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AN APPROACH TO THE PROBLEM OF SAFETY MINING ADJACENT TO THICK LOOSE WATERBEARING STRATA

Summary. The problem of coal mining adjacent to loose strata is of critical either in the safety production of coal mines or in the prevention of hazard of water-inrush, and the raise of coal recovery as well. In this paper, the concept, potential and technical measures about mining adjacent to loose strata are outlined at first, then the characters of hydrogeology associated with thick loose water bearing strata and hidden bedrock waterbearing strata are described. In the pages that follow, four basic types of water bodies of loose strata and the principles of protection against water-inrush are suggested, while the rules related to overlying strata failure in mining adjacent to loose strata and the design of safety pillars of rock and coal as well as the rules of underground water movement induced by the mining are discussed. In conclusion, the generalization of technical means about safety mining adjacent to loose strata in China is given.

In recent years, the problem such as the determination of reasonable mining boundary and the prevention of water hazard arise while mining is under loose strata with complicated hydrogeological condition in newly-opened coal fields in China. In this paper, the brief analysis and discussion about the problems are given as follows.

1. CONCEPT, POTENTIAL AND MEASURES TO BE TAKEN WHEN MINING ADJACENT TO LOOSE STRATA

So-called the technique of mining adjacent to loose strata is that mining of shallow part of seam underlying loose strata, particularly when coal measures are underlying loose strata but immediately overlying the loose waterbearing strata while some kinds of waterbearing layers like sandstone and limestone layers are attaching to the seam. Under these circumstances, the problems such as the determination of safety pillar size of loose strata (or reasonable mining boundary), drainability of mine together with the measures to prevent water hazard have been always of critical and of urgent to coal mine design and production (especially to the design and production of first mining level in mine).

The potential to study the technique when mining adjacent to loose strata is related to following factors:

1) Safe and normal production in mine;

2) The magnitude of pillar size of loose strata and coal recovery in mine;

3) Mining sequence and service life of first level in mine;

4) Design and investment of drainability in mine.

Currently, the main methods to the mining close to loose strata are divided into two sections.

First, when prevention measures are taken specially to loose strata, and then

a. Generally speaking, if information for geology and hydrogeology as well as for fractured height of overlying strata is available and adequate, the waterproof safety pillars of coal and rock are designed in accordance with the appropriate height of caving or fractured zone, while mining is under normal sequence from upper level to lower level. This method has been widely used recently in the design of new mines in China.

b. On the other hand, if the above-mentioned information is not available, or the strata saturated adjacent to coal measures tent to soften, the water-proof pillars of coal and rock, therefore, could be adopted according to the height which is three of four times as much as the height of caving and fractured zone, while the mining sequence should be reversed, i.e. from lower stage to upper stage so as to decrease the pillar size gradually. This measure has been taken in coal mines both at home and abroad.

c. If water content in loose strata is relative small, and water supply is limited, it is a common way that safety sand-proof pillars of coal and rock having the size less than the height of caving or fractured zone are utilized associated with the method of draining while mining. The method is very popular in many mines used in China, which achieves goal of extending mining boundary and minimizing pillar size.

d. Naturally, partial or total draining before mining can be underway provided that static water reserve dominates in loose waterbearing strata, or water supply comes only from precipitation, or long-term draining is not necessary after partial or total draining to the waterbearing strata, or long-term draining is economical to some extent, or mining operation can not be proceeded without partial or total draining to the water-bearing strata same metallic mines and coal mines in China have practised the method.

Second, when the prevention action aims at loose as well as bedrock waterbearing strata, measures taken to latter strata are:

a. Total draining before mining shold be done where immediate roof is bedrock waterbearing strata. Various means could be adopted such as

developing roadgates in advance in waterbearing strata; laying out special drillhole for draining at surface and underground; incorporating gate and drillhole for pre-draining.

b. On the one hand, it is desirable for safety mining to use the method of draining while mining providing the bedrock waterbearing strata are the main roof, as well as the water pressure is relatively small.

c. On the other hand, when the bedrock waterbearing strata are the main roof while the water pressure is higher, it is preferable for safety mining to lower the pressure in the strata before mining.

