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Effect of Step by Step Approach of Underground Mining Working Face on Subgrade Deformation of Existing Railway

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Abstract: Due to the railway construction being ahead and the mining work being behind, it is inevitable for some mining areas to pass under the railway. For the 2311 mining working face across under section from DK3 773 to DK4 773 in Tunliu Special Railway, based on Beidou positioning system, a real-time online monitoring and analysis system was established to monitor the non-uniform deformation of the existing railway above coal seam during the mining process of the 2311 working face. According to the monitoring results, the distribution law of uneven settlement deformation of the existing railway roadbed was analyzed when the mining face approached and passed through under the railway roadbed. The analysis results show that as the distance both the track channeling and the belt fluting from the existing railway gradually decreased, the settlement change rate of the existing railway roadbed above the goaf showed an initial increase, then a decrease, and finally tended to a stable value. The influence range of the track channeling alignment distance on the existing railway subgrade was greater than that of the belt fluting alignment distance on the existing railway subgrade. The vertical displacement of the goaf conformed to a higher order polynomial relationship with time, and this mathematical equation could accurately predict the uneven deformation of the existing railway roadbed above the goaf for a period of time in the future.

1. Introduction

With the continuous mining, due to the railway construction in the front, mining work behind, some mining areas inevitably pass under the railway. Therefore, when the mining face is located below the railway, it is of great significance to analyze and evaluate the deformation and stability of the existing railway roadbed [1,2].

Many engineers have studied the influence of the mining area on the adjacent engineering buildings, and obtained some useful research results. By taking the deep goaf of a coal mine adjacent to a high-speed railway as an example, the engineering geological conditions and boundary conditions of the deep goaf were studied, then the stability of the site was comprehensively analyzed and evaluated based on the surface deformation monitoring [3]. A spatial numerical model of goaf and railway was established, and the influence laws of open pit mining and underground mining on railway engineering was analyzed [4]. The influence range of the goaf in iron ore based on the hypothesis, calculation formula and parameter selection of the analytical method was evaluated [5]. The goaf risk and future deformation prediction were evaluated based on the current situation of the goaf in Nanqin Railway Coal Mine [6]. The load transfer, deformation mechanism and characteristics of pile-plate structure in the goaf roadbed of Hefei-Fuzhou high-speed railway were studied based on Wufushan Station reinforcement and field monitoring [7]. The deformation law and the load transfer law of high-speed railway bridge foundation above the goaf were studied, and the reinforcement effect of pile group measures in the goaf was discussed [8]. By taking the goaf of the coal mine traversed by the expressway as the research object, and the deformation monitoring technology of the goaf under the expressway and its application were discussed. The layout, data acquisition and data processing of goaf deformation monitoring equipment in railway construction were discussed based on the deformation monitoring of a goaf along the Taichina-Yinyin Railway [9]. The status quo and ground pressure activities of the goaf in a mining area were analyzed, and a monitoring scheme was proposed based on multi-channel acoustic emission continuous monitoring, and a ground pressure monitoring scheme supplemented by single-channel intelligent acoustic emission monitoring could meet the requirements of safety monitoring [10]. Aiming at the treatment project of large goaf of railway roadbed, the on-site monitoring of the roadbed deformation of the goaf after treatment was conducted, and according to the monitoring data the deformation trend of the roadbed was evaluated [11]. By taking the Shanghai-Nanjing intercity passenger special railway as the research object, and an effective prediction of subgrade settlement was made based on the measured data [12].

It is worth noting that for the Goaf, because of the Goaf overlying strata repair, the evaluation of the influence of the deformation of the goaf on the deformation of the existing railway roadbed is still lack of research. Therefore, after the Goaf strata were repaired, through the real-time wireless monitoring system of subgrade deformation of Tunliu Special Railway from DK3 773 to DK4 773, this paper will analyze the subgrade deformation law of the existing railway above goaf based on the monitoring of subgrade settlement in section from DK3 773 to DK4 773, and further evaluate the future stability trend of the existing railway subgrade on goaf, and provide technical basis for making scientific and reasonable early warning measures and railway maintenance to ensure the safety of railway operation.

