Study on the change law of soil in subsidence area of horizontal coal seam

Pengfeng LI, Shugang WANG and Wei LIU

Shaanxi Province Land Engineering Construction Group, Xi’an 710075, People’s Republic of China

Email: pfeng_16@163.com

Abstract. In order to provide theoretical basis for land reclamation in subsidence area, the mining subsidence area is divided into three areas: zone I (stretching zone), zone II (compression zone) and zone III (neutral zone). On this basis, the change characteristics of the soil in the three areas of the horizontal coal seam mining subsidence area are studied. The results show that: due to stretching, soil of zone I cracks was developed, the soil continuity damage, poor integrity, serious leakage of soil Water Leakage fertilizer, the area shows the soil water holding capacity decreased, the decline of soil fertility, soil coarsening and barren trend. The soil mass in zone II is compressed and the soil structure is relatively complete, but the soil bulk density increases correspondingly, while the soil porosity decreases gradually and the permeability decreases. The main soil layer in the zone III is vertical deformation, and the soil integrity is better. But the influence of mined out area leads to the movement of water and nutrients to the lower part of the soil. This paper suggests that in the land reclamation process should adopt corresponding reclamation method based on the variation law of the three soil area of reclamation area of mining subsidence, for improving soil physicochemical properties, so as to achieve the purpose of effective reclamation.

1. Introduction

Generally, the area of ground subsidence and ground fissure caused by the underground mining is called mining subsidence area. According to Li Fengming, a branch of Shanghai branch of the Coal Academy of Sciences, China's annual cultivated land area reduced by about 125000hm² by coal mining\[^1\]. The study found that the average land subsidence per million tons of coal 0.2hm²~0.53hm²\[^2\], which can be calculated, China's annual increase in mining subsidence area of more than 71200hm².

According to the survey, the land in the mining subsidence area was destroyed by 20% ~ 30% lower than the normal level. The destruction of the irrigated land, its yield is less than 50% \[^3\]. Soil erosion caused by ground surface deformation in subsidence area has changed the physical and chemical properties of topsoil and its nutritional conditions. At present, there are many researches on the soil water content in coal mining. These researches have proved that the soil water content in the mining area is lower than that in the non mining area due to the ground fissure. \[^4\]~\[^9\]. Seils D E, Roosendaal Van and Datta K of K showed that the corresponding range of land subsidence caused by collapse or cracks, resulting in the deterioration of soil physical properties; caused land desertification; and the surface caused by the hydraulic pressure changes, increased subsidence of soil water evaporation; effects of groundwater level and groundwater movement, its indirect influence plant growth \[^10\]~\[^12\].

At present, the engineering measures of land reclamation area by mining subsidence are digging deep and shallow filling pad reclamation, dredging and draining method, ecological reclamation
method. Liu Jingshuang and other \cite{13} take Fushun coal mine as an example. The reclamation of farmland with the combination of waste land reclamation and waste disposal can not only reduce the occupied land area, but also reclaim the land in the subsided area. Based on the analysis of the ecological environment of coal mining subsidence in Tangshan City by Yan Yunting and other \cite{14}, the ecological reconstruction model was given. But in the engineering application of land reclamation is still relatively extensive, most still in the land subsidence area leveling will be unified, or just the gangue filling in the subsidence area in coal gangue, and then a certain thickness of the overlying loess after as agricultural land use. If the subsidence of land reclamation is the subsidence area leveling, without considering the mining subsidence of subsidence basin evolution in the soil structure of different terrain, in the reclamation process structure and soil fertility is not reasonable design, so land reclamation has lost its meaning.

In view of this, this paper studies on the use of mining damage of coal mining subsidence area surface deformation and stress analysis of the situation in the region, and based on the surface movement and deformation characteristics of different regional soil in mining subsidence area. It can provide theoretical basis for improving land reclamation in mining subsidence area.

2. Characteristics of soil movement and deformation in mining subsidence area

According to the mining subsidence theory and the rock mass mechanics of the mine \cite{15-16}, the cross-section shape of the rock and soil affected by mining in the mining subsidence area is shown in figure 1.

