The Safe Stability Research of the Buttock FRP Bolt Supporting

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Abstract: The safety and stability of mining roadway directly related to the mine production and safety. This article has deeply studied the security and stability of coal through numerical simulations, theoretical analysis and field observation experiments etc. then give the conclusion: The coal walls of the Kangjiatan coal, which have been in the use of the FRP bolts is safe. This method can not only solve the problem that metal bolts can easily be involved in shearers and damage the drum picks, but also prevent coal dust and gas explosion accidents.

Keywords: FRP bolt, coal wall, security and stability, numerical simulation

1. Introduction

It brings stress centralize on the both gangs of the roadway when it is excavating. The coal body of the roadway buttock's state of stress has changed to biaxial state of stress from primary three ways[1,2]. The buttock bearing point will develop into the deep of the coal body at the function of the concentrated stress. Owing to the loosen coal body, so it will appear some degree wall caving.

The safe stability of the buttock has direct relation with the safety and production of mine .There are many factors of infecting the stability of buttock , include the deep of mining ,status of mining of the roadway around ,the roadway radio of height to span ,the stability of roadway wall rock and the supporting status of buttock ,and so on .To the extent that mining，it is essential that the support stress brought by stopping infect to the roadway. On the supporting form, to avoid the distortion of buttock, we should adopt the bolt, the distortion of buttock is because the loosen of the coal body inner part move and the coal body follow the coal seam interface is extrude, the purpose of the buttock bolt supporting is to control the coal body to loosen and to be extruded, it is to prevent wall caving[3-7].

We use the concrete condition of KangJiatan mine which belongs to ShenDong Company to further dissertation.

2. The Local Condition

The field lie the north of shen dong coal field, the structure is simple ,it presents homocline structure ,and develop to have the slow wave form to rise and fall, the strata approximately present to tend towards 350° , dip 260° , the dip angle is 3-9° , general being about 5° , do not see large-scale fault , fold and foundering pole. $8^{\#}$（$8^{-1\#}$）coal seam lies on the bottom S_3 sandstones of the Shan Xi group（P_{1S}）, the thick of coal seam is 2.15 m - 10.39 m , average 6.40 m, between middle thick and very thick coal seam, most part is thick coal seam. The coal seam structure is simple to complicated, containing dirt band 1 - 8 layers, general 3 - 4 layers, the dirt band total thick is 0.3 - 2.6 m, average 1.06 m, the single layer the biggest dirt band thickness is 0.77 m, the rock character mainly is mudstone, second is carbon mudstone. There are 58 crops in the whole coal field, all the thick of coal seam can be mined, the coal seam workable mining sex index number is 1, and the variation coefficient is 33%, belonging to more stable coal seam. The coal seam thick generally present thick in east and thin in west, thick in the center and thin two side variety trend, the most thick place is the part of the middle south of the field, at the section of the drawing 2, drawing 3, checking 4 bore. Immediate roof of the coal seam generally is sandy mudstone and mudstone. part is kern stone，the floor generally is mudstone, the siltstone is second.

The cover rock thick on coal seam is 5.16 m - 555.28 m, average 197.87 m, there are 48 exposure points that are greater than 100 m, they take up 83%, the cover stone thickness is correlative with the landform rise and fall, the total trend is thick in the thin west and thin in the east.

The buttock of the 88202 working face tailentry in KangJiatan mine wall caving is serious, especially the bottom coal seam of the $2^{\#}$ dirt band , the main wall adopt wooden bolt to support at first, but this kind of supporting has obvious disfigurement, The strength of the wooden bolt is insufficiency, It will appear wall caving in large area, when the face push forward to the place supported by wooden bolt, then the most wooden bolt were broken, they do not have the function of maintenance the main wall of roadway.

We adopt the Φ16×2000 mm FRP bolt to strengthen support the main wall, the bolt has some excellences, for example anchor stress is big, the

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cutting is easy, the cost is low, and so on. The height of the tailentry is 3 m. The bolt disposal presents five-flowered form，the upper row bolt is apart from the roof 500mm,the below row bolt is apart from the floor 700 mm, the pitch and spacing are apart from 800×800 mm, the iron tray of the adoption kit, and match with to use the specification as 500×200×50mm wood tray, ZK23×400 mm resin power stick , The torque of installation is 40 Nm.

