Brief discussion on the design of route selection in mountain areas of suspended monorail

HAN Bing, OU Cheng-zhang

(China Railway Liuyuan Group Co., Ltd. Tianjin 300308)

Abstract. The design of route selection in mountain areas is the foundation and soul of survey and design of suspended monorail transport, which directly determines the project cost, operation cost and so on. As the corresponding technical standards or design specifications of the suspended monorail have not been formally promulgated in China, this paper expounds the structure form and technical characteristics of the suspension monorail, and analyzes the key points of the route selection technology of the suspended monorail in mountain areas in order to provide a reference for the similar project in mountain areas.

1. Research background
With the rapid development of social economy and the acceleration of urbanization, the construction of suspended monorail system has gradually been put on the agenda in China. As the corresponding technical standards or design specifications of the suspended monorail have not been formally promulgated in China, a variety of factors should be taken into account while designing a route selection of the suspended monorail in mountain areas, which ultimately could make sure the coordinated development of economy and ecology in the mountain areas. Because of the particularity of the natural environment in mountain areas, many factors will affect the design of route selection for suspended monorail in mountain areas. Therefore, when carrying out route selection design, it is necessary to carry out an in-depth and comprehensive survey in the location of the project, through the comprehensive comparison of various route selection schemes, the best scheme is selected, so as to make the suspended monorail drive the economic development of mountain areas [1].

2. The Structure Type and Technical Characteristics of Suspended Monorail

2.1 The Structure Type of Suspended Monorail
Compared with other rail transit systems, the suspended monorail transit system has a unique vehicle Bogies and track beams. The bogies run on the track beams while the car body is suspended under the track beams, as shown in Figure 1.
Traditional steel frame structure

Modern box-type structure

Figure 1 Suspended monorail diagrams

In the suspended monorail system, the track beam plays the role of guiding the train running and bearing the weight of the train. It is one of the most important components of the suspended monorail system. The track beam includes beam and column, track and turnout. Track beams are generally box-section steel beams with openings at the bottom. Traveling wheels and guide wheels are placed inside the box girder and run along the internal track, as shown in Figure 2. The change of vehicle's driving direction is realized by the horizontal movement of movable rail in box track beam.

Figure 2 Schematic diagram of suspended monorail wheel and rail system

The track beam of the suspended monorail system has many forms, such as "gate" track, "T" track and "inverted L" track, which can suit the erection requirements under different circumstances, as shown in Figure 3.

Bogies are the most important components of suspended monorail vehicles. Each vehicle is equipped with two bogies. The bogies are composed of running wheels, guide wheels, auxiliary wheels, motors, air springs, traction rods, frames and central pins. The running wheels roll in the vertical plane of the running track is used for load-bearing, traction and braking. There are four running wheels on the two axles, which are driven by the longitudinal traction motor; a total of four guide wheel rotates in the horizontal plane, mounted in the four corners of the frame, used for guiding and mitigating lateral vibration. The running wheels and guide wheels are equipped with spare wheels. When a flat tire occurs, the spare wheels can ensure the safety of driving. The suspended monorail adopts disc brake, and the brake disc is installed on the motor shaft. The two-route suspension is an air spring, and the pillow straddles the two air springs. The body suspension member runs through the hole in the center of the frame then connected with the pillow.
2.2 Technical Characteristics of Suspension Monorail
Suspended monorail has the characteristics of high safety, low carbon and environmental protection, less investment, simple construction, good environmental adaptability, high aesthetics and comfort.
3. Design Ideas of Route Selection for Suspended Monorail Mountainous Areas

In the design of route selection of suspended monorail in mountain areas, it is necessary to design according to the overall planning control of the national and provincial cities, combined with the current situation of mountainous terrain, to distinguish the main control points from the secondary control points, and finally to formulate a scientific and reasonable route plan to facilitate the transportation of people in mountain areas [2].

3.1 Selection of Route Selection Schemes for Various Suspended Monorail Mountainous Areas

Before the design, we should actively discuss and negotiate with the location government and other relevant departments of the project, grasp the overall layout of urban planning and design, and adjust the routes according to the consultation results with various government departments and the relevant restriction conditions in general.

3.1.1 Geological Conditions

The geological conditions in mountain areas are complex and changeable. Landslides, debris flows and other natural disasters are prone to occur in areas with weak geological conditions and caves and goafs are below some areas. The design of suspended monorail route selection in mountain areas should stay away from the areas with poor geological conditions as far as possible. When the route selection design is carried out according to the specific survey data, the project budget should be calculated according to the design plan, so that the scheme can be compared and selected.

3.1.2 Protection of Cultivated Land and Water Sources

In the mountain range, the cultivated land resources are very scarce, therefore, the designer in the route selection design, the route scheme selection minimizes the occupation of cultivated land by the project construction. Route selection as close as possible to the construction area, and take evasive measures, so that the route selection as far as possible to avoid arable land, and then in the determination of the route to reduce the amount of basic farmland occupied by the route. In addition, mountain areas are the birthplace of many major rivers, in the design of the route selection, but also to protect water sources, as far as possible to avoid the disturbance of ground runoff, the destruction of water resources to a minimum.

