Solution to the Horizontal Crossing Problem of Transportation System at Key Points in Open-Pit Mines

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Abstract In order to reduce the horizontal crossing transportation problems between coal trucks and stripping trucks, large and small vehicles, and transport trucks and belt conveyors at key points of open pit mine in production, the separate transportation mode of underpass bridge and overpass steel trestle is proposed to optimize the open pit development transportation system, so as to solve the practical problems that the horizontal cross of transport vehicles causes vehicle blockage, affects production schedule and production safety. The results show that the horizontal crossing road can be changed into a separate type of overpass steel trestle, which can realize the classified transportation of large and small vehicles, reduce the traffic density, make vehicles with different functions go their own way, eliminate the hidden danger of traffic accidents, and improve the production efficiency.

Key words Open-pit mines, Cross-transport, Underpass bridge, Overpass steel trestle, Production efficiency

1 Introduction

Optimization of transportation system in open-pit mines is one of the key problems in open-pit mines[1-2]. In recent years, many open-pit coal mines have enlarged capacity for mining. The mining technology is mainly dominated by single-bucket—truck discontinuous mining technology, single-bucket—truck + semi-mobile crushing station—belt conveyor semi-continuous mining technology and wheel-bucket continuous mining technology. Most open-pit mines adopt an outsourcing and self-operated model for production operations. The outsourcing model is mainly based on socialized small equipment, and the self-operated model is mainly based on self-owned large-scale equipment. The main problem caused by this is that there are many key points of horizontal cross-transportation in the development and transportation system, which affects the production efficiency of open-pit mines and increases safety risks. By referring to the concept of separate transportation of underpass bridge and overpass in public transportation, the transportation system of raw coal transportation system of open pit mine, excavation field, inner dump and outer dump in different periods, different regions and different geological structures is optimized[3-4].

2 Project overview

2.1 Open-pit mine development and transportation system

Taking Xiwan open-pit coal mine as an example, the stripping project of this mine adopts a single bucket-truck discontinuous mining process. The coal mining project adopts a single-bucket—truck + semi-mobile crushing station—belt conveyor semi-continuous mining technology, and the coal crushing station is located at level 1 165 ground of Lagou area in the first mining area. The stripping project adopts the self-operated and outsourced production mode for operation. The coal mining project is fully self-operated, and the self-operated engineering equipment is large-scale equipment. The outsourcing projects focus mainly on topsoil, and adopt outsourced small-scale equipment[5].

The coal transportation system is planned to be loaded by a single-bucket excavator at the working face, unloaded to a 220 t coal transportation truck, transported to the 1 160 flat plate of the non-working pit edge through the non-working pit edge transportation road, reaching the ground coal crushing station through the end slope coal transportation road; the rock is loaded and unloaded on the 220 t stripping truck by a single-bucket excavator at the working face, transported to the working pit edge 1 160 flat plate through the moving pit line of working pit edge, and 1 151 to 1 160 east end slope, reaching the outer dump through the ground rock stripping road for discarding; the topsoil stripping and transportation system is that the topsoil is loaded and unloaded by a small hydraulic excavator on the working face to a stripping truck of no less than 40 t, and reaches the outer dump for discarding through the upper working pit edge moving pit line and the 1 160 to 1 175 west end slope (or the west transportation road); part of it is transported to the 1 160 flat plate of the non-working pit edge through the moving pit line of working pit edge, and the 1 151 to 1 160 east end slope, and reaches the outer dump for discarding through the ground earth stripping road. The horizontal crossing point of the current development and transportation system is shown in Fig. 1.

2.2 Traffic light control system for open-pit mine

At present, open-pit mine has outsourced small transport equipment and large self-operated transport equipment for coal and rock, and

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there is a horizontal crossing on the 1 160 flat plate of non-working pit edge on the east side of the mining site. The principle of vehicle passage is "large trucks pass first, small trucks dodge". That is to say, when coal and rock trucks meet with earthmoving trucks, the normal passage of coal and rock trucks should be ensured, and the earthmoving trucks should take the initiative to dodge, and resume driving after the coal and rock trucks pass. Transportation is directed through the " traffic light control system".

Although the cost of installing traffic light safety devices in the transportation system is relatively low, there are many problems to a certain extent:

(i) It affects the transportation and discarding efficiency of small trucks (large trucks pass first, small trucks dodge); (ii) It must be operated manually, and misjudgment may occur; (iii) Small trucks stop and wait on the ramp, which is prone to difficulties in starting; (iv) There are driving blind spots for large equipment, large and small equipment is mixed, and the difference between outsourcing and self-operation management teams increases safety risks[6].

3 Optimization scheme of development and transportation system

According to the current conditions, it is necessary to optimize the key points of horizontal crossing road at the pit mouth of the mining field. According to the topography and geological conditions of the open-pit mine, we should consider the size and load of the vehicle, and two ways are proposed to optimize the development and transportation system: building an underpass bridge and building an interchange trestle bridge. Underpass bridge and overpass adopt steel trestle structure, that is, the superstructure is formed by assembling Bailey beams, and the substructure is composed of steel pipe piles.

