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Basic Structural Forms of Main Roof

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SUMMARY

Based on the results of field observation, experiment and practical engineering, this paper discusses the main roof structure forms from the angles of roof control and loading prediction. The main conclusions are as follows:

1. The structure forms of main roof vary with the qualities of rock masses.
2. The main roof has three basic structure forms: dynamic arch, arch-beam and beam.
3. The movement rules, abutment manifestation and control rules of the three forms are different.

The results of this paper are successfully applied iin Roof Control Expert System and Loading Prediction Expert System.

1. Introduction

One of the features in modern mining development is the demand of up-to-date technology in settlement of practical problems. How to give the rational support design for a certain stope with given conditions, how to make the loading prediction for stopes threatened by loading, etc. are all the knotty problems confronted. Human experts are able to give rational answers to these problems on the basis of their knowledge and experiences they have accumulated, but they are limited in number. Therefore, a knowledge tool containing the knowledge of a number of experts is desired to be developed in place of them in solving these problems. This is the expert system, a high technique in mining science.

For establishing an expert system, it is required that knowledge in "discrete state" become "systematic" knowledge. This is a process of "integration" of knowledge and at the same time a process for verification of completeness and compatibility of existent knowledge.

In loading Prediction Expert System and Roof Control Expert System, the diagnosis of structural forms of main roof is essential. So, completeness and compatibility of knowledge concerning the structural forms of the main roof become the first problem to be solved in the development of these two systems.

In this paper, the main roof refers to the equilibrium structure of rock beds which is located above the immediate roof and has significant influence on stope pressure. It can be formed either through the articulation of hard rock blocks or through the squeeze of relatively loose blocks.

Examination of the existent theories and ideas concludes that these theories on main roof are not perfect yet, and the viewpoints previously regarded as contrary to each other are found compatible from an angle of system. The structural forms of main roof vary with the state of the component beds.

This variation can be expressed by three typical models. The division of them is based on pressure control criteria of the structurally different main roofs.

The observation on pressure of stopes in different strata, simulation tests, and theoretical analyses are performed so that the above opinions could be verified.

2. Relation Between Typical Abutment Manifestation and Main Roof Structure, Shown by Measurement

Displacement transducers installed in the gate-way 10–20 m before the coal wall can detect the abutment manifestation transmitted to this region of coal body in the process of the movement of the main roof. Thereby, the long-term prediction of stope loading can be realized [1]. The principle is that the variation in displacement of coal body indirectly reflects the movement of the main roof, and the latter in turn is the direct reflection of the structural properties of the main roof. That is to say, some of the structural characteristics of the main roof can be deduced from the displacement variation in coal body.

In the mining pressure observation, the displacement variation is described by the approach velocity of the roof and the floor at some fixed points in the gate-way somewhere in front of the coal wall [2]. 8 hours is taken as a timing unit. The distance between fixed points is generally 3 m. Usually the values of approach velocity of 3–4 fixed points are plotted with the related pressure on stope supports. The relation between loading manifestations in the gate-way and in the stope is observed to deduce the structural features of the main roof.

2.1 *Roof Conditions of Three Typical Stopes*

Three longwall stopes with considerably different roof conditions are selected, where DZ single props of NDZ single hydraulic props are used and advance rate is 2–3 m/d.

The roof of face in No. 66 seam ("the Red Crag" mine, Nantong Mining Bureau) is composed of strata over 10 m of shale interbeds, water-laden, with a uniaxial compressive strength of 10–30 MPa, and with very developed bedding and joints (Figure 1a). This is a loose and broken roof.

The face roof in No. 16 seam (Beisu Coal Mine, Yanzhou Mining Bureau) is limestone 5–7 m thick, overlain by sandy shale. The bedding height of limestone is 0.5–1.0 m. Joints are developed. The uniaxial compressive strength is 80–120 MPa. The mining height is 1.1 m (Figure 1b). This roof is of medium hardness.

The immediate roof of the face (Mentougou Coal Mine, Beijing Mining Bureau) is thin-layered siltstone, above which are 3 m of fine-grained sandstone and 2 m of fine-grained siltstone. The uniaxial compressive strength is as high as 180–190 MPa. The roof is intact. The two beds composing the main roof move together. This is an intact and hard roof (Figure 1c).

It is obvious that the three stopes have different types of roof due to the different strength of main roofs.

