COMPARISON BETWEEN PREDICTED AND OBSERVED SUBSIDENCE ALONG A BURIED CONCRETE WATERLINE MINED UNDER BY A LONGWALL PANEL[1]

by

Kewal K Kohli and Lois Uranowski[2]

ABSTRACT

This paper compares the results of the observed subsidence and displacement to a 30-inch diameter concrete waterline by longwall mining with subsidence and displacement predicted using Surface Deformation Prediction System (SDPS) model. The SDPS model has been developed recently by the Virginia Polytechnic Institute and State University (VPI & SU) for the Office and Surface Mining Reclamation and Enforcement (OSM) and demonstrated good correlation. The model also predicts the strains, slope and the curvature. Thereby any potential damages to gas lines, highways, railroad, streams, and hazardous waste fills can be ascertained. These can be minimized or prevented by taking necessary measures.

Background

The study site is located near Washington, PA as shown on Figure 1. A 30-inch diameter concrete waterline was undermined by longwall operations (see Figure 2). The 30-inch concrete waterline lies near the center and curves nearly diagonally across the longwall panel as shown on Figure 2. Mining depth varies from 600 to 650 feet, mining height is 6.0 feet, and the panel width is 900 feet. A mining consultant was also retained to predict subsidence and associated damages to the pipeline caused by mining on the basis of which, necessary measures to prevent damage to the pipeline were taken by cribbing and/or jacking during mining. The observed maximum subsidence to the waterline was 4.5 feet near the middle of the panel, decreasing on both sides over the chain pillars (see Figure 3). The observed maximum displacement was 1.2 feet. The pipeline was kept level at all the time by cribbing and/or jacking.

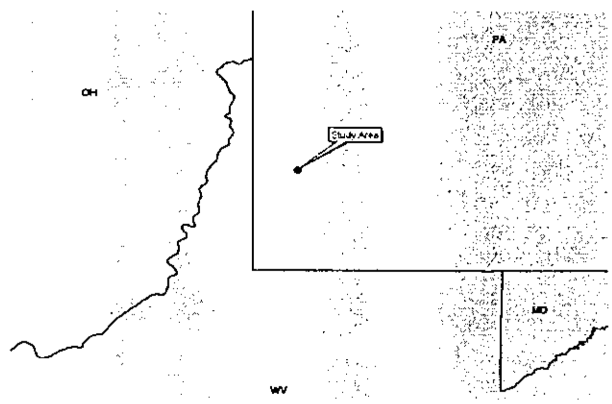

Figure 1. Site Location Map

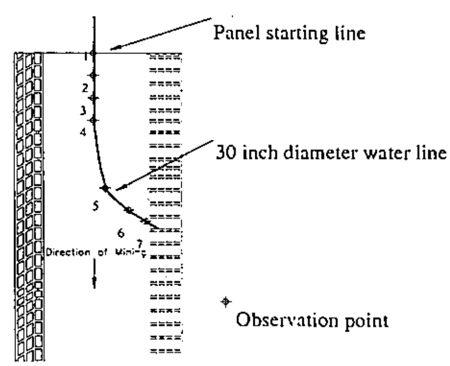

Figure 2. Mine Map and Pipeline Layout

[1] Paper presented at the 2000 National Meeting of the American Society of Surface Mining and Reclamation, Tampa, Florida. June 11 - 15, 2000

[2] Kewal K. Kohli, Mining Engineer, and Lois Uranowski, Physical Scientist, Office of Surface Mining and Reclamation, Pittsburgh, PA 15220

Proceedings America Society of Mining and Reclamation, 2000 pp 144-147
DOI: 10.21000/JASMR00010144

https://doi.org/10.21000/JASMR00010144

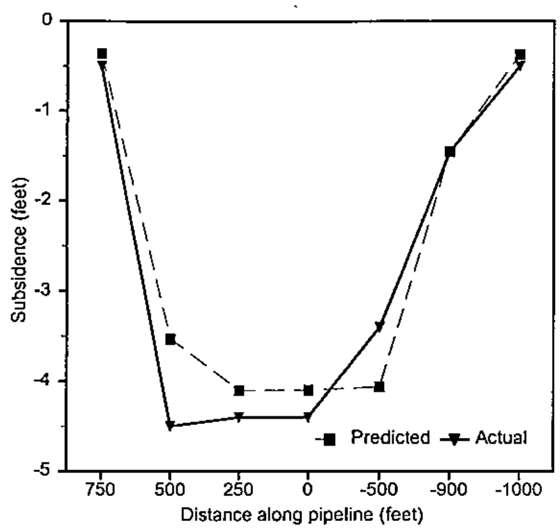

Figure 3. Predicted and Observed Maximum Subsidence

Surface Deformation Prediction System

The Surface Deformation Prediction System (SDPS) developed by VPI & SU for OSM (Karmis &Agioutantis, 1999) is applied to predict the subsidence and the displacement along the waterline. Two popular methods of SDPS namely 1) Profile Function, 2) Influence Function for predicting subsidence and other parameters are explained here. The predicting technique is based on several empirical relationships, developed through statistical analysis of data from many case studies.

