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Stability Analysis of Municipal Roads around Yangzonghai No. 1 Middle School

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Abstract: In this paper, the geotechnical investigation of municipal roads around Yangzonghai No. 1 Middle School is carried out, and the engineering geological conditions such as landform, formation lithology, geological structure and hydrogeological conditions of the proposed project are ascertained. Through qualitative analysis and quantitative calculation, the stability of the road section is evaluated scientifically and reasonably, and the prevention and control measures are proposed to ensure the stability of the roadbed.

1. Introduction

With the acceleration of people's consumption upgrading, the society has entered the peak period of car consumption, and this factor has promoted the steady growth of highway mileage, and the road has become an indispensable part of life[4]. However, Yunnan is located in the plateau, the geological conditions are complex, and bad engineering geological problems often lead to engineering accidents in engineering construction[1,4~6].Therefore, in order to protect the life safety of local people, it is of certain practical significance to do detailed geotechnical engineering investigation and carry out reliable stability evaluation on the road before building the municipal road, so as to provide reliable geological basis for the road construction and provide reference for similar projects. Taking Yangzong Haiyi municipal road engineering survey as an example, this paper uses qualitative and quantitative methods to analyze the instability factors in the study area, and further carries out stability evaluation.

2. Project profile

2.1 Traffic Position

The proposed site is located next to the Aero Art Port community in Qidian Industrial Park, Chenggong District (Fig1). There are high mountains in the southeast and northeast, Yangzonghai and Dianchi Lake in the east and west, with the terrain high in the east and low in the west.Chenggong District is between 1775 and 2820 meters above sea level, and the highest is the main peak of Liangwang Mountain, which is 2820 meters above sea level. The overall terrain of the site is high in the north to the east and low in the south, high in the west and low in the east along

the road. The overall slope is 5 °~ 25 °. The elevation of the survey area ranges from 2015 to 2046m, and the maximum relative elevation difference is 31 m. The site is currently used for agricultural land, fruit orchards, etc. The west side of the middle part of Guangfa Road is a residential building.