2.2 *Abutment Manifestation Features of Three Typical Stopes*

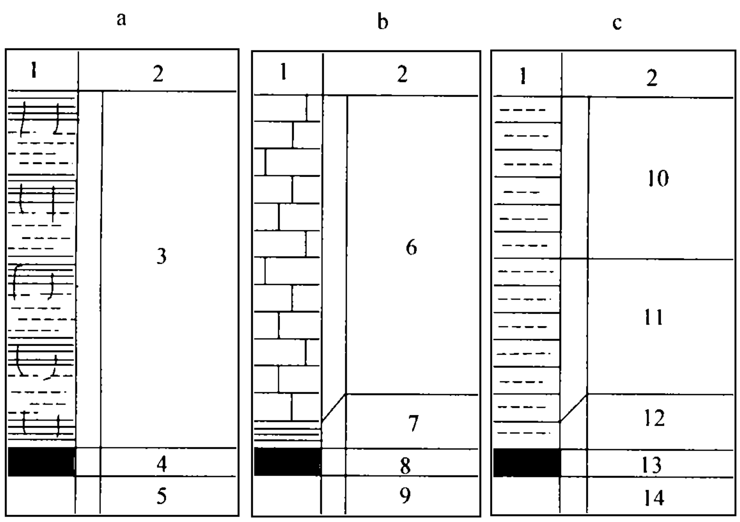
Related to Figure 1, Figure 2 gives the measured velocity of the roof and the floor of the gate-way to approach each other and the supporting load in the three stopes.

From Figure 2 the following can be concluded.

(1) For the main roof composed of loose and soft beds the movement and manifestation are periodic.

(2) Before each loading only one evident peak appears at each of the fixed points in the gate-way, and the evident "rebound" is absent.

(3) In the four loadings observed, the peaks in the air way appear in average 1 hour earlier than those in the working face. This shows that this structure has very weak force transmission capacity, and poor self-stability. The turning point of instability is near the coal wall.



1–Borehole; 2–Rock; 3–Interbed of shale and sandstone, water-laden, over 10 m in thickness; 4–Coal 2 m; 5–Alum clay shale; 6–Limestone with developed joints and cracks, 5–7 m in thickness; 7–Local pseudoroof; 8–Coal 1.1 m; 9–Siltstone; 10–Fine siltstone, 2 m thick; 11–Fine-grained sandstone 3 m thick; 12–Pseudoroof; 13–Coal 2.2 m; 14–Sandstone.

Figure 1. Boreholes of three longwall faces.

(4) The relation between abutment manifestations in the gate-way and in the stope can be shown by Figure 3a. It can be seen that the stope loading prediction based on information from the gate-way is almost impossible.

(5) The movement of the main roof has no evident influence on the deformation of the gate-way 6 m in front of the coal wall. (The average deformation rate is 0.18 cm m/min, at the place 6 m away.)

The features of this type of main roof are found in the observation and control of other stopes with similar conditions.

(1) With low strength, the instability is apt to take place under the action of overlying beds. Therefore, the roof pressure in the state of complete failure of the main roof should be taken into account. When high top failure occurs large static pressure acts on the support sets. For example, the visible collapse height is 5 times the mining height in No. 10 coal mine, Zibo.

(2) The advance of periodic loading is not equal to the length of rock block, but to the instability advance for the whole structure.

(3) The equilibrium conditions and the equation of arch line for the structure depend on the arch span, the size of rock block, strength and specific weight. To exactly express the interrelations of these factors is very difficult.

(4) In some of stopes the equilibrium structure of this squeeze type can be found.

From Figure 2b the following are known.

(1) For the structure of main roof with medium hardness, the movement and abutment manifestation are evidently periodic.

(2) Before each loading, a peak of the approach velocity occurs in the gate-way, which lasts 16–24

hours. And the appearance of the peak in the gate-way is about 24 hours earlier than in the stope. Based on it, the long-term loading prediction can be realized.

(3) The relatively large time difference between the gate-way peak and the support load peak indicates that this structure of main roof has relatively strong self-bearing capacity and good capacity to transmit the rock weight.

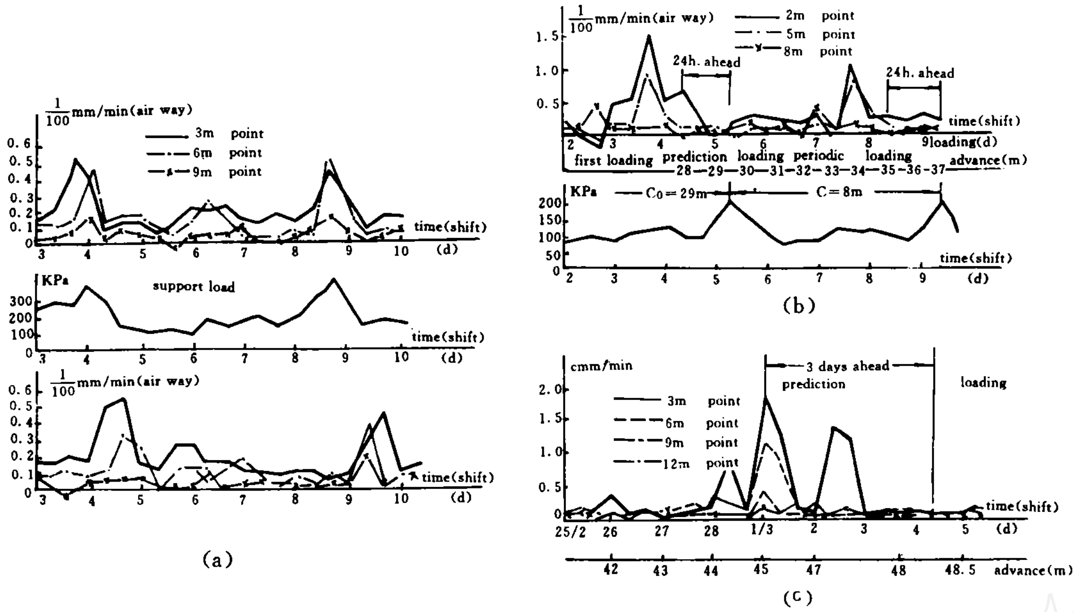
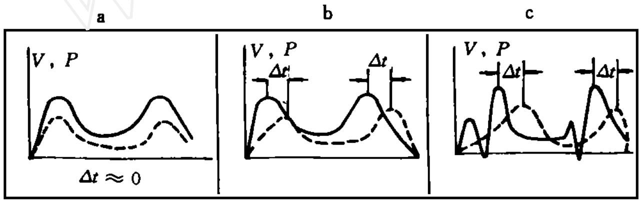


