Testing Research on Moisture Content Effect to Safety of Highway Slope Subgrade

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Keywords: Slope subgrade, Testing research, Compaction, Moisture content, Safety factor.

Abstract. Based on the dynamic monitoring of the moisture content of highway slope subgrade and the corresponding shear strength test, the safety analysis model of slope subgrade was established. Based on the model, the influence of different water content on the subgrade in the test section was analyzed. The results showed that under different moisture content conditions, the safety factor of slope subgrade is obviously different. The moisture content of slope subgrade is dynamically changed after the subgrade filling. The slope safety factor decrease with increase of the moisture content of subgrade, and the slope safety factor is the highest under the condition of the best moisture content.

Introduction

Along with the continuous development of the national economy and the increasing prosperity of the social transport market, the traffic volume of the highway has increased greatly, meanwhile the car load has increased obviously, which requires the highway construction to develop towards high grade and high standard. These are put forward higher requirements to highway designers and builders. According to China's existing highway subgrade design specifications and subgrade construction technical specifications[1-2], the strength of the subgrade is obtained by satisfying the compaction degree standard and the optimum water content state, and with the layers of subgrade filling, subgrade moisture content will be some changes, which directly lead to the working conditions of subgrade changes.

Moisture content is one of the key factors that affect soil compaction. Domestic Standard[3-4] is based on the optimum moisture content of the heavy compaction test, and the standard of "+2, -3" is used to control the moisture content. However, the best moisture content empirical standard obtained by this compaction curve does not adapt to the law of compaction of subgrade. The moisture content of construction control is mainly affected by parameters such as soil property, air temperature, compaction ability of compaction equipment and packing compaction requirement, these parameters are dynamic, that is, the moisture content of the subgrade is not a constant parameter, pay attention to the tracking detection of dynamic moisture content and the influence of the change of moisture content on the stability of subgrade during construction is urgently and important.

Considering a test section in Neimeng highway as the object of the study, the dynamic moisture content change and c and φ values of slope soil were obtained through monitoring by sensors and field shear test respectively, the influence of moisture content change on slope subgrade safety was discussed.
Test Design

During the construction of the slope subgrade test section, the dynamic moisture content sensors imported from the United States is arranged in layers. The sensors can accurately and quickly detect the moisture content of the slope subgrade, reading equipment as shown in Fig.1.

![Reading equipment of moisture content.](image)

Set up Analysis Model

In this paper, GEO-Studio Office software[5-6] was adopted in the simulation of the model. The software was developed by Canada International Limited. And SLOPE/W was used to calculate the stability of slope subgrade with different moisture contents.

(1) Boundary conditions

The subgrade model is defined as symmetric along the centerline of the road with x displacements of zero, 30 m in the transverse direction and 15 m in the longitudinal direction. Bottom Boundary Constraints: vertical and horizontal displacement; two lateral boundaries are bounded by horizontal displacement; and the upper surface is the displacement coupling constraint of the soil.

(2) Division unit

The mesh is divided into four units, the length is 0.5m, the whole subgrade model is divided into 60 horizontal units, vertical divided into 30 units, a total of 1800 units. Calculation model shown in Fig.2, 1 represent for the subgrade part, 2 to 5 represent for the foundation part, which are the boundary conditions for the establishment of part of the partition.

(3) External load

For the subgrade, the external load is mainly from the weight of the embankment and vehicle dynamic load. This paper focuses on the influence of moisture content on the stability of slope subgrade, so the load on the foundation is assumed to be 120 kPa, and the safety analysis is carried out with the results of field c and φ values.

The model calculate the safety factor of slope subgrade by the subgrade moisture content data and the parameters obtained from the shear test.
Discussion

Field test data of test section in Neimeng highway were shown in Tab.1 and Tab.2.

Table 1. Moisture content of slope subgrade in different detection date.

<table>
<thead>
<tr>
<th>Detection date</th>
<th>Moisture content /%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>13.8</td>
</tr>
<tr>
<td>6.6</td>
<td>15.0</td>
</tr>
<tr>
<td>6.23</td>
<td>17.8</td>
</tr>
<tr>
<td>7.15</td>
<td>23.4</td>
</tr>
<tr>
<td>8.3</td>
<td>26.7</td>
</tr>
</tbody>
</table>

Table 2. Parameters of slope subgrade under different moisture content.

<table>
<thead>
<tr>
<th>Moisture content /%</th>
<th>Unit weight /kN/m³</th>
<th>c /kPa</th>
<th>φ /°</th>
</tr>
</thead>
<tbody>
<tr>
<td>13.8</td>
<td>19.6</td>
<td>28.0</td>
<td>27.0</td>
</tr>
<tr>
<td>15.0</td>
<td>18.6</td>
<td>15.5</td>
<td>29.9</td>
</tr>
<tr>
<td>17.82</td>
<td>18.1</td>
<td>14.1</td>
<td>22.0</td>
</tr>
<tr>
<td>23.4</td>
<td>18.7</td>
<td>9.4</td>
<td>22.5</td>
</tr>
<tr>
<td>26.7</td>
<td>18.5</td>
<td>8.3</td>
<td>23.2</td>
</tr>
</tbody>
</table>

As shown in Tab.1 and Tab.2, the moisture content 13.8% is determined by indoor compaction standard test, and the other percentage of moisture content is measured by dynamic moisture content sensors[7-8]. When the moisture content of the slope subgrade is different, the measured values of c and φ are significantly different. When the moisture content of the slope subgrade is larger, the anti-shear performance of the subgrade is worse. In order to theoretically analyze the effect of this change on slope subgrade safety, the GEO-Studio Office was used to evaluate the effect of the slope subgrade safety factor at the optimum moisture content of test section. The results are shown in Tab.3.
Table 3. Safety factor of test section.

<table>
<thead>
<tr>
<th>Morgenstern-Price</th>
<th>Ordinary</th>
<th>Bishop</th>
<th>Janbu</th>
<th>GLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety factor</td>
<td>1.698</td>
<td>1.622</td>
<td>1.683</td>
<td>1.558</td>
</tr>
</tbody>
</table>

Through the analysis, the safety factor from Tab.3 shows, in full compliance with design requirements. The GLE method was used to calculate the safety factor of the subgrade at other percentages of moisture content in test section as follows.

Figure 3. GLE method moisture content and safety factor.

Figure 4. Moisture Content and Safety Factor of Different Calculation Methods.

As shown in Fig.3 and Fig.4, the safety factor of slope subgrade soil is different, and the safety factor is decreasing with the increase of moisture content. When the moisture content is 13.8%, the safety factor of subgrade is in accordance with the design requirements, when the moisture content is more than 20%, the safety factor is less than 1, slope subgrade is instability.

Conclusions

(1) Under different moisture content conditions, the safety factor of slope subgrade is obviously different. The subgrade is basically stable when the moisture content of subgrade is the best, but the subgrade is in unstable state when the moisture content is more than the best.
(2) The moisture content of slope subgrade is dynamically changed after the subgrade filling. The slope safety factor decreases with an increase of the moisture content of subgrade, and the slope safety factor is the highest under the condition of the best moisture content.

(3) When the moisture content is changed, the stability of the slope subgrade also changed. When the water content is more than 20%, the safety factor of slope subgrade is less than 1, and the subgrade is not stable.

Acknowledgement

This research was financially supported by the Ministry of Transport to Promote Scientific and Technological Achievements Project (No. 2014316802080).

References


