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Geological survey and drilling technology of karst land

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ABSTRACT

The nature of karst soil is complex in the karst area. Before construction, it is necessary to investigate karst geological conditions in an all-round way to provide security for construction. Based on the karst treatment of a city bridge, a comprehensive geological survey method is studied, including engineering geological mapping technology, drilling technology and remote sensing technology. The task of a geological survey and mapping is to compare and select routes and engineering schemes, formulate survey outlines and provide basic geological survey data. Drilling technology designs construction scheme based on geological data and drilling depth of the study area calculates the action load of drilling casing to ensure the safety of drilling tool cross-section, strictly controls drilling quality, and finds out the lithology, geological structure and karst development conditions of the stratum in a certain depth of underground. Finally, the geological survey of the karst area is completed by referring to remote sensing images acquired by remote sensing technology. The results show that karst grooves, stone buds, depressions, karst caves, and underground rivers are distributed in the study area, and the composition of karst strata and lithology of each stratum is analyzed in detail based on drilling technology and geological survey technology.

Keywords: Karst area; Rock and soil; Geological exploration; Drilling technology; Borehole; Remote sensing

1. Introduction

Karst, also known as karst, refers to the comprehensive geological action of water on soluble rocks (carbonate rock, sulfate rock, halide salt, etc.) characterized by chemical dissolution (including mechanical erosion of water and transport and re-precipitation of materials), and the various phenomena resulting therefrom [1]. Karst is a very common adverse geological phenomenon in China. For a long time, various karst forms, karst groundwater and other adverse geological effects in the construction of various projects in karst areas are the main factors affecting the stability of the foundation, engineering quality, and safe use, and are also the main hidden dangers in the use process [2]. Usually, the geological structure of the karst area is very complex, karst of various ages and genesis is very developed, and the engineering construction is difficult. Today, with the rapid development of economy, the exploitation of resources in karst areas around the world is becoming more and more intensive, and the karst collapse induced by it is becoming more and more frequent, and it has become the main environmental geological hazard in karst areas [3–5]. The extensiveness and harmfulness of karst collapse geological hazards have aroused the widespread concern of the international community [6].

The purpose of karst site investigation is to find out the laws of karst development, the scale, density and spatial distribution of various forms of karst, the thickness, spatial distribution and engineering properties of shallow soil at the top of karst, and the cyclic alternation of karst water, which have an impact on-site safety and foundation stability [7]. The study of karst collapse formation mechanism, prediction and evaluation, and comprehensive treatment in China

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involves many disciplines and methods and has achieved some results.

Based on the full analysis of the successful experience of karst exploration technology in China and abroad, new construction technology and pile foundation construction technology, this paper adopts a comprehensive geological survey method to study the geological structure of the karst area [8–10]. Based on the Karst Treatment of a certain bridge in a city, according to the karst problems that occur and may occur, and according to the specific situation and investigation results, the appropriate survey methods and construction treatment methods are put forward [11].

2. Materials and methods

2.1. Survey of research areas

The study area is a city bridge, the bridge location mileage pile number is *K*0+540–*K*1+400, the total length is 860 m. The survey work is mainly carried out under the relevant requirements of "code for highway engineering geological survey" (JTJ064-98), "code for design of foundation and foundation of highway bridges and culverts" (JTJ024-85) and "code for geotechnical engineering survey" (GB50021-2001); the exploration workload is mainly based on "code for highway engineering geological survey" (JTJ064-98). The location and quantity of exploration boreholes are arranged by Changsha Planning and Design Institute Limited Liability Company, China. A total of 32 exploration boreholes are arranged. Due to the complex geological conditions and karst development in the construction site, and the influence of the faults near the site, secondary structures were found in the site. After consultation with the headquarters and design units, three additional exploration boreholes (ZK33–ZK35 boreholes) were set up in the upper reaches of Liuyang River to conduct geophysical prospecting as a comparative bridge site [12].

According to the rectangular coordinate system of Changsha provided by the bridge construction command and the borehole coordinates on the "drilling plane map of bridge location" provided by the designer, the total station is used to survey and locate the borehole, and its elevation is the Yellow Sea elevation [13].

2.1.1. Topographic features

The bridge is located at the intersection of a road and a river in a city. The bridge site belongs to Alluvial-diluvial terrace landform with a riverbed width of about 220 M. The South Bank Avenue has been built under the embankment of the river area, and the north bank is an alluvial accumulation area with relatively flat and open terrain, covering vegetable fields and ponds.

