International Journal of Coal Geology 89 (2012) 62–69

Contents lists available at SciVerse ScienceDirect

International Journal of Coal Geology

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

Determination of underground mining induced displacements using GPS observations in Zonguldak-Kozlu Hard Coal Basin

Eray Can *, Şenol Kuşcu, Cetin Mekik

Zonguldak Karaelmas University, Department of Geodesy and Photogrammetry Engineering, 67100, Zonguldak, Turkey

ARTICLE INFO

Article history:
Received 10 January 2011
Received in revised form 16 August 2011
Accepted 17 August 2011
Available online 23 August 2011

Keywords:
Coal mining
GPS measurements
Horizontal displacements
Kozlu Hard Coal Region
Mining subsidence
Subsidence monitoring
Zonguldak Hard Coal Basin

ABSTRACT

Mining activities cause horizontal and vertical movements on the earth's surface as well as in underground, which give rise to environmental, economical, judicial and urbanization problems. These movements or displacements – the results of collapsing, vertical displacement, swelling, slope change, bending and cracking – are referred to as mining subsidence which depends on the depth and dimension of mined area, production methods, underground operating speed, time and geological structure of area. The mining subsidence eventually affects the development of cities and city life by causing damages and destruction on buildings and structures on the surface. In order to study the displacements caused by on-going mining activities, City of Zonguldak, its town Kozlu and its near surroundings are chosen since they constitute the center for hard coal basin in Turkey for 160 years with a population of 300 000 and an area of 80 km^2.
This study details the results from a GPS Network conducted in the basin to determine the horizontal displacements on the surface created by the mining activities. The displacement results obtained from this study have been found to range from 10 to 78 mm with 4.4 to 7.9 mm RMSE values. These results indicate that the surface of the basin is under these effects today.

1. Introduction

Underground mining activities are prone to cause movement in geological strata and also on the earth's surface leading to mining subsidence and subsidence damages (Can et al., 2011; Deck et al., 2003; Duzgun, 2005; Kratzsch, 1983; Perski and Jura, 2003; Saeidi et al., 2009). Fig. 1 depicts the subsidence effects resulting from operating a horizontal mining seam and its maximum subsidence (vertical displacement), strain and horizontal displacement curves. Determining mining subsidence depends upon regional subsidence parameters, underground operating speed, duration of production, production methods, geometry of the mined area (such as dimensions of opening, shape and depth) (Can et al., 2011). This initiates damages on surface structures, utilities, buildings, farmlands, and also disturbs the natural balance of surface, underground water resources, natural and man-made surface drainage systems as well as engineering structures such as reinforced concrete and masonry buildings, railways and highways (Altun et al., 2010; Deck et al., 2003; Li et al., 2010; Stecchi et al., 2009). In many European countries, systematic subsidence investigations on underground coal mining productions and their subsidence effects have been widely conducted using field observations so as to reduce and control the adverse subsidence effects on urbanization since 1880 (Kuşcu, 1991). Furthermore, these studies have paved the way to emerging a new discipline called subsidence engineering specializing in five main subjects which are subsidence monitoring, subsidence prediction, subsidence control, material damage and subsidence laws and regulations. Subsidence monitoring constitutes the base for the rest of the subject topics and provides reliable and general data for the

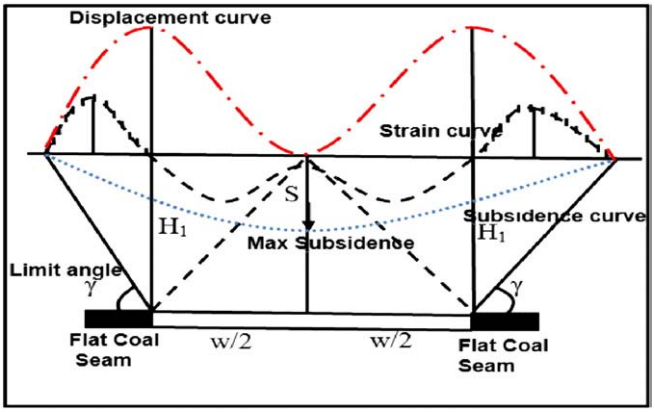

Fig. 1. Vertical and horizontal displacements and strain curves in a flat seam.

* Corresponding author. Tel.: +90 372 257 40 10; fax: +90 372 257 29 96.
E-mail address: can.eray@hotmail.com (E. Can).

