International Journal of Rock Mechanics & Mining Sciences 78 (2015) 27–35

Contents lists available at ScienceDirect

International Journal of Rock Mechanics & Mining Sciences

journal homepage: www.elsevier.com/locate/ijrmms

Technical Note

Surface stepped subsidence related to top-coal caving longwall mining of extremely thick coal seam under shallow cover

Jinfeng Ju [a,b], Jialin Xu [c,*]

[a] IoT Perception Mine Research Center, China University of Mining and Technology, Xuzhou 221008, PR China
[b] National and Local Joint Engineering Laboratory of Internet Application Technology on Mine, Xuzhou 221008, PR China
[c] State Key Laboratory of Coal Resources and Safe Mining, China University of Mining and Technology, Xuzhou 221116, PR China

ARTICLE INFO

Article history:
Received 11 January 2015
Received in revised form
14 May 2015
Accepted 21 May 2015
Available online 5 June 2015

Keywords:
Shallow cover
Stepped subsidence
Key Stratum (KS)
Green mining

1. Introduction

There are a large number of coal seams characterized by shallow cover and extreme thickness in the northwest part of China. The total reserves of these coal seams account for one-third of the national gross proved reserves. The base rock of these coal seams is thin but the extraction height is large. As a result, mining-induced surface subsidence is extremely severe, which poses a great threat to landscape, roads, buildings, forest resources, water bodies, etc. The Taian coal mine has a typical thick coal seam under shallow cover. Upon the start of the 9308 top-coal caving longwall face, an oval stepped subsidence trough with a maximum depth of 9.5 m was created and a surface road was cut off (details will be presented in Section 2.3), which poses a great threat to the local environment and road traffic safety. Therefore, studying the mechanism of formation of the shallow buried thick coal seam mining induced surface stepped subsidence and proposing any feasible remedies will have practical significance in protecting the environment and public infrastructure.

The intensity of subsidence due to mining activities depends on a number of factors as diverse as mining depth, extraction height, overlying strata properties, mining method, panel dimensions, geological disturbances, surface topography, etc. To minimise adverse impacts of subsidence, many research papers and reports have been published pertaining to subsidence problems for both operational and abandoned coal mines. Among these endeavours mainly related to mining subsidence mechanisms,[1–4] subsidence prediction methods,[4–12] ground-movement investigations,[13–16] and subsidence control measures.[5,17–19] Most of these studies are restricted to continuous or trough subsidence profiles, which are very common forms of subsidence. However, in cases of longwall mining under shallow depth, like the Taian coal mine, the fractured zone and even the caved zone in the overlying strata are likely to propagate to surface and result in large ground cracks, steps and even stepped subsidence as shown in Fig. 1.[20, 21] Singh and Dhar[22,23] studied special subsidence profiles such as sinkholes or pot-holes induced by shallow coal seam mining, but research on large areas of stepped subsidence which occurred over the Taian coal mine has not been published. Therefore, it is necessary to study this particular coal mine subsidence profile and provide information for surface stepped subsidence management. To this end, a thorough understanding of the mechanism of stepped subsidence profiles over the Taian coal mine is required to explain and justify the proposed protection for the ecological environment and the public infrastructure.

Ground deformations and subsidence depend on the mining-induced movement of overlying strata. Nevertheless, the rock strata react differently after coal extraction due to the difference in thickness and strength of rock layers. The strong and thick rock strata govern the main deformation behaviour of the whole strata, which can be referred as the main body. The relatively soft and thin layers can only impose their load on the competent rock

* Corresponding author.
E-mail addresses: jujinfeng2012@163.com (J. Ju), cumtxjl@cumt.edu.cn (J. Xu).

http://dx.doi.org/10.1016/j.ijrmms.2015.05.003

layers or main body but yet incapable of governing the main caving behaviour. For easy understanding the mining-induced movement of overlying strata, the “Key Strata (KS)” theory was proposed by Chinese Academician Qian in 1996.[24] According to this theory,[24–26] the stratum which controls the movement of part or all of the overburden is defined as the Key Stratum (KS), which means when the KS breaks, the part or all of the overburden above the KS will subside simultaneously. To be more specific the former is defined as Primary Key Stratum (PKS), while the latter is defined as Sub-key Stratum (SKS). There may be more than one SKS in the overburden whereas the PKS is unique in a specific longwall (LW) project. With reference to Fig. 2, for example, the strata between the SKS and the PKS are controlled by the SKS. In other words as long as the SKS breaks, the strata between the SKS and the PKS will break simultaneously. In this regard it is safe to say the strata above the PKS up to the surface are also controlled by the stability of PKS. So, the strata behaviour is primarily controlled by the breakage and movement of the KS. This theory provides a robust basis for studying strata movement and its impacts on ground subsidence. In addition this theory has been demonstrated and widely used in the Chinese mining industry.[27–30] According to the theory, movement of the KS directly determines the ground subsidence profile (details will be presented in Section 3.1) and thus understanding the rules of movement of KS and stability analysis is an important path to investigate ground subsidence. This study is also based on this theory.