2.1.2. Climate and hydrogeological conditions

The study area is a subtropical monsoon climate with warm, humid and abundant rainfall. The annual average temperature is 28.9°C, the annual precipitation is 1,562 mm, the annual sunshine is 1,695 h, the frost-free period is 272 d, the rainstorm occurs at the turn of spring and summer, which accounts for 40% of the annual precipitation in April-June. The water network is dense and there are rivers. The water flows into the river basin of the study area [14]. The main groundwater types in the bridge site are groundwater and confined water (upper stagnant water is only locally distributed), pore water (micro-confined water) in the gravel is the main source of recharge. The groundwater level is generally between 6.40 and 15.00 m, equivalent to the elevation of 24.01 to 26.21 m, with abundant water and underground water. The variation of water level and water volume is influenced by seasonal factors and river water in the basin. Surface water recharges groundwater in the rainy season and surface water recharges groundwater in the dry season [15]. Confined water is mainly karst fissure water in a calcareous conglomerate. The recharge source is mainly overflow recharge of surface water and groundwater, and the groundwater level is generally 7.40 to 15.10 m, equivalent to the elevation of 23.71 to 24.82 m, water is abundant, and the change of groundwater level and water volume is less affected by season: the upper layer of stagnant water is only pored water in filling soil and silt, and the source of recharge is atmospheric precipitation and pond water. The water volume is small, and the depth of the water level is 1.10 m, which is equivalent to the elevation of 31.05 m.

2.1.3. Regional geological structure and earthquake

The survey area is located in a city depression, which belongs to the South and west end of YonganDiwa. Under the action of continuous arch faults, the red basin with gentle folds is composed of diwa sediments, and the active fault zone composed of three main faults which are active until late and recent periods is characterized by gentle stratigraphic occurrence [16]. According to the outline map of the geological structure of a city (1:50000), three faults are intersecting near the bridge site (east side) and striking nearly east-west, north-east and north-west (*F*2), of which *F*2 is a geophysical interpretation fault and has the nature of the reverse fault.

2.2. Comprehensive geological survey method of karst land geology

Karst is heterogeneous and uncertain in spatial development, and the engineering geological and hydrogeological conditions are very complex. In karst engineering investigation, it is generally difficult to obtain satisfactory results if a single survey method is adopted. In the past, owing to insufficient understanding of karst, single survey method, unknown karst development conditions in the engineering area, unreasonable engineering treatment measures or inadequate treatment, the construction period of some large-scale engineering projects was delayed, and major engineering events such as subgrade collapse, subgrade water damage, tunnel water inrush occurred during construction or during the project operation stage. As a result, great losses have been caused [17]. Therefore, engineering investigation in the karst area plays a very important role. Through comprehensive investigation, the engineering geological conditions and hydrogeological conditions of the site are ascertained, the distribution conditions and filling conditions of karst caves are ascertained, and the conditions of groundwater recharge, runoff and discharge are ascertained, to provide reliable and comprehensive geological data for engineering construction [18].

Through an extensive collection of relevant engineering data and previous research results, the collected data are sorted out, analyzed and studied, and reliable methods suitable for engineering geological investigation in karst areas are summarized. The specific application of these methods in engineering is analyzed and summarized, and the statistical tables of karst distribution in engineering areas are obtained.

2.2.1. Engineering geological mapping technology

Engineering geological mapping is one of the most basic and important survey methods in the karst area and is also the preferred one among many survey methods. Its results are the selection of routes and engineering schemes, the formulation of survey outlines, and the preparation of basic information for engineering geological survey reports [19]. Engineering geological mapping is characterized by simple instruments and equipment, easy operation, practical and convenient, less capital consumption, shorter working cycle. Surveyors can intuitively obtain field engineering geological related data and information. In practical work, geotechnical engineers should obtain as much geological information as possible within the scope of engineering geological mapping, understand the engineering geological conditions of the engineering site, and make a more accurate judgment of the underground geological conditions, to provide a basis for the layout of drilling, geophysical exploration and other work [20,21].

Engineering geological mapping in the karst area includes surface mapping and cave surveys. The basic requirement of surface surveying and mapping is to ascertain the distribution of karst, soil cave, groundwater and its migration law in the engineering area based on analysis of various geological elements. The research contents mainly include: (1) the horizontal and vertical distribution of karst and non-karst strata in the engineering area and the relationship between them; (2) field surveying and mapping engineering. The occurrence, extension length, filling and fluctuation degree of structural planes with different mechanical properties in the area are investigated, the relationship between structural planes with different occurrences is identified, and the dominant direction of structural planes with different hydraulic properties is distinguished. Thirdly, according to the distribution of groundwater outcrop, the outcrop point of groundwater is evaluated to be related to the underground River system.