Under above two cases, water-proof pillars of coal and rock should be designed if the water content in loose waterbearing strata is larger and water supply is sufficient. Also the method of total draining before mining is not advisable, particularly in the initial stage of mine production.

2. HYDROGEOLOGICAL CHARACTERS OF THICK LOOSE WATERBEARING STRATA

The waterbearing characters of thick loose strata in coal fields of China are of vertical and transverse zonal distribution which are described as follows:

1) Loose strata are on the whole of mutiple structures with waterbearing and water-proof layers interlacing with one another, such as three waterbearing strata with two water-proof strata, or vice-versa; while the waterbearing or water-proof layers themselves are of multiple structure separately, with a smaller size in thickness each, and appearing in interlacing state of lenses occasionally.

2) Usually, there are some stable water-proof layers in loose strata where the poor connection between the water of upper layers and that of lower layers exist, shown by the obvious difference among such factors as unit water gushing amount, permeability coefficient water quality and water temperature, etc.

3) Vertical structure of loose waterbearing strata is as a rule described as the open-type waterbearing layers, while the close-type waterbearing layers with compact media and limited water supply in lower part of the layers. As a result, the richness of water content as well as permeability of whole loose strata seemingly posesses the character of "upper strong and lower weak".

4) Distribution of lithology for loose waterbearing strata is not homogeneous in transverse section, which is characterized by that the change of richness of water content varies as lithology, for instance,

the richness gets stronger in such area as low basin of rockhead or old river bed together with the zone of sandstone and gravelstone. On the contrary, the richness would get weaker if the content of plastic powdery materials in the structure is higher.

Because of these characters, it is our suggestion that the key measures to prevent water hazard when mining adjacent to loose strata should be focused on the ways to cope with the waterbearing layers in lower part of loose strata. In other words, the determination of the size of safety pillars of rock and coal in loose strata, reasonable mining boundary and drainability of mine as well as the means to prevent water hazard mainly depend on the action taken to the lower part of waterbearing layers, rather than to middle or upper part of the layers in loose strata.

3. THE HYDROGEOLOGICAL CHARACTERS OF HIDDEN BEDROCK WATERBEARING STRATA

Waterbearing characters of hidden bedrock waterbearing strata, to some degree, not only possess the vertical and tranverse zonal features but also relate to the characters of tectonics as well as the tectonic failure, which is illustrated in following:

1) Generally speaking, strata lithology is capable of determining the amount of water in weathered zone in bedrock. It is proved by observation in situ that water-proof rock layers as siltstone, shalestone, sandstone with silty media interlaced after being weathered are of good impermeability, and can be classified as relative water-proof layers.

2) Synclinal tectonic zone being rich in water content is frequently a good spot for underground water draining.

3) The change of impermeability and conductivity of water in fissured zone is dependent on strata lithology. Where the fissured zone made up of siltstone, shalestone and sandstone with silt media interlaced might be regarded as impermeable zone, otherwise as conductive zone.

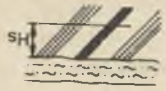
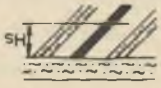
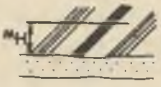
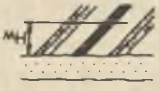
4) The interlayer connecting bedrock with loose strata could be possible a leaking way if the lower part of loose strata are rich waterbearing layers, as well as loose strata terminate in front of hills.

5) The water in bedrock is frequently supplied along cleats of joints of the bedrock, or from the tectonic fissured zone. The crop area of the bedrock is often the passage for water supply as well. However, water supply could be limited provided that the crop area is of impermeability, or is overlying by clayish soil, or is cut off by fault. In either cases, water content in bedrock layers is primarily static. Otherwise the crop area might become a stable passage for underground water supply.

4. TYPES OF WATER BODIES ADJACENT TO LOOSE STRATA AND THE PRINCIPLE TO PREVENT THE WATER HAZARD

1. Types

Based on the coal field features in China as well as the above analysis, water bodies adjacent to loose strata could be divided into several types as shown in table.

