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Behavior of twin inclined shafts excavated for +30 levels surface stability in Ha Lam coal mine

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ABSTRACT

The process of excavating roadway, shafts, and exploiting coal seams located near the ground may cause subsidence of the ground surface, cracking, damage to structures on the surface. Therefore, it is necessary to rely on the specific conditions of the site to calculate and forecast the level of impact on the works on the surface, ground subsidence when excavated roadway, shafts, exploiting coal seams located near the ground. Based on the topographical conditions, geological hydrogeological conditions and current status of works on the surface, the technical design of the excavation of the twin inclined shafts from +30÷-300 levels in the Ha Lam coal mine is proposed. This paper uses the numerical method by FLAC3D software to build the model with a height of 450 m and a width of 700 m to study the effect of the twin inclined shafts construction on the deformation of rock mass on the ground surface. This research has shown that after the construction of the twin inclined shafts from +30÷-300 levels, the area of each inclined shaft is 15.8 m^2, rock mass on the ground surface is deformed, the maximum value of vertical deformation is about 5 cm, horizontally deformation is about 3 cm, the effect range of deformation the surface is within a radius of 25 m. So on the +30 level of Ha Lam coal mines when constructing works serving the coal mining within a radius of 25 m in the twin inclined shafts entrance area, it is necessary to consider the impact excavation of the twin inclined shafts. But when constructing works outside a radius of 25 m in the twin inclined shafts entrance area will not be affected. Recommendations for the Ha Lam coal mine process need to install more deformation monitoring stations to monitor the deformation process of the surface of +30 level when excavation of the twin inclined shafts.

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1. Introduction

The deformation of the surface is mainly affected by mining besides shaft excavation in underground mining. Regional rock mass movement and deformation caused by shallow mining have occurred in many large underground coal mines in Viet Nam and the world. It had a significant impact on the mine and nearby works on the surface, and the suffering area was unexpected. Currently, several deformations of mine surface studies were conducted in a wide range of mine engineering. Study on the ground movement in an open-pit mine in the case of combined surface and underground mining (Wang, et al., 2020). Deformation evolution regulation of loess floor earth-disposal site affected by open pit and underground mining papers (Wang et al., (2008). Study on the stability of surface mine slope influenced by underground mining below the end wall slope papers (Hong et al., 2020). Analysis of dynamic mechanical behavior during construction from an inclined shaft to the main tunnel in soft surrounding rock (Zhang et al., 2013).

The above research focuses on open-pit mining and underground mining affecting ground movement. However, the effect of excavated twin inclined shafts on ground movement is not well understood.

This paper is the basis on the topographical conditions, geological and hydrogeological conditions, technical design, excavation of twin inclined shafts from +30÷-300 levels in the Ha Lam coal mines, and studies on twin inclined shafts excavated affecting the ground movement.

With an exploitation depth of 300 meters, Ha Lam is the deepest mine applying modern technologies and the first mechanized mine in Vietnam. The construction of the project began in 2009 and it is expected to achieve a capacity of 2.4 million tonnes of coal annually by 2018.

The twin inclined shafts from +30 to -300 levels were constructed to serve the exploitation of the 14 coal seams of the Ha Lam coal mine. To serve the construction of the twin inclined shafts and later go into the operation of 14 coal seams on the ground + 30 levels, several supporting and long-term works must be built (Vinacomin - HaLam Coal Joint Stock Company, 2007). In which, some projects must be built before constructing the twin inclined shafts. For the works around the twin inclined shafts entrance to ensure safety during construction and use, it is necessary to evaluate the impact of the construction of the twin inclined shafts to stabilize the surface rock around the twin inclined shafts entrance.

2. Project overview

The twin inclined shafts and the roadway in 14 coal seam started excavation from +30÷-300 levels, The distance between twin inclined shafts is 25 m, the excavated area of the inclined shaft is 15.8 m^2, the twin inclined shafts excavation through layers of coal and siltstone, sandstone, sandstone, conglomerate (Vinacomin Informatics, Technology, Environment Joint Stock Company, 2005). The entrance of twin inclined shafts is supported by CBII-27 steel, concrete poured for stability, the levels of +30, and the schematic of the twin inclined shafts is shown in Figure 1 (Vinacomin Industry Investment Consulting Joint Stock Company, 2007).