Figure 2a. The abutment manifestations in two roads and the support load in face of dynamic arch structure main roof; **2b.** The prediction figure of Beisu Coal Mine No. 4601; **2c.** The first loading prediction figure of Mentougou Coal Mine.

(4) The movement of the structure has no significant effect on the deformation of the gate-way more than 8 m in front of the coal wall (the average approach velocity at the place 8 m away is 0.15 cm m/min).

(5) The abutment manifestation relation is shown in Figure 3b.



v–approach time of the roof and the floor. *p*–face support load. *Δt*–prediction time. *t*–time

Figure 3. Manifestation relationship between face and road.

From Figure 2c we can conclude the following.

(1) Around the time when the fracture of the hard main rook takes place, the peak values of the velocity of the roof and the floor of the gate-way to approach repeatedly appear. The time difference of the first peak and the stope support peak is as high as 72 hours. This makes the long-term loading prediction very easy and provides sufficient time for preparation.

(2) This time difference indicates that this structure has a strong bearing capacity and the rock fracture and block squeeze are the chief reason for instability.

(3) The movement of the main roof has no significant effect on the deformation of the gate-way beyond 12 m in front of the coal wall (the average approach velocity at the place 12 m away is 0.16 cm m/min).

(4) The relation between abutment manifestations in the gate-way and in the stope is shown in Figure 3c.

It should be noted that the magnitude of manifestation value in the gate-way and in the stope are reversely proportional to the thickness of the immediate roof, but the relation between the two and the regularities of their own exist generally.

2.3 *Comparison of Abutment Manifestation Features of the Three Typical Stopes*

From the previous comparison and analysis, and the measured data of stopes with similar conditions. the abutment manifestation features for the three typical stopes can be summarized as follows:

(1) With the stope advancement, the periodic movement of the three types of main roof is observed. The stope supports do not carry all the forces of the main roof. The exposure of the main roofs can be seen frequently. The proves that the three types of main roof exist in the form of structure.

(2) Before the main roof instability, the roof and the floor of the gate-way not far from the coal wall approach each other with an increasing velocity, which is twice as much as the usual value. In the case of the hard main roof there are multiple peaks and "rebounds", as well.

(3) There exists a time interval between abutment manifestation peaks in the gate-way and in the stope, with the peak in the gate-way followed by the one in the stope. This makes the stope loading prediction possible. This interval is short, medium and long for the loose and soft, the medium-hard and the hard main roof, respectively.

(4) The causes of main roof instability are fracture and deformation. For the hard main roof, the fracture instability is dominant, with the fracture length of the block being the advancement of periodic pressure. In the case of loose and soft main roof, the deformation instability plays an important role, with the instability advancement being the advancement of periodic pressure. The main roof of medium hardness has both the features mentioned above.

(5) On the condition of the similar coal hardness and mining height. the hard main roof has the longest influence distance in front of the coal wall. and the loose and soft one has the shortest.

2.4 *Three Basic Structures Proposed*

The measurement in stopes different in main roof strength shows that the influence distance of the main roof movement in front of the coal wall, the time difference between the manifestation peaks in the gate-way and in the stope, and the intensity of the gate-way manifestation and the peak frequency, all increase with main roof strength increasing. This proves that the structural forms of the main roof experiences a qualitative variation with the quantitative variation of strength of rock beds.

On the basis of the features of loading prediction and the requirement of roof control, the variation range of main roof strength can be divided into three representative sections. The physical meaning of the composition and the movement of each of such sections is indicated by a structural model of main roof. Thus this facilitates the concrete control and explanation of mining pressure.

The first model is for the structure of the loose and soft main roof. It is formed with small blocks through squeeze. The trace of force transmission is like a half arch, which periodically moves with the stope advancement. It is called the "dynamic arch" for distinguishing it from the static arch (Figure 4a).