3.1 Underpass bridge project: "small trucks pass underneath, large trucks pass above" In order to reduce the project investment in underpass bridge, it is necessary to shorten the construction period and reduce the time of impact on production. The underpass bridge project determines that small trucks pass underneath and large trucks move on the ground. The road for coal and rock trucks and the road for earthmoving trucks realize three-dimensional intersection. The large trucks pass on the top along the 1 160 m flat plate, while the small trucks pass under the underpass bridge, realizing the large and small trucks passing without horizontal crossing, avoiding the phenomenon of small trucks queuing and congestion, improving the transportation efficiency of small trucks, and reducing the transportation cost of small trucks. The clearance height of the underpass bridge is determined to be 5.5 m according to the outsourced vehicles. Along the driving route of small trucks, the existing 1 160 m meeting platform is excavated to 1 153.5 m to set up an underpass bridge, that is, the designed elevation of the bottom board of the underpass bridge is 1 153.5 m. The total area of the underpass bridge is 400 m^2. The excavation for the underpass bridge generates an earthwork volume of about 367 000 m^3, and the road reconstruction (rerouting) generates an earthwork volume of 31 500 m^3. The shortest construction period is 90 d. The layout of the underpass bridge at the intersection of the transportation roads from the excavation site to the dump site is shown in Fig. 2.

The underpass bridge project has increased the investment in bridge construction and road reconstruction (rerouting). During the construction period of the bridge body, except that the topsoil can reach the dump from the transportation road on the west side of the mining site, rock stripping and coal mining are suspended.

3.2 Trestle bridge project—"small trucks rolling on ground, large trucks rolling on bridge" In order to realize the three-dimensional intersection between the road for self-operated coal and rock large trucks and the road for outsourced earthwork small trucks, this scheme proposes the interchange mode of small trucks on ground and large trucks on bridge: the small trucks pass along the 1 160 m flat plate below, the large trucks pass via the overpass above, and the small trucks need a clearance height of 5.5 m. The large trucks need to climb to 1 166.5 m on the bridge, and the climbing lane needs to be long enough. The area of steel bridge floor is 400 m^2. Small trucks on ground, and large trucks on bridge can reduce the investment of overpass.

Road reconstruction (rerouting) generates 257 300 m^3 of earth and stone. The construction period is 40 d. This can realize the passage of large and small trucks without horizontal crossing, avoid the phenomenon of small trucks queuing and congestion caused by the large and small trucks crossing, improve the transportation efficiency of the small trucks, and reduce the transportation cost of the small trucks. During the construction period of the bridge body, the production vehicles can reach the crushing station and the external dump site along the temporary road outside the red line, which has little impact on normal production. The layout of the trestle bridge on the transportation roads from the excavation site to the dump site ("small trucks on ground, large trucks on bridge") is shown in Fig. 3.

3.3 Trestle bridge project—"large trucks rolling on ground, small trucks rolling on bridge" In order to realize the three-dimensional intersection between the road for self-operated coal and rock large trucks and the road for outsourced earthwork small trucks, this scheme proposes the interchange mode of large trucks on ground and small trucks on bridge: the large trucks pass along the 1 160 m flat plate below, the small trucks pass via the overpass above. Compared with the large vehicle transporting on the bridge, this scheme increases the clearance required by the overpass. According to the parameters such as the height of the self-operated large equipment transport vehicle, the clearance height of the steel bridge is calculated to be 9.0 m. The small trucks need to climb to 1 170 m to go on the bridge, and the

climbing lane needs to be long enough. The area of steel bridge floor is 600 m^2.

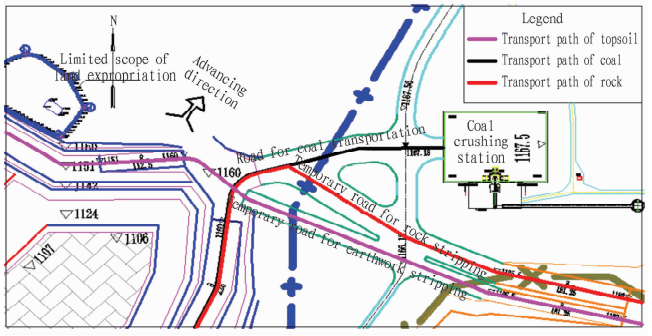

Fig. 1 Layout diagram of the intersection of transportation roads from the excavation site to the dump site