These twin inclined shafts and roadways are used to ventilate, travel, transport materials, transport for production from the ground level of +30 down to underground areas at -50, -150, -300 levels.

Construction diagram using mixed construction: excavation, temporary support, and permanent support are carried out in the working cycle. Excavation of comprehensive section, break the rock mass by drilling and blasting.

The entrance of the twin inclined shafts from +30÷-300 levels was excavated in the highly fractured rock layer, constructed, erected for supporting and pouring concrete with a length of 11.44 m. The basic parameters are shown in Figures 2 and 3 (Vinacomin - HaLam Coal Joint Stock Company, 2007).

The body of the twin inclined shafts has an angle of 23 degrees excavation in the silt layer with f=4÷6 (Vinacomin Informatics, Technology, Environment Joint Stock Company, 2007), supported by the СВП-27 steel-resistant structure. The distance of support in stable surrounding rock is 0.7 m, the distance of support in unstable surrounding rock is 0.5 m.

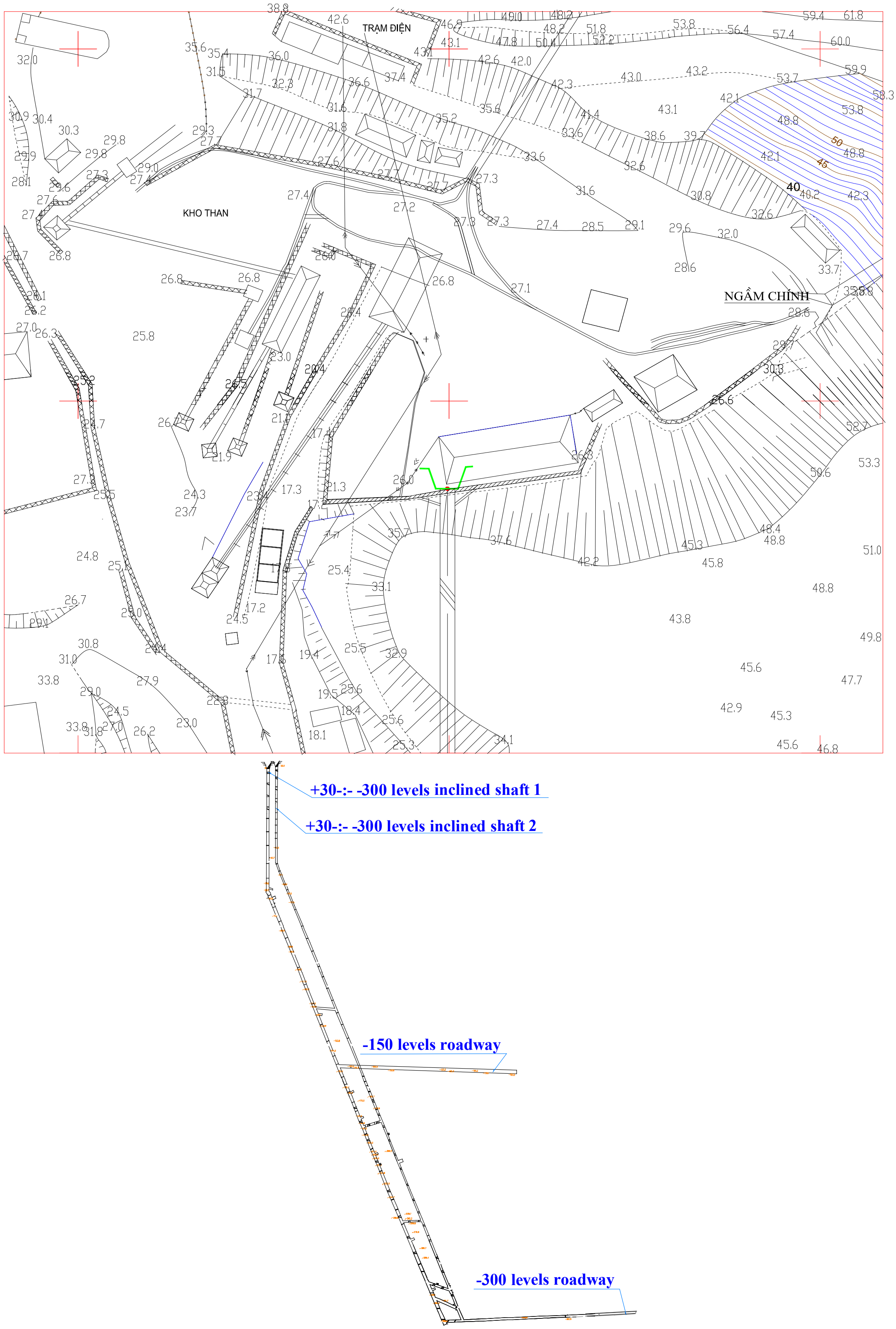

Figure 1. The ground-level of + 30 and diagram of the twin inclined shafts, roadway.

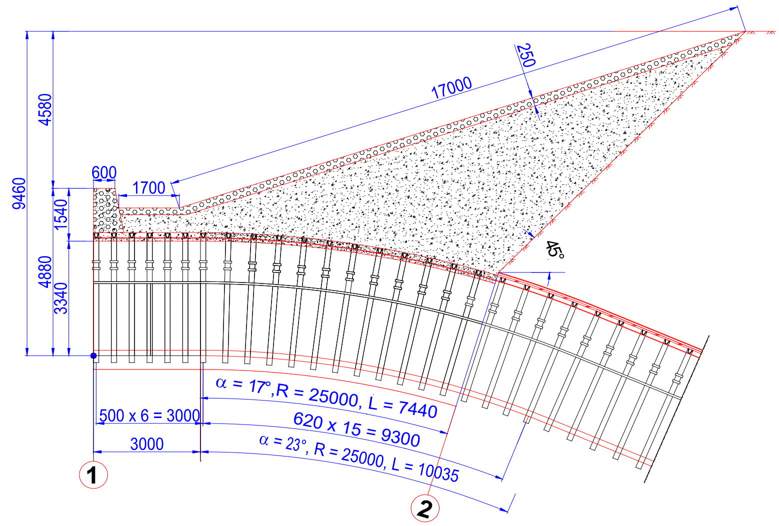

Figure 2. Cross-section the entrance of the twin inclined shafts.