The dynamic arch has two extremities. One of them is a half arch formed with crushed blocks through irregular squeeze. For instance, a caving face in Zhengzhou Mining Bureau is the case where an arch is formed when the coal in the overlying roofs are blocky. The other is a half arch formed through the regular arrangement of blocks in the stratified roofs with very developed joints and cracks.

The second model represents the structure of the main roof with medium hardness, which is formed with blocks through regular arrangement and articulation. The force transmission trace is broken line. The number of blocks in the structure varies with rock strength and thickness. One of its two extremities is the upper limit of the dynamic arch, that is, many blocks are involved. For the other case, the number of blocks is 3 or 4 only, and the mechanical analysis of interblock equilibrium can be made. The lower limit of the structure has the features of the dynamic arch and the upper one has the features of hard main roof. Therefore this structure is called "arch-beam" (Figure 4b).

The third model stands for the structure of hard main roof. It is formed with 2–3 rock blocks through squeeze and articulation, and is traditionally called "beam" structure (Figure 4c).

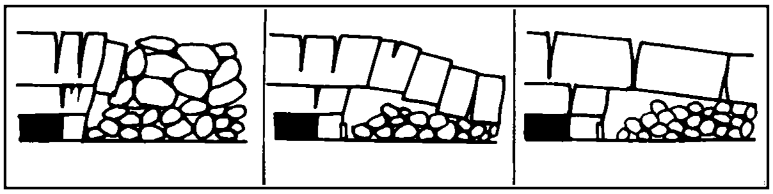


Figure 4. Three basic structure forms.

Beam structure has also two extremities. One is the upper limit of the arch-beam structure, the other is an equilibrium structure containing one long rock block. For example, the hard main roof in Datong mine is overhanging before fracturing, and rapidly overturns and settles after fracturing until one end is supported on the coal wall and support sets and the other is on the block which is collapsed and almost in the horizontal direction. Thus on single block forms an equilibrium structure (Figure 5).

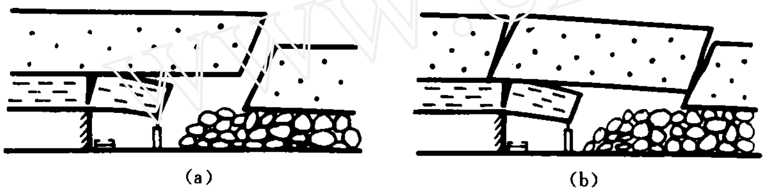


Figure 5. Single rock block structure.

For some stopes, the movement of the second main roof has a considerable influence on the stope due to the relatively small thickness of the immediate roof and the first main roof. Therefore the combinations of the above three basic structures sometimes came into being.

The above analysis is an inference based on observation data and histograms with no difference between pressure manifestations at ends and on the middle of the stope taken into consideration, that is, with no influence of measurement positions on observation results taken into account. Therefore, the mechanical simulation tests are conducted. With the method of reduction to absurdity, first, the fracture positions of the main roof are properly designed, then is observed the variation regularity of support pressure with fracture position.

3. Relation Between Main Roof Movement and Support Pressure, Shown by Simulation Tests

3.1 *Model Design*

Simulation tests with elastic plates and with simulate material display that arcuate triangular plates on upper and lower ends exist and the fracture of the main roof in the middle of the stope occurs when it penetrates deeply into the coal wall [3]. However, the position of the fracture line of rock plate depends on factors such as strength, thickness and bearing capacity of rock plate. The fracture line of the arcuate triangular plate can also go deep into the coal wall. The fracture line of rock plate in the middle of the stope can appear near the coal wall. Therefore, two schemes are adopted in tests, namely, the fracture of rock beam is near the coal wall and in the deep part. Electromagnetic valve is used to assure the fracture of main roof happening in the deep part and in the vicinity of the coal wall.

3.2 *Mechanical Simulation Test Device* [4]

The device is composed of the main simulation set and the computer-controlled measuring system. The coal seam is simulated with gassy colloid blocks, in which gas pressure is controlled with electromagnetic valve so that elastic modulus is similar to that of the coal body. The immediate roof is simulated with polyvinyl chloride or other material. The main roof is made of iron blocks and hard colloid blocks. The bending resistance can be adjusted according to the field conditions, the fracture of the main roof is controlled with the above valve. Overburden pressure simulated is provided by colloid blocks and iron blocks, with a loading system available. The working face advancement is simulated by the successive gas release of the colloid blocks. The device is shown in Figure 6.

