof structure instability regional mining conditions under key layer structure instability due to sliding stent don't was killed the reasonable work resistance should be greater6 566 kN.

6. Of On

Explain the key layer structure instability due to sliding after working face in roof steps sinking and not killed support phenomenon of reason. With the key layer instability due to sliding block back to corner of increase instability block by the lateral level force the greater the hinder its further fall of friction resistance the greater the instability block may in killed support before stop down. In addition instability block may in killed support ago contact goaf gangue and stop down.

Cladding rock key layer structure instability due to sliding after key layer instability due to sliding block of slide of not certain will to support allow of roof

Maximum slide of and killed support but may be in killed support before to rotary extrusion stability or touch gangue stable state reveal the to two kind of "stable" state of conditions.

Working Face support model number certain of situation under in support height range in reduce of High is not conducive to achieve rotary extrusion stable state. Certain conditions under can in support height range in by security reasonable of Mining High make key layer instability block has enough of allow slide of and rotary space to rotary extrusion stability state prevent killed support. Qidong

Coal Mine7/130Working Face Conditions under avoid killed support of minimum reasonable mining high3.5 m.

Improve support resistance can promote key layer instability due to sliding block to rotary extrusion stability state prevent killed support from the key layer structure instability due to sliding stent don't was killed of Support Resistance requirements. Qidong Coal Mine7/130Working Face the first4Times roof structure instability regional mining conditions under prevent killed support required of Minimum Support Resistance

6 566 kN.

References

1. Qian ming gao Samuel Hip Hing what fu lian. stope "masonry beam" structure of Key Block Analysis[J]. Coal Journal,199419 (6):557-563.QIAN minggaoMIAO xiexingHE fulian.Analysis. Key Block. structure. voussoir beam. longwall mining [J].Journal. Coal Society199419 (6):557-563.
2. Qian ming gao. stope overlying rock of Balance Conditions[J]. Journal of China University of Mining & Technology,198110 (2):31-40.

3. Qian ming gao bed establishs Li Liang and. masonry beam of"S-R"Stability and Its Application[J]. Mine Pressure and roof management,199421 (3):6-11.QIAN minggaoZHANG DingliLI liangjieEt al."S-R"Stability. voussoir beam, its application [J].Mine Pressure, Roof Management199421 (3):6-11.

4. Samuel Hip Hing qian ming gao. stope Surrounding Rock overall structure and masonry beam mechanical model[J]. Mine Pressure and roof management,199522 (3/4):3-12.MIAO xiexingQIAN minggao.Solid structure, model. voussoir beam. face of "surveillance rock [J].Mine Pressure, Roof Management199522 (3/4):3-12.

5. Cao wins root. stope Surrounding Rock overall Mechanical Model and Application Research[J]. Rock Mechanical and engineering Journal,199918 (6):721-721.

6. Cao wins root qian ming gao Liu Changyou and. of support-Surrounding Rock relationship New Study[J]. Coal Journal,199823 (6):575-579.

7. Xu Jia forest Zhu guards bowed Golden Peak and. Stope Large Area pressure frame roof fall Accident Prevention and Control Technology Research[J]. Coal Science Technology,201543 (6):1-8.

8. Cao wins root ginger Navy King Fuhai and. stope overlying hard rock breaking of Numerical Simulation Research[J]. Mining and Security Engineering Journal,201330 (2):205-210.

9. Xu Jia forest Zhu guards bowed Golden Peak. Shallow Coal Seam Mining Pressure Frame Type[J]. Coal Journal,201439 (8):1625-1634.

10. Lin Qing. Qidong Coal Mine7/130Fully Mechanized Mining surface of the Pressure Water Inrush Reason Analysis[J]., China Coal,201238 (12):44-47.

11. Xu Jia forest Zhu guards WANG Xiao vibration. Loose pressure aquifer under coal mining Water Inrush Mechanism and Prevention and Control Research[J]. Mining and Security Engineering Journal,201128 (3):333-339.

12. Rowan. Shallow Large Mining Height Fully Mechanized Mining Working face the end of Mining Pressure frame roof fall Processing Technology

13. Wang Zhigang Lee access qeneral and Chief Analyst and. Large Mining Height Working Face. stone area pressure frame Reason Research[J]. Coal and chemical,201437 (3):86-88.WANG ZhigangLI tongdaLI ShijunEt al.Study.

14. Yin Hebrew. Large Mining Height Fully Mechanized Mining Working Face Pressure frame Reason Analysis and Prevention and Control Countermeasures [J]. Coal Science Technology,201442 (7):26-29.

15. Hao Constitution Jay Xu Jia forest Zhu guards and. High pressure loose aquifer the lower support of the reasonable work resistance of determine[J]. Journal of mining and safety engineering, 2010,27 (3):416-420.

16. Wu Fengfeng, Yang jingxuan, Yu Bin, *et al.*. Determination of Roof Caving height of thick and extra thick coal seam working face[J]. Journal of China University of Mining and technology,2014,43 (5):765-772.