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Analysis of the surface horizontal displacement changes due to longwall panel advance

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1. Introduction

Movements of rock mass and soils, resulting from underground mining extraction are likely to cause mining damage to building structures, which is a serious issue in urbanised Europe.[1,2] The better knowledge of mining-induced surface and rock mass deformation could provide to more accurate prognosis, but the estimation of the values and distribution of horizontal movement are still unclear.[3–6] Describing the horizontal movements caused by mining operations, the dependency provided in [7] is used. It asserts that there is a linear relationship between the vertical movement vector u and the tilt vector T. The relationship can be described with the following formula:

$$u = -B \cdot T \quad (1)$$

where B is the horizontal movement or horizontal strain factor with the value depending on the local mining and geological conditions.[8]

Formula (1) shows that the relation between the horizontal strain tensor ε and the vertical curvature tensor K is as follows:

$$\varepsilon = -B \cdot K \quad (2)$$

The most important indicator of deformation, from the point of view of threat to civil structures, is horizontal strain ε.[2,9,10] For this reason, the correct determination of the value of the B factor is crucial.[11,12]

This article presents the results of the identification of the B parameter based on the discrete measurement results made within the span of approx. 2.5 years (unpublished materials received from Deutsche Montan Technologie –DMT- GmbH).

2. Description of the mining and geological conditions and the results of measurement made in the analysed region of the mine

The Prosper Haniel hard coal mine started production from the longwall no. 698 in seam O/N located at the average depth of $H = 960$ m in 1999. The length of the production face was 270 m, panel length 970 m and the height – from 3.6 m to 4.3 m (materials DMT). The seam was dipping towards the south-west at the angle of 7°. Production from the longwall started in early May 1999 and was completed by the end of November 1999. After completing production from the longwall no. 698, however still during the measurements of the subsidence and horizontal movements of measurement points, the production was started in longwall no. 682 in seam P with the thickness of 1.6 m and the depth of $H = 920$ m. Longwall no. 682 was located about 350 to 450 m towards the east from the left edge of longwall 697. During the period of production from longwall 682, the mine started operations in longwall 697 in seam O/N (starting mid-June 2000, completed by the end of March 2001). Mining production in longwalls 698 and 697 in seam O/N was carried out in an area relatively free from the effects of other operations (only one seam R approx. 110 m above seam O/N – Fig. 1).

On the surface, the Prosper Haniel mine established a measurement grid in the form of a network of distributed measurement points. The measurements of the movement of points were made using GPS satellite technology.[1] The locations of the individual measurement points are presented in Fig. 2. The first, reference measurement was made in early April 1999, before starting production from longwall 698. These

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[1] GPS measurements were made using the Rapid Static Messmodus (rapid static measurement mode) method and, in some points, the measurements were made continuously (Permanentstationen).