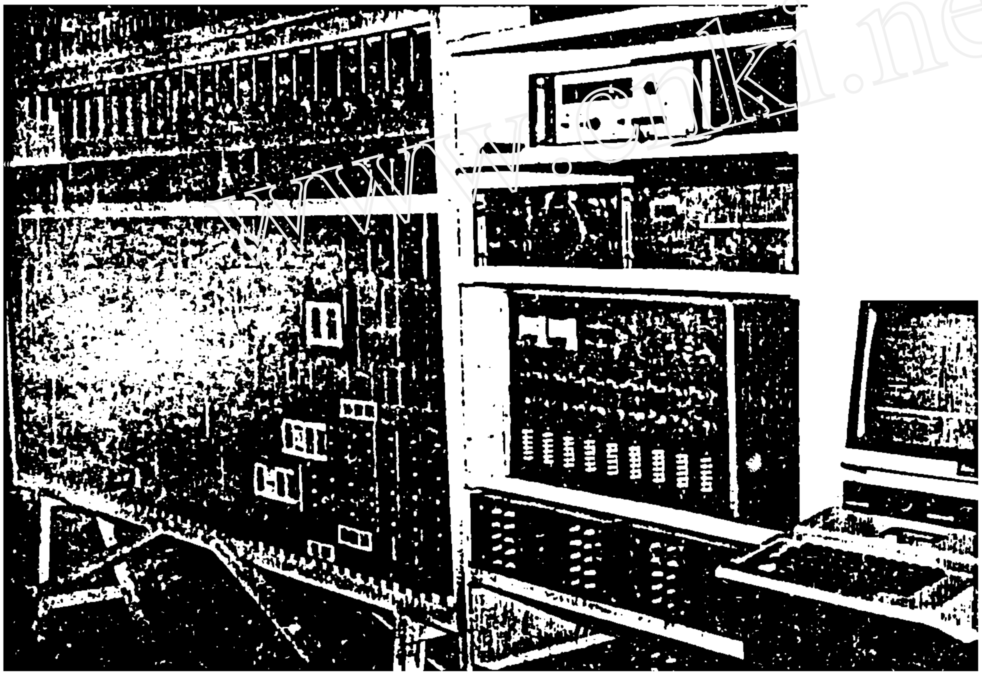


Figure 6. Mechanical experiment device.

3.3 *Test Method and Data Processing*

3.3.1 *Test method*

One primary loading and two periodic loadings are simulated with the model. The external load exerted is 11.4 MPa. The pressure of gas within the colloid is 100 KPa. Each gas release for one colloid block simulates a cutting. The advance is 2.5 m. For each cutting a measurement is made of the support pressure in front of the coal wall. Two colloid blocks with gas being incompletely released simulate plastic zones in the coal wall.

For the two models, 22 tests are conducted with good repeatability. The model is shown in Fig. 7.

3.3.2 *Data processing*

The measured data are from the micro pressure transducers under the colloid blocks. The colloid has different stiffness compared with the external wall of transducers, therefore, data are not the pressure on the colloid blocks, but the distribution is identical to that of the actual support force. By this reason, it remains to be called support pressure in this paper though it is an equivalent one.

For each cutting the distribution of the support force in pillars, in goafs and in front of the wall are shown in the screen, and the support force increments $\Delta\sigma$ in the main roof due to fracture and due to cutting are given.

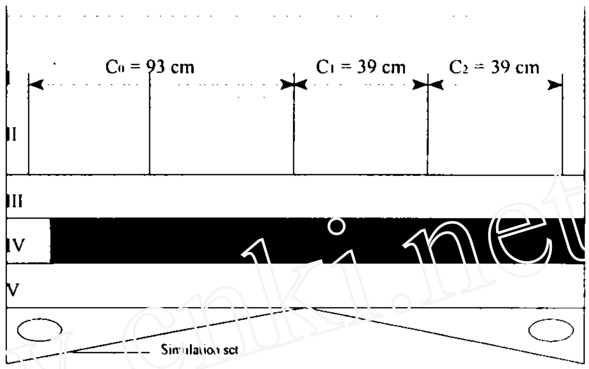


Figure 7. Single rock beam model.
I–load layer; II–main roof; III–immediate roof 8 cm; IV–seal 5 cm; V–floor, no transducer.

3.4 *Main Test Calculation*

3.4.1 *Abutment distribution when the fracture is deep in the coal wall*

(1) *At the eve of the primary loading*

With the advancement of the stope, the support pressure σ increases with the expansion of the exposed area of rock beds. The feature of the support pressure distribution in this stage is that the peak forms a boundary. The external side of the boundary (far from the coal wall) is an elastic zone, where σ and $\Delta\sigma$ are negative exponential functions, while the internal side is an elasto-plastic zone, where both σ and $\Delta\sigma$ are in a distribution of quadratic parabola concave downwards. For example, when 35 m in face advance is attained in No. 9 test, the σ distribution in the external side of the peak (correlation coefficient $r = 0.93$) is

$$\sigma = 31.7e^{-0.006x} \qquad x \in [10, \infty] \qquad (1)$$

The distribution in the internal side ($r = 0.91$) is

$$\sigma = -0.383x^2 + 7.23x \qquad x \in [0, 10] \qquad (2)$$

(2) *Around the primary fracturing the ends of rock beam*

Around the fracturing at the ends the distribution of σ is unchanged, but that of $\Delta\sigma$ varies greatly. The appearance of the fracture weakens the capacity of the rock beam to transmit force toward the front of the wall. Most of the weight of the moving beam is transmitted to the coal body in the internal side of the fracture, which causes a stress decrease near the fracture and in the external side, and a stress increase in the internal side (Figure 8).

