An optimal surveying procedure for roadway from two endpoints: A case study of Ha Long underground coal mine

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An optimal surveying procedure for roadway from two endpoints: A case study of Ha Long underground coal mine

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Abstract - Roadways are usually driven simultaneously from two opposite entrances. The construction of an inclined transportation roadway of Ha Long underground coal mine from two endpoints in special geological conditions, such as weak strata and coal seams requires an optimal surveying procedure. The procedure normally includes the design of the survey control for the alignment of the roadway axis and provision of orientation and level with the highest possible accuracy so that the opposing headings meet at the breakthrough points without any need for an adjustment of the excavation. This paper presents a surveying approach in which establishing the ground control network using GNSS technology, transmitting orientation using a shaft-based and gyroscopic method, establishing an underground control network, and providing direction by using laser equipment were performed. The successful completion of the bored transportation roadway proved the high accuracy of the proposed surveying approach.

Keywords - Roadway, mine surveying, breakthrough error, open-ended traverse.

1. INTRODUCTION

The excavation of roadways from two portals is one of the crucially important tasks in the field of roadway construction in general and underground mining in particular. This approach of excavation saves the time of the construction project and improves its economic efficiency. Therefore, it is the common approach of roadway excavation. In addition, this approach often requires accurate surveying. This is because of the possibility of an error in the roadway alignment which is one of the most important dangers in this type of project [1, 2]. Survey errors usually lead to important delays and additional costs [3]. Therefore, an optimal surveying approach for roadway alignment is necessary to ensure the success of roadway excavation.

According to the production plan of Vietnam National Coal – Mineral Industries Holding Corporation Limited, the 2021 coal production of Ha Long underground coal mine in the Khe Cham area is 1,000,000 tons/year [4]. In order to meet this goal, it was necessary to expand the excavation site in the Khe Cham IV area. Seams 9, and 10 of zone IV of the Khe Cham area are necessary to be excavated [5]. However, this production goal can only be achieved when the ventilation and transportation systems are built and upgraded. In addition, the construction of an inclined roadway from two endpoints for the transportation between elevations of -350 m and -250 m was carried out for the purpose of connecting Khe Cham I with Khe Cham IV [5]. This work was considered as a necessary condition to perform important tasks, such as ventilation, transporting materials during excavation and mining at Khe Cham IV, especially in the final construction phase of the main and the auxiliary mineshafts, which will take place in 2022. This was a complicated boring-from-both-endpoint excavation plan, which should be accurately undertaken in both the horizontal and vertical dimensions in complex geological conditions, such as rock hardness parameters ranging from 4 to 6, and boring through coal seams [6]. Therefore, it was necessary to make a comprehensive analysis and selection of an optimal surveying solution to ensure accurate alignment of the roadways in terms of a plane (X, Y), elevation (H), and slope (i).

In this paper, we proposed an optimal surveying approach for the construction of the transport roadway from levels -350 m to - 250 m which was to connect Khe Cham I with Khe Cham IV.

2. METHODS

2.1. Construction of the transport roadway

The plan to dig a transport roadway from an elevation of -350 m to -250 m to connect Khe Cham I with Khe Cham IV was described as follows:

From roadway XV which was previously built at the elevation of -250 m, a transport roadway was built to connect the main transport roadway at the elevation of -350 m for the ventilation and transportation of Khe Cham IV and Khe Cham I. The purpose of this work was to expand the excavation area and shorten the construction time to the -350 m level of the Khe Cham II-IV project. The roadway with conveyor lines between elevations of -250 m and -350 m was the first work to connect Khe Cham II-IV with Khe Cham I, aiming at the connection of ventilation and transportation systems of the entire Khe Cham II-IV area during the excavation of the roadway for the basic construction of the Khe Cham II-IV project, which was carried out by Ha Long Coal Company. After the completion of the construction of the -350/-250 roadway, a B1000 conveyor system, the P24 rail winch system with the track size of 900 will be installed for the transportation of coal and equipment, and workers from the elevation of -350 m to -250 m, in order to meet the designing transport capacity of the project (Fig. 1).