2. Wireless Monitoring Layout

The 2311 mining working face was located in the south of the Chang village, the main mining seam was No. 3 coal, belonging to the 23th mining area, the width of the mining working face was 300m, the advancing length was about 1350m, as of August 2020, the remaining advancing length from the existing stop-mining line was less than 550 m. The coal seam thickness of the mining working face was 5.8 - 6.05 m, the average thickness was 5.92 m, the coal cutting height of the mining working face was 3.4m, the coal drawing height was 2.52m, the ratio of mining and drawing was 1:0.74, and the recoverable reserves were about 3.43 million tons.

Before coal seam mining, according to the underground space formed by coal to be mined, according to the theory and principle of surface subsidence control, and based on the grouting and filling technology in the mining overlying rock separation area, the slurry made of fly ash will be filled in the mining overlying rock separation area through ground drilling, and a grouting and compaction bearing area of a certain width will be formed in the middle of the goaf. By intervening the activity state of the overlying layer in advance, the stability of the main key layer or the target key layer will be kept, in control of the caving process by forming the bearing area of the overlying rock structure and filling compaction. Finally, the key layer structure of overlying rock, the compacted bearing layer of filling area and the composite supporting bearing structure of isolated coal pillar were formed, and then the surface settlement was controlled and the surface collapse of mining gob was effectively controlled.

According to the subsidence characteristics of the 2311 mining working face in mining area, the railway monitoring area was divided into mined-out area, transition area and relatively stable area.

The railway monitoring range of the goaf was form DK4 125 to DK4 425, the total length was 300m, the longitudinal spacing of the monitoring section was 30 m, and two subgrade GNSS monitoring stations were set up in each monitoring section. The railway monitoring range in the first transition zone was from DK3 815 to DK4 125, with a length of 310 m; the railway monitoring range in the second transition zone was from DK4 425 to DK4 735, with a length of 310m. The monitoring section spacing in the transition zone was appropriately enlarged to 100m, and two subgrade GNSS monitoring stations were still set for each monitoring section.

A real-time wireless monitoring and analysis system for railway roadbed deformation was established based on GNSS deformation monitoring equipment located by Beidou positioning Satellite, and the real-time deformation data of existing railway roadbed above goaf will be collected.

The layout of GNSS monitoring equipment and actual influence area were designed, when the distance between the coal seam mining face and the existing railway was 50 m, all GNSS monitoring stations had been installed, and the layout of measuring points was shown in Figure 1.

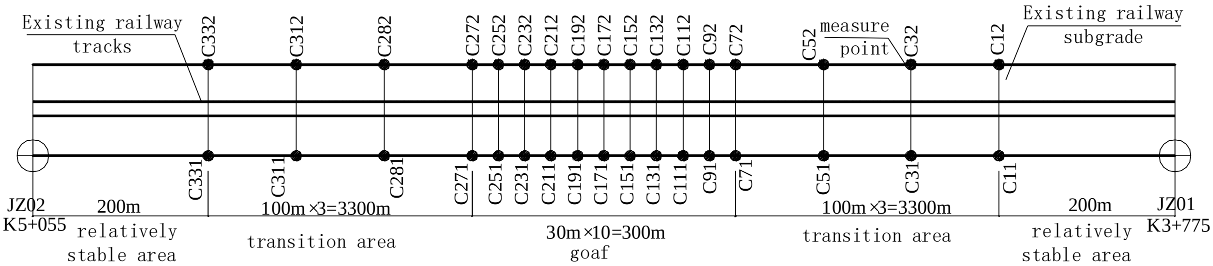

Figure 1: Layout diagram of monitoring points

The basis for the deployment of measurement points: the ground subsidence and deformation observation points should be arranged in the area affected by the project; Deformation observation points should be placed on both sides of the ground with cracks or fault zones; The surface displacement observation station should be arranged at the deformation characteristic position. The surface throwing line can be arranged in the funnel area where the ground settlement is obvious.