Cave investigation should be carried out in karst and soil cave development areas. The contents of karst cave investigation mainly include the following two aspects: first, to find out the morphological characteristics of caves and their relationship with geological structure, especially the measurement of roof height and structural plane occurrence, to provide information for the study of karst development law and roof stability analysis; second, to clarify the supplementary drainage conditions of the groundwater system and to identify the underground water outcrop point and recharge and drainage of surface water and groundwater system [22,23].

2.2.2. Drilling technology

Drilling technology has always been the most commonly used method in geological prospecting. This method can not only ascertain the drilling location and the formation conditions nearby (such as geotechnical properties, thickness, groundwater level, etc.) but also conduct in-situ tests in boreholes and laboratory tests using drilled core samples to obtain more and more accurate geotechnical information. Drilling methods can be used under almost any conditions except that topographic conditions have an impact on the placement of tools [24]. The purpose of drilling work is to find out the stratum lithology, geological structure and karst development conditions within a certain depth of underground, especially when there is no karst phenomenon or overburden on the surface, it is necessary to arrange drilling holes reasonably based on engineering geological mapping and engineering geophysical prospecting results, combined with engineering requirements. Various drilling methods can be used in engineering geological investigation. It is necessary to select suitable drilling methods according to specific geological conditions and design requirements. Also, to make better use of boreholes to find out the hydrogeological conditions of the site, the existing boreholes can be used to carry out hydrogeological tests such as borehole pressure test, water injection test or pumping test. When conditions permit, geophysical exploration wells and borehole television can also be carried out in boreholes to cooperate with core cataloging data to better identify the geological conditions around boreholes.

2.2.2.1. Drilling construction design Reasonable drilling construction design should be based on the geological data, drilling depth, drilling technology level, drilling equipment and tools of the project area. Under reasonable construction conditions, the main principles of drilling construction design in the project area are to obtain the highest drilling efficiency, the best drilling engineering quality and the lowest drilling cost [25–27]. The main contents of drilling construction design include borehole structure, casing program, mud system, selection of drilling equipment, selection of drilling methods, prevention and treatment of accidents in boreholes, optimization of rules and parameters, etc. At the same time, various geological factors of the geological environment also have an important influence on drilling construction design, and geological factors mainly include stratigraphic structure, geological structure, rock mass structure, rock properties, mineral composition, geological weathering, groundwater and so on. Fig. 1 shows the geological influence factor of drilling design.

Stratigraphic structural factors provide the structure and distribution of various lithologic units, and give the corresponding physical, chemical and mechanical characteristics. Geological structure refers to a form leftover by deformation or displacement of rock strata or rock mass under the action of internal and external stresses of the earth. Rock mass structure is determined by rock texture, grain size, rock density, types and characteristics of rock joints. Rock properties can be divided into two types. One is the physical properties of rock, which refers to the interaction between rock and the external force field. The other is the mechanical properties of rock, which are the characteristics of rock under mechanical external force, such as strength, hardness, elasticity, plasticity and abrasiveness. Geographic weathering has a great influence on the effectiveness of drilling fluids. Geographic

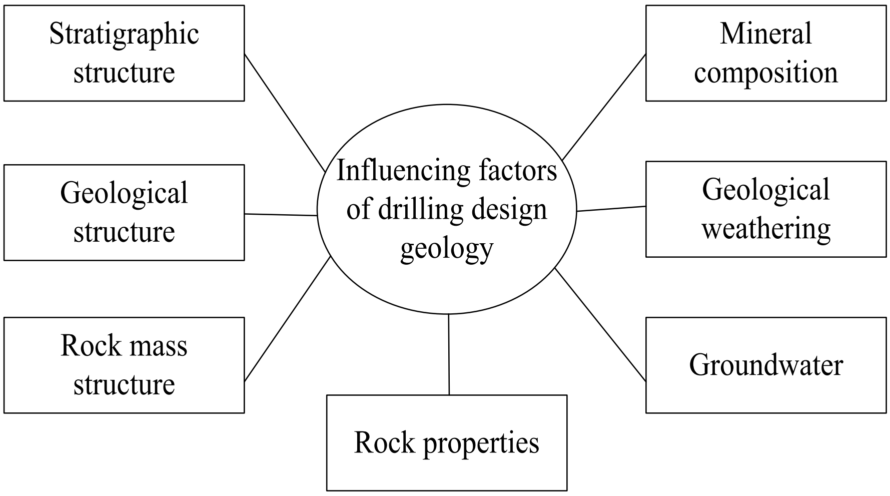

Fig. 1. Geological influencing factors of borehole design.

weathering can change the geological and chemical properties and mineral composition structure of rocks, and then change their hardness, stress and other characteristics. The sudden increase of groundwater in the drilling process will not only erode the core, resulting in a low core recovery rate but also cause damage to the borehole wall of overpressure formation. Therefore, the groundwater factor is also an important factor that must be taken into account in drilling design and drilling quality control.