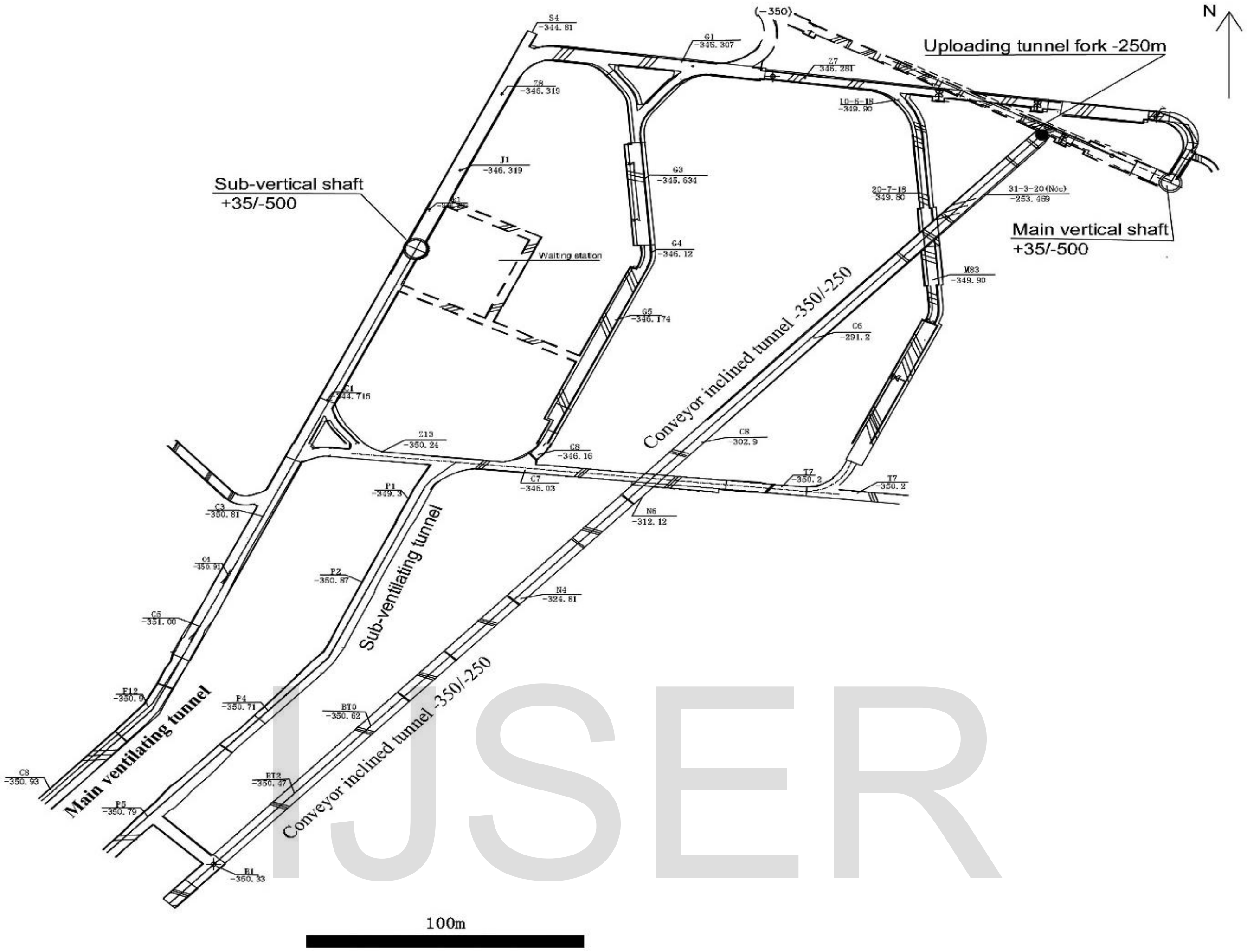

Fig. 1. Plan of Khe Cham roadways and the designed roadway [5]

2.2. surveying approach for the construction of the transport roadway from two endpoints

The construction of the transport roadway from two endpoints was a special type of work that requires geodetic techniques, including both fieldwork and processing to be carried out with high precision. In this study, an optimal surveying workflow was proposed (Fig. 2).