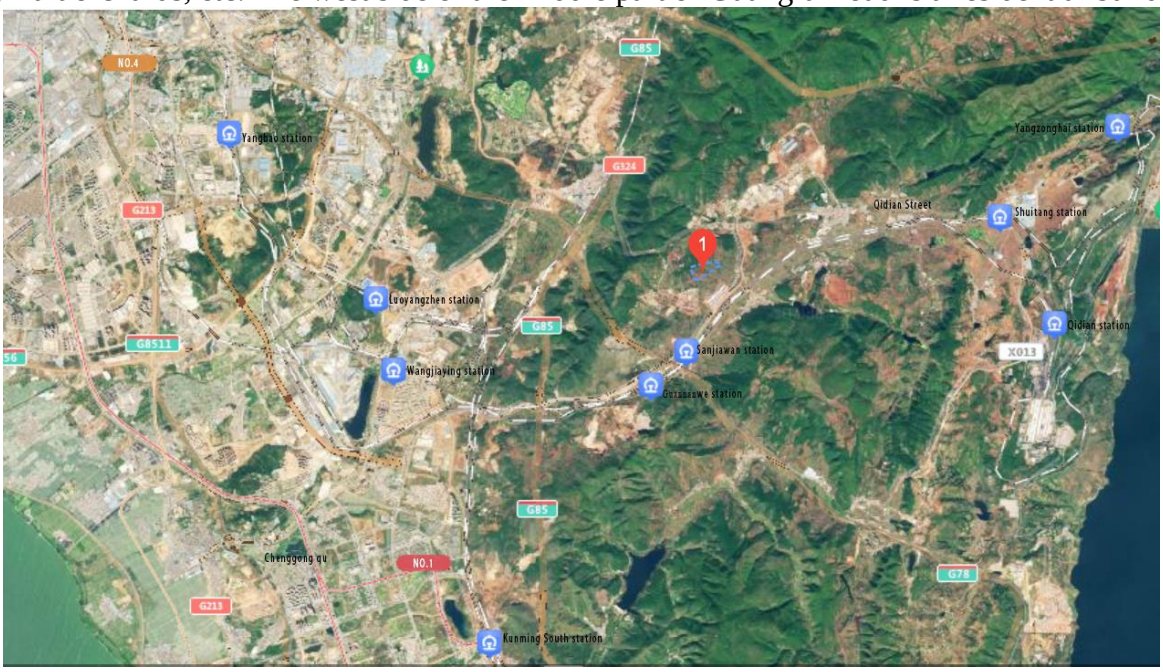

Figure 1: Traffic location map

2.2 Meteorology and Hydrology

Qidian belongs to the subtropical plateau monsoon climate type, the annual temperature difference is not large, the four seasons are not obvious, dry and wet seasons are distinct, and the amount of frost and snow is very large Under the influence of two warm and humid air currents in the southeast and southwest, rainfall is mainly concentrated from June to October every year, forming the characteristics of hot and humid rain in summer and autumn, and drought and little rain in winter and spring. The average annual precipitation in the area is 900-1200mm, with the maximum monthly rainfall of 208.3mm and the maximum daily rainfall of 153.0mm. The annual sunshine is 2327.5 hours, and the annual evaporation is 1685.0mm. Maximum wind speed 40m/s, southwest wind. The relative humidity is 76%. The climate of Kunming city has the characteristics of large daily temperature difference, small annual temperature difference, no cold winter, no hot summer, and spring all year round. The annual average daily evaporation is 175.1mm, and from March to May every year, the evaporation is larger, of which the maximum value is 275.5mm in April, which decreases after May, and the minimum value is 111.1mm in December. The annual average temperature is 14.7℃. The lowest temperature is 7.9-9.7 °C from December to February, and 11.2-19.9 °C from March to August.

2.3 Overview of regional geological environment

2.3.1 Tectonic location

The proposed site is located on the east side of Xiaojiang fault zone, and under the influence of east-west extrusion pressure, the structural systems in the area mainly include north-south structural system, east-west tectonic system, in-type structural system, Cathaysian structural system, and mountain-shaped structural system [2,7,8](Fig. 2).

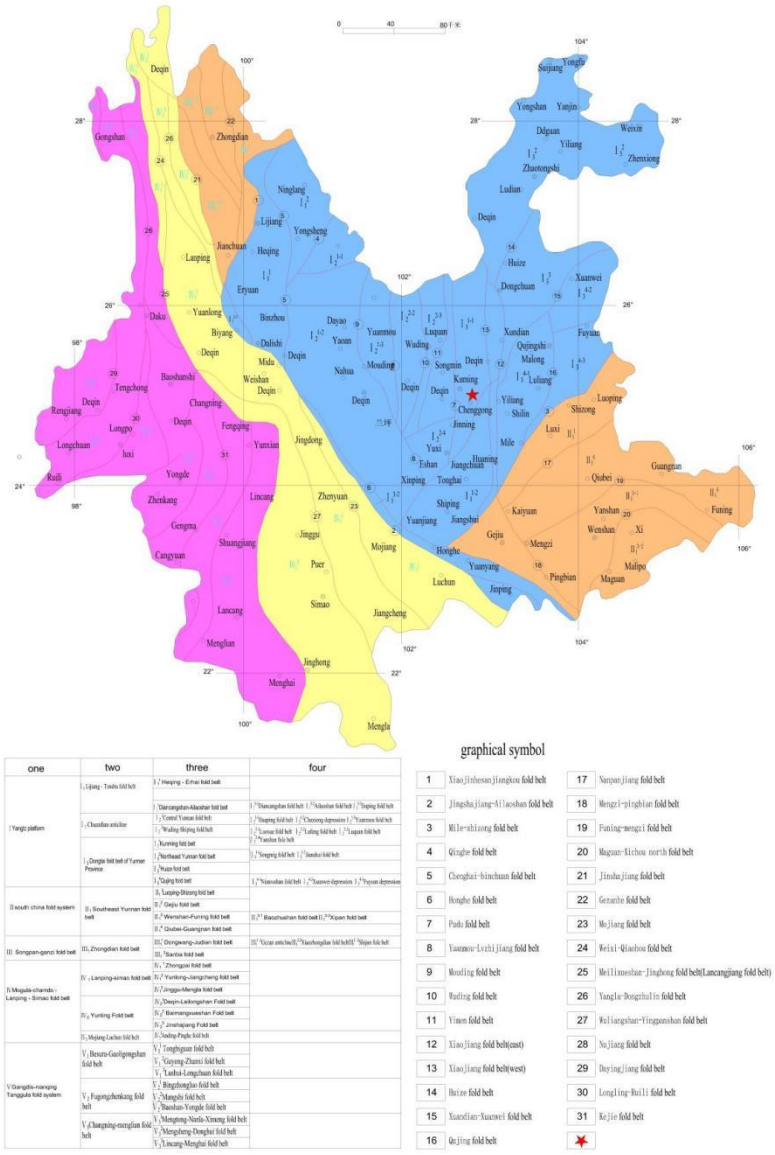

Figure 2: Regional structure map of proposed site (modified from regional geological structure map (Kunming))

2.3.2 Regional strata

According to the disclosure of this drilling, combined with the "1:200,000 Regional Geological map of Kunming", the main outcrop layers in the project area are new to old: The composition of the Quaternary Holocene artificial deposit (Q4ml), the quaternary plant layer (Q4pd) cultivated soil, the quaternary residual slope deposit (Q4el+dl) red clay and the Lower Permian Qixia Formation (P1q) dolomitic limestone. According to the data revealed by drilling, the stratum is divided into 4 engineering geological unit layers according to genesis, lithology and mechanical properties (see Fig. 3).

