International Journal of Mining Science and Technology 25 (2015) 185–192

Contents lists available at ScienceDirect

International Journal of Mining Science and Technology

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

Assessment of pot-hole subsidence risk for Indian coal mines

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ARTICLE INFO

Article history:
Received 18 July 2014
Received in revised form 15 August 2014
Accepted 13 October 2014
Available online 16 March 2015

Keywords:
Underground coal mining
Pot-hole subsidence
PHSR
CPHSR

ABSTRACT

Ground subsidence induced by extraction of coal seam belowground brings about changes in surface environment leading to trough and pot-hole subsidence. Pot-hole subsidence is extremely hazardous and does not give any prior indication before its occurrence. In India, several pot-holes have occurred in the coal mines of South Eastern Coalfields Limited triggering the need for in-depth studies. In line with the requirement, literature review and field investigations were conducted to develop an in-depth understanding of various parameters influencing the occurrence of pot-holes. The critical parameters identified were rock to soil ratio, depth to height of extraction ratio, brittleness index of rock and rock density. Risk assessment of pot-hole subsidence has been done by developing an empirical rating approach named as pot-hole subsidence rating (PHSR), involving the critical parameters with suitable corrections for certain structural and mining conditions to obtain corrected PHSR (CPHSR). CPHSR was then applied for all the 34 pot-holes studied and it was found that all the pot-holes fall under Class I and Class II category of risk representing a very high to high risk class. An effort was made for the estimation of pot-hole depth utilizing the developed CPHSR in both the development and depillaring cases. The developed approach was found to yield consistent results in pot-hole depth prediction.

1. Introduction

Underground excavations created for coal mining purpose may create secondary cavities in the subsurface due to deformations and displacements of the overlying strata. These cavities may lead to instability of underground workings and form a depression on the ground surface and cause pot-hole subsidence. Pot-hole, generally, is associated with shallow mining though its occurrence is seen for depths upto 12 m. It is a localized phenomenon occurring due to sudden collapse of overburden into the underground voids. Several underground mines in India are closely located near urban areas. There is also a growing trend of human occupation near mining sites due to foreseen benefits of employment and lively hood. Pot-hole formation in such locations can be dangerous to life and often lead to severe damage to surface features by causing collapse of houses as shown in Fig. 1a and b. Human can either improve the environment or inflict damage to the environment that will endanger their development and existence [1]. Therefore, proper care must be exercised for preventing possible damage through scientific studies.

Pot-hole is the most dominant type of subsidence in some of the Indian coalfields. Although several studies have been conducted regarding trough subsidence in India, no focused research was carried out concerning pot-hole subsidence. There is no accurate and comprehensive means available to predict pot-hole subsidence though a couple of approaches are available with limited applicability. Moreover, the models related to prediction of trough subsidence cannot be applied directly to pot-hole subsidence.

Considering the acuteness of problem, research was taken up to develop a risk assessment technique which can help save human life, prevent the loss to property and save the environment. This is apart from colossal loss in time, resources and coal production due to the need for immediately plugging the pot-holes and set the system working. In this paper, the authors discuss about the critical parameters for pot-hole subsidence and their relative

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http://dx.doi.org/10.1016/j.ijmst.2015.02.004
2095-2686/

(a) (b)

Fig. 1. Danger to the life and property due to pot-hole.

importance followed by development of a risk assessment model through pot-hole subsidence rating (PHSR) approach which will help in arriving at the proneness to pot-hole subsidence in a given geo-mining regime.

2. Mechanism of pot-hole subsidence

The most probable cause of the formation of a pot-hole is a roof fall in underground, especially, over mine junctions. During the coal extraction process the overburden load which was previously been supported by the virgin coal seam is transferred to nearby pillars. This causes accumulation of stress in the material directly above the mined out area. Tensile stress in the immediate roof and/or high compressive stresses at the upper corners of the opening may develop depending on the initial state of stress and bending of roof layers. If the roof contains vertical fractures or joints tensile stresses will not develop, though fractures may start appearing. In either case, the roof will deflect downwards slightly and a self-supported linear arch will form. Changes in the state of stress and strength are likely to occur through deterioration of pillar and roof over time and this may be due in part to ground water fluctuations and creep. Finally, the phenomenon results in formation of pot-hole subsidence. A conceptual model for pot-hole subsidence is given in Fig. 2.

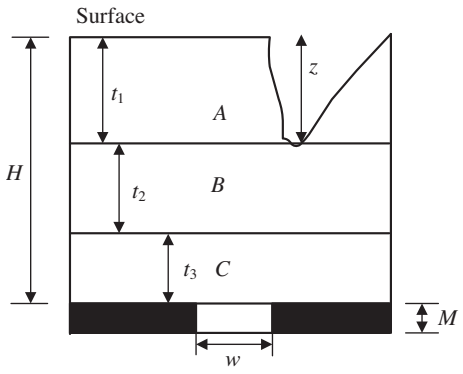

Fig. 2. Conceptual model for determination of pot-hole depth due to underground coal mining.

where H is the cover depth (m), M is the extraction height of the coal seam (m), z is the pot-hole depth (m), t_1, t_2 and t_3 are the layer thicknesses of the strata A, B and C above the underground working.

3. Field investigations

It is necessary to understand the field parameters namely the geo-mining conditions and geological disturbances which play an important role in the occurrence of pot-hole subsidence due to underground coal mining. Accordingly, field investigations were carried out in seven mines of three different areas of South Eastern Coalfields Limited (SECL), India, namely, Jamuna Kotma, Hasdeo and Bisrampur where pot-hole subsidence occurred. The location map of the mines is given in Fig. 3. In Jamuna Kotma Area, five mines, namely, Meera incline, Govinda colliery, Jamuna 9 & 10 incline, Kotma West (Middle Kotma and Lower Kotma-II seams) and Kotma colliery (Middle Kotma and Lower Kotma-I seams) were covered in the study. Investigations were also carried out in one mine each of Hasdeo and Bisrampur area, namely, Bijuri and New Jainagar colliery. A total of 34 pot-hole cases with different geo-mining conditions (method of working and geologically disturbances) were investigated in the study.

4. Methodology

Investigations included collection of data form surface and underground mines where pot-holes have occurred. Emphasis was given to the presence of geological discontinuities and water bodies near or along the pot-hole occurrence.

The pot-holing phenomenon is influenced by several geo-mining parameters with each of them having a varied degree of influence. These parameters were determined based on the literature review and field experience. The parameters which influence the most have been identified through correlation studies as the "critical parameters". The critical parameters identified in the present study are depth of underground excavation, height of extraction, thickness of rock in overburden, thickness of soil in overburden, compressive strength, tensile strength, weighted density (WDEN) of roof rocks, presence of faults/slips/fissures, proximity to water bodies and stage of underground extraction (development/depillaring or extraction).