![Fig. 1 Influence profile of soil under mining subsidence](image)

As shown in Figure 1, after the coal seam is mined, the goaf will be formed in the stope space, and the overlying strata in the goaf will collapse and bend down due to the gravity force due to the lack of support. The goaf overburden damage to the surface, gradually expanding the scope, intensity gradually weakened, as the basic roof coal seam with mining, filling in goaf, and the roof in roof caving on the masonry beam structure is gradually formed. The overlying rock on the upper part of the masonry beam will bend downward and produce a large number of vertical or oblique open cracks in the rock. At the same time, with the expanding scope of goaf, destruction of the overlying rock and soil and the intensity will gradually increase, the rock mass produced in internal bending and fracture opening will always conduction to the surface, causing the soil tillage, plow the soil structure changes.

According to the existing research, when the mining face is advancing the distance from the cutting hole to the average depth \(H_0\) of 1/4~1/2, it will cause the surface movement and deformation, and form the surface movement basin, that is, the mining subsidence area. With the increase of mining area, the influence area of the surface is expanding, and the sinking value is increasing gradually. Thus, a large subsidence basin is formed in the surface, that is, the mining subsidence area.

Generally, when the length and width of mined out area reaches 1.2\(H_0\)~1.4\(H_0\), or when the working face is stopped for 1~3 years, the surface can reach a stable state and no longer sink and deform. In order to reduce the influence of repeated mining subsidence of soil, reduce the project investment, generally choose to reach a stable state in the surface of the ground, only to land reclamation in mining subsidence area, so the mining subsidence area has formed a full mining subsidence basin as the
research object, analysis of the level of coal mining subsidence area of soil layer movement characteristics.

![Diagram showing characteristics of movement and deformation of subsidence soil in horizontal coal seam.](image)

**Fig. 2** Characteristics of movement and deformation of subsidence soil in horizontal coal seam

Figure 2 shows the full mining subsidence basin soil deformation characteristics, where \( r \) is the radius of influence, \( r = \frac{H_0}{\tan \beta} \), \( w \) is surface subsidence; \( i \) for tilt; \( \varepsilon \) is horizontal deformation; \( u \) is horizontal displacement; \( \beta \) is the mining influence angle, which is related to the lithology of the mine area, and the tan beta value is generally between 1.2~2.6.

According to the deformation and stress of the stratum, the basin is divided into zone I, zone II and zone III. The surface area of zone I is BC section in the map; the surface area of the zone II is AB section in the map; the surface area of the zone III is OA section in the map.

As can be seen from Figure 1, the zone I is the tensile zone, and the ground surface produces uneven settlement, which moves from the edge of the basin to the center of the basin point by point.

According to the level of mining subsidence deformation theory\([15, 17]\), horizontal deformation (\( \varepsilon \)) in the mining goaf at the boundary distance 0.4r reached the maximum value, where the surface horizontal deformation value reaches the maximum value, the maximum surface horizontal tensile force. \( \varepsilon \) is a positive number indicating that the adjacent soil particles are far away in the horizontal direction, and \( \varepsilon \) is negative, indicating that the adjacent soil particles are near in the horizontal direction.

Because \( \varepsilon \) is a negative number, and zone II is the compression zone, the soil is mainly subjected to compression, and the surface is generally free of cracks.

zone II (compression zone) and zone III

The zone III is the neutral zone, in where the subsidence is uniform, and the tilt and horizontal deformation and movement is approximately zero, so the ground without obvious cracks, while the surface subsidence of the basin subsidence reached the maximum value of \( w_{\text{max}} \) in the region.

3. Characteristics of soil change during mining subsidence

Because the movement and deformation characteristics of soil in different areas of the mining basin are different, the influence on the soil layer structure, nutrient and physical and chemical properties is
also different. According to the characteristics of soil movement and deformation in three regions, the characteristics of soil change in different regions are analyzed respectively.

3.1. Characteristics of soil change in zone I
Due to the tensile action, the soil in this area is often distributed with a large number of vertical and inclined cracks and extends to the surface. On the one hand, these cracks will increase the evaporation of moisture in the soil, cause the soil moisture decreased significantly at the same time will change the flow direction within the soil, resulting in coal mining by horizontal migration into vertical direction, which cause the regional decline, the water leakage; on the other hand, these cracks make damage to the soil continuity, integrity poor. Nutrients in soil surface are leaking from the surface soil layer and shallow soil layer along the cracks to the lower parent material layer and the rock stratum, resulting in the decrease of soil nutrients near the surface. Finally, the water retention capacity of soil in this area decreased, soil fertility decreased, soil coarse granulation and barren, and it was not conducive to crop growth in the region.