Stratigraphic numbering	age and cause	Floor elevation /m	lift height /m	histogram	Geotechnical characteristics
①	Q_4^{ml}	2021.81--2023.21	1.5--2.8		Artificially filled soil, maroon red, local gray brown, mainly composed of red clay, local containing gravel, block stone, isolated stone, the parent rock composition is dolomitic limestone
②	Q_4^{pd}	2024.37--2045.75	1.5--2.8		
③	Q_4^{el+dl}	2003.64--2041.45	1.3--15.20		Cultivated soil, reddish-brown, containing plant roots, dry, loose state, mainly composed of red clay, partial containing gravel, breccia, uneven soil Red clay, brown red, local brown yellow, slightly wet, hard plastic, the core is short columnar, the knife section is slightly smooth, dry, high strength, medium toughness, partial visible gravel, breccia, the core is easy to disperse in water.
④	P_1^q	--	1--24.7		Dolomitic limestone, grayish white, bluish gray, medium weathering degree, aphanocrystalline - phanerocrystalline structure, medium thickness and thin layer structure, joint and fissure development, solution hole and solution gap development, hard rock, hammer brittle sound, core mostly columnar, short columnar, core recovery rate is 75%-98%.

Figure 3: Bore hole columnar section

2.3.3 Regional structure

The main faults in the vicinity of the proposed site include the main trunk fault of the West branch of Xiaojiang (F7), the Baiye-transverse fault (F149), and the Huayuan Cloud fault (F153) (see Fig. 4).

The West Branch of Xiaojiang Main fault (F7) belongs to the Holocene active fault, which starts in the north of Daduo and may intersect with the East Branch main fault near Xiaojiang village. It runs south through Wulong Basin, west margin of Cangxi Basin, west margin of Dianzhong Basin, Qingshuihai, upstream reservoir and west Luliangshan, and enters Songming Basin to be covered. After the north of Yanglin emerges again, it passes through Yanglin, Nanchong, Dongguying, Qianji, to the people of Shijiazui Yangzonghai, and after leaving Yangzonghai, it extends to the northwest margin of Chengjiang Basin through the southwest margin of Yangzonghai Basin. With a total length of about 220km and a general trend of nearly North-South, westward and steep dip Angle, the fault belongs to the Holocene active fault and belongs to seismic fault. It is located on the east side of the proposed site, about 5.5km away from the proposed site.

The Baiyi-Hengchong fault (F149) belongs to the early and middle Pleistocene fault. The fault starts from Songgongyi in the north, passes through Guiguan, Tongniusi Reservoir and Guolin Reservoir in the south and is covered by the fourth system, and is presumed to continue south to Daxinche Village and Baizhiying line, with a length of more than 100km, which is a deep regional fault. North of Tongniu Temple is the northern section, the fault extends in a soothing wave shape with good continuity, which is reflected as a series of small river valleys and quaternary intermountain basins. A series of secondary faults parallel to the main faults are developed in both the upper and lower plates of the faults, forming a wide fault zone composed of several secondary faults.The occurrence of the fault is generally eastward, and the dip Angle varies greatly, about 40 ~ 70 °. The dip Angle of the northern section is slow from north to south, and the local dip Angle is 30 °. The strata in the eastern part of the fault are relatively older than that in the western part, indicating that the eastern branch of the fault is the ascending wall of the eastern part, and its nature is a left-moving translator-reverse fault. It is the eastern boundary of the lower Pleistocene lake basin in Kunming Basin and is a basement fault. Located on the west side of the proposed site,

approximately 11.5m away from the proposed site.