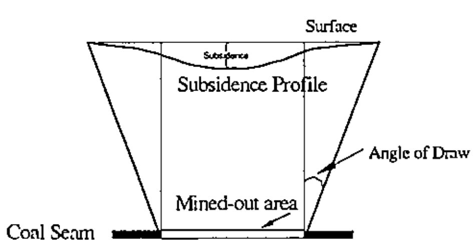

Figure 4. Subsidence Profile and Angle of Draw

The Profile Function Method. The Profile Function Method can predict maximum subsidence, the subsidence profile and the angle of draw (see Figure 4) for simple mine layouts. The location of prediction points is automatically calculated, from the point of maximum subsidence (i.e., the center line of the panel) to the zero subsidence limit. The empirical parameters required are already built into the profile function equation (VPI & SU, 1994)

The input parameters for this method are;

a) Percent of hard rock in the overburden
b) Mining height
c) Depth and width of mine opening

The Influence Function Method. The influence Function Method can predict the following for complex mine layouts:

a) the vertical subsidence at any point the surface,
b) the subsidence profile,
c) the horizontal displacement,
d) the angle of draw,
e) the slope,
f) the strains
g) the curvature at any point on the surface.

These parameters are shown in Figure 5.

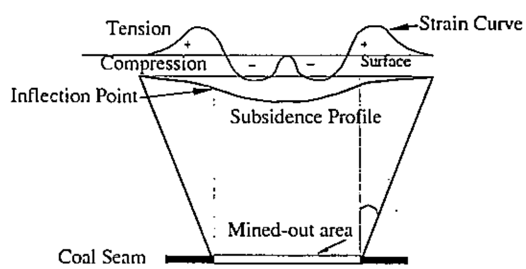

Figure 5. Stain and Infection Point

SUBSIDENCE AND DAMAGE CRITERIA

Surface ground movements caused by underground mining are usually described by a number of characteristic indices (Singh, 1992), including:

Vertical Subsidence. Uniform vertical subsidence over an area does not cause damage, even the structure may subside several feet. However, the structure must be strong enough to resist the dynamic strains caused during mining to prevent any damage.

Horizontal Displacement and Strains. Horizontal displacement induces tensile and compressive strains on the structures. Most damages are caused by the strains. Tensile strain has been found to be a major factor to cause structural damages because the masonry structures are weaker in tension. Also, pipes, cables, roads, railways, walls and other types of building components buckle readily under compressive strains. Strains can also induce distortion, fractures, or even failure.

When the stresses/strains caused by surface ground movement on the structure exceed the strength of the structure, it will cause damage. The severity of the damages depend on the structure's ability to resist additional stresses caused by subsidence.

Slope (Tilt). Differential vertical ground displacement causes slopes to form and induce tilting. The formation of slopes may cause structures to tilt and can greatly change the gradients of a railroad and highways. Tall structures with small base areas, such as water towers, chimneys, power transmission tower, and buried transportation lines are sensitive to slope.

Curvature (flexure). Curvature causes two types of deformation on the structures:

1. Shear strain that induces angular distortion to the buildings.

2. Flexure (bending) that causes strains in long load-bearing members. Concave curvature causes tension along the bottom and compression along the top of the building.

The surface ground movements have been utilized in a number of damage classification schemes to develop structural damage criteria. The National Coal Board (1975), proposed one of the earliest and most widely used damage classification system.

Similar system was developed by Bruhn et. al. (1982) for the North Appalachian Coalfields.

Singh (1992) published a table showing damage classification schemes in several European countries in which building categories, movement types and range of damage-limits are summarized.

DISCUSSION OF ANALYSIS

Since the pipeline layout over the longwall panel is complex, the Influence Function Method can be applied to predict the maximum vertical subsidence, subsidence profile, horizontal displacements and strains. The strains predicted were higher than the maximum allowable for the pipeline. Therefore to prevent damage to the pipeline, the line was uncovered and kept level as it was being undermined. The pipeline was shut down during this period. Within six weeks after the pipeline was undermined, the subsidence was determined to be complete. The pipeline was covered and commissioned. Figure 3 shows the predicted and observed maximum vertical subsidence profiles along the pipeline over the longwall panel.

1) The predicted and the observed maximum vertical subsidence are 4.2 and 4.5 ft. respectively. This is a good correlation.

2) The predicted and observed subsidence profiles along the pipeline are shown in Figure 3; also has a good correlation.

3) The predicted and the observed maximum horizontal displacements are 1.4 and 1.2 ft. respectively.

4) The predicted maximum horizontal strain was 3×10^{-3}. The maximum allowable strain for the waterline is 1×10^{-3}. It was prudent to uncover the pipeline, maintain a level position and prevent damage.

5) The predicted maximum angular strain was 4×10^{-3}. The allowable maximum angular strain was 5×10^{-3}. This supported the uncovering of the pipeline and keep it level to prevent damage.

ACKNOWLEDGMENTS

We thank;

Jeffery Maize and the management of Pennsylvania-American Water Company for providing us the subsidence information.

Gary Slagel and the management of Consolidation Coal Company for providing us the mine maps and other mining information needed to do the analysis.

Jesse Craft for assisting us to make drawings and giving suggestions in writing this paper.

REFERENCES

Bruhn, R.W., McCann, W.S., Speck, R.C. and Gray, R.E., 1982, "Damage to Structures Above Underground Coal Mines in the Northern Appalachian Coalfields," Proceedings, 1st International Conference on Stability in Underground Mining, Vancouver, Canada, pp. 1022-1042

Karmis, M. and Agioutantis, Z., 1999, "Surface Deformation Prediction System," developed for the Office of Surface Mining and Reclamation, Pittsburgh, PA., 15220, 60p.

National Coal Board, 1975, "Subsidence Engineer's Handbook," Mining Department of the N.C.B., United Kingdom. 111p.

VPI & SU - Dept. of Mining and Minerals Engineering, 1994, "Surface Deformation Prediction System (version 4) - User's Manual," 140 p.

Singh, M.M., 1992, "Mine Subsidence," SME Mining Engineering Handbook, 2nd Edition, Vol. 1, Society of Mining, Metallurgy and Exploration Inc., Littleton, CO., pp. 938-971.