3. Data Analysis

Based on the established real-time online monitoring and analysis system for railway subgrade deformation, the existing railway above the coal seam was monitored in real time during the mining process of the 2311 mining working face, and the real-time deformation data of the existing railway subgrade above the coal seam was collected.

According to the data collected by GNSS monitoring points C011, C031, C111, C151, C191, C231, C311 and C331 above the goaf, transition area and relatively stable area, the vertical displacement of existing railway roadbed above the coal seam in the mining process of the 2311 mining working face was analyzed. Among them, GNSS monitoring points in the relatively stable area were C011 and C331, in the transition area were C031 and C311, and GNSS monitoring points were C111, C151, C191 and C231 in the goaf. The monitoring results of each measuring point were shown in Figure 2.

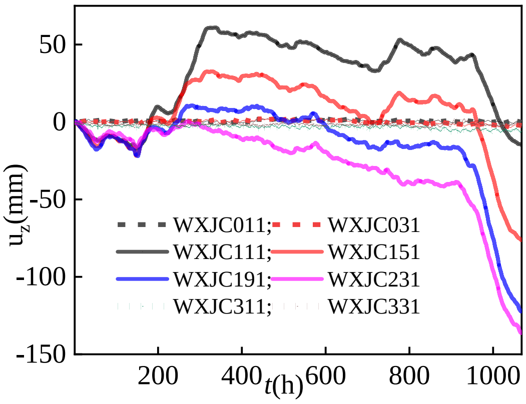

Figure 2: Vertical Displacement of Measurement Points

As can be seen from Figure 2, the vertical displacement change rate of measuring points C011, C031, C311 and C331 on the existing railway roadbed above the transition area and the relatively stable area during the mining process of the 2311 working face was 0, while the change rate of measuring points C111, C151, C191 and C231 above the goaf was non-linear. During the mining process of the 2311 mining working face, the deformation of the existing railway roadbed above the goaf first bulged upward and then unevenly subsided, which was caused by the grouting pressure slightly greater than the rock gravity during the grouting filling and compaction process in the goaf formed by coal mining before the mining process.

In the mining process of the 2311 mining working face, the analysis and fitting results of each measuring point above the goaf were shown in Figure 3- Figure 6. The non-uniform settlement deformation of existing railway roadbed above the goaf can be predicted by the mathematical fitted equation.