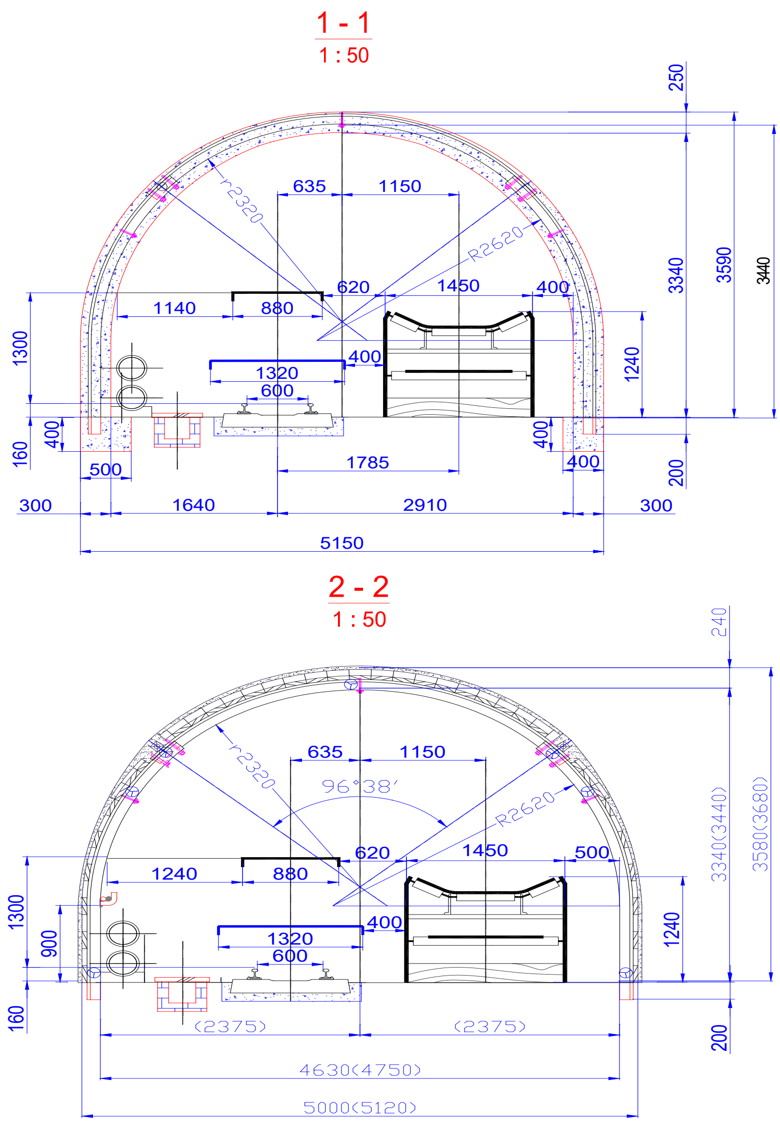

Figure 3. Support in the entrance of the twin inclined shafts.

3. Stability of rock mass in the excavation of twin inclined shafts

3.1. Numerical modelling

The length, width, and height of the model are 700x1x450 m as shown in Figure 4, respectively, which correspond to directions X, Y, and Z. Once the 3D model is created, the following boundary conditions are assumed (Itasca, 2005):

- Nodes on the left and right sides of the model are fixed in the horizontal (X) direction.
- Nodes at the bottom of the model are fixed in all directions X, Y, and Z.
- Nodes on the top of the model are free.

The following failure criterion named Mohr-coulomb is applied (Itasca, 2005):

$$f_s = \sigma_3 \frac{1 + sin\varphi}{1 - sin\varphi} + 2c\sqrt{\frac{1 + sin\varphi}{1 - sin\varphi}} \qquad (1)$$

Where: σ_1 - the major principal stress; σ_3 - the minor principal stress; c is the cohesion; φ - the internal friction angle.

Mechanical parameters of rock mass are shown in Table 1 (Vinacomin - HaLam Coal Joint Stock Company, 2007).

Based on the numerical simulation model as shown in Figure 4. The excavation steps in the model are conducted as follows:

Step 1: Excavation of inclined shaft 1, unsupported as shown in Figure 5;

Step 2: Excavation of inclined shaft 2, unsupported as shown in Figure 6.

Table 1. The mechanical parameters of rock mass.

Rock layers	U-W (kg.m-3)	E (GPa)	Es (GPa)	C (MPa)	I-F-A (d)
Sandstone	2640	4.3	2.6	33.4	31
Siltstone	2650	3.2	1.8	21.3	30
Coal seam	1500	1.2	0.7	2.2	26
Packsand	2650	4.8	3.0	37.3	32
Claystone	2520	1.4	0.8	7.1	27

3.2. Discussion of numerical results

The vertical stress distribution in the rock mass after the excavation of the twin inclined shafts is shown in Figure 7.

From the simulation results shown in Figure 7, it can be stated that after excavation of the twin inclined shafts, the primary stress state is broken and forms a new equilibrium stress state or secondary stress state, accompanied by the mechanical changes in the rock mass around twin inclined shafts. In general, stress distribution increases with depth. The stress value at the location close to the ground surface is approximately 0 MPa, at the depth from -140÷-170 m the stress value is about 4.5÷6 MPa and about 10 MPa at the - 300 m levels.

The yielded zone distribution in surrounding rock mass after excavation of twin inclined shafts is shown in Figure 8.