As the slope gradually increases, the soil layer in the area will move along the slope facing the basin, so that the stripping of the soil layer in the process of coal face will be serious and the thickness will decrease. And with the migration of soil layers, the nutrients and water in the soil will also migrate to the pelvic floor. Moreover, Chen's investigation revealed that the topsoil had a sandy tendency to due to the small amount of fine particles in the surface soil[18], which led to a decrease in soil mass. At the same time, when the slope slope value is large, even the soil will collapse along the slope facing the basin, and it will cause serious damage to the structure of the soil.

Finally, due to stretching, soil in the zone I is away from each other, resulting in soil bulk density decreased gradually from point A to point B, the porosity increased, soil cohesion decreased, resulting in decreased soil particle binding ability.

3.2. Characteristics of soil change in zone II
In the second section, due to the adjacent soil particles in the horizontal direction, the soil is mainly affected by compression, and horizontal movement of point decreases toward the center direction, and soil structure on the whole is still relatively complete. However, because the zone II is located on the slope of the subsidence basin, the soil layer also has the characteristics of movement along the slope to the basin, which makes the soil layer and the subsidiary branch move towards the pelvic floor. However, the soil and nutrients in the zone II are better than those in the zone I because of the movement of the soil in the zone I into the zone II.

In addition, as the soil is squeezed, the soil compactness in the same soil layer will increase significantly compared with that in zone I. the soil bulk density will increase correspondingly, while the soil porosity will decrease and the permeability of the soil will decrease. Therefore, soil reclamation should take full account of the change of soil physical properties in the area, and accordingly reduce soil compaction and increase soil porosity.

3.3. Characteristics of soil change in zone III
As can be seen from figures 1 and 2, the zone III is located at the bottom of the mining subsidence basin, and its surface inclination is almost zero. The change of soil mass in this area is mainly affected by the lower goaf. After the coal seam is mined, the mined out area will be formed. In the overlying strata above the goaf, there will be a large number of vertical or oblique open cracks due to bending and sinking. On the other hand, due to the great difference of mechanical properties between overlying strata, the bending subsidence of rock strata shows asynchronous bending, resulting in the separation of adjacent rock strata above the mined out area, resulting in separation cracks. These open cracks and delamination fracture will become the reservoir water and water channel, surface water and soil in the water through the open fracture and rock in goaf into separated strata, resulting in soil water and nutrient III area to the lower strata of leakage.
At the same time, the soil and nutrients from the zone I and zone II accumulated in the zone III, which made the soil and nutrients in the area more abundant than that in the zone I and the zone II\[^{19-20}\].

4. Conclusions

(1) According to the deformation of the formation stress, the mining damage of horizontal coal seam full mining subsidence basin soil movement and deformation characteristics were analyzed, and the subsidence basin is divided into three regions of zone I, zone II and zone III.

(2) According to the characteristics of soil movement and deformation, the deformation characteristics of soil in three areas are analyzed respectively. The development of cracks in the interior of zone I, the continuity of the soil layer is destroyed, and the integrity is poor, which makes the soil water leaking and the fertilizer is seriously damaged. The soil water retention capacity, soil fertility decrease, soil coarse granulation and impoverishment trend are generally presented in this area. The soil mass in the zone II is compressed and the soil structure is relatively complete, but the soil bulk density increases correspondingly, while the soil porosity decreases gradually and the permeability decreases. The main soil layer in the zone III is vertical deformation, and the soil integrity is better. But the influence of mined out area leads to the movement of water and nutrients to the lower part of the soil.

5. Suggestions

Under the influence of mining subsidence, in the land reclamation process should be based on the changes of soil above three regions by reclamation measures accordingly as each area of the soil change characteristics is different. According to the characteristics of the zone I, the zone II and the zone III in the mining subsidence area, different methods are adopted to reclaim the land in different areas so as to achieve the purpose of effective reclamation.

The general method of soil reclamation technology of mining subsidence of the partition should be as follows: firstly, to determine the scope of mining subsidence area, clear land reclamation area; secondly, according to the range of goaf and subsidence in mining subsidence area will form, further divided into the zone I, II and III; finally according to the variation of the soil regional different measures of land reclamation in subsidence area.

