Preliminary geological route selection research on the controlling section of the 2nd route of Xinjiang-Tibet highway

Junan Chen[1,3,4], Weidong Liu[1,5], Luwen Wang[2,6], Zhongchao Shen[1,7]

[1]Sichuan Communication Surveying & Design Institute Co., Ltd, Chengdu, 610017, China
[2]Shanghai Thousand Year Design Co., Ltd, Chengdu, 610000, China
[3]Corresponding author

[4]55255363@qq.com
[5]704362878@qq.com
[6]471769848@qq.com
[7]43408908@qq.com

Abstract. The Kuyake Canyon is a controlling section of the second line of the Xinjiang-Tibet Highway. The canyon is a fault basin formed by multiple periods of left-lateral strike-slip on the southern edge of the Altun Mountains fault, has extremely complex geological structures and a variety of adverse geological phenomena. Through the process of analysing obscure and symptomatic undesirable geological phenomena, we summarized the ideas for geological alignment selection of strategic highways in high- altitude uninhabited areas, that is, taking highway construction goals as the premise, long-term operational safety as the foundation, and quick repairs as the core. According to the sensitivity of the highway to adverse geology, comprehensive consideration, retaining the big and letting go of the small, to ensure the achievement of the highway construction goals.

Keywords: geological alignment selection, comprehensive comparison and selection, hidden faults, permafrost.

1. Introduction

Since the introduction of engineering geology to highway surveying and design in my country in 1954, it has not been well integrated with highway engineering for a long time, and is often limited to engineering geomorphological line selection. In 1981, Kong Xiangjin elaborated on the engineering geological line selection method in more detail [1], pointing out an explorable path for the combination of geology and highways [2].

For a long time, it has been the common aspiration of the central government and Xinjiang to explore the strategic roundabout of the Xinjiang-Tibet Highway and open up a second strategic passage out of Xinjiang and into Tibet [3]. From April to May 2010, the Chinese Academy of Sciences organized a number of experts and scholars to investigate the "strategic highway passage out of Xinjiang and into Tibet" in southern Xinjiang [4]. The study believed that from the strategic perspective of maintaining national security, managing the northwest, and stabilizing Xinjiang and stabilizing Tibet, it is

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DOI: 10.54254/2755-2721/65/20240534

recommended to establish a project to build a strategic highway from Xinjiang Minfeng to Tibet as soon as possible [5].

The implementation of this project is of great significance for the in-depth implementation of the Western Development and the "Belt and Road" development strategy [6], improving regional transportation conditions, maintaining border stability, promoting the development of advantageous resources along the route and coordinated economic and social development [7].

2. Project geological background

2.1. Geographical background

The route is located in the middle section of the Kunlun Mountains and the southern edge of the Taklimakan Desert [8]. It passes through the desert Gobi plain, Zhongshan hills, Zhongshan mountains, mid- alpine canyons and the northern Tibetan plateau area. Except for the Zhongshan mountains and some gullies, most of the other sections have undulating terrain [9]. The overall terrain is relatively flat and open. Most of the sections along the route are uninhabited areas with harsh natural climate conditions.

2.2. Construction background

The route passes through the southeastern fault step of the fifth-level structural unit under the first-level structural unit of the Tarim Platform, the second-level structural unit under the first-level structural unit of the East Kunlun Fold System, the Alkhash Mountain Maogeosyncline fold belt, and the Songpan-Ganzi fold system. The secondary structural unit of the Muztagemao geosyncline fold belt. The deep and large faults that pass through in sequence mainly include the Kengda-Kepa fault (F7), the southern edge of the Altyn Mountains fault (F), the Muztage-Whale Lake fault (F8), and the adjacent deep and large fault Kangxiwa fault (F15), and intersects with 9 secondary faults (figure1).

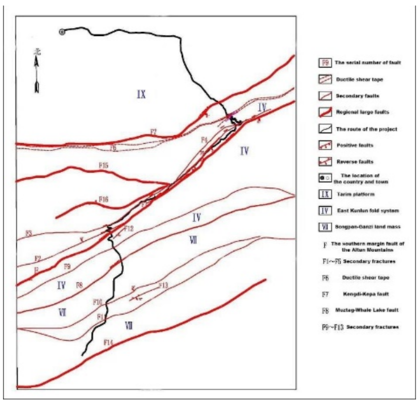

Figure 1. Outline of Route Area Structure

2.3. Earthquake background

The project area has developed structures and earthquake relics are widely distributed along the fault zone. In 1924, there were two consecutive earthquakes of magnitude 7 or above, a magnitude 5.6 earthquake in December 1979, and a magnitude 5 earthquake in November 1982. On November 14, 2001, a magnitude 8.1 earthquake occurred at the Kunlun Pass. The epicenter of the Buka Daban Peak was located at 36.2° north latitude and 90.9° east longitude. The earthquake -producing fault was the eastern section of the Muztag-Whale Lake fault, and the epicenter was far away from the route.