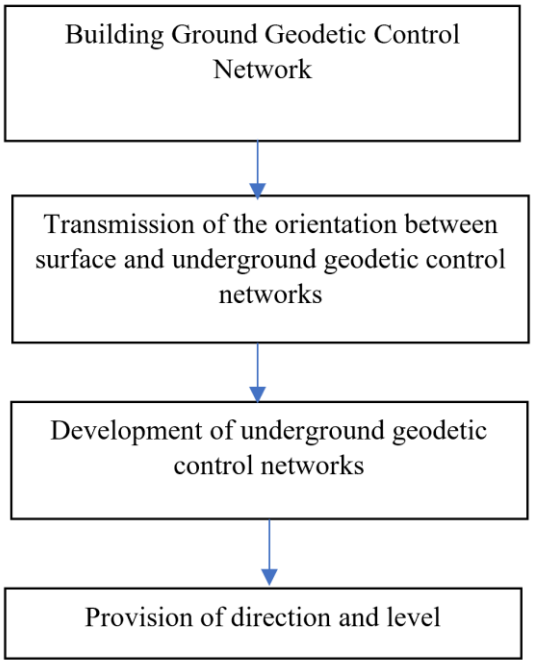

Fig. 2. The proposed surveying workflow

2.2.1 Building Surface Geodetic Control Network

On the ground, near the mine shaft, a surface geodetic control network was established using GNSS technology. The GNSS network includes nine control points with a well-distributed configuration (Fig. 3), and their location was favourable for the orientation survey [7].

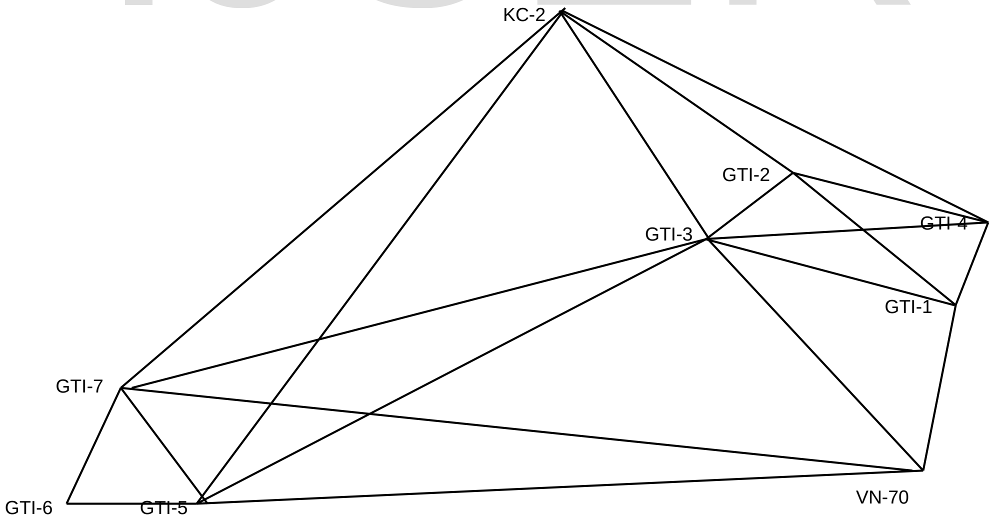

Fig. 3. The ground geodetic control network [7]

2.2.2. Transmission of the orientation between surface and underground geodetic control networks

Excavating works are guided by a geodetic control network, so the quality of this network was important to ensure the correct alignment of the roadways over time. The network contains a series of control points in a configuration of an open traverse which was with only one end orientation. The guidance was the provision of direction and level for the excavation of the roadway. As the roadway was dug from both two endpoints at the same time and each working site was accessible only from one side of development works, it was required to establish two open traverses [8].