Types Diagram	Description
1 	The rich content waterbearing layers of loose strata are of thick and thin in size; Spatial relation between rich content waterbearing layers of bedrock and the seam is of far, middle, close, contact in character.
2 	The rich content waterbearing layers of loose strata are of thick and thin in size.
3 	The poor content waterbearing layers of loose strata are of thick and thin in size; Spatial relation between rich content waterbearing layers of bedrock and the seam is of far, middle, close, contact in character.
4 	The poor waterbearing layers of loose strata are of thick and thin in size.

From the above-described types of waterbearing strata we could arrange a sequence which illustrates the intensity of danger to the shallow mining of coal as follows:

Angle of judgement	Sequence (from danger to safer)
On the whole	1 > 2 > 3 > 4
As for loose strata	Thick, rich > thin, rich > thick, poor > thin, poor
As for bedrock strata	close, contact > far, middle

2. The principle to prevent water hazard

As for water body in loose strata water-proof pillars of coal and rock are generally planned when the water body is immediately overlying coal measures, as well as there are no stable claypans underlying the body which has sufficient water supply. Draining while mining could be underway providing the water supply is limited, together with the bedrock is of relative impermeability; otherwise partial draining and total draining should be done befor mining.

As for water body in bedrock strata, it is recommended that partial or total draining before mining should be proceeded where the water body with sufficient supply is in close contact with the seam. Where water body is far from the seam, it is possible that total draining is eliminated and draining while mining comes into effect. However, if pressure in bedrock waterbearing strata is rather higher, it is advisable to lower the water pressure before mining in order to prevent water gushing at coal face due to the insufficient safety pillars between the waterbearing strata and the seam.

5. CHARACTERS OF STRATA FAILURE WHEN MINING ADJACENT TO THICK LOOSE STRATA

Aside from considering the main factors as strata lithology and its combined structure, the study of the characters of strata failure when mining adjacent to thick loose strata should also pay attention to various state factors while mining close to normal strata, weathered zone, fissured zone of fault, as well as to clayish soil strata. The characters in accordance with the research into the problems in China can be summarised as follows:

1) As far as the types of strata failure are concerned, the "three zones" failure is still a main form of strata failure. If caving zone extends into loose strata, sinkholes are likely formed with large quantity of silt coming into goaf all at once. Where overlying strata compose of very strong rock, and the roof is incollapsible immediately after mining, the extensive sudden caving tends to happen in an indefinite time when mining is over.

2) The overlying strata adjacent to loose layers are inclined to weaken because of underground water erosion. Therefore the height of the fractured zone would greatly decrease. The height of the fractured zone in shallower part of seam (e.g. tailgate) is generally different from the height in deeper part (e.g. maingate), even though the overlying strata possess the same type of lithology. Naturally, when the overlying strata lithology is quite different between this for maingate and that for

tailgate, the prediction and analysis of the height of fractured zone should be varied accordingly.

3) However, the height of fractured zone might be expected to be lower when mining under loose strata where clayish layers exist at the bottom than mining under normal strata.

4) Apparently, the height of fractured zone in weathered zone and fissured zone which compose of siltstone, shaleetone and silty sandstone generally has little difference from the height in normal strata, otherwise the height of former one could be possible 1,5 to 2,0 times more than that of latter one.

5) If the characters of overlying strata adjacent to loose strata are of medium strong, weak or very weak (clay), under same geological conditions, the heights of fractured zone induced by power mechanized mining, ordinary mechanized minign, and manpower mining are almost equal to one another.

6. THE METHOD OF DESIGNING SAFETY PILLARS OF COAL AND ROCK WHEN MINING ADJACENT TO LOOSE STRATA

There are three different types of safety pillars of coal and rock currently being used in China as shown in following, so as not only to ensure the safe production in mine, but to reduce the loss of coal recovery as well.

