The Study of Large-Scale Triaxial Texts on Metamorphic Soft Rock Embankment Filler

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ABSTRACT: In order to study the wetting deformation characteristics of the metamorphic soft rock embankment filler, large-scale triaxial tests are conducted with double lines method respectively. Variation of wetting strains (i.e., the differences between strains of dry and saturated states under the same vertical deviator stress) is analyzed. Results show that, under different confining pressures, the wetting strain $\Delta \varepsilon_1^w$ is increased with the increase of vertical deviator stress $\left( \sigma_1 - \sigma_3 \right)$, the curve presents weak strain hardening. $\Delta \varepsilon_1^w - \left( \sigma_1 - \sigma_3 \right)$ the curve have turning points under different confining pressures, the turning points position are located in about 70% of the maximum deviator stress. The position of the turning points gradually move back with the increase of confining pressures, show that confining pressure is not only influence the magnitude of wetting deformation, also influence its change rules. There are two development stages of filler wetting strain curves. The size of the critical wetting strains are closely related to the ratio of vertical deviator stress and confining pressure. In contrast with the metamorphic soft rock embankment the value of $\alpha$ and $\alpha_u$ under the condition of actual work, the development law of the wetting deformation after the water is analyzed.

INTRODUCTION

Engineering practices show that the metamorphic soft rock after flooding will case wetting deformation and make the embankment produce settlement. It also will affect driving safety and bring serious effects on the project. But for metamorphic soft rock used for highway embankment packing research is not much, its engineering properties and wetting deformation rules of research data are lacking. Therefore, it is important to research some work which is related to soft rock embankment filler.

Wetting deformation refers to the packing of flooding under a certain stress state, particles in mineral water immersion to soften and by water lubrication between particles cause mutual sliding between particles, crushing and rearranged, these make the packing part of wetting deformation and cause the phenomenon of stress redistribution. The deformation is mainly produced by the soil material from dry to wet on the basis of the stress state. Abroad, Nobari and Duncan (1973) for the first time in the calculation of deformation and stress of the earth and rockfill dam considered the coarse aggregate of wetting deformation. Nobari put forward a full amount of the initial stress method; Marsal, Nolezalova and Leihter etc. got the empirical formula of calculation of wetting strain on the basis of a large number of consolidation test and apply this method specific to finite element method. In the domestic, Zhujiang Shen, etc. got wet model and improved this model on the basis of

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"single line method"; according to the no tensile stress numerical calculation model, Junxian Zou obtained the wetting deformation under the different impacted parameters. But in general, the researching of taking the soft rock filler as the subgrade filler are far from mature. Studying for the law of development of wetting deformation is less.

This paper has carried on the large-scale triaxial compression experiments in view of the metamorphic soft packing. The double line method was adopted, wetting deformation characteristics of dry and saturated state metamorphic soft packing were studied under different confining pressures.

THE STRUCTURE AND BASIC PROPERTIES OF METAMORPHIC SOFT ROCK

Through the analysis of the grinding electron microscopy metamorphic rock test named the rock accurately and analyzed the rock mineral composition and content. The rock is composed of 60% ~ 70% sericite and crystallite biotite and 30% ~ 40% felsic minerals, and contain 1% ~ 3% a small amount of tourmaline, sphene and so on. The size of the platy mineral particles is less than or equal to 0.1mm. It is mainly composed of feldspar, quartz, a small amount of tourmaline accessory mineral, etc. So the rocks entitled thousand pieces of mylonite, referred to Qian-mi rock. Using the highway engineering specification for rock test and through the particle density, collapse resistance index, water absorption and the uniaxial compressive strength test, got the basic physical and mechanical properties of metamorphic rocks. As shown in the table 1.

Table 1. Metamorphic soft rock physical and mechanical properties.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Particle proportion</th>
<th>Uniaxial compressive strength /MPa</th>
<th>Softening coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Collapse resistance</td>
<td>dry</td>
<td>saturation</td>
</tr>
<tr>
<td>Qin-mi</td>
<td>2.7</td>
<td>31.07</td>
<td>21.42</td>
</tr>
</tbody>
</table>

Metamorphic soft rock physical and mechanical properties data show that the Qian-mi rock collapse resistance index is not high, Such metamorphic rock in only high durability and easy disintegrate in the long-term wind or sunshine; the bibulous rate of metamorphic soft rock is low, also prove that the rock is not easy to swell; but at the same time, rock softening coefficient is small, show that the rock after flooding under the action of external force is easy to damage. The influence of water is obvious. In this area according to the classification indexes of rock strength, Qian-mi rock saturated uniaxial compressive strength is less than 30 MPa, belong to the soft rock.

LARGE-SCALE TRIAXIAL COMPRESSION EXPERIMENTS OF METAMORPHIC SOFT ROCK

In order to make the grading of the soil close to the actual situation as far as possible, test determine the test packing similar gradation based on the method of similar grading. As shown in the table 2.
### Table 2. Metamorphic soft packing grading table.