3. General principles of geological line selection

Geological line selection can be divided into macro geological line selection and micro geological line selection. Macro geological line selection is mainly reflected in the selection of corridors, but in actual operations. At this time, micro route selection becomes the ballast stone to ensure the safety of highway construction [10], and its importance is particularly prominent. To this end, three microscopic line selection principles have been formulated:

1. First of all, the impact of earthquakes on large structures must be minimized, especially the threat to bridges from active fault zones, and the location of bridges must meet relevant regulatory requirements.
2. Secondly, ensure that no large-scale road sections on the route will be cut off due to adverse geological hazards.
3. When route control cannot completely avoid adverse geological disasters, try to make it easier and faster to clear the route later.

4. Macro-geological line selection in the canyon area

Figure 2. Summary Map of Canyon Section Route Selection

The lower part is alluvial pebble gravel soil with a thickness of tens to hundreds of meters, which is medium to dense. Collapses, slides, and landslides develop in the scarp areas at the edge of local debris flow gullies [11]. Debris flows, salivary ice, saline soil and seasonally frozen soil develop in some sections (figure 2).

Table 1. Comprehensive comparison and selection table of route options on the north and south sides of the canyon area

Evaluation index	Canyon South Line	Canyon North Line	
		Northern line to the north	Northern line to the south
Earthquake peak acceleration (g)	0.15~0.2	0.15~0.2	0.15~0.2
Route distance from fault fracture zone (m)	0≤L≤600	30≤L≤200	230≤L≤1800
Parallel length of route and active fault zone (km)	about 81km	about 81km	about 81km
The relationship between the route and the upper and lower walls of the fracture	Offering	Offering	Offering
Whether the route crosses an active fault zone	no	Partially span the secondary fracture in the form of roadbed	Partially span the secondary fracture in the form of roadbed

Therefore, the overall concept of geological route selection in the canyon section is that the route runs in the north of the canyon, close to the north edge of the canyon but not close to the north edge.

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5. Micro-geological line selection in the canyon area

5.1. Geological line selection of hidden faults

Figure 3. High-Resolution Aerial Photos of The Canyon Section

It can be basically determined that the formation of the solitary hill is the result of the uplift of the hanging wall of the lower hidden fault [8]. The thin line is the manifestation of the secondary hidden fault on the ground (figure 3). By applying the principles of structural geology to combine and analyze the on-site survey data with the collected relevant regional geological data, the cross-section structure of this section of the canyon was deduced (figure 4).

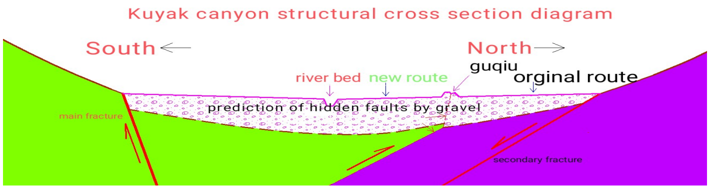

Figure 4. Local Structural Section of The Canyon Section

Under the influence of the above factors, if the original route plan is continued, there will be the following two disadvantages:

1. In order to avoid the impact of the fault zone on the bridge as much as possible, the route needs to pass through the middle of the secondary fault and the hidden fault. The bridge will intersect the debris flow gully at a small angle here, and the gully does not have the conditions for ditching, resulting in a large-scale bridge. increase.
2. The three-dimensional spatial range of the covering layer between the secondary faults and hidden faults is relatively narrow, and its site stability is relatively poor.

5.2. Geological line selection in permafrost areas

This section of the route is located in the combination zone of plateau and canyon. It is divided into north and south parts by the secondary fault on the southern edge of the Altyn Mountains. The north is the Kuyak Canyon and the south is the North Tibet Plateau. The route needs to be repeatedly extended in the canyon area to raise the altitude to climb over the 5026 plateau to reach the plateau platform area. The slope area of the foothills of the plateau has large terrain undulations, with cross slopes of about 22° to 44°, and obvious scour and cutting phenomena. The altitude is between 4927m and 5029m, with a relative height difference of about 102m (figure 5).

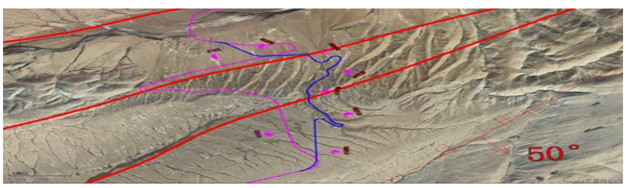

Figure 5. Summary Diagram of Route Selection for The Combined Section of The Canyon and Plateau

Pit exploration shows that the natural upper limit of permafrost in this section is 1.0m to 1.3m (Figure 4). The active layer plays the role of frozen soil insulation. The permafrost layer and its lower part are

DOI: 10.54254/2755-2721/65/20240534

composed of Quaternary Holocene alluvial pebbles and breccias (Figure 5), which are medium to dense in shape, filled with clay and silty clay, and are generally thicker than 100m (regional geological map). Ice and ice-rich permafrost are dominant. The trenches are dominated by ice-rich to ice-rich permafrost, with soil and ice layers partially intercalated (Figure 6).