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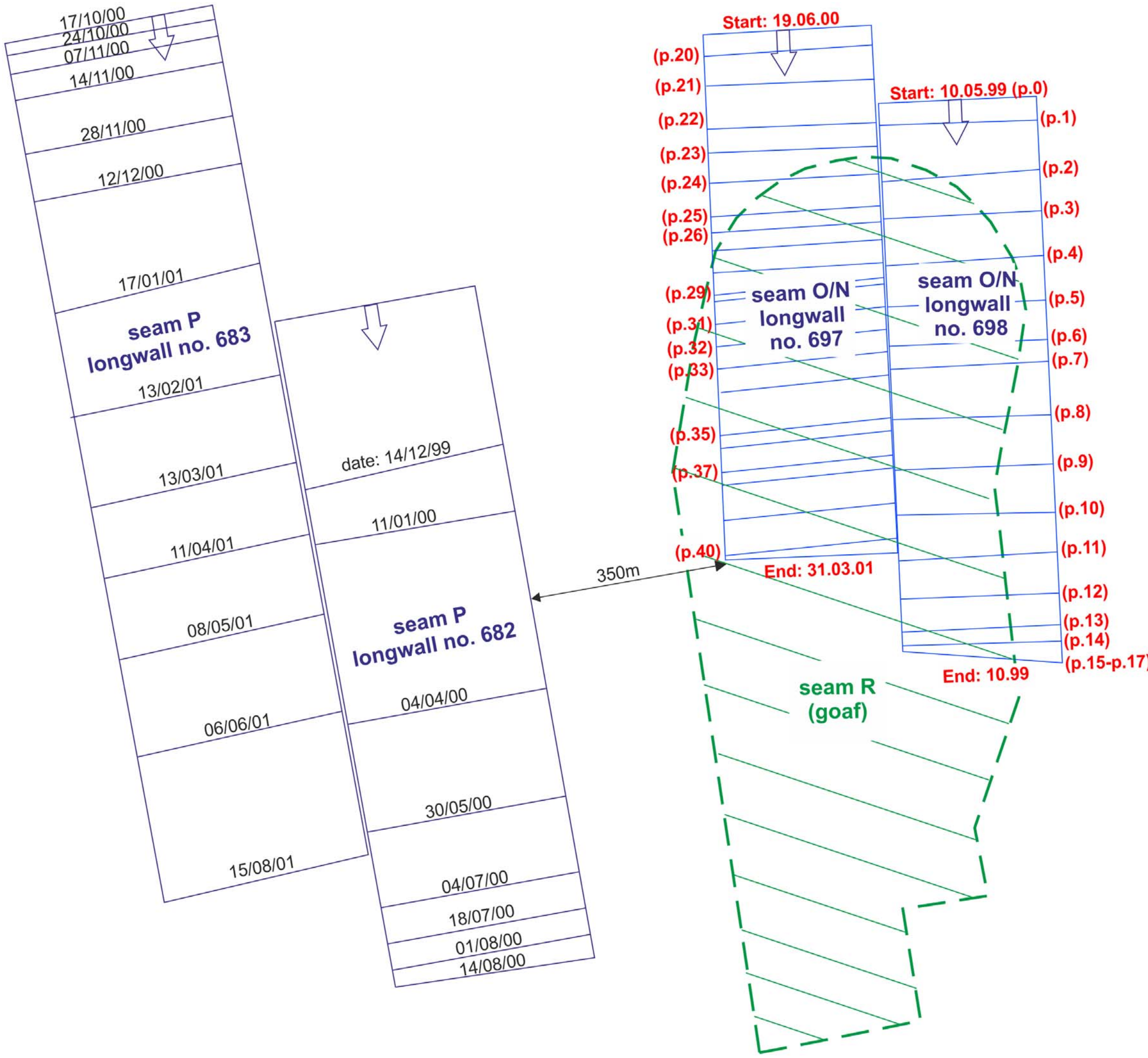

Fig. 1. Diagram of the mining conditions in the production area of longwalls 698 and 697 of seam O/N.

measurements were continued until January 2000 (measurement no. 17).

The results showed that at the time of finishing the observations, the subsidence of points located in the central part of the trough practically achieved a stable status, only the points located within the area of the end edge of longwall 698 were still in the final subsidence phase. In addition, it should be noted that the strong sandstone layer with the thickness of approx. 90 m located above seam O/N as well as the small size of the mined longwall panel 698 (face length of 270 m) resulted in the creation of an incomplete trough on the surface. The measured trough showed deformation values some 50% lower than the forecast values.[13]

In order to record the changes in the behaviour of the surface during the production from the next longwall – 697, the surveying measurements were made further in these points until mid-August 2001 (measurement no. 44). In order to provide a graphical representation of the results of measurements, based on the distributed points network, a measurement profile was created for points 12–21 (Fig. 2). The profile corresponds with the layout of the liquid fuel pipeline connecting the port of Rotterdam and Frankfurt.

The measurements of movements for the aforementioned points are presented in the form of a profile of subsidence w and horizontal movements towards the measurement line $u(\alpha)$ (Fig. 3). As demonstrated in Fig. 3, the maximum subsidence for the measurement line is located between points 15 and 16 and is 560 mm, when taking into account only the production from longwall 698; after completing the production from longwall 697, the maximum value of measured subsidence increases over three times to approx. 1685mm. This value is also found between points 15 and 16 – in the area of the shared edge of longwalls 698 and 697.

A similar situation can be observed in the chart of measured horizontal movements of observation points towards the measurement line. For longwall 698, the zero point of the horizontal movement curve is located in the middle section of the longwall, some 270 m from the eastern edge of the production zone (Fig. 3b – measurement 17). After completing the production from longwall 697, the zero point of horizontal movement moves to the area near the shared edge of longwalls 698 and 697 (approx. 40 m towards the goaf).

3. Determination of the horizontal movement factor *B* based on the results of measurements along the measurement line, depending on the location of the production face

A total of 44 measurement cycles were completed in order to observe the effects of longwall operations 698 and 697 in seam O/N on the structures located on the surface. For the selected individual measurement cycles, the values of the spatial movement vector for the measurement line points were established using GPS measurement, followed by the values of their horizontal movement and tilt towards this line. Examples of these relationships are depicted for the 17th and 44th