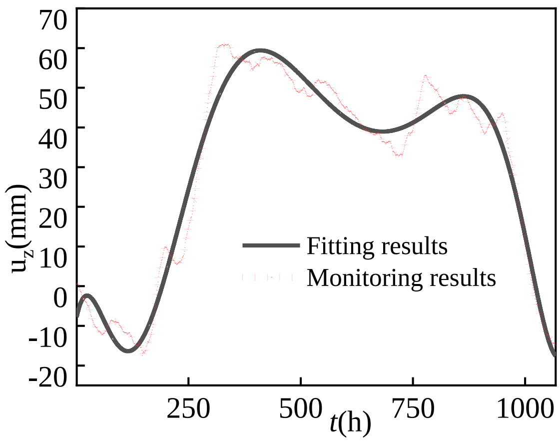

Figure 3: Displacement and Fitting Results in C111 Measurement Point

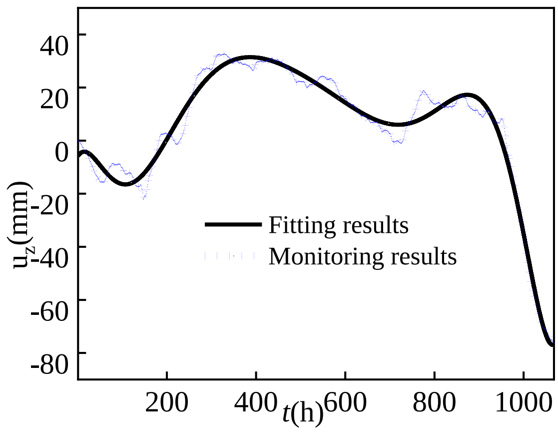

Figure 4: Displacement and Fitting Results in C151 Measurement Point

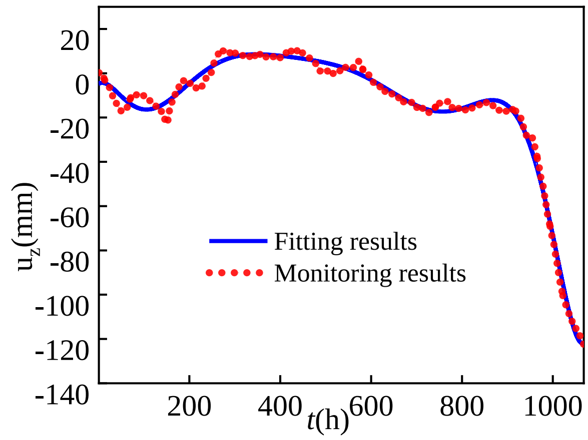

Figure 5: Displacement and Fitting Results in C191 Measurement Point

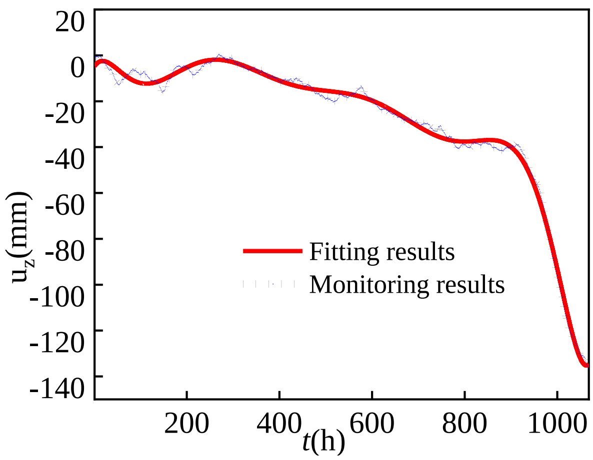

Figure 6: Displacement and Fitting Results in C231 Measurement Point

By analyzing the monitoring data of the settlement and displacement of C111,C151,C191 and C231 above the goaf, the trend of the monitoring curve of the settlement and displacement was in accordance with the high order polynomial:

$$u_z = k_9 t^9 + k_8 t^8 + k_7 t^7 + k_6 t^6 + k_5 t^5 + k_4 t^4 + k_3 t^3 + k_2 t^2 + kt + b \quad (1)$$

Where t was time (hour) and b、k_i were fitting constants. The fitting parameters of measuring points C111, C151, C191 and C231 were detailed in Table 1.

Table 1: Fitting Parameter Parameters

name	C111	C151	C191	C231
b	-8.26602	-5.98305	-4.79114	-4.89636
k_1	0.56391	0.26976	0.12424	0.30356
k_2	-0.0166	-0.01167	-0.00881	-0.01141
k_3	1.54E-04	1.26E-04	1.06E-04	1.26E-04
k_4	-6.52E-07	-6.06E-07	-5.58E-07	-6.56E-07
k_5	1.53E-09	1.60E-09	1.59E-09	1.87E-09
k_6	-2.15E-12	-2.52E-12	-2.66E-12	-3.10E-12
k_7	1.81E-15	2.35E-15	2.59E-15	3.00E-15
k_8	-8.42E-19	-1.20E-18	-1.36E-18	-1.56E-18
k_9	1.67E-22	2.56E-22	2.96E-22	3.36E-22
R^2	0.96636	0.97219	0.98814	0.99362

The analysis of the roadbed deformation with the alignment distance between the mining face and the existing railway were shown in Figure 7 and Figure 8. Among them, Figure 7 showed the deformation relationship between the track channeling alignment distance and the existing railway roadbed, and Figure 8 showed the deformation relationship between the belt fluting alignment distance and the existing railway roadbed.