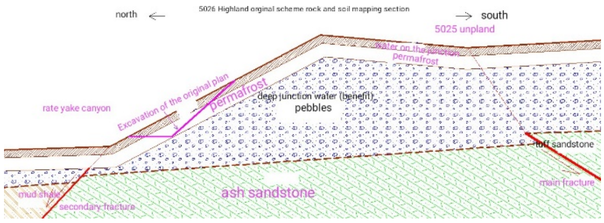

Figure 6. Upper limit of frozen soil

Figure 7. Cross-Sectional View of The Rock and Soil Mass of the 5026 Highland Plan

This gully also cuts off the seepage channel of groundwater from the highland platform to the northeastern side. Affected by the steep slopes on both sides of the dendritic mountain, surface water drains quickly and there is no large-area water catchment platform to recharge groundwater. When the rock and soil types are similar, the ice content of the frozen soil and the soil moisture content should be less. At 5026 Highlands. Based on the above qualitative analysis and Table 2, quantitative analysis was carried out.

Based on the above qualitative analysis and Table 2, quantitative analysis was carried out.

Table 2. Comprehensive comparison and selection table of new and old route options in permafrost areas

Evaluation index	Old plan	New plan
Compare route length (km)	9.393	7.476
route line indicator	Height (minimum radius of flat curve 90m)	Relatively low (minimum radius of flat curve 40m)
Length of route affected by active fault zones (km)	5.67km (bounded by 200m outside the fault)	3.15km (bounded by 200m outside the fault)
Length of route located on the hanging wall of the fault (km)	6.919	4.856
Number of times the route crosses active fault zones	2 (roadbed form)	2 (roadbed form)
Are there any large structures such as bridges?	none	none
Ice (water) content of road cutting slope	high	low
Impact on construction period	Large (dynamic design of segmented excavation and segmented treatment)	Small (the entire section can be excavated at one time, with few changes)
Cost	100%	97%
Select results	Not recommended	recommend

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Therefore, two principals have been drawn up for the line adjustment plan of this section:

1. Before the route enters the mountainous area, the roadbed elevation should be raised as soon as possible with maximum longitudinal slope control. After reaching the mountainous area, the excavation height of the road cutting can be effectively reduced. The higher the roadbed elevation, the less affected the slope will be by frozen soil and mountain groundwater (figure 8).
2. The alignment plan will eventually intersect with the original plan at the 5026-highland platform. Therefore, when the roadbed elevation reaches a certain elevation, the alignment needs to be extended to the north-south gully as soon as possible, and the flow will be reversed along the side of the gully in the form of filling back pressure on the inner mountain. Then, cut through the gully and cut into the high platform at the appropriate location. Then the cross slopes on both sides of the roadbed will be gentle, and there will be conditions to slow down the slope ratio of the excavation.

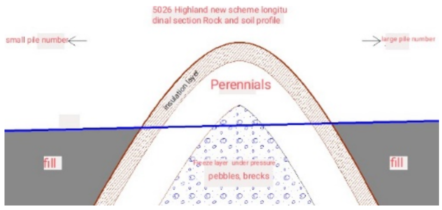

Figure 8. Longitudinal Section of Rock and Soil Mass in the New Scheme of 5026 Highland

The advantage of the new plan is that it reduces the uncontrollable factors affected by earthquakes, melting permafrost and groundwater after the original plan's slope excavation. Although the linear index is worse than the original plan, some sections have a large fill height and are affected by gully water erosion of the roadbed. The impact is controllable and treatable. The cost of the new plan has not increased, and the construction risks and operational risks are significantly less than the original plan. Its comprehensive benefits over the entire life cycle of the highway are relatively good.

Figure 9. The Original Plan of Mountain Excavation and Exposed Soil-Containing Ice Layer; The New Plan of Mountain Excavation and Exposed Low-Ice Frozen Soil

6. Summary

Geological route selection is a matter of trade-offs. Restricted by a series of early-stage constraints such as project construction purpose and construction funds, various unfavorable geological factors can be summarized and analyzed, and different risk levels can be divided according to their impact on the route. Achieve the relatively optimal solution.

If we encounter multiple constraints during line selection and it is difficult to make a choice, choose the option with the fewest uncontrollable factors on the premise that the treatment results are controllable and the project cost is controllable.

Through advance collection of geological data and on-site verification, discovering "anomalies" in common geological phenomena and making reasonable assumptions about obscure adverse geological phenomena are effective means to avoid potential adverse geological phenomena.

Postscript: Through the application examples of geological line selection that have been successfully verified by construction in complex geological environments, the article hopes to serve as a starting point.

DOI: 10.54254/2755-2721/65/20240534

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