

# Research on Key Problems and Strategies of Subgrade and Pavement Design of Highway in Mountainous Area: Taking Meng'a Highway as an Example

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**Abstract:** Building expressways in mountainous areas is a necessary way to promote local economic development. Due to the complex terrain, changeable geological conditions and vulgar climate conditions in mountainous areas, there are many key design problems to be solved in the subgrade and pavement design of mountainous expressway. Taking meng'a expressway as an example, the design method of subgrade cross section with staggered abutment and separation and the design concept of zero waste square are proposed.

**Keywords:** mountainous expressway; subgrade and pavement; key design issues

## 1. Introduction

The subgrade and pavement design of mountainous expressway has an important impact on the construction quality and economy of Mountainous Expressway [1,2]. Since mountainous expressway has to cross karst landform [3], active fault zone [4], and alpine region [5,6], it is of great significance to summarize and analyze the key problems and solutions in the subgrade and pavement design of mountain expressway [7]. Taking meng'a expressway as an example, this paper analyzes the existing problems and solutions of subgrade and pavement design of Mountainous Expressway in Yunnan Province of China.

## 2. Main Problems and Strategies of Subgrade and Pavement Structure Design of Mountainous Expressway

### 2.1. Subgrade Design of Active Fault Zone

The harm of active fracture to highway subgrade can be divided into two categories: the harm to subgrade and pavement and the harm to highway slope.

(1) The damage of fracture activity to subgrade and pavement often results in settlement deformation of subgrade and pavement, undulation of pavement, structural crack penetrating subgrade, pavement collapse, cracking, subgrade distortion and collapse, pavement

bulge fracture and pit damage with long axis nearly parallel to fracture trend.

(2) The damage of fracture activity to highway slope can lead to the cracking, deformation and loosening of rock and soil mass of cutting slope, and more often lead to disasters such as collapse, instability and sliding, blocking traffic, etc. For embankment slope, especially for high embankment, under the action of fault creep and stick slip, landslide and other disasters are very easy to occur, and even cause the overall instability and sliding of subgrade and pavement.

Combined with the mechanism of active fault and its harm to highway, the following countermeasures are mainly adopted in the design.

(1) Appropriate horizontal and vertical sections shall be adopted to cross the fault zone with large angle and short distance as far as possible, and high filling and deep excavation of subgrade shall be avoided.

(2) Fill with high quality filler.

(3) Non rigid subgrade and flexible layered reinforcement measures are adopted to increase the stability of road foundation and adapt to the deformation of fault zone.

(4) Slow down the slope.

(5) Widen the side ditch platform and cutting classification platform to reduce the cutting classification height.

### 2.2. Subgrade Design under High Seismic Intensity, Broken Rock Mass and Unfavorable Geological Conditions

Due to the influence of tectonic action, the project has high seismic intensity, broken rock mass, collapse, landslide, unstable slope, karst and other unfavorable geology and special rock and soil development. The key point of the project is to make good treatment measures.

(1) Comprehensive survey technology is adopted to find out the distribution of unfavorable geological sections such as collapse, landslide, unstable slope and karst.

(2) Strengthen the hydrogeological analysis and grasp the regional hydrogeological conditions macroscopically.

(3) Carry out geological survey ahead of time to find out adverse geological problems.

(4) Comprehensive use of various survey means to conduct comprehensive geological survey.

(5) Flexible use of new technologies such as digital borehole imaging and 3D geological modeling.

(6) Carry out special geological survey for key and difficult problems.

Strengthen the analysis of the influence of highway subgrade safety under the condition of high earthquake intensity in the bad geological rock soil sections such as collapse, landslide, unstable slope and karst, and put forward the corresponding measures

(1) Analyze the stability of the subgrade and its slope, and reasonably select the protection form.

(2) According to the bad geological characteristics, the impact on the subgrade and the corresponding countermeasures are analyzed.

(3) Based on the analysis of the impact of adverse geology on structures, targeted preventive measures should be taken.

(4) Collect and investigate its distribution and influence scope on the subgrade, determine its physical and mechanical properties, and provide support for the analysis of its stress mode.