The small increase of stress which occurs 25 m away is caused by the settlement of the overlying beds after fracturing of the rock beam.

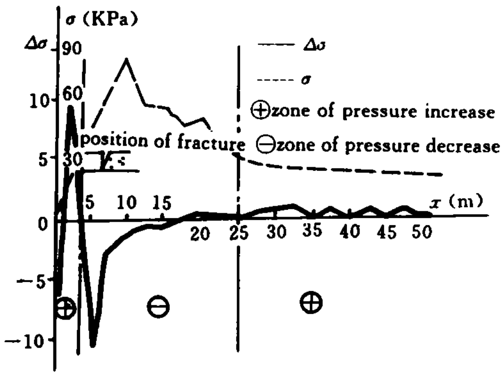


Figure 8. Experiment results of first fracture at the end point.

(3) *Fracture at the middle of the beam and the primary loading on the main roof*

When the fracture at the middle part of the rock beam takes place and the beam is overhanging, the weight of the overhanging main roof is transmitted to the front of the coal wall through interblock articulation. This induces the stress increase in an extent in front of the wall and the small stress decrease outside (Figure 9).

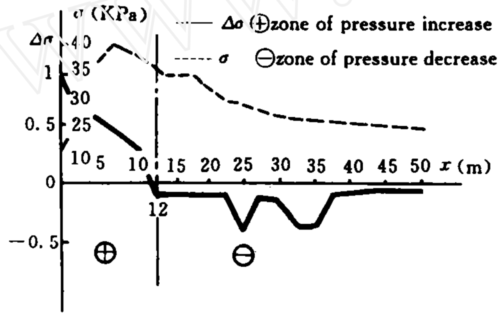


Figure 9. Curve of Δσ, σ of overhanging rock beam

In this stage the peaks of approach velocity of the roof and of the floor of the gate-way are obtained. With the settlement of the rock beam the stress peak at the internal side of the fracture shifts toward the coal wall, while in the external side there is no evident change.

When the fracture is near the coal wall, the instability of the main roof induces the stope loading, and the support force in front of the coal wall slightly decreases.

(4) *The relatively stable stage*

With the further advancement comes the relatively stable stage of the primary periodic loading. In this stage, as the range of the movement of the overlying beds expands, the distribution range and values of σ increase greatly. In the conditions simulated, the range in which stress increases greatly is about 20 m. Before loading the range of rapid stress increase is reduced, in general to about 10 m. For example, in No. 16 test, in stable advancement, the peak of $\Delta\sigma$ appears at a place of 7.5 m, $\Delta\sigma_{max}$ = 8.9 KPa. Before loading $\Delta\sigma$ peak shifts to 4.5 m, $\Delta\sigma$ = 9.2 KPa.

(5) *During the primary periodic loading*

Before fracture of rock beam occurs, the coal body is under high pressure, the σ distribution is shown in Figure 10. After fracturing the evident stress decrease can be found near the fracture, while the peak of stress increment appears on the internal side, 5 m away from the fracture. This peak gradually shifts toward the coal wall as beam settles. Small stress increase occurs on the external side of the fracture. When loading is over a general decrease in stress follows.

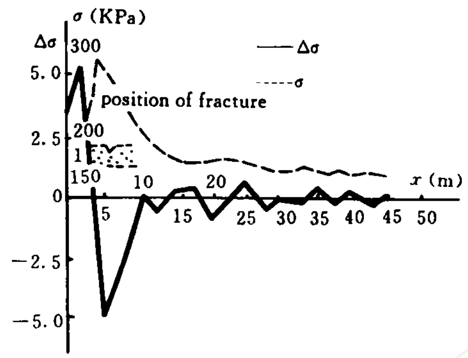


Figure 10. Curve of $\Delta\sigma$, σ before fracture.

As is known from the above test, in front of the coal wall there is a peak of support pressure before fracturing of the main roof occurs in the depth of the coal wall. Multiple peaks of support pressure will appear near the coal wall due to the block settlement after fracturing. At the moment of fracturing, the stress nearby will decrease considerable.

3.4.3 *Abutment distribution when fracture is near the coal wall*

The tests are so arranged that the primary fracture and the periodic fracture of the rock beam take place 1 m before the coal wall and 1 m behind it, respectively. Results show that the movement of the continuous beam before the coal wall simplifies the variation of the support pressure. Before fracturing, with the advancement of the stope, the stress in coal body increases and it reaches the peak at the eve of fracturing. After fracturing, there is a general decrease of support pressure, and no significant variation exists far away. The distribution of support pressure is in the form of attenuation before and after the only peak. The value of $\Delta\sigma$ has opposite signs before and after fracturing, with the maximum at the coal wall.