2.2.2.2. Load calculation of drilling casing In the process of drilling construction in the project area, sometimes the cross-section of the drilling tool may be dangerous if too much force is exerted or too much load is exerted on the drilling tool in the process of moving the drilling tool. How to find out the problem in time and accurately before the danger occurs and take corresponding measures is the premise to ensure the smooth drilling construction, which needs to be applied. The related formulas of drilling construction can calculate the maximum tension and the maximum depth of the drilling tool, and solve the problems in the drilling process in time [28].

The maximum tensile stress is produced at the dangerous section of the pipe by the self-weight of the casing string. The calculation of the tension P_k produced in the casing string immersed in the flushing fluid and not suspended on the casing clamping device is shown in Eq. (1):

$$P_k = gqL\left(1-\frac{\rho}{\rho_M}\right) \tag{1}$$

In the formula, q is the mass of a pipe per meter in kg, L is the length of a casing string in m, ρ and ρ_M are the density of flushing fluid and pipe respectively in kg/m^3.

Eq. (1) directly calculates the tension generated in the casing string, and judges whether the casing string will be dangerous or not, whether it can continue to be used, to discover problems in time and solve them in time.

The lowering limit depth Z_{np} (m) of the casing string is calculated according to the strength of the weakest section of the pipe. It can be calculated according to Eq. (2):

$$Z_{\text{np}} = \frac{F_0\sigma_T}{2gq\left(1-\frac{\rho}{\rho_M}\right)} \tag{2}$$

In the formula, σ_T is the yield limit of pipes in-unit Pa. F_0 is the dangerous section of the fastening part of the pipe car, in m^2. The calculation of F_0 is shown in Eq. (3).

$$F_0 = \frac{\pi}{4}(d_{\text{BP}}^2 - d_{\text{BH}}^2) \tag{3}$$

In the formula: d_{BP} is the inner diameter of the thread; d_{BH} is the inner diameter of the joint. Eq. (1) and (3) can simplify the calculation of the ultimate depth Z_{np} of the casing string to a quantity related to the tension P_k, thread inner diameter d_{BP}, joint inner diameter d_{BH} pipe yield limit σ_T and casing string length generated in the casing string. The simplified results can be found in Eq. (4):

$$dZ_{\text{np}} = \frac{F_0\sigma_T}{2gq\left(1-\frac{\rho}{\rho_M}\right)} = \frac{\pi(d_{\text{BP}}^2 - d_{\text{BH}}^2)\sigma_T L}{8P_k} \tag{4}$$

2.2.2.3. Drilling quality control *Borehole location*: Borehole location is determined strictly according to the coordinates in the "exploration work scale". The measurement error is controlled inland area with horizontal accuracy ±0.10 m and elevation ±0.01 m; water area with horizontal accuracy ±0.50 m and elevation ±0.10 m.

Drilling hole depth: In the actual drilling process, the drilling design hole depth should be reached, and more than 10 cm should be drilled, to avoid the drilling rod quantity depth not reaching the drilling design hole depth when accepting the drilling hole depth.

Drilling sampling: General roadbed silt and rubbery soil should be taken as original sample, sampling spacing 1.0–2.0 m, sand, and gravel soil sampling disturbance, sampling spacing 1.0–2.0 m. In high embankment, silt and clay should be sampled as they are. In the depth range of 0–10 m, the sampling interval should be 1.0 m, and the sampling interval below 10 m should be 1.5 m. In the course of drilling, the variable layer should be sampled immediately. Disturbance samples can be taken for Sandy and gravel soils, the sampling interval should be 2.0 m, and the changing layer should be sampled immediately.

Drilling record: The content of the drilling record is clear, comprehensive and standardized. It is necessary to record in detail the change of stratum, the thickness of the stratum, the depth of the groundwater table, and the drilling conditions and drilling methods.

Hydrological observation: Stable water level is measured and recorded within 24 h at the end of borehole.