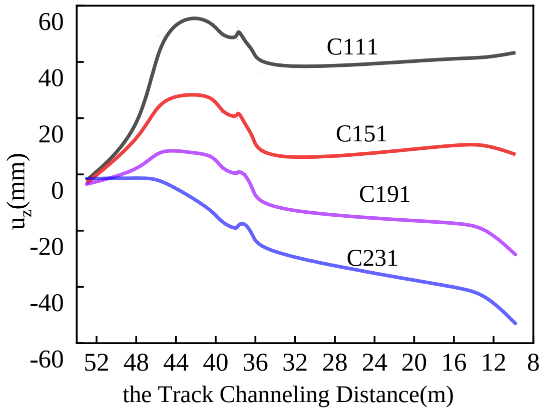

Figure 7: Relationship between the Track Channeling Distance and the Deformation of Existing Railway Roadbed

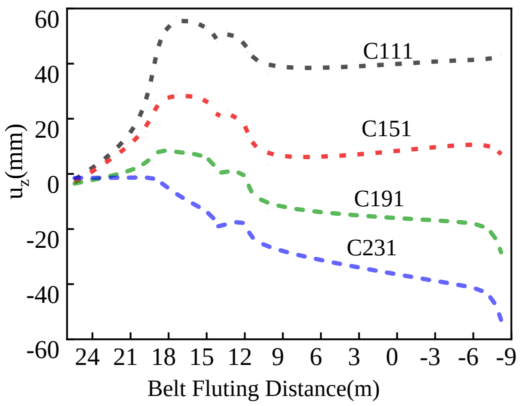

Figure 8: Relationship between Belt Fluting Distance and Deformation of Existing Railway Roadbed

As can be seen from Figure 7, in the process of the mining, when the track channeling alignment distance was greater than 45 m, the settlement change rate of the existing railway roadbed gradually increased. When the the track channeling alignment distance was 35m ~ 45m, the settlement change rate of existing railway subgrade gradually decreased. When the track channeling alignment distance was 12m ~ 35m, the settlement change rate of the existing railway subgrade gradually tended to be stable.

As can be seen from Figure 8, in the process of mining, the settlement change rate of the existing railway roadbed gradually increased when the belt fluting alignment distance was greater than 16m. When the belt fluting alignment distance was from 10m to 16m, the settlement change rate of existing railway roadbed decreased gradually. When the belt fluting alignment distance was from 8m to 10m, the settlement change rate of existing railway subgrade gradually tended to a certain stable value.

According to the comparative analysis results in Figure 7 and Figure 8, it can also be found that the influence range of track channeling alignment distance on existing railway roadbed was larger than that of belt fluting alignment distance on existing railway roadbed.

This is because in the mining process of the 2311 mining working face, the belt fluting was in the front, the track channeling was in the back, the mining working face was pushed diagonally, the width of the goaf formed by the belt fluting was small, and the width of the goaf formed by the track channeling was increased after the mining was finished. Therefore, the influence range of track channeling alignment distance on existing railway roadbed above coal seam was larger than that of belt fluting alignment distance on existing railway roadbed above coal seam.

4. Conclusion

After the Goaf strata were repaired, through the real-time wireless monitoring system of subgrade deformation of Tunliu Special Railway from DK3 773 to DK4 773, this paper analyzed the subgrade deformation law of the existing railway above goaf based on the monitoring of subgrade settlement in section from DK3 773 to DK4 773, the influence of the distance between the mining face and the existing railway on the uneven deformation of railway subgrade was compared, and further evaluated the future stability trend of the existing railway subgrade on goaf. The analysis led to the following main conclusions:

(1) As the distance both the track channeling and the belt fluting from the existing railway gradually decreased, the settlement change rate of the existing railway roadbed above the goaf showed an initial increase, then a decrease, and finally tended to a stable value.

(2) The vertical displacement of the goaf conformed to a higher order polynomial relationship with time, and this mathematical equation could accurately predict the uneven deformation of the existing railway roadbed above the goaf for a period of time in the future.

(3) The influence range of the track channeling alignment distance on the existing railway subgrade was greater than that of the belt fluting alignment distance on the existing railway subgrade.

The research achievement will provide technical basis for making scientific and reasonable early warning measures and railway maintenance to ensure the safety of railway operation.

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