The traverse was originating from a base with known coordinates which was the result of the transmission of the cartographic system and orientation from the surface to the underground with high accuracy. In this study, on the Khe Cham IV site, there was a mineshaft, so the orientation transmission was the shaft plumbing and gyroscopic methods (Fig. 4). The horizontal orientation was conducted using a plumb that was connected to a wire, in the conventional system, running from the top of the shaft to the bottom. The depth of the shaft was 550 m, and the effect of natural airflow was quantified by using a Leica Flexline TS09 and minimized using special equipment called a holding disk (Fig. 5a).

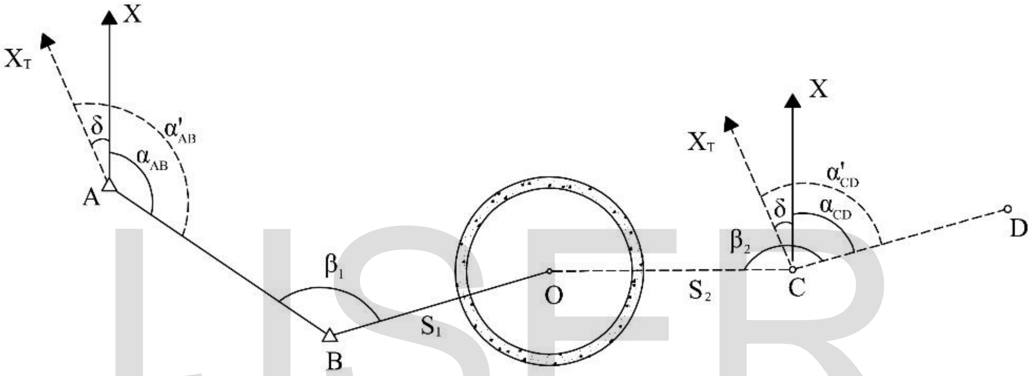

Fig. 4. The mine shaft orientation

A GTA1800R gyroscope produced by China is used for measuring the first base side of the open underground traverse. Its accuracy of measuring bearing is less than 10" (Fig. 5b). In addition a Leica FlexLine TS09 total station used for measuring angles and distances of the traverse has an angle measurement accuracy of 1" and the distance measurement accuracies of 1.5 mm + 2 ppm for the prism mode and 2 mm + 2 ppm for the reflectorless mode (Fig. 5c).

(a) (b) (c)

Fig. 5. (a) A holding disk mounted on the steel frame, (b) Gyroscope, and (c) Leica FlexLine TS09

The bearing of the base side of the traverse was determined using the gyroscope, and was calculated by the following formulas:

$$\propto = \alpha_g + \delta \quad (1)$$

where α_g- the azimuth determined by the gyroscope,

δ – the difference between the gyroscopic North direction and the coordinate North direction.

In order to determine δ, on the ground, measuring the bearing of one known coordinate baseline, AB as an example, then the following formula was used:

$$\delta = \propto_{AB} - \propto_g \quad (2)$$

where: $\propto_{AB} = arctg \frac{\Delta X_{AB}}{\Delta Y_{AB}}$ (3)

2.2.3. Development of underground geodetic control networks

Based on the construction design of the transport roadway, open traverses are designed, including one originating from the shaft and one originating from the main transport roadway (Fig. 6). For the shaft originating traverse, the first base side's coordinates are determined by the above shaft orientation transmission. For another traverse, in the main transport roadway, the first base side is one of the sides of the underground control network which is already established.

