Construction summary of karst grouting treatment for Railway Subgrade

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Abstract: The karst is one of the main bad geological problems, which determines the design of the subgrade treatment plan and the safety of the engineering construction. This paper summarizes the key technology of grouting in karst roadbed regulation, and the following factors should be considered in grouting scheme selection: grouting method, technology, material, equipment, grouting control and detection means and standard of grouting effect. Through the use of high density electrical method, transient surface wave method, core drilling method, pressure water test method and so on, study the targeted detection methods for different coverage karst types and different remediation methods.

Keywords: Railway; subgrade; karst; grouting

1. Introduction

In the process of construction of Railway Subgrade in karst strata, because there is a lot of construction of regional groundwater and karst, which makes the subgrade construction risk and difficulty have significantly improved, easily lead to great accidents in the region, or geological disasters caused by the size of a set. In addition, the karst geology itself has some complexity, diversity and high risk. Therefore, the construction of Subgrade in karst stratum is still one of the key technologies in the current roadbed construction.

2. Engineering survey

The management section of the 10 standard project of Chongqing Guizhou railway is DK239 to DK290, which is located in Zunyi county and Xifeng County of Guizhou province. The total length of the subgrade is 59. The geology along the line is complex and the karst develops. The mulching layer is quaternary silty clay, and the underlying bedrock is mainly limestone and marl, and the joints are more developed. The depth of groundwater is large, and the infiltration of surface water is the main cause of the karst ground collapse in this section.

3. Design principles for the regulation of Karst Subgrade

3.1 Scope and object of regulation

3.1.1 on dissolution trough and ditch cover layer thickness is greater than 30m or karst slope cover layer thickness is greater than 20m, generally not remediation (except easily collapse area).

3.1.2 The regulation range includes the easily collapsing area and the easily collapsing area in the karst collapse assessment area. The geophysical profile reveals the general development area of karst form, and is designed according to the combination of exploration and irrigation. In the center line interval 14m, the layout of exploration irrigation

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holes (left and right staggered layout) is used to identify karst development and decide whether to carry out remediation.

### 3.2 Renovation depth and measures

3.2.1 Shallow and open cavern
Cave roof and overburden soil thickness is less than 3m, generally take uncovery backfill gravel, stone processing or closed treatment measures.

3.2.2 Nude karstification
In order to eliminate the uneven foundation and prevent the ground collapse and deformation, we should strengthen the treatment of scattered small shallow caverns and dissolutions. the depth of grouting shall be no less than 5m. If there is a cavern in the depth of 15m below the ground, it shall be reinforced to not less than 1m below the cavern.

3.2.3 Covered karst
1. The karst cave and dissolution fracture zone in the slope area: the thickness of the surface covered soil is less than 20m, and the regulation is designed to 5M below the base rock surface.
2. The average thickness of overburden is less than 2m and the pit is not fully developed. After excavation and replacement, the exposed karst remediation measures are adopted for treatment.

3.3 The width of regulation

3.3.1 General regulation to 2.0m interval embankment outside the toe of the embankment; cutting general renovation to the new railway cutting side ditch platform.

3.3.2 Set up the section of the retaining wall of the shoulder and the retaining wall of the embankment and renovate to the 3.0m outside the toe of the wall.

3.4 The layout of the grouting hole

3.4.1 Easily collapsing area: for a section with a continuous length of more than 30m in the karst collapse area, the first pilot hole is carried out along the middle line with the distance of 7m. According to the comprehensive analysis of the strata, karst development and the grouting quantity revealed by the forerunner, it is determined whether the grouting treatment of the second order hole is implemented. If we need to carry out the second order hole encryption grouting, then the order hole is inserted and encrypted in the square center consisting of the first order pilot. I order the hole and the second order hole to form a diamond layout, and the spacing is 5m. When the support structure foundation needs grouting, I, II and III sequence holes are synchronously implemented. The third order hole is inserted between the first order pilot hole and the second order hole, and the grouting hole is encrypted to 3.5m. The first pilot hole need to adopt core and drilled column chart, etc.

3.4.2 Easily collapsing area and easily collapsing area: the drilling grouting is generally carried out in two sequence (I, II). The sequence of I and the second order formed a rhombus arrangement with a distance of 5m. Need to encrypt the grouting in collapse, cave, fracture zone, karst crack intensive development of regional or retaining engineering and station throat area, simultaneous implementation of third order hole grouting, III sequence hole in the pilot hole, the middle I and II ordered sequence is inserted into a hole encryption, encrypted hole the distance is 3.5m.

3.4.3 Exploring the geophysical prospecting section to reveal the general development areas of karst formations, designing them according to the combination of exploration and irrigation, and setting up prospecting irrigation holes (distributed by 7m left and right) along the centerline vertical distance of 14m to ascertain the development of karst and determine whether to carry out remediation.