The above requirements of drilling quality control require strict control in the process of drilling construction, to avoid the implementation of drilling construction according to the requirements, resulting in unsatisfactory quality of cores taken out, inaccurate data of geotechnical tests conducted by geotechnical samples, resulting in misjudgment of stratum lithology, thus affecting the accuracy of geological data. Furthermore, it cannot help the follow-up work [29,30].

2.2.3. Remote sensing technique

According to the theory of electromagnetic radiation, remote sensing technology receives electromagnetic wave information from long-range targets by various detectors in modern technology and transmits it to ground receiving station to process remote sensing data (image or data) for detecting and identifying targets [31]. It is based on modern physics, mathematics, electronic computer technology, and geoscience law, and has the characteristics of large investigation area and good repeatability. Remote sensing image can reflect the characteristics of a certain depth of the surface and subsurface macroscopically and truly, and the spatial relationship of various geological phenomena. Remote sensing image has a wide horizon and a large amount of information. In recognition of karst geomorphology, division of karst strata and geological structural characteristics, it has advantages that other exploration methods cannot do. Since the introduction of satellite remote sensing, aerial remote sensing, thermal infrared remote sensing, and side-looking radar remote sensing into China in the 1970s, the earth resources satellite remote sensing has brought into play the characteristics of the large survey area and good repeatability in engineering practice, which has been achieved for the research and practical application of karst topography, stratigraphic division, groundwater distribution, geological structure, etc. It is widely used in geological mapping in karst areas. Generally speaking, this technology is usually applied to the feasibility study stage of large-scale projects.

3. Results

3.1. Analysis of karst geological development in the study area

Based on the comprehensive survey results of rock geology in the study area obtained by this method, it is shown that karst mainly develops in exposed and overburden karst areas. The karst development patterns are different in strata of different ages and tectonic locations. The main types of karst are karst grooves, stone buds, depressions, karst caves, and underground rivers. No historical karst collapse has been observed in the study area.

3.1.1. Dissolving ditch, dissolving trough and stone bud

When rainwater or surface water flows along cracks or fissures on the bare surface of carbonate rocks on slopes, the cracks or fissures of rocks are often dissolved and expanded to form deep solution ditches and solution troughs; there are many conical or pointed ridges between the crisscross solution ditches and grooves, which are called stone buds, and the solution ditches and stone buds are symbiotic. This type of karst is mostly developed in the middle and upper reaches of the study area, as shown in Fig. 2.

3.1.2. Solution depression

The dissolution of depression is formed by the further dissolution of a funnel and the action of groundwater. The bottom or edge of the depression often develops falling water caves or collapses to absorb surface water flow. It is the product of the vertical action of karst evolution. It has been found that the karst depression developed in the study area mainly distributes in the downstream interruption part of the study area, as shown in Fig. 3.

3.1.3. Karst caves and underground rivers

The karst cave is a general term for caves formed by karst water dissolution with potential erosion and mechanical collapse. The survey results show that karst caves are widespread in the upper limestone section of the study area. Generally, it is full-filled karst caves, filled with brown-red clay, mainly plastic, a small amount of soft plastic caves, including breccia; individual caves are non-filled karst caves. The depth and thickness of the karst cave roof are different in different locations of the project area. The depth and thickness of karst

Fig. 2. Ditches, troughs and stone buds developed in the study area.

Fig. 3. Dissolution depression developed in the study area.

Fig. 4. Karst caves developed in the study area.

cave roof developed in the first section are about 14.30 and 3.20 m; the depth and thickness of karst cave roof developed in the second section are about 18.2 and 4.2 m; and the depth and thickness of karst cave roof developed in the third section are 1.60–46.10 m and 0.15–15.80 m. When there is regular flow in karst caves and the flow is large, it is called a hidden river. The karst underground river is blocked by faults in the fault fracture zone and exposes to the surface in the form of karst springs. Fig. 4 shows the karst caves developed in the first section of the study area.

3.2. Karst stratum analysis

The results of the geological survey and drilling exposures in the study area are obtained by this method. The lithology of the karst bottom strata from top to bottom in the bridge site is summarized as follows:

3.2.1. Quaternary holocene

- *Filling soil*: brown-red, brown-yellow, grey-brown, Mars road foundation on the South bank, slightly wet, compacted, the upper part is leached concrete pavement (thickness 0.40–0.50 m), the lower part is clay; the northern bank is slightly wet-wet, loose structure, mainly composed of sub-clay, with a small amount of tile. The thickness of this layer is 0.20–15.50 m.
- *Planting soil*: grey-brown, slightly wet, loose. It is mainly distributed in vegetable fields on the north coast with a thickness of 0.60–0.80 m.
- *Quaternary silt*: grey-brown to grey-black, fluid-plastic to soft-plastic. It mainly distributes at the bottom of rivers and ponds with a thickness of 0.60–4.30 m.