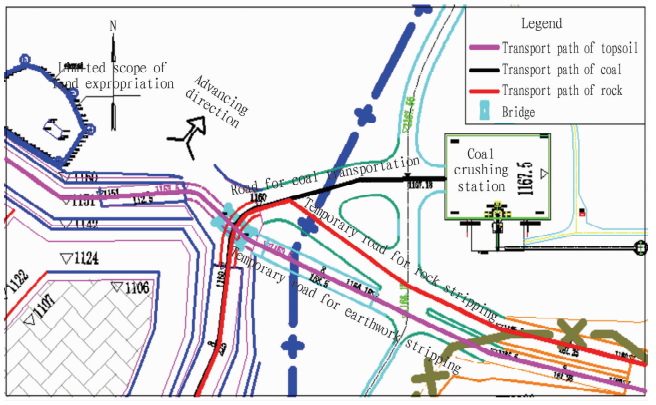

Fig. 2 Schematic diagram of underpass bridge layout

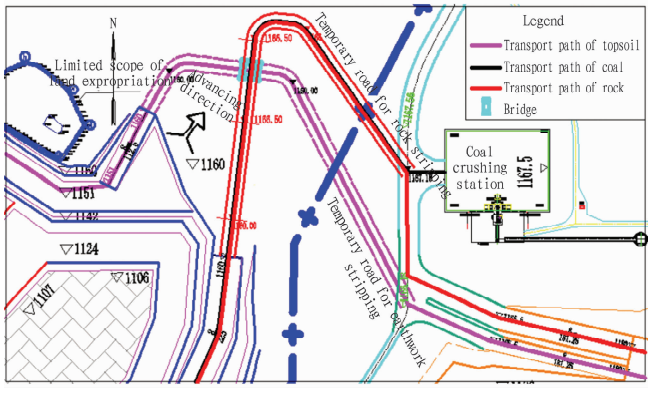

Fig. 3 Schematic diagram of trestle bridge layout—"small trucks on ground, large trucks on bridge"

Road reconstruction (rerouting) generates 190 000 m^3 of earth and stone, and the construction period is 40 d. This can realize the passage of large and small trucks without horizontal crossing, avoid the phenomenon of small trucks queuing and congestion caused by the large and small trucks crossing, improve the transportation efficiency of the small trucks, and reduce the transportation cost of the small trucks. During the construction period of the bridge body, except that the topsoil can reach the dump from the transportation road on the west side of the mining site, rock stripping and coal mining are suspended. The layout of the trestle bridge on the transportation roads from the excavation site to the dump site ("large trucks on ground, small trucks on bridge") is shown in Fig. 4.

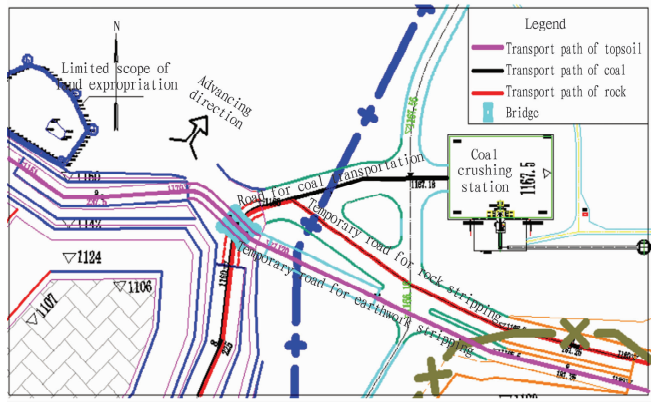

Fig. 4 Schematic diagram of trestle bridge layout—"large trucks on ground, small trucks on bridge"

4 Project investment

With the change of mining working face and the position of soil removal in the open-pit mine, the intersection position of the key points of the development and transportation system also changes. In order to facilitate the repeated use of the underpass bridge and overpass project, and the need of the overall relocation, the integrated steel structure form is selected.

This study refers to the steel structure trestle bridge put into use in Yimin open-pit mine and the underpass bridge project used in urban road project for investment estimation[7-8]. The comparison of the main technical and economic indicators of each scheme is shown in Table 1. As can be seen from Table 1, the trestle bridge project investment in the scheme—"small trucks on ground, large trucks on bridge" is relatively low, the amount of earth and stone is small, and the impact on the production of open-pit mines is relatively small. This can realize the passage of large and small trucks without horizontal crossing, avoid the phenomenon of small trucks queuing and congestion caused by the large and small trucks crossing, improve the transportation efficiency of the small trucks, and reduce the transportation cost of the small trucks, and is conducive to the safe production of open-pit mines.

5 Conclusion

Underpass bridge and overpass steel trestle are mainly used when urban freeways, expressways and major highways intersect, and are rarely used in coal system engineering. With the diversification of open-pit mining technology, the horizontal crossing of transport trucks, belt conveyors, rock trucks, coal trucks, and large and small equipment in the transportation system at key points is becoming more and more obvious. The design concept of overpass steel trestle can realize safe and efficient production of open-pit mines.

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Table 1 Comparison of main technical and economic indicators

No.	Project		Underpass bridge project "small trucks pass underneath, large trucks pass above"	Trestle bridge project "small trucks rolling on ground, large trucks rolling on bridge"	Trestle bridge project "large trucks rolling on ground, small trucks rolling on bridge"
1	Investment (10 000 yuan)	Bridge body	1 500	1 500	2 250
		Bridge earthwork	367.0	0	0
		Road reconstruction	31.5	257.3	190.0
		Total	1 898.5	1 757.3	2 440.0
2	Small truck efficiency change		Higher	Higher	Higher
3	Small truck transportation cost change		Lower	Higher	Lower
4	Construction period//d		90	40	40
5	Idling period//d		90	0	40
6	Degree of road congestion		Mild	Mild	Mild
7	Difficulty level of vehicle scheduling		Easy	Easy	Easy
8	Ranking by comparison		2	1	3

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