### 4. Mix proportion of grouting in construction

Parameter table of proportioning of karst grouting
5. Mechanical configuration and staffing

5.1 Staffing

According to the number of personnel allocated according to the construction stage, the construction is carried out by fourth teams of second subdivisions. There are 4 managers, 1 tester, 10 to 15 drilling rigs, 6 to 10 grouting workers, 1 electrician, and 2 to 4 ordinary workers.

5.2 Mechanical Configuration

Mechanical configurations include geological drilling rigs, hydraulic grouting pumps, slurry mixers, plug stoppers, screens, high-pressure grouting tubes, orifice covers, and associated instruments.

6. The process and process requirements of the construction process

6.1 Process flow

<table>
<thead>
<tr>
<th>Denomination</th>
<th>Parameter</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single liquid</td>
<td>Water cement ratio</td>
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<td></td>
<td>Water cement ratio (kg/m³)</td>
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<td>Water cement ratio</td>
<td>Water cement ratio</td>
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<tr>
<td></td>
<td>Water cement ratio (kg/m³)</td>
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<tr>
<td></td>
<td>Water glass (kg/m³)</td>
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<tr>
<td>Water cement ratio</td>
<td>Water cement ratio</td>
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<tr>
<td></td>
<td>Water cement ratio (kg/m³)</td>
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</tr>
<tr>
<td></td>
<td>Water glass (kg/m³)</td>
<td>22 ~ 32</td>
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</table>

<table>
<thead>
<tr>
<th>Denomination</th>
<th>Parameter</th>
<th>Remarks</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Volume ratio: 0.6 ~ 1:1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Weight ratio cement: water glass = 1:0.03</td>
</tr>
</tbody>
</table>

![Process flow chart of construction of Karst Subgrade](image)
6.2 Process requirements

6.2.1 The construction technology of karst grouting

①The principle of grouting

According to the center of the line from the embankment slope to the order of the first two sides after the middle, in order to ensure grouting quality, first dilute and later thickening, gradually adding thickening slurry according to the condition of suction, grouting in the hole. The water cement ratio is controlled from 0.6:1 to 1:1, the grouting pressure is 0.2 to 0.3Mpa, and the end injection pressure is 0.3 to 0.5Mpa. Under the final injection pressure, the injection rate of continuous grouting 10min is not greater than 5L/min, and the injection is terminated.

②Intermittent grouting

If the grouting amount is greater than 2m3 or the continuous grouting time is more than 20 minutes, it should be adopted and the interval time is not less than 45min. When the grouting amount of intermittent grouting is still greater than that of 2m3, the cement slurry with a high level of concentration is used, and so on, until the grouting requirement is met. The intermittent grouting should be used when the corrosion fracture is developed, the connectivity is good, and the leakage is serious. When the water cement ratio is 0.6 to 1, the slurry can not be effectively intercepted. When the intermittent grouting is still unable to form effective intercepting, the batch grouting is used after the sand aggregate. In order to shorten the interval time, the early strength agent was added directly in the slurry, and the amount of admixture was 15%. At the same time, intermittent grouting was used, and the interval time of grouting was 45 ~ 54min.

③Double liquid grouting

When the cement single liquid surface is pulping, it is blocked by double liquid. The grouting has exceeded the effective range or regulation range, and the slurry is controlled by double liquid when the slurry is spread too far. The vertical fracture of karst has good penetration, and the seepage of the slurry is too deep, which should be treated with double liquid. The grouting quantity is large, the single hole grouting amount is larger than the average grouting quantity, it is appropriate to use double liquid control. Cement slurry cement dosage of 50% ~ 100% water glass slurry for continuous karst grouting, still do not see the emergency treatment of grouting pressure rise and the surface of the mud.

④In order to effectively control the grouting amount, to prevent the waste of cost, to monitor the cost of using CJ-G3 grouting automatic recorder, instant machine small ticket machine.

Cement slurry control: the cement slurry is measured by standard electronic measurement equipment, and the amount of each plate is measured accurately.

Grouting measurement: the grouting equipment configuring electromagnetic flowmeter and printing instant grouting pressure and small flow ticket, and preparing the grouting amount.

7. Effect detection

7.1 Core inspection

The grouting inspection hole is 5% extracted according to the grouting hole. The hole position is designated by the supervision site, and the third party is detected. The core hole sampling is used to detect 12 holes. The cement core body can be seen in the core, basically filling up the slot to meet the design requirements.

7.2 Test of pressure water test

The water absorption of the unit length should be less than 3% ~ 5% before the grouting, and the grouting effect can be reached. According to the requirements of design and supervision, representative boreholes are selected to test the pressure water test. The range of water permeability of 12 holes is 5.21 ~ 9.76Lu, which meets the design requirements.