3. Theory Analysis

At present, the buttock is supported by wooden bolt and bamboo bolt, although, they are advantageous to the incision of mining machine and the cost is low, the anchor stress is low and the anchor performance is not good, and so on. At the initial days of installing bolt, the inherent stress which inflict to the coal body mainly comes from the extrusion between coal body and tray, and the orifice is tightened by wooden wedge. In the course of stressing, the tail of the bolt abscises easily, and the pole body shear failure to the coal body can't provide enough shearing resistance. We should inflict the inherent stress to prevent the buttock becoming flexible when installing buttock bolt. This point is same to the function of roof bolt to prevent inchoate roof apart. We should improve the anchor stress form improving the anchor effect of the single bolt, to achieve the purpose of improving the supporting effect, reducing the drift and improving the rate of progress.

Therefore, we will calculate FRP bolt whether suffice the request of anchor stress. The side dead load of buttock Q_{bs}, from the soil mechanics easily get the Q_{bs} formula when the roof character is different.

When the roof rock character is same,

$$Q_{bs} = 2r_d R_b h \tan^2\left(\frac{\pi}{4} - \frac{\varphi}{2}\right)$$

In the type: r_d—— the bulk density of roof rock, t/m^3

R_b—— the radius of breaking zone, m

φ —— internal friction angle, °

h —— half height of the roadway , m

The radius of break zone can be obtained by making use of on the field measure which is according to concrete the engineering condition or using the formula which roundly consider the rock strain softening and fracture expansibility, we use the concretely measure method, it can get the loose range of buttock body, that is the radius of break zone .By the field measure of loose cycle in KangJiatan mine, it knows that the radius of break zone is 1.2 m, the width of subsidiary haulageway is 5.1 m, the height is 3.45 m, so the lateral dead load of the buttock is 2.54.

Therefore, in order to make the system of anchor do not invalidate and keep the stabilization of the roadway in the period of service, the support design of the system of anchor must satisfy: the maximal engineering the stress of supporting $P_{s\max}$ should be greater than the dead load Q which is transformed from the roadway engineering stress. Considering the similarity of the design and the disadvantageous factors in the course of construction, here considering $P_{s\max} = KQ$,K is the coefficient of safety, K＝1.0～2.0. In order to safe, there is a supporting system of side buttock bolt:

$$P_{s\max} > KQ$$

Because the roof of KangJiatan mine is coal body, we can use the formula and calculate whether the FRP bolt can satisfy to supporting stress of the system engineering of buttock anchor and ensure the safety production. Because the pulling capacity of the FRP bolt that KangJiatan mine used average 8—9 t, when k=2, the side dead load is 5.08t, from the anchor stress, the FRP bolt can sanctify the need and play the function of supporting.

4. The Numerical Simulation

4.1 Similar Models Establishment

The RFPA (rock failure process analysis) which developed by breakup and instability research central of northeastern university found on theory of finite element and fire-new material rupture process algorithm concept, it simulate nonlinearity by means of the nonhomogeneity of material, simulate the discrete of deformation and breakage , it can be used on researching the course form microscopic damage to macroscopic breakage , it can be used on computation and dynamic demo the course of breakup .

This model fetches 16m along the horizontal direction and 25m along the vertical direction. The thickness of coal seam is 3m.We can see the specific parameter of rock mechanics from table 1,and the model cell is divided to 125×80＝10000, each cell represents the practical situation of the minute rock. We adopt Weibull distribution here to change the heterogeneity of material by regulating the parameter of Weibull, in which the homogeneous degree of Elastic ratio and Monopodium resist compression is 3, the homogeneous degree of Poisson ratio and rock bulk density is 100.We adopt the modified coulomb principle (it can consider tensile failure) as the cell destroyed principle, the strength ratio of tension and press of primitive material in principle is given in 1/5. In the numerical calculating chart every layer shade of gray represents the magnitude of rock mechanical parameter (Elastic ratio, compression strength and etc), brighter shade of gray is, bigger the value is.