3.2.2. Quaternary Pleistocene

- *Quaternary alluvial-diluvial clay*: brown-yellow, yellowish-brown, plasticize to a hard plastic state, with a small amount of gray-white kaolin and ferromanganese nodules locally, no shaking response, slightly smooth, medium dry strength, medium toughness. The thickness of this layer is 0.60–9.50 m.
- *Quaternary alluvial-diluvial silt*: yellow, slightly wet to wet, loose to slightly dense, mainly silt, containing a small amount of fine sand, mainly quartz, argillaceous content of about 40%. The thickness of this layer is 0.50–2.20 m.
- *Quaternary alluvial-diluvial gravel*: brown-yellow, slightly wet-saturated, slightly dense to medium-dense, with a gravel content of about 60%–75%, a particle size of 2–20 mm, the larger of 80 mm, is subcircular, mainly composed of quartz and siliceous rocks, filled by medium-coarse sand, shale content of about 10%. This layer is widely distributed with a thickness of 1.00–10.00 m.
- *Quaternary residual clay*: brown-red, brown-yellow, plastic to a hard plastic state, containing a small amount of gravel, local gravel is relatively concentrated, is formed by calcareous conglomerate weathering residual. This layer is mainly distributed to the north of hole ZK14, and its thickness ranges from 1.00 to 16.50 m.

3.2.3. Lower cretaceous Shenhuangshan formation

- *Strongly weathered conglomerate*: grey-green, dark purple, gravel structure, massive structure, gravel composition is mainly slate, a small amount of vein quartz and limestone, particle size 20–50 mm, larger 100 mm, sub-angular-sub-circular, sandy-argillaceous cementation, local calcareous cementation, joint fracture development, rock is very soft, the core is mostly fragmental, less. The rock core is easy to soften and crack due to water loss due to its block size, difficult percussion drilling, fast rotary drilling footage. The layer is mainly distributed in ZK1–ZK11 holes with a thickness of 6.50–13.30 m.
- *Weak weathered conglomerate*: grey-green, dark purple, gravel structure, massive structure, gravel composition is mainly slate, see a small amount of vein quartz and limestone, gravel particle size is generally 20–50 mm, larger 100 mm, sub-angular to sub-circular, sandy-muddy cementation, local calcareous cementation, rock is softer, cracks are more developed, the upper part of the rock mass is more. The core is mostly massive, the lower part of the rock mass is relatively complete, and the core is mostly columnar. This layer is mainly distributed in

ZK1–ZK11 holes, and the thickness of this survey is 13.10–57.90 m.

- *Fully weathered breccia*: grey-green, brown-yellow, with brown-red. The breccia mainly consists of slate and metamorphic sandstone, with a small amount of vein quartz. The diameter of the breccia is generally 10–50 mm, and the breccia is prismatic, and the breccia has been weathered in the form of soil. It is only distributed in ZK11–ZK13 and ZK33 holes with a thickness of 15.50–3.10 m.
- *Fully weathered calcareous conglomerate*: brown-yellow, purple-red, partially intercalated with thin argillaceous siltstone, the original rock structure is still recognizable, the rock is extremely soft, the gravel composition is mainly limestone, dolomite, a small amount of siliceous rock, sandstone and vein quartz, most of the gravel weathering is soil-like, contains a small amount of quartz gravel, local gravel is relatively concentrated. It is mainly distributed to the north of hole ZK12 with a thickness of 2.20–32.10 m.
- *Strongly weathered calcareous conglomerate*: purple-red, partially intercalated with thin argillaceous siltstone, gravel structure, massive structure, gravel composition is mainly limestone, dolomite, a small amount of siliceous rock, sandstone and vein quartz, the particle size is generally 2–40 mm, the larger is 80 mm, is subangular and round, calcareous cementation, joints, and fissures are developed, the rock is extremely soft. The rock mass is extremely fragmented, and the cores are mostly fragmented to massive. Water leakage is serious in some boreholes. This layer is generally distributed to the north of the ZK7 hole with a thickness of 0.80–23.50 m.
- *Weak weathered calcareous conglomerate*: purple-red, partially sandwiched with thin argillaceous siltstone, gravel structure, massive structure, well-developed fissures, gravel composition is mainly limestone, dolomite, a small amount of siliceous rock, sandstone and vein quartz, gravel size is generally 2–40 mm, the larger is 80 mm. Strong foaming, hard rock, core mostly short to long columnar, with dissolution pore, a pore diameter of 2–10 mm, strong local dissolution, core dissolution is half-sided, part of the boreholes (ZK10, ZK12, ZK14, ZK16, ZK17, ZK20–ZK25, ZK33 and ZK35) developed dissolution (soil) caves, the height of the caves is 1.60 m, the maximum is 20.20 m, brown. Soft-plastic to plastic clay is fully filled with more sand and gravel in part. Detailed data are shown in the table of karst caves encountered in the drilling hole in Table 1. Some boreholes leak in this layer during drilling. This layer is generally distributed to the north of the ZK7 hole with a thickness of 0.20–27.30 m.