From the simulation results shown in Figure 8, it can be stated that after excavated the twin inclined shafts, yielded destruction zone around the twin inclined shafts developed along two sides

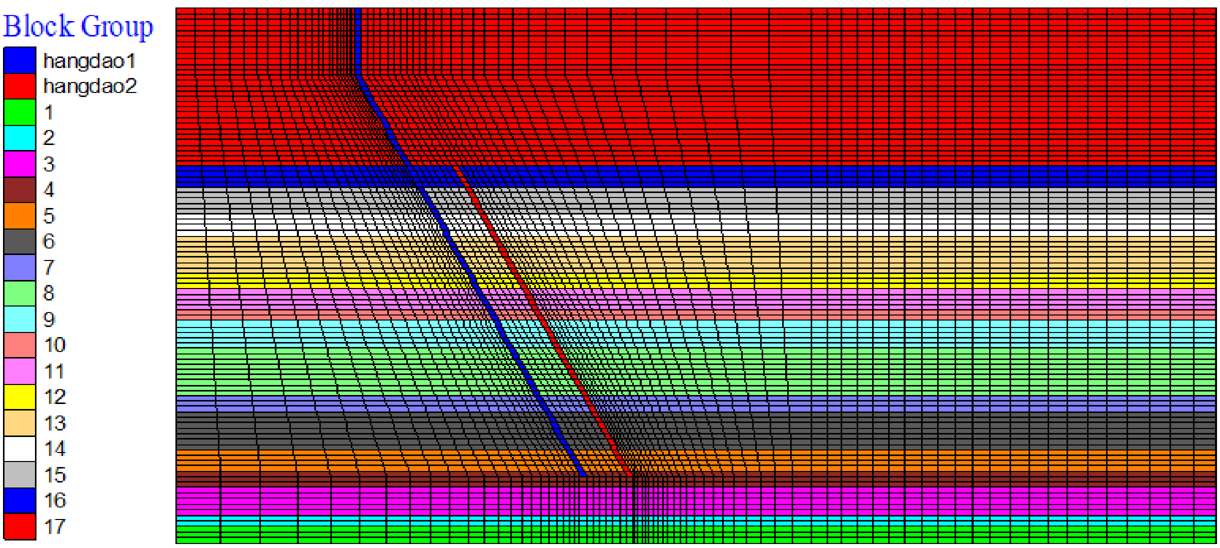

Figure 4. Numerical simulation model.

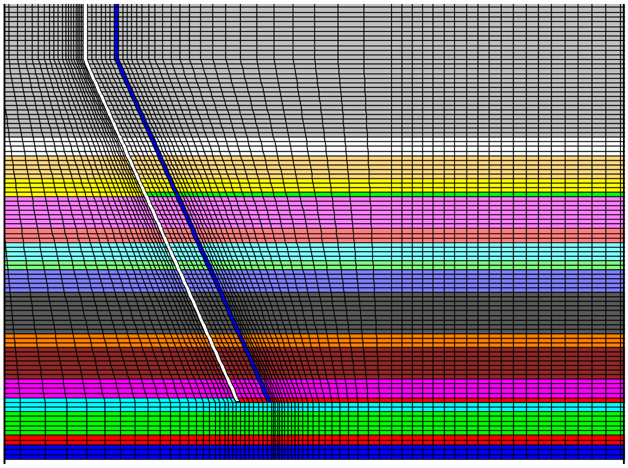

Figure 5. Excavation inclined shaft 1 of model.

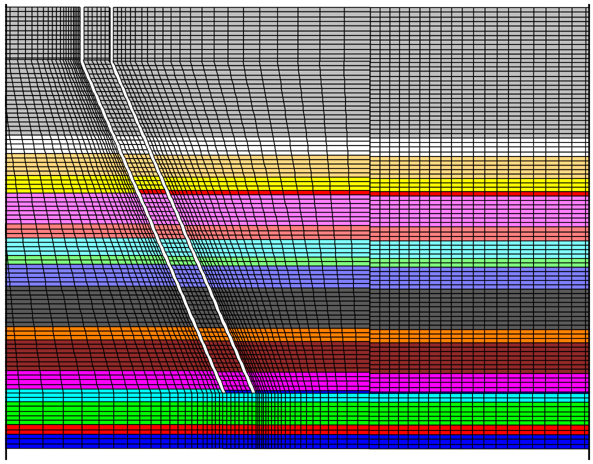

Figure 6. Excavation inclined shaft 2 of model.