1) Water-proof safety pillars of coal and rock

Its purpose is to prevent the water in overlying waterbearing strata from permeating into mine. It is suggested that this kind of pillars should be designed under following water bodies:

a. Various surface water bodies which are directly overlying bedrock or under which there are no stable claypans.

b. Rich or medium content water bodies in loose porous strata which are directly overlying bedrock or under which there are no stable claypans.

c. Rich or medium content water bodies in bedrock under which there are no stable silty impermeable layers.

d. Various surface water bodies and water bodies in loose waterbearing strata overlying steep seam.

e. Water bodies regarded as important water supply or water bodies in some popular resorts.

2) Sand-proof safety pillars of coal and rock

On the one hand, their purpose is to prevent sand in poor content waterbearing strata from gushing into the mine; On the other hand, they permit water to permeate into the mine.

Practically, sand-proof safety pillars of coal and rock are laid out under following water bodies:

a. Middle or small surface water bodies under which there are loose poor content waterbearing strata with multiple structure and great thickness, or water bodies where rich content waterbearing layers are in middle or upper part of loose strata and poor content waterbearing layers in lower part.

b. Rich or medium content water bodies in loose strata characterized by porous layers in middle and upor part of the strata or under which there are stable thick claypans.

c. Water bodies of poor content waterbearing strata in bedrock strata where draining is possible.

3) Sinkhole-proof safety pillars of coal and rock. Their purpose is to avoid poor content waterbearing layers of clays subsiding into mines. The sinkhole-proof safety pillars are considered desirable under following water bodies:

a. Poor content water bodies in loose strata characterized by porous layers in middle and upper part of the strata or under which there are stable thick claypans.

b. Water bodies in loose strata or in bedrock where total draining is possible.

7. CHARACTERS OF UNDERGROUND WATER MOVEMENT CAUSED BY MINING ADJACENT TO LOOSE STRATA

The main characters of underground water movement caused by mining adjacent to loose strata can therefore be concluded as follows:

1) Where loose strata compose of multiple structure the water level in upper part of waterbearing layers is generally stable, such gives rise to temporary decline of water level only during the period of active ground movement. However, the water level will restore its original state when the active ground movement is over.

2) On the contrary, water level in lower part of loose waterbearing strata or in middle and upper part of the strata but where there are no stable impermeable layers tends to decline continuously, constructing an extensive water decline funnel. Its decline velocity depends on such

factors as the extent and intensity of mining effect on the waterbearing layers, the existence of clayish layers at the bottom of the strata and the combined structure in waterbearing layers, together with the value of water pressure and the hydrogeological coefficient. Basically, the magnitude of water level decline in a year is ranging from a few meters to tens of meters, usually larger at the beginning and smaller in the end. It is noted that the decline magnitude and velocity in loose waterbearing strata are always smaller than those in bedrock waterbearing strata. Under the circumstance of long-term draining in mine, the difference of water level in the two strata becomes larger and larger, until the water in bedrock waterbearing strata or in bedrock and loose waterbearing strata is drained off.

3) When water level in loose waterbearing strata declines to some value, then the decline velocity of remaining water pressure slows down, as a result, total draining become more difficult.

4) Under mining effect, however, the decline velocity in bedrock waterbearing strata is larger so that partial and total draining seem easier. Inhomogeneous phenomenon would occur during the period of partial or total draining. For example, after the drainage in lower part of dip seam, the content in upper part of the seam might decrease or cease as a result; while the drainage in remote area on strike is completed, water content at adjacent district might decrease or even drain off.

5) The water content of draining in both loose strata and bedrock is dependent on the goaf length along strike in first stage of first mining level, and usually has nothing to do with the goaf length on incline. Therefore, underground water gushing content remains basically stable when the goaf length on strike is kept unchanged.

8. THE TECHNICAL SAFETY MEASURES TO BE TAKEN WHEN MINING ADJACENT TO LOOSE STRATA

1) General measures

a. Using the method of slicing intermittent mining, so as to control mining height, particularly to decrease mining height in first and second slicing.

b. Strengthening support management at coal face and driving head to eliminate caving accident (e.g. sinkhole).

c. Having sufficient information about level of bedrock head to ensure the vertical distance designed for safety pillars of coal and rock.

d. When water seeping occurs at coal face, the face along strike should be veered to along incline. Other alternative is that it is

desirable for the advance of coal face to be on rise, resulting in the seeping water flowing into goaf.

e. As there is a tendency of water gushing from the roof at coal face, the normal advance of coal face together with the quality of support work should be ensured to decrease the roof convergence and roof fracture in front of coal face, so as to avoid water seeping or gushing at the face.