The flowing table is model of terrane character parameter

Table1 the rock mechanics parameters of every rock strata of roof strata

Rock character	Monopodium compression strength MPa	thickness m	Elastic ratio MPa	Poisson ratio μ	Internal friction angle	Density g·cm^{-3}
Sandstone	45.5	9	5680	0.25		2.5
Cleaving stone	37.8	6	4910	0.24	47.5	2.3
Mud stone	29.2	2	4470	0.25	47.1	2.3
coal	18.6	3	3700	0.45	44.2	1.84
Mud stone	29.2	3	4470	0.25	26.1	2.3
Lime rock	57.3	2	8890	0.23	40.7	2.6

4.2 The analysis of Numerical Simulation Result

The RFPA is used to simulation and calculation; it can get the graph of deformation and destroy of buttock in case of dynamic analogies state. In the low figure, it is the shear stress graphs in condition of unsupported and supported by FRP bolt coal pillar.

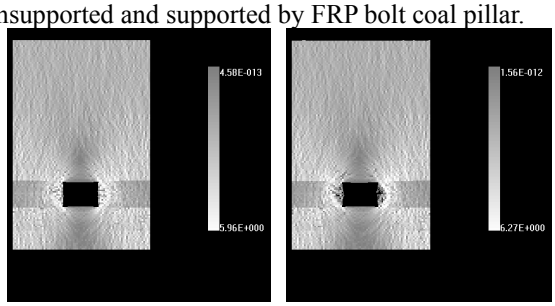

Fig 1. Destroyed state when coal pillar is not supported by FRP bolt

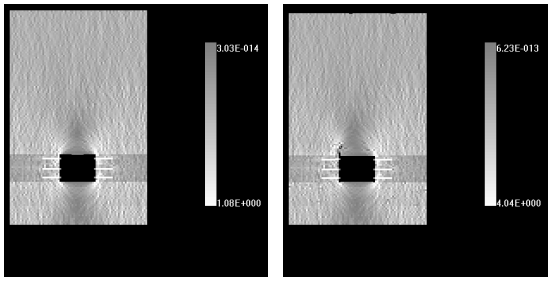

Fig 2 Destroyed state when coal pillar is supported by FRP bolt

After support, the degree of stress concentration substantially lower, and because of fractional compression，the practicable stress of adjacent rock has been larger than the unsupported stress.

By means of numerical simulation we can see the cola pillar stress regularities of distribution as following states.

1）when both sides of the roadway is unsupported, as the workings gradually advance, the bilateral coal body appears stress concentration, the shear stress concentrates at the four corners and both sides, buttock shift-in apparently; and buttock occurs destroy from inferior horn to about the middle position of roadway; the destroyed points approach elastic-plasticity border of adjacent rock, then develop upwards after reaching the mid roadway, connectivity with upper horn, form a destroyed subtriangular zone; when the workings go on, the destroyed subtriangular zone completely rap, break, collapse, appear wall caving. During this process, the largest shear stress gradually increases, from 0.79 to 12.7, that is, the stress concentration coefficient of coal pillar gradually increases. Evidently, in KangJiatan mine, buttock will appear wall caving, and the degree is more serious in condition of buttock unsupported by FRP bolt or supported by wood bolt.

2）when buttock is supported by FRP bolt, FRP bolt and the coal body in anchoring range form a unified supporting anchorage body, its shear ability and load-bearing nature substantially increase, as the workings advance, it appears stress concentration in anchoring body, but its numerical value still can not reach the ultimate strength of anchoring body, it will not destroy, the coal body will not appear wall caving, the problem of the safety of production in the coal and safety of the workers is solved completely.

5. Field Experiment

In KangJiatan mine the observation reach of deep displacement has been done to further prove buttock stability in condition of FRP bolt supporting. Relative displacement inner the adjacent rock of roadway is that the displacement quantity among the multiple-point inner the adjacent rock, the main purpose of interior displacement monitor is to judge the rap range of the adjacent rock, and appropriately select the bolting parameter, also judge the safe rationality of buttock in condition of FRP bolt supporting. Measuring device is DW-type mechanical multiple-point displacement meter.