7.3 Transient surface wave detection
Based on the comparative analysis of borehole data and early geophysical data, 32 surface wave points were selected for the purpose of finding out the wave velocity of soil and rock surface after grouting, and finding out the grouting quality. The test results meet the evaluation criteria.

7.4 Electric sounding detection

Based on the comparative analysis of borehole data and early geophysical data, this selected electrical sounding survey line is 55 meters (12 points) for testing. The purpose is to identify the resistivity of rock and soil before grouting and meet the design requirements.

8. Process summary

After comprehensive analysis, the selection of the parameters of the process is as follows:

8.1 Mechanical combination: geological drilling machine, pulping machine, slurry cylinder 1000L, hydraulic grouting pump, high-pressure grouting pipe, pressure meter, electromagnetic flowmeter.

8.2 Grouting pressure, clay layer control in 0.1 ~ 0.2MPa, rock layer control in 0.2 ~ 0.3MPa, final injection pressure control in 0.3 ~ 0.5MPa.

8.3 When grouting reaches the following standards, the grouting can be finished. 1) the pressure of grouting hole is maintained at 0.3 ~ 0.5Mpa, and the volume of slurry suction is no more than 5L/min, and 10min is maintained. 2) the bedrock of the grouting hole is complete, or multiple grouting, when the pore pressure exceeds 1.5Mpa. 3) when the pulping point has been out of the grouting range from 3 to 5m. 4) the single hole grouting amount reached 1.5 to 2 times the average grouting quantity, and when the feed volume decreased obviously, when the above end standard was not reached, it should be empty again.

The grouting can be stopped by one of the above conditions, but it should be judged according to the geological drilling record and the grouting method.

This condition is the criterion to judge the use of stopping grouting, and the grouting pressure and grouting flow should be recorded at any time:

This condition is the criterion to judge the use of stopping grouting, and the grouting pressure and grouting flow should be recorded at any time. When grouting time is short and there is no pressure value, intermittent grouting shall be used for grouting until the pressure and suction conditions are satisfied. If the development of karst fractures is connected with the ground, the grouting volume must be increased.

Grouting hole bedrock complete, or multiple grouting, the entrance pressure more than 1.5Mpa determination and attention:

The condition is a lot of situation in the actual construction process, but it must be combined with the situation of water injection test and grouting.

In the process of grouting, pouring slurry amount is greater than 2m and fand slurry return should be used for intermittent grouting treatment, when using intermittent Grouting grouting amount determination and attention of more than 2m is still not back to the pulp fand:

The condition is a lot of situation in the actual construction process, the cement + water glass double liquid slurry can be used to plug the leakage treatment. When the water glass and other double liquid slurry are used, two pipes must be perfused to prevent the slurry from clogging the grouting pipe.

In summary, the experimental process can meet the requirements of the design specification and can guide large area construction.
9. Experience and summary

9.1 Mastered the process flow of rock solution grouting, reasonable personnel and mechanical configuration, and can optimize the construction work to the maximum extent.

9.2 In order to effectively control the grouting amount in time, configure the electronic grouting recorder and flowmeter to strengthen the process control.

9.3 In the process of grouting, because of ground fissure and solution cavity development factors, the grouting amount is larger, and the slurry return should be used for intermittent grouting treatment, and the use of "cement and water glass grouting plugging" treatment according to the situation, when the water glass grout, must be used to prevent double perfusion. Slurry condensation blockage grouting pipe.

9.4 In the process of washing holes, if there is a series of holes, two holes should be injected simultaneously in the grouting to ensure the quality of grouting. If there is no return water, should be recorded in grouting grout ratio adjustment by grouting or oars.

9.5 In grouting construction, the grouting pressure is controlled in 0.2 ~ 0.3Mp, and the final injection pressure is controlled in 0.3 ~ 0.5Mp, which is stable at the final injection pressure. The slurry return or slurry volume is no more than 5L/min, and 10min is continuous. When grouting point has been out of grouting range 3 ~ 5m, grouting can be stopped. If the above requirements are not met, the batch grouting or double slurry grouting should be used in inert materials (fly ash, accelerator, etc.).

10. Conclusion

To sum up, in the course of the construction of the railway subgrade in the karst stratigraphic region, first of all, it is to investigate and explore the geological conditions of the region. Secondly, according to the actual situation, the concrete karst cave treatment and reinforcement measures are put forward, and a set of feasible, scientific and reasonable road base rock solution construction scheme is formulated. Through continuous improvement and improvement in work process, the related construction methods and construction processes for Karst regulation projects suitable for project characteristics are summarized, and the expected results are achieved, which provide reference data and construction experience for railway subgrade renovation projects.

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