3.1.3 Reduction of the Impact on Residents Along the Route

The most important significance of the construction of suspended monorail is to provide convenience for local residents to travel. Therefore, the design of route selection of suspended monorail should be people-oriented and humanized, so as to promote the integrated development of local production, tourism and transportation. The design of route selection suspended monorail should avoid the graves, ancestral halls and religious places of local people as far as possible, and it is inevitable to consult with local people and obtain their consent or change the route in advance.

3.1.4 The Feasibility of Construction

The feasibility of construction should be fully considered in the design of the route selection of suspended monorail. Because the mountainous terrain is complex and changeable, therefore, in the construction process will encounter a lot of safety problems, especially in rainy season, which is easy to form landslides or debris flows and other disasters. Therefore, the designer should synthesize the construction scheme of the existing projects in this area to minimize the potential safety hazards.

3.2 Harmonization with the Surrounding Landscape

When the suspended monorail is being constructed, the protection of the surrounding environment should be pointed out especially, so as to avoid greater disturbance to the environment and make the environmental problems more and more seriously. In the construction of suspended monorail, we should always recognize the importance of protecting resources and environment and how to coordinate with
the surrounding. Moreover, it is also important to correctly handle the relationship between the surrounding and the project, in order to integrate the suspended monorail with the local environment. In this way, it can not only make the local people live conveniently, but also attract more tourists to mountainous areas, which can develop the low-carbon, efficient and sustainable development of mountainous economy. Although this kind of design needs more investment in the early stage of construction, the analysis of successful cases abroad shows that these projects have achieved good economic returns for tourism, and will continue to play a greater role in the local economy.

3.3 Location selection of depots and parking area
Vehicle depots and parking area should make full use of the topographic features of mountain vehicle depots, combine with the functional characteristics of buildings and reasonably layout under the premise of meeting the technological and safe requirements; Moreover, it should also rationally use the topography for vertical design to minimize high fill, high retaining wall and slope protection projects; and reasonably determine mountain vehicle depots in combination with the topographic features and surrounding environmental conditions of the depots. The elevation of the field level can reduce the quantity of earthwork and rock works and achieve the balance of filling and excavation as far as possible.

4. Key Technologies of Suspended Monorail route Selection Design in Mountain Areas
Suspension monorail route selection design runs through the whole process of the project and plays a decisive role in the quality of the project. Next, the key technical points of route selection in the process of project survey and design are analyzed.

4.1 Plane Design and Longitudinal Section Design
Because of the complex terrain and geological conditions in mountainous areas and the huge workload of route selection, it is inevitable to neglect one thing or the other in the selection of route schemes, which results in unreasonable sections of route schemes. In the design work, designers rely more on their own work experience and combine the graphic design and surface design to ensure the coordination of the whole route design.

4.2 determination
The fixed surveying route plays a decisive role in the design quality of construction drawings. The optimization of the fixed surveying route is a gradual and in-depth process. On the basis of the preliminary results, it connects with the bridge and tunnel specialties, perfects the disposal measures for each difficult point of the project, and tries to analyze the engineering effect and existing problems after the implementation of the project, so each disposal measure at the difficult points is practicable [3].

4.3 complex curve
The complex curve is a curve formed by two different radius of the same direction circular curve tangent. Because the curvature of two same direction circular curves tangent directly, there is a sudden change in curvature, which affects train operation. Therefore, a transition curve should be added between the two circular curves to make the curvature of the curve and the super-high continuous change. These two circular curves and the transition curve connecting them are complex curves. Compared with the ordinary transition curve, the transition curve is a part of the ordinary transition curve, so it is called incomplete transition curve [4, 5].
Because of the restriction of route selection conditions, when two circular curves in the same direction are very close, and cannot set up independent transition curves of each circular curve, a transition curve adapted to the two circular curves is often used to connect them, that is, to design a complex curve form.

But the complex curve has the following shortcomings:
1) It will increase the difficulty of route survey design and track beam design and manufacture.
2) The centrifugal force produced by the curves with different radius on the complex curve is different. When the radius changes, the train offset changes and the driving comfort decreases.
3) Because of the different resistance of curves on the complex curves, the force on the train is changed in a short time, which reduces the smoothness of the train operation.

It is suggested that complex curve routes should not be used in design. If terrain restriction is not allowed, it is suggested that the length of circular curve and transition curve of complex curve should not be less than 20m.

5. conclusion
In the mountainous area of suspended monorail, route selection design is a systematic project that integrates various control factors. It requires the route designer to accumulate and ponder over a long period of time. According to the specific control factors in the terrain, along with the deepening of the survey and design stage of suspended monorail, the horizontal and vertical section design of the whole route should be optimized step by step in accordance with the design concepts of safety, economy, environmental protection and comfort. In order to improve the rationality of suspended monorail route selection design in mountainous areas, and promote the rapid development of mountainous economy.

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