3.3. Analysis of physical and mechanical properties of rock and soil

The standard penetration tests of filling soil, quaternary silt, quaternary alluvial-diluvial clay, quaternary alluvial-diluvial silt, quaternary residual clay, fully weathered breccia, and fully weathered calcareous conglomerate were carried out in this area, and the quaternary alluvial-diluvial conglomerate strongly weathered conglomerate and strongly weathered calcareous conglomerate were heavily eroded. In this survey, rock and soil samples are used for laboratory tests. The results of soil physical properties and rock physical properties tests are summarized as shown in Tables 2 and 3.

4. Discussions

According to the geological data of the study area and the research results obtained by using the geotechnical survey and drilling technology in this paper, the geological structure in the survey area of the bridge is more complex. According to the outline map of the geological structure of the city (1:50000), three faults intersect near the bridge site (east side), and their strike directions are near east-west, north-east and north-west (F2). Influenced by the above faults, the geological conditions of the bridge site are complex and secondary structures are developed. A small fault develops on the South Bank of the river basin (near hole ZK11). The fault strikes the

Table 1
List of karst caves encountered in boreholes

Borehole number		ZK10	ZK12	ZK14	ZK16		ZK17	ZK20	ZK21
Depth (m)	Cave roof	54.75	32.95	34.85	16.05	34.15	33.55	46.25	37.15
	Cave floor	65.25	36.35	44.05	21.25	42.25	45.65	56.25	52.25
Cave height (m)		10.55	3.45	9.25	5.25	8.15	12.15	10.05	15.15
Elevation (m)	Cave roof	–19.27	–2.84	–11.91	6.35	–11.85	–11.65	–11.87	–5.61
	Cave floor	–29.77	–6.24	–21.11	1.15	–19.95	–23.75	–21.87	–20.71
Filling in a karst cave		Full filling	Full filling	Full filling	Full filling	Full filling	Full filling	Full filling	Full filling
Borehole number		ZK22		ZK23		ZK24	ZK25	ZK33	ZK35
Depth (m)	Cave roof	37.45	57.85	36.55	51.55	45.55	38.55	68.05	62.85
	Cave floor	57.65	59.45	45.15	57.85	48.05	40.55	85.95	67.85
Cave height (m)		20.25	1.65	8.65	6.35	6.55	2.05	17.95	5.05
Elevation (m)	Cave roof	–2.56	–22.96	–3.72	–18.72	–9.36	–7.07	–28.91	–24.68
	Cave floor	–22.76	–24.56	–12.32	–25.2	–15.86	–9.07	–46.81	–29.68
Filling in a karst cave		Full filling	Full filling	Full filling	Full filling	Full filling	Full filling	Full filling	Full filling

Table 2
Statistical table of experimental results of soil physical and mechanical properties

Stratigraphic name	Quaternary silt				Quaternary alluvial clay				Quaternary eluvial clay			
	Maximum	Minimum value	Average value	Allowable bearing capacity	Maximum	Minimum value	Average value	Allowable bearing capacity	Maximum	Minimum value	Average value	Allowable bearing capacity
Natural water content /10–2	57.2	56.5	56.9		26.8	9.7	21.2		22.9	14.7	18.8	
Natural density	1.65	1.64	1.65		2.15	1.90	2.01		2.11	1.89	2.01	
Proportion	2.64	2.63	2.64		2.71	2.64	2.67		2.75	2.68	2.72	
Void ratio	1.536	1.506	1.517		0.712	0.384	0.616		0.722	0.496	0.623	
Plasticity index	14.6	12.6	13.3		16.9	11.3	13.3		16.5	12.9	14.3	
Liquid index	2.94	2.34	2.74	50	0.15	0	0.05	230	0.08	0	0.02	250
Compression coefficient	0.68	0.63	0.66		0.30	0.20	0.25		0.37	0.13	0.21	
Compressive modulus	4.06	3.75	3.89		8.8	5.9	7.1		13.1	4.61	9.39	
Internal friction angle	14.2	11.8	13.0		67.1	17.1	40.2		19.1	20.1	31.8	
Cohesive force	3.9	1.9	2.9		24.8	12.5	20.8		28.2	14.2	20.1	