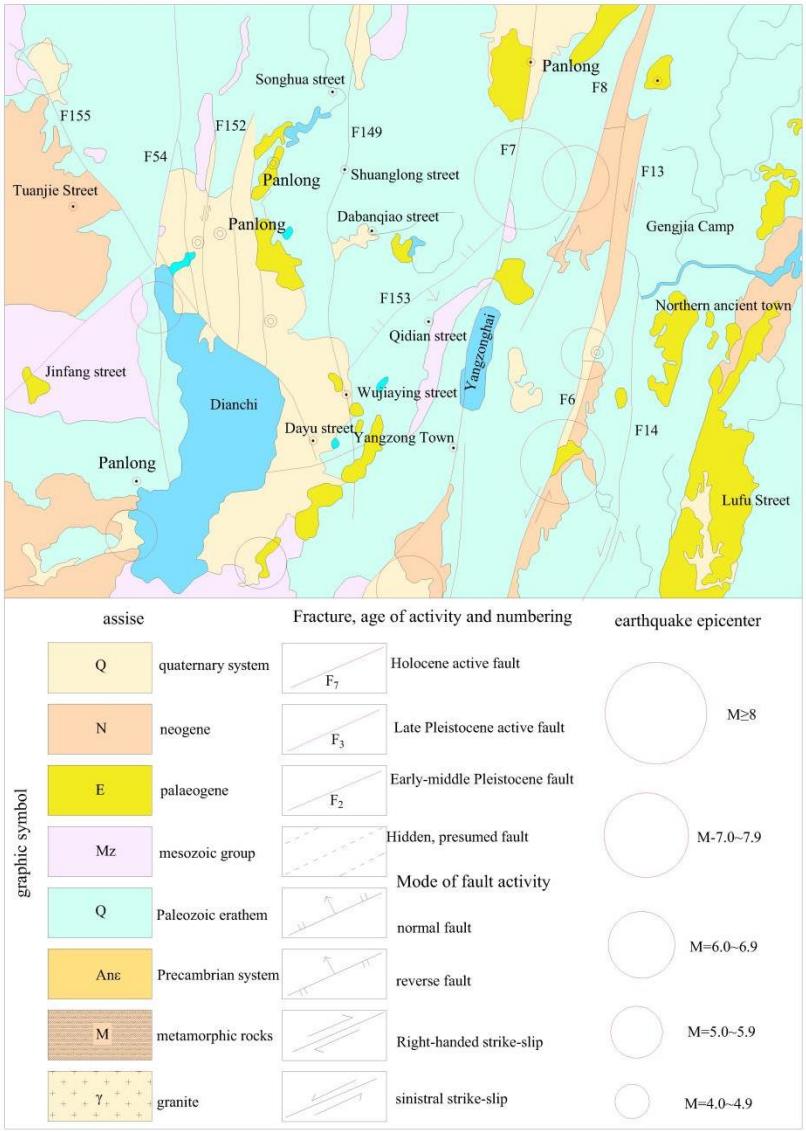

Figure 4: Structural fracture map of the proposed site area (Modified according to Yunnan Quaternary active fault distribution map 2018)

One cloud fault (F153) belongs to the late Pleistocene active fault. A cloud fault spread in the southeast of Kunming Basin east of Jincheng-Chenggong basin edge, south from Dachunhe reservoir, north east through Longze Mountain, Daqingshi Rock reservoir, a cloud to the northeast of Xiaozhai village. There are obvious landforms along the fault, which are linear gullies and small basins extending northeastward. Tectonic rocks are developed, generally 5 ~ 10m wide, mainly cataclastic rocks, including extrusion lenses, and gouges of varying thickness near the main section, indicating that the fault has compressive characteristics. The length of the fault is about 25km, with a dip to the southeast and a dip Angle of 30 ~ 36 º. The area of Daxinshu shows a normal fault, and a cloud with a certain compressive torsion. Located on the north west side of the proposed site, about 3.5km away from the proposed site.

Xiaojiang West Branch main fault passes through, and the nearest distance from the proposed project is about 5.5km. For the buildings within the influence range of the seismic fault, the ground motion parameters should account for the near-field influence during the foundation design, and it

is recommended to multiply the increase factor of not less than 1.25.

2.3.4 Neotectonics and earthquakes

The neotectonic movement zone of the project area belongs to the middle Yunnan fault block uplift area, and is further classified into the Kunming ~ Shiping fault block differential uplift area according to the intensity of the neotectonic movement. The crustal stability zone belongs to Dongchuan ~ Gejiu unstable region, which is located in the southeast corner of Kangdian Ling Block. The Xiaojiang fault zone is the main active fault in this region. The fault zone stretches from the north of Qiaojia to the southeast of Jianshui in the south, with a total length of over 400 kilometers. The fault zone was formed in an early age, has a long development history, and has experienced multiple periods of tectonic activity. Since the Neotectonic period, the fault activity is characterized by strong left-lateral strike-slip movement and vertical difference of fault blocks on both sides. The fault zone is composed of multiple secondary shear faults and tension-shear faults, and its internal structure is complicated. According to its structural characteristics and the difference in the degree of new activity, it can be roughly divided into three major segments: north, middle and south, and the middle and south segments can be subdivided into a number of more secondary segments.