According to the condition of KangJiatan mine, we locate a drill of 7m deep and ϕ 42 in both sides of roadway in every observation station, and install observation basing-point of different depth,(figure 3). Drawing graduated cable to a degree, by using spring dynamometer, and then we can read the number of length of exposed graduated cable.

Expressing monitoring data by picture can get curve diagram of cumulative convergence quantities of measuring point, decelerating this through figure 4.

It is learned from observation result, even though buttock is supported by bolt, the bilateral coal body will still be force out. But because of the bolting effect, the extrusion displacement quantity is decreasing, and

the displacement towards the roadway present globality. The deformation of the adjacent rock in the stopping way has the trend of gradual diminution from rib to the interior coal body; it is large deformation in the superficial coal body and small in the interior. The bolting effect of buttock is to control the deformation and destroy of the superficial coal body. Because of the bolting grasp effect, it makes the deformation of the coal body which is under the control of bolt in the length range get synchronized, so the coal body build-up a load-supporting layer which both bear top pressure and integrally move at the horizontal direction.

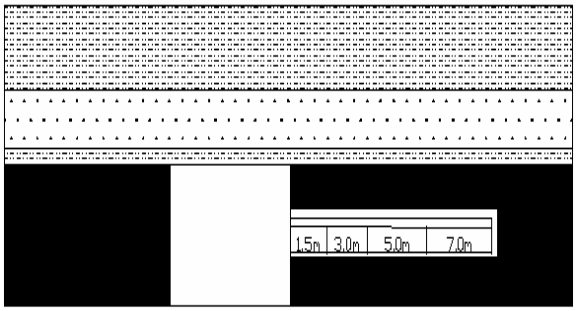

Fig.3 The picture of measuring points

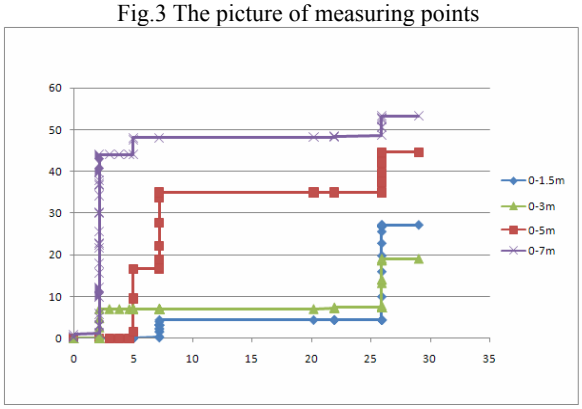

Fig.4 The picture of deep displacement

It is learned from the effect of local FRP bolt supporting, when the workings advance to the less than 30m distances from the FRP bolt supporting zone, as it is not supported by FRP bolt in the 30m range, nearby the workings still appear wall caving, the average dropping thickness is 10cm, the largest is 30cm, wall caving will always continue until it gets to the front distance about 500mm of the FRP bolt supporting zone, however, the supporting zone has never appeared wall caving even if the workings approach. Although buttock in the supporting zone is influenced by mining, it still basically complete because of the effect of FRP bolt, no new wall caving appears. The 88202 face advances to near the Φ16 FRP bolt supporting zone, FRP bolt is directly cut by coal mining machine, no influencing the normal working of coal mining machine, and the tail metal bolt and tray salver can slough automatically, are taken out by conveyer, the resin bar has no damage with belt.

It is known by the local monitor, the main wall which is no FRP bolt appears wall caving many times, that is, as the workings advance, and new wall caving appears at the special zone that has appeared wall caving ever. It is no wall caving in the range of the FRP bolt supporting zone whether it is near the workings or not, integrity of the main wall is very good, if FRP bolt is erected at the special zone, it can control its further development effectively.

6. Conclusions

So the main wall of the workings in KangJiatan mine is unstable in condition of no FRP bolt supporting, wall caving is more serious, however, effectiveness is better while FRP bolt supporting, not only control the problem of wall caving better, enhance the safe stability of the coal body, but also avoid the spark problem while coal mining machine cut, make sure the safe and highly active production of the mine.

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