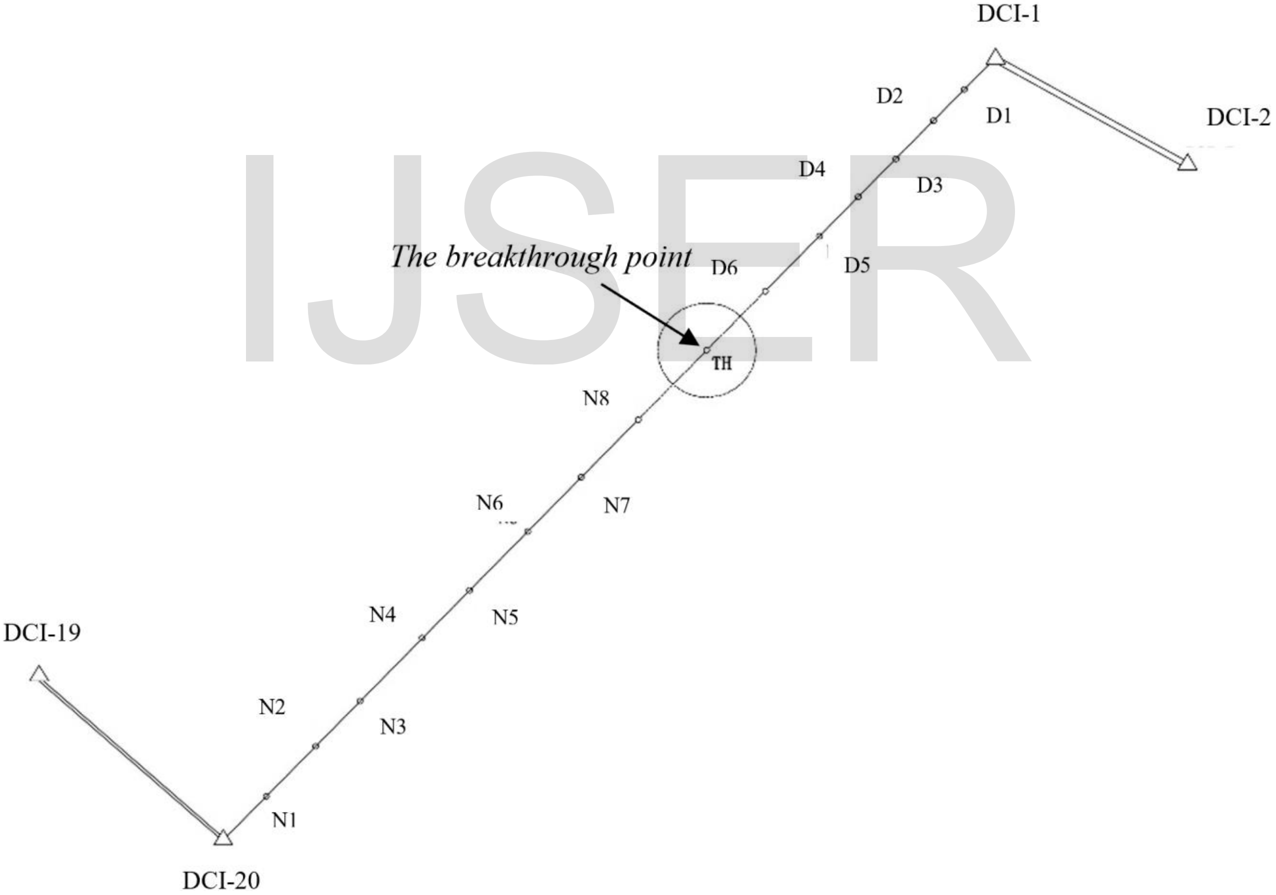

Fig. 6. The designed open traverses

In order to estimate the accuracy of the breakthrough point and confirm the designing traverses, the standard deviations of northing and easting coordinates of the breakthrough point are calculated using the following formulas [9]:

$$\sigma_N^2 = \sigma_{Nq}^2 = \sigma_{No}^2 + R_0^2 \, sin^2\gamma_0 \frac{\sigma_{Ao}^2}{\rho^2} + \sum_{i=0}^{n} (R_i sin\gamma_i)^2 \frac{\sigma_{\beta_i}^2}{\rho^2} + \sum_{i=0}^{n} cos^2 A_i \sigma_{l_i}^2 \quad (4)$$