The project area is located in the eastern edge of Xiaojiang Seismic Belt (Fig. 5), where the neotectonic movement is strong and the surrounding seismic activities are frequent and intense.

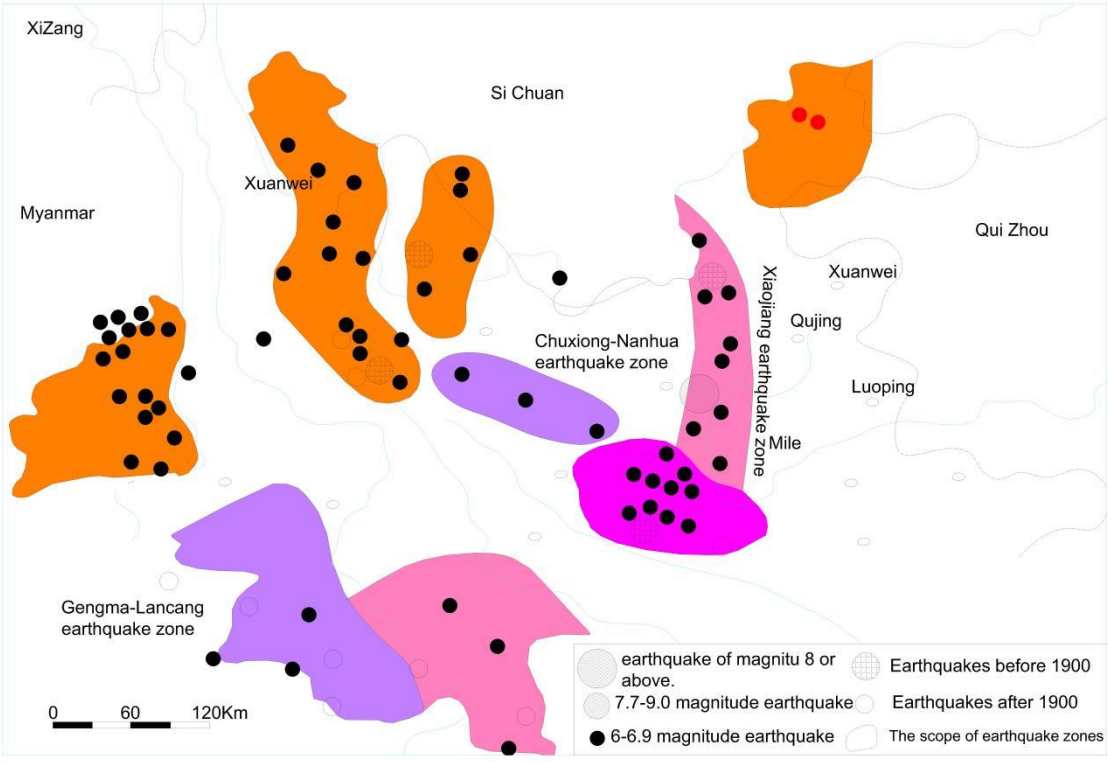

Figure 5: Distribution map of M≥6 earthquake in Yunnan region[9,10]

2.4 Hydrogeological characteristics

The Qidian River flow system belongs to the Yangzonghai Basin in the upper reaches of the Pearl River System. Yangzonghai lake is a fault depression tectonic lake[7]. Located in the

Xiaojiang fault zone, it is a graben-type fault depression lake formed due to the strong development of ground faults. With the evolution of the tectonic depression, Yangzong and Tangchi fault basins were formed first, and on the basis of the basins, tectonic lakes were developed. Yangzonghai basin covers an area of about 252.7km², the lake surface is 31.1km², the annual water level is 1770.46m, the average water depth is 20m, and the total water storage capacity is 604 million m³.The main rivers into the lake are Yangzong River, Baiyi River and Seven Star River, among which Yangzong River is the main natural river into the lake in Yangzonghai, and there are two sources: the right branch of Mazhuang River is the right river, the second is the left branch of Shizhai River; Qixing River, originated from the southwest of Yangzonghai mountainside Qing, the source elevation of 2300 meters, the river length of 6.37 kilometers, built in the middle of the small (I) Qixing River reservoir; Baiyi River, which does not belong to the natural basin of Yangzonghai, was connected to Yangzonghai in 1960 through a man-made flood diversion channel.