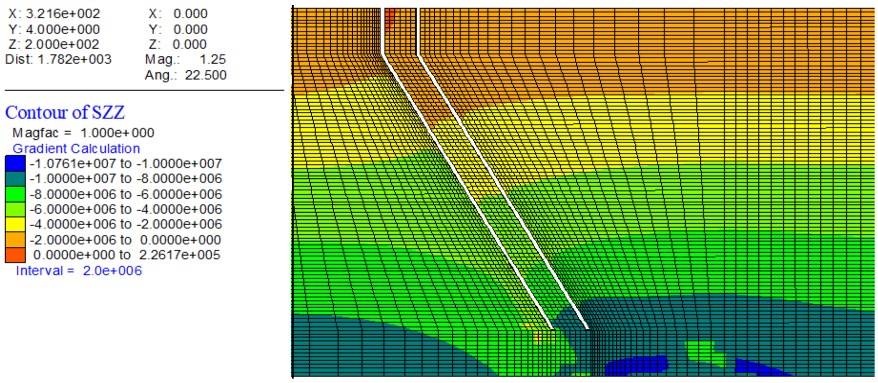

Figure 7. Vertical stress after excavated the twin inclined shafts.

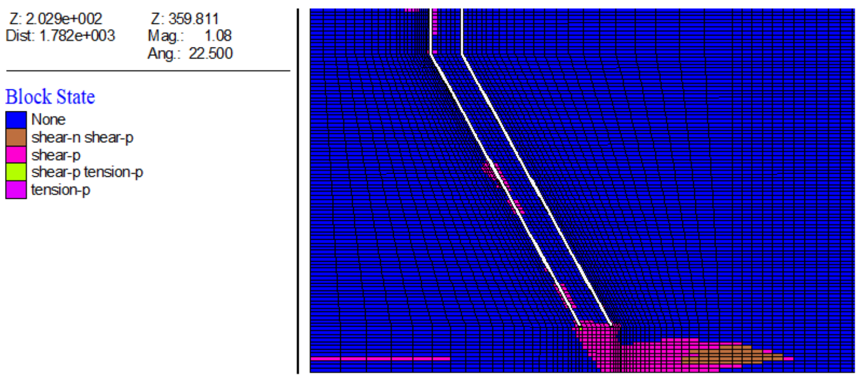

Figure 8. Yielded zone distribution after excavated the twin inclined shafts.

of twin inclined shafts but mainly concentrated in the rock mass near the boundary of the twin inclined shafts without growing deep into the rock mass. The state of destruction at different levels such as destruction by shear, the mixture of tension and shear. The development of the largest yielded failure zone is at the bottom of the twin inclined shafts, this is explained as the greater depth, the greater formation pressure, this is the cause of the large area yielded failure zone. Yielded destruction zone in the surrounding rock at the twin inclined shafts entrance is also developed along twin inclined shafts walls, but yielded destruction area is not large and the range of yielded destruction is about 3÷5 m.

The horizontal deformation of the rock mass after the excavation of the twin inclined shafts is shown in Figure 9.

From the simulation results shown in Figure 9, it can be stated that after the excavation of twin inclined shafts, the horizontal deformation of the rock mass around twin inclined shafts and on the ground has occurred.

At the twin inclined shafts entrance and the bottom of the twin inclined shafts, the horizontal deformation occurred the most, the value of horizontal deformation at the twin inclined shafts entrance of the largest is 3.09 cm. At a location more than 20 m from the shaft entrance, the maximum deformation value is 2.4 cm. At the bottom of the twin inclined shafts, the maximum deformation value is 6.5 cm. Thus, it can be stated that the deformation value at the bottom of the inclined shaft is greater than the deformation value at the shaft entrance. This is also explained because the deeper the stratigraphic pressure, The surrounding rock mechanics change greatly. Therefore, the deformation value is also larger.

The vertical deformation of the rock mass after the excavation of the twin inclined shafts is shown in Figure 10.

From the simulation results shown in Figure 10, it can be stated that after excavation of the twin inclined shafts, mechanical transformation occurs in the rock mass, the vertical deformation of the rock mass around the twin inclined shafts, and on the ground has occurred.