Table 3
Statistical table of test results of rock physical and mechanical properties

Rock name		Weakly weathered conglomerate	Weakly weathered calcareous conglomerate
Uniaxial ultimate compressive strength of rock	Range value	7.18–16.55	13.88–35.12
	Average value	11.81	28.21
	Standard deviation	3.722	7.974
	Coefficient of variation	0.316	0.284
	Standard value	8.74	21.7
Remarks		Natural compressive strength	Saturated compressive strength

northeast and tends to the southeast. There are no fault signs on the North Bank of Hebei (near hole ZK22), but there are dissolution fissures and caves in the calcareous conglomerate. Near 30 holes) the deep geological conditions are good, and there are no faults and karst phenomena.

According to the results of karst strata lithology obtained by drilling technology, it can be concluded that the fault cut through the lower part of the Shenhuangshan formation (conglomerate and calcareous conglomerate) of Cretaceous but did not cut off the quaternary conglomerate. Based on this, it is inferred that the fault was developed after cretaceous and before the Pleistocene of quaternary, so it is considered as a non-Holocene active fault. There are calcareous conglomerates with high calcareous content in the bridge site, which are influenced by faults near the site and developed fissures in the rock, and the strong hydraulic connection between surface water and groundwater in the site results in strong karst development in Liuyang River and its vicinity. According to drilling data, the site ZK10, ZK12, ZK14, ZK16, ZK17, ZK20–ZK25, ZK33, ZK3 are well developed. There are karst caves in the 5th-grade boreholes, and multi-layer karst caves are locally developed. The height of the caves is only 1.60 m, and the height of the caves is 20.2 m. Karst development is extremely uneven. The elevation of the floor of the karst caves at the proposed bridge site ranges from 1.10 to 29.76 m. The fillings in the caves are soft-plastic sub-clay, and there are a lot of gravels in part, which is a full-filling type. Based on the geological investigation and drilling technology, the geophysical and mechanical properties of the studied area are obtained, and the physical properties of the quaternary silt, quaternary alluvial-diluvial clay, quaternary residual clay, such as natural water content, natural density, specific gravity, void ratio, plasticity, and liquid index, as well as the weakly weathered conglomerate, etc. are understood. Weak weathered calcareous conglomerate and other rock physical properties can reasonably determine the ultimate uniaxial compressive strength of rock, which provides a theoretical basis for further study of rock and soil geology in this area.

The results show that the stratigraphic structure of the study area is complex, and the adverse geological phenomena are well developed. The site can be considered according to the unfavorable seismic zones of the building. The site is generally stable and can be constructed. The engineering geological conditions, especially the distribution of faults and the development of karst in the study area are ascertained through comprehensive geological survey technology, which provides accurate geological data for the design of bridge foundation. The application of drilling technology in engineering geological investigation of major engineering construction projects in karst areas has a strong guiding significance for the next implementation of engineering geological drilling and in-situ testing and avoids blindness in work.

5. Conclusions

To accurately grasp the karst area and study an effective geological survey and drilling technology, a city bridge is taken as the research area, and the geological condition of the karst area where the bridge is located is studied by using the comprehensive geological survey technology of rock and soil. The research focuses on the most commonly used drilling technology in the geological survey. Through rational drilling construction design, the main principles of drilling construction design in the study area are to obtain the highest drilling efficiency, the best drilling engineering quality and the lowest drilling cost. The action load of drilling casing in the drilling process is calculated to avoid active drilling. In the process of drilling tools, too much force or too high load on drilling tools will cause danger to the cross-section of drilling tools. Through the requirements of drilling quality control, every link in the process of drilling construction will be strictly controlled to avoid the implementation of drilling construction because of not meeting the requirements, which will affect the accuracy of geological data. Although the comprehensive geological survey method is adopted in this paper, the geological survey of the karst area is very realistic, and various methods should be flexibly used. Therefore, a lot of study and practice of karst geological properties should be carried out in future work to better guide the engineering construction of the karst area.

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