References

[1] LI Feng-ming. Application Status and Development Trends of Surface Subsidence Reducing Technology in Mining Area [J]. Coal Mining Technology, 2006, 11(1): 3-7.
[2] ZHANG Fa-wang, HOUXin-wei, HANZhan-tao, YANG Hui-feng, SONG Ya-xin. Impact of Coal Mining Subsidence on Soil Quality and Some Protecting Technique for the Soil Quality [J]. Geography and Geo-Information Science, 2003, 19(3): 67-70.
[3] BI Zhong-wei, DING De-xin. Environmental Destruction by Surface Subsidence due to Mining and Its Prevention [J]. Geography and Geo-Information Science, 2003, 10(3): 54-57.
[4] WEI Jiang-sheng, HE Xiao, HU Chun-yuan, WANG Jian. Influence of Ground Collapse Caused by Coal Mining Activities on the Water Characteristics of Sandy Soil in Arid and Semi-arid Area [J]. Journal of Arid Land Resources and Environment, 2006, 20(5): 84-88.
[5] BIAN Zheng-fu, LEI Shao-gang, CHANG Lu-qun, ZHANG Ri-chen. Affecting factors analysis of soil moisture for arid mining area based on TM images [J]. Journal of China Coal Society, 2009, 34(4): 520-525.
[6] LEI Shao-gang. Monitoring and analyzing the mining impacts on key environmental elements in desert area [J]. Journal of China Coal Society, 2010, 35(9): 1587-1588.
[7] Bian Zhengfu, Xu Jialin, Lei Shaogang. Discussion on mine ecological construction [J]. Journal of China Coal Society, 2007, 32(1): 13-19.
[8] LI Hui-di, YANG Qi, NIE Zhen-long, HANG Guang-hui. Response of Vulnerable Ecological Environment to Mining Collapsing in Arid Area [J]. Journal of Arid Land Resources and Environment, 2003, 17(5): 30-35.
[9] Ma Yingbin, Huang Yaru, Wang Huailiang, Dang Xiaohong, Wang Ji, Gao Yong. Effects of collapse fissures caused by coal mining on soil moisture in slope lands after rain [J]. Acta Pedologica Sinica, 2014, 51(3): 497-504.

[10] Seils D E, Darmody R G, Simmons F W. The effects of coal mine subsidence on soil macroporosity and water flow [A]. Robert E D, Barnhisel R I, Darmody R G. Proceeding of 1992 National Symposium on Prime Farmland Reclamation [C]. Urbana: University of Illinois Press, 1992, 137-146.

[11] Roosendaal Van D J. Long wall mine subsidence of farmland in Southern Illinois: Near-surface fracturing and associated hydrogeological affects [A]. Robert E D, Barnhisel R I, Darmody R G. Proceeding of 1992 National symposium on Prime Farmland Reclamation [C]. Urbana: University of Illinois Press, 1992, 147-158.

[12] Datta K K, Jong C. Adverse effect of water logging and soil salinity on crop and land productivity in northwest region of Haryana, India [J]. Agricultural Water Management, 2002, 57(3): 223-238.

[13] LIU Jing-shuang, WANG Ji-da, ZHANG Xue-lin, YU Jun-bao, YAN Deng-hua. Study on the Reclamation and Ecological Reconstruction Coal Mine Area-A Case of Fushun Coal Mine [J]. Scientia Geographica Sinica, 2000, 20(2): 189-192.

[14] Li Jun, et al. Dynamics of moisture of soil profile in Loess area of western Shanxi [J]. Science of Soil and Water Conser-vation, 2006, 4(4): 72-77.

[15] Yu Xueyi, Zhang Enqiang. Mining damage Science [M]. Coal Industry Press, 2010.

[16] Qian Minggao, Shi Pingwu. Mining pressure and strata control [M]. China University of Mining and Technology press, 2010.

[17] Zang Yin tong, Wang Ji, Ding Guo dong, Gao Yong, He Xiao, Yan Lin, He Zhi. Variation of Physico-chemical Properties of Aeolian Sandy Soil at Coal Mining Subsidence and its Evaluation [J]. Acta Pedologica Sinica, 2010, 47(2): 262-269.

[18] CHEN Long-qian, DENG Ka-zhong, ZHAO Zhi-hai, XU Shan-kuan, CHAI De-guang, ZHENG Zhao-feng, LI Jian-min. Space variation law of physical characteristics about farmland soil due to mining subsidence [J]. Journal of China Coal Society, 1999, 24(6): 586-590.

[19] HU Zong-ze, CHEN Zhi-chao, HAO Cheng-yuan. Variation of Soil Composition in Coal Mining Subsidence Areas [J]. Soil and Water Conservation in China, 2011(4): 44-46.

[20] Gu Hehe, Hu Zhenqi, Liu Dehui, Hu Feng. Mechanism of farmland damage due to mining subsidence in the region with high level of subsurface water [J]. Journal of China Coal Society, 1998, 5(23): 522-525.