2) Special measures

a. The distribution of faults and its relation with gushing water content should be well aware if the faults close to the coal face are likely to conduct water.

b. Total draining before mining should be done where immediate roof or floor consist of waterbearing strata of sandstone and limestone.

c. The method of using gate, drillhole separately or incorporately to drain water or method of partial draining before mining as well as total draining after mining could be arranged according to the distance between the waterbearing layers and the seam where main roof consists of waterbearing strata of sandstone and limestone.

d. Discontinuous mining is preferable where the gushing water content around fissured zone is somewhat larger.

e. Special draining gate should be designed while the gushing water content in goaf or at coal face is larger. It is suggested that sectional draining gate (drillhole) is laid along main gate or placed into seam floor for water draining, while designing draining gate in goaf is also an alternative to solve the problem.

f. Partial draining is recommended while water pressure in main sandstone roof or limestone roof is higher in order to prevent water gushing at coal face.

g. It is advisable to narrow the face length in first mining stage so as to lower the height of fractured zone.

h. If possible, it is our suggestion that water in loose waterbearing strata be drained off before mining begins.

Recenzent: Doc. dr hab. inż. Bernard Drzęźla

Wpłynęło do Redakcji w grudniu 1985 r.

PODEJŚCIE DO PROBLEMU BEZPIECZENSTWA WYBIERANIA WĘGLA
W SĄSIEDZTWIE GRUBYCH LUŹNYCH WODONOŚNYCH
WARSTW GEOLOGICZNYCH

S t r e s z c z e n i e

Problem wybierania węgla w sąsiedztwie luźnych warstw geologicznych jest istotny, jeśli chodzi o bezpieczeństwo wydobywania węgla, jak i zapobiegania przed wtargnięciem wody oraz zwiększenia wydobycia. Artykuł przedstawia najpierw koncepcję, możliwości i środki techniczne wybierania w sąsiedztwie luźnych warstw, a następnie opisuje charakter hydrogeologii związanej z grubymi luźnymi warstwami wodnośnymi oraz ukrytymi warstwami wodonośnymi skały macierzystej. Wyszczególniono cztery podstawowe rodzaje wody występującej w luźnych warstwach oraz zaproponowano zasady ochrony przed wtargnięciem wody. Równocześnie przedyskutowano zasady dotyczące górniczych uszkodzeń warstw wierzchnich sąsiadujących z luźnymi warstwami oraz zasady ruchu wód podziemnych wywołanego wybieraniem węgla. We wnioskach przedstawiono uogólnione środki techniczne bezpieczeństwa podczas wybierania węgla w pobliżu luźnych warstw w kopalniach chińskich.

ПОДХОД К ПРОБЛЕМЕ БЕЗОПАСНОСТИ ВЫЕМКИ УГЛЯ ВБЛИЗИ
МОЩНЫХ РЫХЛЫХ ВОДОНОСНЫХ ГЕОЛОГИЧЕСКИХ СЛОЁВ

Р е з ю м е

Проблема выемки угля вблизи рыхлых геологических слоёв очень существенна как для проблемы безопасности добычи угля, так и для предупреждения вторжения воды, а также для увеличения добычи угля. В статье представлены, в первую очередь, концепцию, возможности и технические средства для выемки вблизи рыхлых слоёв, а затем описан характер гидрогеологии, связанной с мощными рыхлыми водоносными слоями и укрытыми водоносными слоями основной скалы. Перечислены четыре основных типа воды, выступающей в рыхлых слоях и предложены правила охраны перед вторжением воды. Одновременно обсуждено правила относительно горных повреждений верхних слоёв, находящихся рядом с рыхлыми слоями и правила перемещения подземных вод, вызванного выемкой угля. В заключении представлено обобщённые технические средства безопасности при выемке угля вблизи рыхлых слоёв в китайских угольных шахтах.