Treatment methods for soft foundation of gullies and slopes

(1) Paying attention to drainage and compaction, the shallow soft foundation is treated by gravel cushion or rubble replacement, and the deep soft foundation is treated by gravel pile or CFG pile, which can significantly improve the strength and anti sliding ability of the soft foundation and play the role of strengthening the foundation;

(2) The treatment method of combining plastic drainage board and back pressure berm is adopted. The water in soft foundation is quickly discharged by using plastic drainage board to accelerate soil consolidation. The back pressure berm is added at the filling foot of subgrade to enhance the stability of subgrade.

(3) For slope soft foundation, pile foundation retaining wall, anchor foundation retaining wall and other methods are considered to support the embankment at the steep side of the subgrade to prevent lateral sliding; cushion and replacement measures are added within the subgrade to ensure the stability of the subgrade; geogrid is added in the filling to enhance the overall stability of the subgrade.

### 2.3. Hydrogeological Conditions

There are rivers and gullies distributed along the line with extremely complex groundwater type and water yield, which can be used for construction. The water quality is good, and there is no corrosion micro corrosion to engineering structures, which can meet the needs of engineering construction.

The rock and soil distributed in the area are mainly soft rock group or extremely soft rock group, with low hardness, poor cohesion, weak erosion resistance and weathering resistance, and poor stability. Under the joint action of the above two factors, the stability of rock and

soil mass in the area is poor, which is prone to geological disasters such as landslide and collapse.

In the project area, adverse geological process and special rock and soil are relatively developed, and landslide, potential unstable slope, strong earthquake area, earthquake liquefaction, karst, dangerous rock, collapse and rock pile, goaf, bedding slope, soft soil, red clay, etc. are all developed. The main unfavorable geology and special rock and soil that have great influence on the route are strong earthquake area, earthquake liquefaction, landslide, unstable slope, dangerous rock and collapse, karst, slope soft soil, etc. In addition, the strata in the route area are mostly mudstone, shale and other soft rock strata.

According to different types of unfavorable geology and special rock and soil, avoidance and corresponding engineering measures should be taken in the design.

### 2.4. Pavement Design under Special Climatic Conditions

Due to the hot and humid climate and abundant rainfall in the project area, higher requirements are put forward for pavement design under heavy traffic conditions. The selection of pavement structure should be based on the local climate, hydrology, geology and other natural conditions, follow the principles of suiting measures to local conditions, reasonable material selection and convenient construction, so as to ensure the requirements of smoothness, skid resistance, drainage and durability.

Countermeasures were as follows:

(1) In order to ensure the driving safety of continuous long longitudinal slope section, tunnel and tunnel group section, and the section before and after toll station, special design of pavement structure, improvement of road material selection and performance requirements and other measures should be taken to improve the skid resistance, rutting resistance, water loss resistance and durability of the above road sections.

(2) The climate of the project area is high temperature and rainy. The upper layer of the pavement surface structure adopts the modified asphalt, and the pavement gradation type adopts the skeleton dense structure. If necessary, the mixture is mixed with anti track agent to improve the high temperature stability and improve the durability of the surface course.

(3) SBS modified asphalt synchronous macadam should be used for the lower seal coat of semi-rigid base and asphalt surface course, and asphalt pre wrapped macadam can be used for synchronous macadam to ensure the functionality of seal coat.

(4) In order to remove the free water remaining in the pavement and subgrade, and ensure that the pavement structure is in dry or medium wet state, graded gravel cushion is considered in pavement design.

(5) In areas with local rainfall greater than 1500mm, large gap drainage asphalt pavement PAC is considered to discharge pavement rainfall in time, reduce surface water retention time and water film thickness, eliminate water mist at rear of wheel, and effectively improve driving comfort and safety.

### 3. Key Problems and Strategies of Subgrade and Pavement Design of Meng'a Expressway

#### 3.1. Project Overview

The total length of Lancang Menglian expressway is 488 km, which mainly passes through Lancang subduction accretion complex belt and Menglian Ophiolitic Melange belt in Changning Menglian junction zone. The strata fold deformation is strong, the fault structure is developed and the density is high, and the geological structure is very complex. The engineering route selection area is located in the typical complex geological structure area. The project area is located in the active structural area of Southwest Yunnan, and the active faults are well developed. The stability of the line is mainly affected by Lancang Mengzha F<sub>107</sub> fault zone and Lancang Menglian F<sub>108</sub> fault zone.