The project area is mainly based on atmospheric precipitation recharge. Due to the relatively high terrain of the proposed route (2015~2046m) and good natural drainage conditions, there is no karst water development in the site, and the atmospheric precipitation flows into the karst depression after falling on the surface, and is discharged to the southeast through the fall cave and the dissolution cave. According to the topography and the lithology of the site, the water in the interior of the site is deeply buried, and the boreholes in the site have not revealed the stable groundwater level, and there is only a small amount of pore water in the quaternary overlying layer, which has good natural drainage conditions, and belongs to the dry site.

3. Rock and soil physical and mechanical properties

Table 1: Statistics of physical and mechanical properties of soil

index value	Water content	**wet density**	Pore ratio	Particle density	liquid limit	Fluidity exponent	**compression characteristic**	
							Compressibility factor	Compression Modulus
	ω	ρ	e	Gs	ω_L	I_L	$av_{0.1-0.2}$	$Es_{0.1-0.2}$
	%	g/cm^3	--	--	%	--	MPa^{-1}	MPa
Quaternary Holocene artificial deposit(Q_4^{ml}) ① artificial fill								
frequent and continuous	7	5	5	7	7		5	5
Maximum value	31	1.94	1.01	2.84	62		0.24	11.9
Minimum value	23	1.81	0.86	2.84	48		0.17	8.4
Mean value	27	1.86	0.95	2.84	54		0.20	9.8
Calibration difference	2.752	0.052	0.067	0.000	5.589		0.027	1.385
variable coefficient	0.103	0.028	0.070	0.000	0.103		0.132	0.142
correction factor	1.076	0.973	1.067	1.000	0.924		1.126	0.865
Standard value	29	1.81	1.01	2.84	50		0.23	8.4
Quaternary residual slope deposit(Q_4^{el+dl})③**red clay**								
frequent and continuous	34	34	34	34	34	34	34	34
Maximum value	46	1.86	1.43	2.92	83	0.21	0.49	13.3
Minimum value	32	1.68	1.04	2.84	51	0.00	0.17	4.6
Mean value	37	1.79	1.21	2.88	69	0.03	0.26	9.0
Calibration difference	3.832	0.043	0.100	0.025	7.440	0.054	0.069	1.980
variable coefficient	0.102	0.024	0.082	0.009	0.108	1.746	0.264	0.221
correction factor	1.030	0.993	1.024	0.997	0.968	1.517	1.078	0.934
Standard value	39	1.78	1.24	2.87	67	0.05	0.28	8.4

In order to obtain the physical and mechanical indexes of soil, a total of 41 soil samples were taken in this survey (31 samples were used for preliminary exploration), and conventional

geotechnical tests were carried out in the laboratory. 8 groups of rock samples were taken (1 group was used for preliminary exploration) and compressive strength tests were carried out. The mechanical indexes of Quaternary Holocene artificial deposits (Q^{ml}), Quaternary residual slope deposits ($Q4^{el+dl}$) and weathered dolomitic limestone in the Lower Permian Qixia Formation ($P1^{q}$) in the area are analyzed, and the analysis results are shown in Table 1 and Table 2.

Table 2: Statistical table of rock test results

Rock and soil name and stratification code	age and cause	**index value**	**grain density** (g/cm^3)	**wet density** (g/cm^3)	**dry density** (g/cm^3)	**water absorption** (%)	**void ratio** %	Compressive strength value(Mpa)
④Medium weathered dolomitic limestone	Lower Permian Qixia Formation (P_1^q)	**frequent and continuous**	8	8	8	8	8	8
		Maximum value	2.82	2.76	2.74	3.86	9.44	45.60
		Minimum value	2.70	2.54	2.45	0.49	1.33	25.83
		Mean value	2.77	2.70	2.66	1.58	4.12	35.16
		Calibration difference	0.040	0.070	0.090	1.017	2.424	6.065
		variable coefficient	0.015	0.026	0.034	0.644	0.589	0.172
		correction factor	0.990	0.983	0.977	0.565	0.602	0.883
		Standard value	2.74	2.65	2.59	0.89	2.48	31.06

The maximum water content (ω) of Quaternary Holocene artificial deposit (Q4ml) in the project area is 31%, the minimum value is 23%, the average value is 27%, and the coefficient of variation is 0.103. The average liquid limit ωL is 54%, and the average wet density (ρ) is 1.86g/cm3. The moisture content (ω) of quaternary residual slope deposit (Q4el+dl) red clay ranges from 32% to 46%, with an average value of 37% and a coefficient of variation of 0.102. The average liquid limit ωL was 69%, higher than the average (67%), and the average wet density (ρ) was 1.86g/cm3. The average wet density (ρ) of the weathered dolomitic limestone in the Lower Permian Qixia Formation (P1q) is 2.70g/cm3, and the compressive strength is 35.16Mpa.