At the twin inclined shafts entrance, the maximum horizontal deformation value is about 5 cm. At a location more than 25 m from the shaft entrance, the maximum horizontal deformation value is 3 cm.

From the above data, it can be stated that the deformation of the rock mass occurring on the ground surface and around the twin inclined shafts is negligible, and after the installation of the permanent support, deformation of the rock mass will not continue to develop, constructions on the surface more than 25 m from the twin inclined shafts entrance will not be affected after the rock mass deformation stability.

4. Conclusions

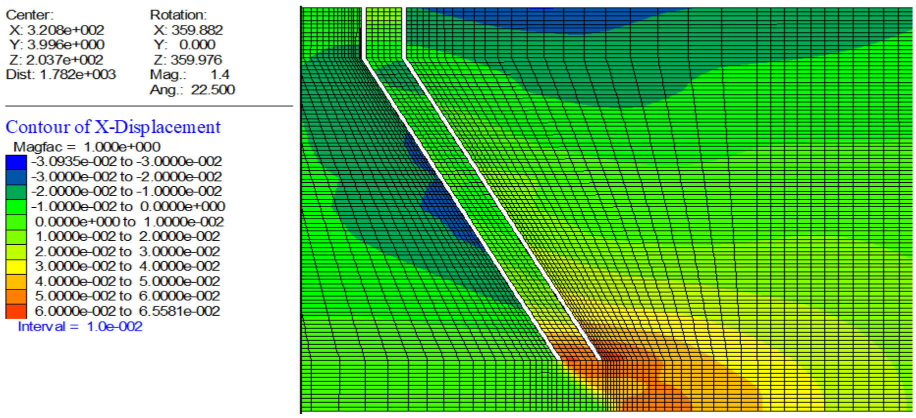

Figure 9. Horizontal deformation after excavated the twin inclined shafts.

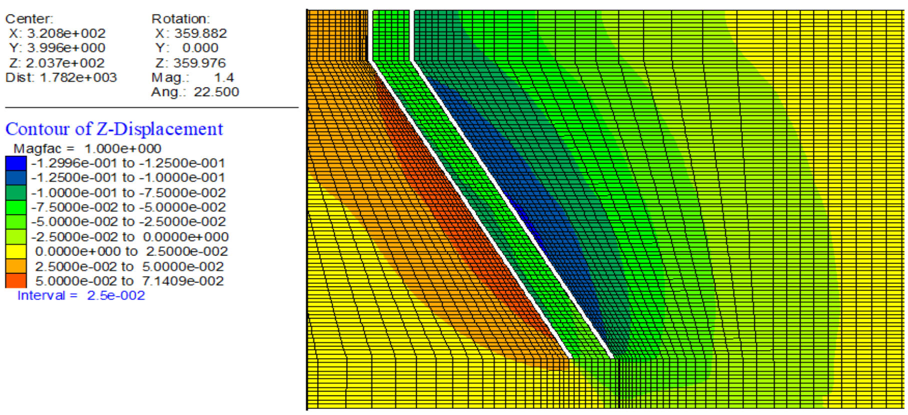

Figure 10. Vertical deformation after excavated the twin inclined shafts.

From the simulation results, it can draw:

After excavation and unsupported of the twin inclined shafts unsupported from +30÷-300 levels, the maximum value of vertical deformation is about 5 cm, horizontally deformation is about 3 cm, deformation effect range of rock mass on the surface within the radius of 25 m from twin inclined shafts entrance. But only occurs during excavation, and after twin inclined shafts are permanent support, the rock mass will not be deformed and so the construction on the surface will not be affected by the excavation of the twin inclined shafts.

Outside the range of 25 m from the twin inclined shafts entrance, the rock mass on the ground surface is not affected by the excavation of the twin inclined shafts from +30÷-300 levels. Recommendations for the Ha Lam coal mine process need to install more deformation monitoring stations to monitor the deformation process of the surface of +30 level when excavation of the twin inclined shafts.

Contribution of authors

The article is carried out completely by the author.

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