The project is located in the southwest of Yunnan Province, belonging to the south edge of the Nu mountain system of Hengduan Mountains, with rugged natural environment and continuous mountains. The relative height difference between the high point and the low point is more than 500 meters. The area is a shallow cut middle mountain area, and some areas develop structural basins. Along the route, the terrain is characterized by mountains and hills as a whole, and some parts are fault controlled basins. The overall landform is low and medium mountain, middle mountain, piedmont slope, river erosion accumulation and tectonic dissolution. Therefore, most of the roads are crossed by tunnels and bridges.

#### 3.2. Flexible Use of Subgrade Section Design (Staggering, Separation, etc.)

The terrain conditions of the project route are complex, the cross slope of the ground is steep, and the natural slope of local ground is more than 45 degrees. When the cross slope of the ground is steep, if the cross-section type of full width subgrade is adopted, the excavation slope is high, the mountain vegetation is seriously damaged, the protection and support engineering quantity is large, there are potential safety hazards in the construction and operation period, and the project cost is high.

In order to reduce the height of fill and cut slope, reduce the damage to natural slope of mountain and ensure the stability of subgrade slope, the following measures are adopted:

(1) Staggered bench type subgrade: when the terrain is divided into upper and lower slabs in the cross-section direction, and the width of each panel is less than the width of the whole subgrade, staggered bench type subgrade is adopted to reduce the excavation of the upper slope and the support of the lower slope.

(2) Separated subgrade: for special sections with complex terrain or long tunnels, flexible and changeable separated subgrade is used for design, and the independence, mutual relationship and correlation with the integral subgrade are flexibly used to adapt to the terrain and features and control the project cost.

(3) Half side bridge and half side subgrade: the subgrade is constructed for half of the small retaining work quantity, and the bridge or shed hole is adopted for the other half according to the topographical and geological conditions.

(4) Pile sheet wall and retaining wall subgrade: retaining walls are set up on the upper and lower slopes to reduce the excavation height and prevent the lateral sliding of subgrade.

(5) Overhanging abutment: when the site is narrow and the construction is difficult, it is economical and reasonable, beautiful and environmental protection.

#### 3.3. Subgrade Design Based on the Concept of Zero Waste

The terrain of the project route is complex, the subgrade section is filled and excavated frequently, and the amount of earthwork is large. There are many fishery protection areas, scenic spots and water environment sensitive points in the project area; the tunnel and bridge works are concentrated, and it is difficult to digest the waste; in addition, there are many cities and tourism planning points along the line, and the cultivated land and forest land need to be protected, so it is difficult to select the site of the borrow and spoil ground during the construction of the project.

(1) Optimize the horizontal and vertical plane design of the route: further optimize the route scheme determined by the preliminary design, on the premise of meeting the technical standards, combining with the layout of structures, taking and discarding soil, reasonably control the filling and excavation height of the subgrade, and fully reflect the "zero waste" concept of subgrade design.

(2) The filling and leveling treatment of roadside intermountain depression can solve the problem of drainage difficulty of depression, reduce the setting of culverts, and make rational use of waste soil to increase roadside greening rate.

(3) Take full advantage of the suitable terrain conditions and good alignment, and set up sightseeing platform, parking area and other tourism service facilities, which can effectively consume waste land and increase tourism benefits.

(4) Connect with the local government, and consider the allocation and transportation of waste land in accordance with the site leveling scheme of local urban planning, the design of resettlement sites, and the treatment of geological hazards.

(5) The concept of "tolerance design" is introduced, and the locations of separated subgrade middle zone, turning lane position, interchange triangle area, subgrade filling slope and other positions are slowed down to returnable slope design as far as possible, which can improve the safety of highway service conditions and operation environment, eliminate the adverse factors affecting driving safety, and comprehensively consume waste, reflecting the zero waste concept of subgrade design.

### 4. Conclusions

Through the analysis of the key problems existing in the design of highway subgrade and pavement in mountainous areas, and the general solutions are analyzed. Combined with the analysis of the key problems in the subgrade and pavement design of Meng'a expressway, it can be concluded that flexible use of subgrade section design and design concept based on zero waste square is a feasible design method for Subgrade and pavement design of Expressway in mountainous areas.

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