$$\sigma_E^2 = \sigma_s^2 = \sigma_{No}^2 + R_0^2 \, cos^2\gamma_0 \frac{\sigma_{Ao}^2}{\rho^2} + \sum_{i=0}^{n} (R_i cos\gamma_i)^2 \frac{\sigma_{\beta_i}^2}{\rho^2} + \sum_{i=0}^{n} sin^2 A_i \sigma_{l_i}^2 \tag{5}$$

It can be observed from Equations 3 and 4 that, Risinγi is a projection of a link between the breakthrough point and each point of each transverse on the northing axis, while Ricosγi is a similar projection, but on the easting axis (Fig. 7).

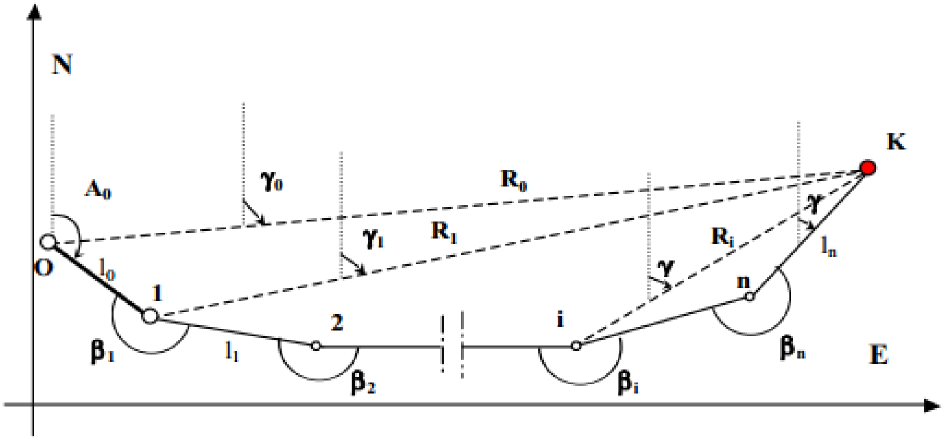

Fig 7. Graphical interpretation of R factors [9]

However, in this study, the designed roadway is typically straight, so its open traverses are also straight (Fig. 7). In addition, all sides' orientation and distance are equal, so the lateral location error of the breakthrough point is computed as follows [9]:

$$q = \frac{L}{\rho}\sqrt{\sigma_{A_o}^2 + \sigma_\beta^2 \frac{2n^2 + 3n + 1}{6n}} \tag{6}$$

where: q = lateral error, L = length of a traverse (from an orientation point), ΣAo = standard deviation of the orientation azimuth, σβ = standard deviation of measured angles, ϙ = rho (206265''), n = number of traverse legs (number of measured angles).

The longitudinal location error (s) of the breakthrough point may be expressed by the equation:

$$s = \sigma_l \sqrt{n} \tag{7}$$

where:

S = longitudinal error,

σl = standard (distance) deviation of each traverse leg,

n = number of traverse legs.

The location error of the breakthrough point can be calculated by the equation:

$$M_{TH} = \sqrt{q^2 + s^2} \tag{8}$$

The location error of the breakthrough point can be estimated from two open traverses. From the shaft originating transverse and the main inclined transport roadway originating transverse, we have MTH1, and MTH2, respectively. The value of MTH of both traverses should meet the Vietnam Standards for mine surveying [8, 10]. As MTH is estimated before the construction of the roadway, inputs of the above formulas, such as (L) and (n) are acquired from the designed traverses, while standard deviations of bearing, each traverse leg, and measured angles are from the shaft orientation work or the underground control network of the mine and specifications of the used total station (Leica TS09) [8].