As is shown in tests, no matter where fracture takes place, the support pressure increases gradually and reaches the peak before fracture. After the fracture appears in the depth of the coal wall, multiple peaks of support pressure will occur along with the settlement of the rock beam. When the fracture is near the coal wall, there is only a single σ peak. As a rule, at the moment of fracturing a "rebound" can be found near the fracture rent.

These results show that for some stopes multiple peaks can be detected in the gate-way before loading, while for the others, only one peak can be found, a fact from which can be deduced the structural features of the main roof and the fracture position, on the basis of measured data.

4. Typical Bed Condition for the Existence of These Three Basic Structures

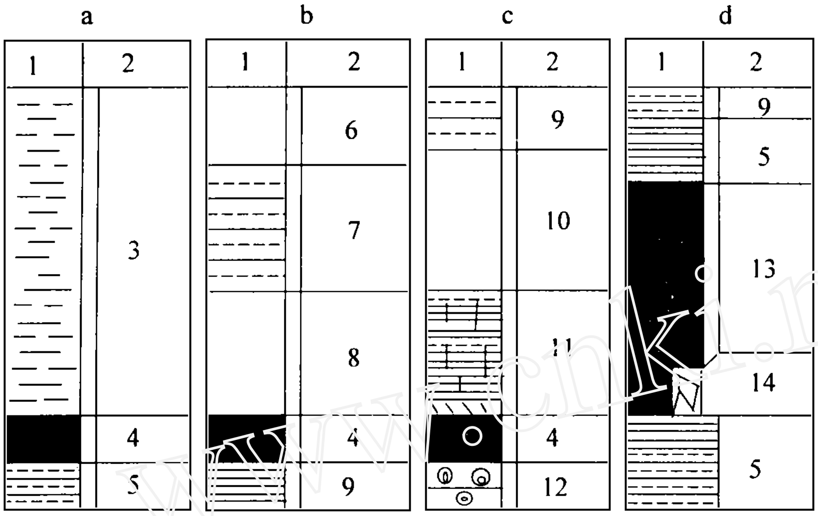
Through investigation of field data of many stopes and the observations previously made, the authors are of the opinion that the typical bed conditions for the dynamic arch structure are as follows:

(1) Loose and soft rock beds (Figure 11a).

(2) Face of thick seam, the rook of which has a strength lower than "medium".

(3) Underlying seam face of the seam close to the soft intercalations (Figure 11c).

(4) Caving face (arching degree and parameters depend on roof coal rate, the state of roof and roof coal)(Figure 11d).



1–Borehole; 2–Rock; 3–Sandstone with poor cementation; 4–Coal; 5–Shale; 6–Sandstone; 7–Sandy shale; 8–Regenerated roof; 9–Siltstone; 10–Goaf; 11–Interbed of sandstone and shale; 12–Alum clay shale; 13–Roof coal; 14–Bottom.

Figure 11. Typical boreholes of dynamic arch structure.

The typical bed conditions for beam-arch structure are given below (Figure 12).

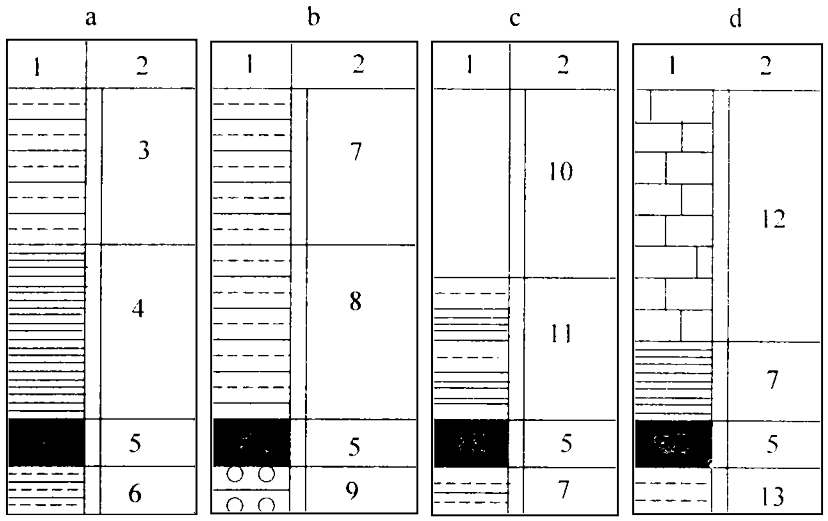
(1) Rock beds of small bedding and medium hardness.

(2) Rock beds of medium strength (shale, mudstone, siltstone and their interbeds).

(3) Rock beds of high strength and with developed joints and cracks, which suffered from damages of mining or tectonic stress.

(4) Limestone beds with developed bedding and joints.

(5) Deep rock beds under high pressure.