4. Geotechnical engineering evaluation

4.1 Subgrade stability and suitability evaluation

The faults and folds are developed in the project area, which have great influence on the proposed line. According to the active fault distribution map of Yunnan Quaternary (1: 1 million) (jointly compiled by Map Institute of Yunnan Province and Seismological Bureau of Yunnan Province, May 2018), active faults develop in the project area, among which the Holocene active fault Small Jiangxi Branch Main fault (F7) belongs to the seismic fault, which is located on the east side of the proposed site, about 5.6km away from the proposed site, and has a great impact on the proposed line. The seismic fortification of the line should be carried out according to the regulations, and the near-field influence should be taken into account in the ground motion parameters of the foundation design.

According to the Comprehensive Survey Report of Yunnan Geological Structure and Regional Stability by Remote Sensing and the 1:100,000 Regional crustal stability evaluation map of Yunnan

Province, the crustal stability of the proposed project area belongs to the sub-unstable area (II2 area).

In this field, the landform type is single, the bad geology is relatively developed, the main type is karst development, and the special soil is mainly red clay on the surface of the site. The necessary engineering measures can ensure the stability of the site and the roadbed after proper treatment of the bad geology and special soil, and the suitable route can be passed.

To sum up, the site along the line is relatively stable and suitable for project construction after proper engineering treatment.

4.2 Evaluation of engineering properties of foundation soil

Based on geological survey, borehole disclosure, geotechnical test results, and standard penetration test results, the subsoil within the proposed road range is commented as follows:

(1) Quaternary Holocene artificial Deposit (Q4ml)

Artificial soil filling: the composition of this layer is mainly red clay, partially containing gravel, block stone and lone stone, the composition of the mother rock is dolomitic limestone and lone stone, and the abandoned soil is accumulated around the site. The backfilling time is 3 ~ 5 years, and it is located in the surface layer, and the backfilling is not systematically rolled, and it is loose. This layer of soil is distributed in the starting point of Guangfa Middle Road, which is an excavated subgrade, and the field is clear and has no impact on the proposed road.

(2) Quaternary plant layer (Q4pd)

Cultivated soil: the proposed road is widely distributed within the scope, the soil uniformity is poor, distributed in the surface layer, relatively thin, this layer of soil can not be used directly as the subgrade, it is recommended to remove the subgrade filling.

(3) Quaternary residual slope volume (Q4el+dl)

Red clay: The proposed road is widely distributed in the range of hard plastic shape, the average pore ratio e is 1.21, the average liquid index IL is 0.03, and the average compression coefficient A1-2 is 0.26MPa-1, with medium compressibility. The standard value of direct shear is 51.10kPa and the standard value of φ is 11.30°. The average number of blows measured in the standard penetration test (N63.5) is 21.1 blows, the bearing capacity characteristic value fak=160KPa, and the mechanical properties are general. When the load and deformation requirements are met, it can be used as the supporting layer of the proposed road foundation.

(4) Lower Permian Qixia Formation (P1q)

Medium weathered dolomitic limestone: Cryptocrystalline to fine crystalline structure, medium and thick layer structure, joint fissure development, solution hole and solution gap development, hard rock, hammer sound brittle, relatively complete rock mass, core mostly columnar or short columnar, distributed in the site, this layer is stable underlying bedrock, bearing capacity characteristic value fak=1500KPa, good mechanical properties, is a good foundation bearing layer.

4.3 Evaluation of foundation soil uniformity

The survey scope of the proposed site is large, and the composition of the foundation soil layer is quite complex. Although the main strata of the foundation soil are relatively stable, the sedimentary thickness varies in different sections, and the transformation of the stratum lithology and physical and mechanical properties also change greatly. From the analysis of different sections of the whole survey site, the geological unit layers of the foundation are different in thickness, burial depth and mechanical properties. The ground soil is uneven in the horizontal and vertical directions. Therefore, the site is an uneven foundation.

5. Conclusions and Suggestions

(1) The proposed site is located next to the Aero-Art Port area of Qidian Industrial Park, Chenggong District. It is a low-middle mountain gentle slope area with structural denudation. The site along the proposed road is an uneven foundation and the road is an unfavorable seismic zone. However, the site along the line is more stable and suitable for project construction after proper engineering treatment.