2.2.4. Provision of direction

The direction of the roadway's main axis in the horizontal plane was determined by the angle ß formed by the side of the traverse and the main axis of the roadway. The direction of the roadway's axis was provided by the program "Setting out" according to the designed azimuth. After the direction of the roadway's axis was set, it was fixed with a YBJ-1200 laser device (Fig. 8) according to the plan. Next, the laser projector was mounted on a dedicated stand, so that the laser device can move on the rack in a direction perpendicular to the main axis of the roadway (Fig. 9).

Fig. 8. YBJ-1200 laser equipment

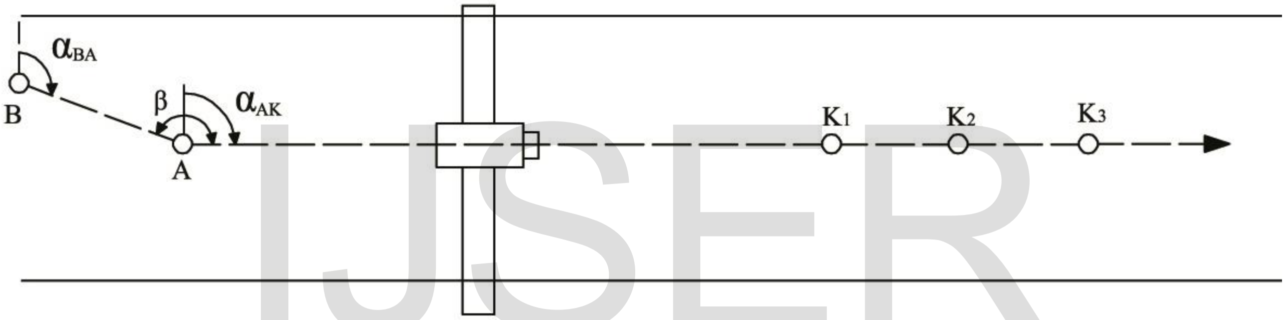

Fig. 9. Providing the direction using YBJ-1200

3. RESULTS

Table 1 shows the results of shaft orientation in which the bearing of the first side of the open traverse was measured using a GTA1800R gyroscope. The residual of the **bearing** was 15‘45“. This result meets the accuracy requirement of Vietnam Standards for mine surveying.

Table 1. Results of measuring the bearing of the first baseline

	Bearing of the ground baseline	Bearing of the first underground baseline
Side	GT4 — IV-2	DCI-19 — DCI-20
Bearing calculated from coordinates	152°14′28″	359°18′32″
Bearing measured by a GTA1800R Gyroscope	152°30′13″	359°34′17″
Bearing residual ($\Delta\alpha$)	0o15’45”	0o15’45”

Each traverse station is linked by means of survey observations as they advance along the roadway. With a length of 1,0 km, the traverse contains two branches with 15 stations. In order to be used for a long time, these marks are placed on the ceiling of the roadway, while some were placed on the floor of the roadway are built with concrete. The network was adjusted and its results met the following standard requirements:

- The standard deviation of distance measurement: $\frac{fs}{S} < \frac{1}{10000}$;
- The standard deviation of angle measurement: $M_\beta < 15"$;

During the development of the underground works at each phase of construction, surveyors do their works, including measuring and checking the survey, comparing the measurement error with the estimated error, regularly updating the status of the working site, and promptly aligning the direction using its design. With the above reasonable geodetic procedure, the construction of the transport roadway from the level -350 to -225 m has been successful with high accuracy as being confirmed by the standard deviation of orientation: $Mp = \pm 0.150\ m$.

4. CONCLUSION

Surveying plays an important role in special roadwaying works like the excavation of roadways from two endpoints. The boring of a roadway from two portals connecting Khe Cham II with the Khe Cham IV area was a complex work. A reasonable surveying solution in which establishing ground control network using GNSS technology, transmitting orientation and level using shaft combined gyroscopic methods, establishing underground control network, and providing direction by using laser equipment are the key factors for the completion of the transportation roadway construction with high accuracy.

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