0166-5162/$ – see front matter © 2011 Elsevier B.V. All rights reserved.
doi:10.1016/j.coal.2011.08.006

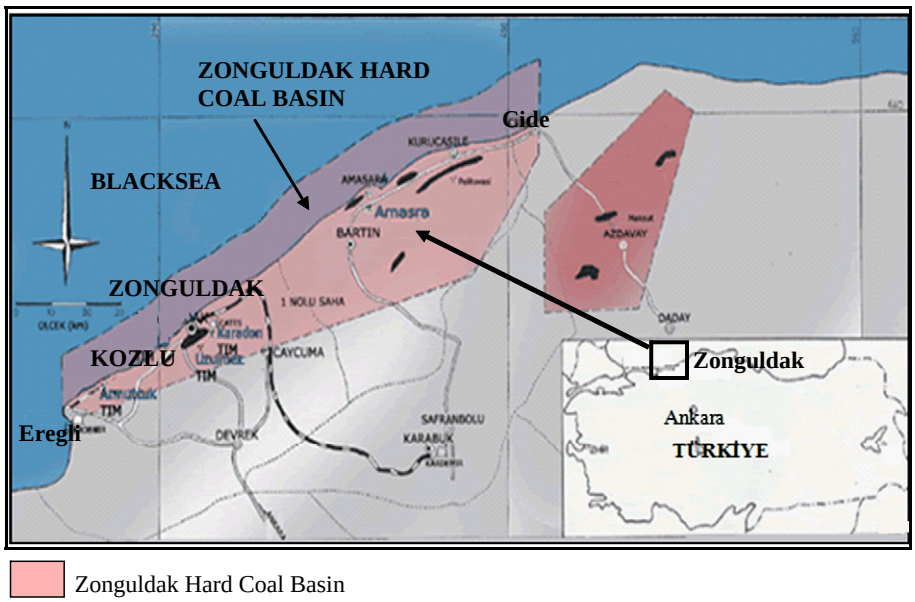

Fig. 2. Location map of the study area (URL 1, 2011).

formation and problems created by mining subsidence. Subsidence monitoring is conducted to determine:

- Regional subsidence parameters such as vertical and horizontal movement of points, critical angle, subsidence inclination and horizontal deformations.
- Correlation between the subsidence and geological, structural topographic features.
- Association of subsidence to underground working place and time dependence.
- Relationship between subsidence and production methods.
- Damaging effects of subsidence on structures and utilities.
- Connections between subsidence and geometry of mined out area (i.e. dimension of opening shape and depth).

Subsidence monitoring results also serve to:

1. test the applicability of subsidence prediction methods or other subsidence hypothesis in the monitoring area;
2. clarify legal problems resulted from subsidence effects between mine administration and public; and
3. determine regional subsidence parameters accurately.

Various scientists recently have conducted studies on adverse mining subsidence effects, especially with regard to urbanization and

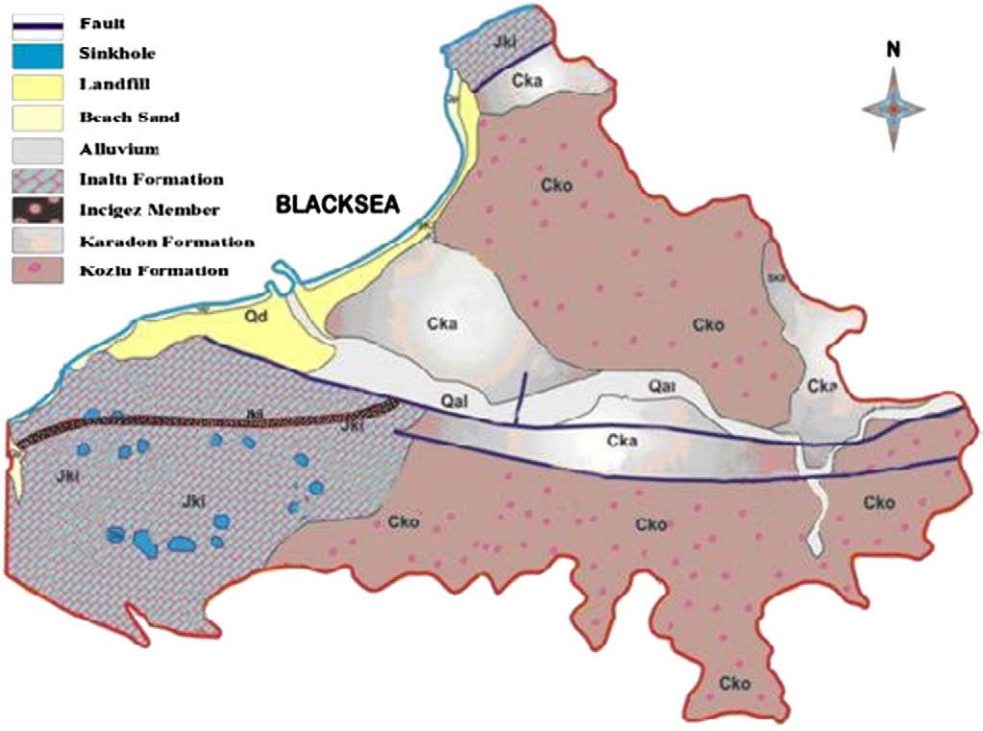

Fig. 3. The geological map of the study area (Alan and Aksay 2002; Citiroglu and Baysal, 2011).