(2) There are seismic faults within 10km of the site of the project area. For structures within 10km of both sides of the seismic faults, the ground motion parameters should take into account the near-field influence. Beyond 5km, it is appropriate to multiply by an increase factor of not less than 1.25.

(3) The proposed site is located in the territory of Qidian Street, Chenggong District, according to the relevant provisions of Code for Seismic Design of Buildings (GB50011-2010 edition), Code for Seismic Design of Highway Engineering (JTG B02-2013) and General Code for Seismic Resistance of Building and Municipal Engineering (GB 55002-2021) : The basic ground motion peak acceleration of the site is 0.30g, the response spectrum characteristic period is 0.45s, the design earthquake group is the third group, and the seismic fortification intensity should be 8 degrees.

(5) According to the Comprehensive Survey Report of Yunnan Geological Structure and Regional Stability by Remote Sensing and the Evaluation Map of Regional Crust Stability in Yunnan Province (1:100,000), the site area belongs to the sub-unstable area of crust (II2 area).

(6) The area of the proposed site is mainly supplied by atmospheric precipitation. Due to the relatively high terrain of the proposed route, there is no karst water development in the site, and the atmospheric precipitation flows into the karst depression after falling on the surface, and is discharged to the southeast through the drainage caves and dissolution caves. According to the topography and the lithology of the site, the water in the interior of the site is deeply buried, and the boreholes in the site have not revealed the stable groundwater level, and there is only a small amount of pore water in the quaternary overlying layer, which has good natural drainage conditions, and belongs to the dry site.

(7) The bad geological processes along the line are mainly karst, and the special rock and soil along the line are mainly red clay.

(8) When the subgrade base is directly located in layer 3 red clay, if the load and deformation requirements are met, this layer can be directly used as the supporting layer. However, this layer belongs to red clay (high liquid limit soil) and has local expansibility, so it should be treated according to relevant red clay subgrade specifications. When subgrade is backfilled, this layer of soil in the site cannot be backfilled. The foundation treatment should be carried out, the composite foundation should be used, and the treatment method can be dynamic compaction or replacement filling. When the subgrade foundation is directly located in ④ dolomitic limestone, this layer can be directly used as the supporting layer. However, the rock-filled subgrade should be used in the boundary section of the rock-soil subgrade, especially in the heavily weathered section, to ensure the compactiness of the rock-filled subgrade and avoid the formation of large uneven settlement. If the subgrade basement exposes karst caves, the foundation treatment should be carried out, and the treatment methods can be backfill, crossing, etc., to meet the requirements of the subgrade load.

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References

[1] Qiang Chen. Application analysis of defect strengthening technology of highway subgrade [J].Engineering and technological research, 2023, 129(8):211-213.
[2] Jianying Qi, Zhencheng Xu, Xiangping Li, et al. Study on the morphological distribution and source of arsenic in Yangzong Sea water[J]. Anhui Agricultural Sciences, 2010, 38(20):10789-10792.
[3] Ren S C. Karst groundwater system and its vulnerability assessment in Yangzonghai Basin, central Yunnan [D]. Yunnan: Kunming University of Science and Technology, 2010:7~60.
[4] Wang Zhaoxin, Zhou Wentao. Stability analysis of highway subgrade filling construction process [J]. Value Engineering, 2024, (2): 106~108.
[5] Zhongqiu Xie, Wan Zhiqing, Qian Haitao. Mechanism analysis and control of subgrade collapse caused by pumping in karst area [J]. Highway, 2006, 7 (7):25-28.
[6] Yingchun Xu. Analysis on causes of urban road surface collapse and discussion on prevention measures [J]. Shanxi Architecture,2016,42 (14) : 138~140.
[7] Yang Xiaoyan,Ren Shichuan. Structure model of karst groundwater system in Yangzonghai Basin, Yunnan Province [J]. Yunnan Geology,2014,33 (1) : 103 ~ 107.
[8] Xiao Shan Yu. History of forest fires in Yangzonghai Basin in recent 1300 years and their relationship with climate change and human activities [D]. Yunnan: Yunnan Normal University, 2016:10~11.
[9] Zhang Yumei, Liu Wenlong, ZHONG Ting. Fault and seismicity in the middle south section of the west branch of Xiaojiang Fault zone [J]. Journal of Yunnan University (Natural Science Edition),2023,45 (S1) : 290-299.
[10] Zou Jianye, Zhou Qiongli, Fan Qian, Zhang Yi, Chen Liang. Study on suitability evaluation of construction land in seismic planning of Yangzonghai Area [J]. Shanxi Architecture,2023,49 (9) : 56~65.