1–Borehole; 2–Rock; 3–Interbed of siltstone and sandstone; 4–Shale; 5–Coal; 6–Sandy shale; 7–Siltstone; 8–Mudstone; 9–Alum clay shale; 10–Fine sandstone being weathered; 11–Mud shale; 12–Limestone with developed lamination and joints; 13–Sandstone

Figure 12. Typical boreholes of arch-beam.

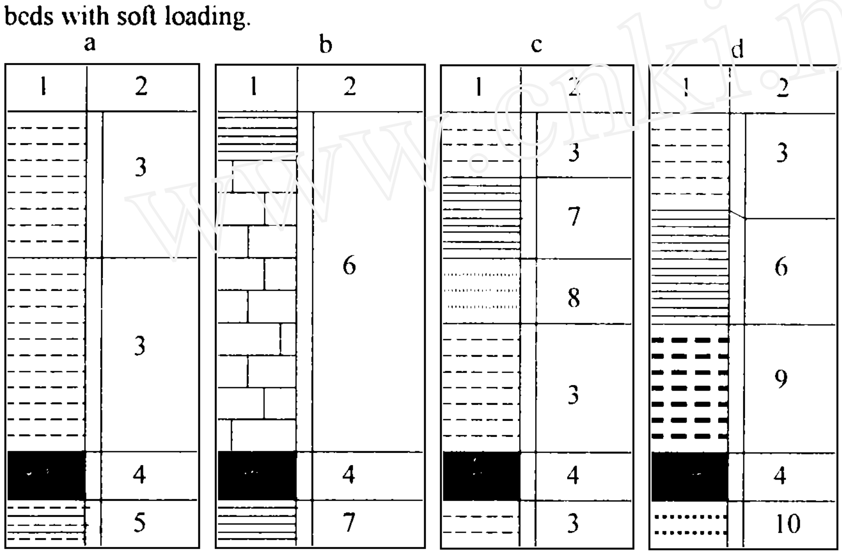
The typical bed condition for beam structure are as follows (Figure 13):

(1) Hard sandstone and conglomerate with large thickness (greater than 5 m).

(2) Intact limestone beds with large thickness.

(3) A number of hard beds with medium thickness (2–5 m).

(4) Hard beds with soft loading.



1–Borehole; 2–Rock; 3–Sandstone; 4–Coal; 5–Siltstone; 6–Limestone with good integrity; 7–Shale; 8–Shale interbed; 9–Conglomerate; 10–Alum clay shale.

Figure 13. Typical boreholes of beam.

5. Relation of Three Basic Structures to "Block Beam" and "Transmission Beam"

Based on measured data, Professor Qian has presented hypothesis of block beam for main roof, in which the structural equilibrium conditions are analyzed in detail for the first time, criteria of the deformation instability and sliding instability for structure are proposed. One of its prerequisites is that hard beds exist in the main roof, and the main roof is composed of a number of articulated rock blocks.

If there are no hard beds in the main roof, and the existence of equilibrium structure of main roof is proved by measurement, it can be regarded as a block beam composed of an increased number of blocks. The structure changes from the block beam into the dynamic arch, another of basic structure.

Through a long-term observation of hard roofs and the control practice, Professor Song has proposed the hypothesis of transmission beam, in which the main roof in the normal advancement is regarded as a structure of two articulated blocks. Based on the study of support pressure and its manifestation induced by bed settlement and fracture, he has established the method for hard roof loading prediction. On the basis of the relation between fracture and settlement of the immediate roof and the main roof to the bearing capacity of the support set, he has presented a set of theory and method for roof control design.

The structure of two articulated blocks is equivalent to the "hard beds" in hardness, which is mentioned in the prerequisite of block beam theory. So, only two blocks compose the block beam and the block length is the advance of periodic loading.

The two hypotheses are consistent in most of conclusions. The difference in two conclusions may result from the fact that they have the most suitable application ranges of their own, respectively.

The presentation of the three basic structures aims at the computer automatic identification of the movement characteristics of the main roof according to the input borehole data, and the determination of the related methods of control. A main roof structure series and the identification method are required to be stored in the computer.

The presentation of dynamic arch is for describing the features of movement for the main roof without hard beds. It is not contained in the above hypotheses, so it is a complement to them.

Arch-beam and beam are representative abstractive models in the structural series. They are defined from the viewpoint that the quantitative variation in the quality of rock beds causes the qualitative variation in structure. The research fruits of block beam and transmission beam are entirely suitable for them, for they are presented on the basis of the two hypotheses.

6. Application of Classification of Main Roof Structures

The viewpoint of the three basic structures has found successful application in Roof Control Expert System" [5], which has been verified on nearly 100 stope faces. This idea makes the quantitative determination of structural forms for main roof become possible, and provides a basis for "making control design according to the concrete roof conditions".

The classification of main roof structures is also used in "Loading Prediction Expert System"[6] It is the basis for classification of abutment manifestation and for automatic loading prediction.

It should be noted that in the range of 6–8 times the mining height, sometimes the main roof does not assume one or anther of the basic structures, but the combination of 2 or 3 basic structures.

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