2. Geological conditions and field observations of stepped subsidence

2.1. Geological conditions

The 9308 top coal caving longwall face (LW9308) of the Taian coal mine was operated in the #9 coal seam. The thickness of the coal seam ranges from 7.2 m to 16.4 m with an average thickness of 9.9 m. The longwall panel was 555 m long and 120 m wide (Fig. 3). The designed cutting height was 3.0 m and the recovery rate of top caving coal was approximately 70%. The LW face employed ZF8000-20/33 caving hydraulic supports, which had 8000 kN rated resistance and 2.0–3.3 m support height. The depth of the coal seam was from 133.9 m to 177.7 m. The overburden was composed of 83.9–98.7 m topsoil and 50–80 m hard rock. Fig. 4 shows the stratigraphic column interpreted from three boreholes

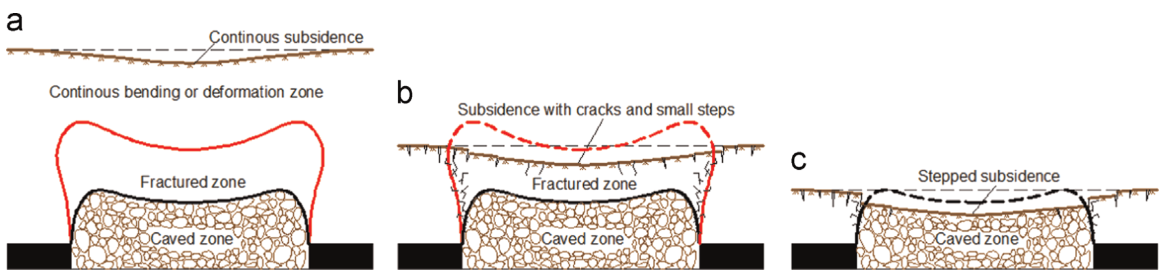

Fig. 1. Surface subsidence profile resulting from longwall mining under different depths. (a) Deep buried seam ("three zones"), (b) shallow buried seam ("two zones"), and (c) shallow buried seam ("one zone").

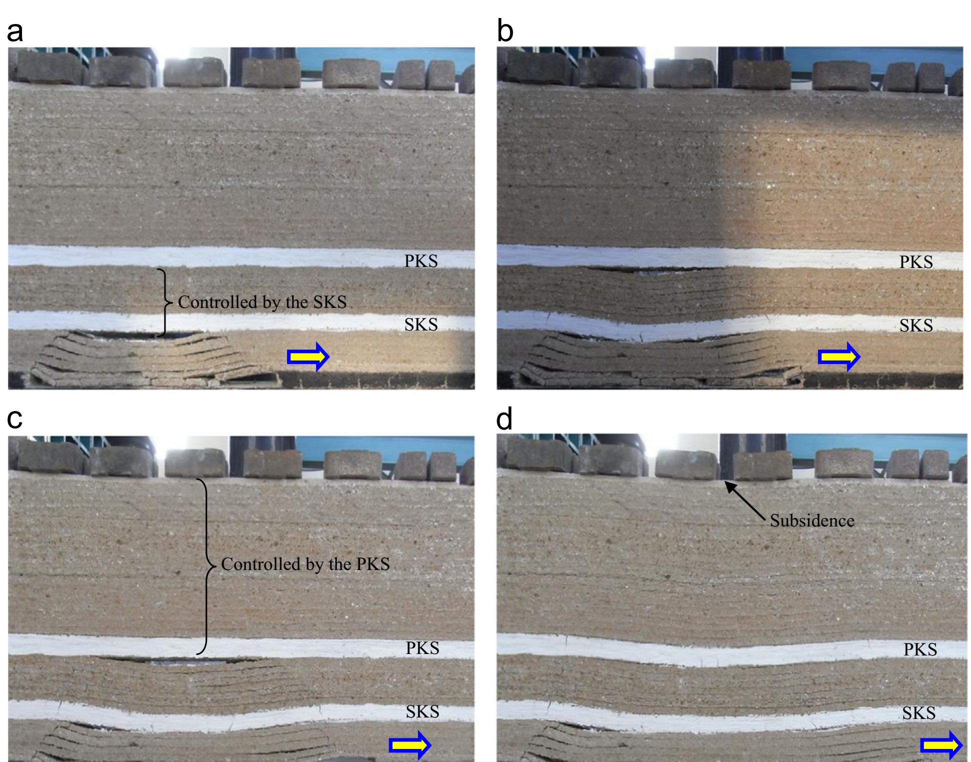

Fig. 2. Control action of the KS on the overlying strata movement. (a) Immediate roof caved, (b) SKS broke and the strata between the SKS and the PKS subsided simultaneously, (c) SKS broke and (d) PKS broke and surface subsided.