<table>
<thead>
<tr>
<th>Particle diameter $D$(mm)</th>
<th>Percentage of test gradation (%)</th>
<th>Particle diameter $D$(mm)</th>
<th>Percentage of test gradation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>200~100</td>
<td>18.1</td>
<td>60~40</td>
<td>20.7</td>
</tr>
<tr>
<td>100~80</td>
<td>1.9</td>
<td>40~20</td>
<td>24.9</td>
</tr>
<tr>
<td>80~60</td>
<td>2.6</td>
<td>20~10</td>
<td>7.09</td>
</tr>
<tr>
<td>60~40</td>
<td>14.1</td>
<td>40~20</td>
<td>27.8</td>
</tr>
<tr>
<td>40~20</td>
<td>20</td>
<td>20~10</td>
<td>19.51</td>
</tr>
<tr>
<td>20~10</td>
<td>17.9</td>
<td>10~5</td>
<td>7.09</td>
</tr>
<tr>
<td>10~5</td>
<td>5.09</td>
<td>5~1</td>
<td>19.51</td>
</tr>
</tbody>
</table>

### Relationship between stress and strain

The Qin-mi metamorphic soft rock filler was selected as the test sample. With a diameter of 30cm, 60cm high, the maximum size of particles are not more than 6cm for triaxial test, select the density is 2.2 g/cm$^3$, respectively in the confining pressures for the 200kpa, 300kpa, 400kpa, 600kpa, the samples of the dry and saturated with double line method is studied. The shear rate of the test is 0.1mm/min, tests would stop when the shear is the axial strain of 15%. Under the four kinds of confining pressure (200kpa, 300kpa, 400kpa, 600kpa), dry sample’s stress-strain curve are shown in figure 1 below. Under the four kinds of confining pressure (200kpa, 300kpa, 400kpa, 600kpa), saturated sample’s stress-strain curve are shown in figure 2 below.

![Figure 1. Relationship between stress and strain under different confining pressure for dry metamorphic soft rock.](image)

As is shown in figure 1, the strain of the sample under different confining pressures increase with the increase of the vertical deviator stress ($\sigma_1 - \sigma_3$), and under the dry state, the metamorphic soft rock filler’s curve of stress-strain’ relationship is softening, which has a peak, after the peak, the strain shows a trend of decline with the increase.
of the vertical deviator stress, and the lower the confining pressure is, the earlier the peak appears, suggests that the confining pressure has certain influence to the peak; under the saturation state, the metamorphic soft rock filler’s curve of stress-strain’ relationship behaves hardening type and there is no peak, the strain increases with the increasing of vertical deviator stress slowly. No matter what the sample is dry or saturated, the vertical deviator stress increase with the increase of confining pressure when the strain is same, and there is less vertical deviator stress when the strain is small. It implies that confining pressure can affect the mechanical properties of the filler. In addition, the filler’s elastic modulus increases with the increase of confining pressure, and the drying condition of initial elastic modulus is generally greater than the saturation state of elastic modulus, the drying condition of the fillers show the characteristics that plastic first then elastic.

Figure 2. Relationship between stress and strain under different confining pressure for saturated metamorphic soft rock.

The figure 3 shows the relationship of the filler between the vertical deviator stress and the strain when the confining pressure is respectively 200kpa, 300kpa, 400kpa, 600kpa. In figure (a), when the confining pressure is 200kpa, the deformation caused by the saturation is greater than the dry state with the same axial deviator stress, and the deformation caused by the wetting increases gradually with the increasing of the axial deviator stress \( \left( \sigma_i - \sigma_j \right) \); Under the dry condition, a turning point of axial deviation stress appears when the strain is from 2% to 4%, at this point, it has the biggest differences from the deviator stress of saturated state, and the gap increases with the increasing of confining pressure gradually, which is respectively 4.21x10^2kpa, 4.25x10^2kpa, 8.07x10^2kpa, 11.68x10^2kpa. The dry state deviator stress decreases after the peak point, the vertical deviator stress of saturated state increases gradually after the strain is from 3% - 6%, what can be seen from figure 3 is when the strain reaches 15%, the deviator stress of saturated and dry state has little difference. Also, when the confining pressure is 300kpa, 400kpa, 600kpa, we can get the similar regularity of stress and strain, as is shown in figure 3 (b), (c), (d). Accordingly, when the sample was saturated by water, due to the mineral particles immersed softening and the
function of lubrication, it shows slip, broken and rearranged between the particles. Making a part of wetting deformation, and the intensity is reduced.

**Analysis of wetting settlement of the soft metamorphic rock**

Under the condition of same confining pressure and the same deviator stress, the differences strain between of the saturated state and dry metamorphic soft rock are defined as the wet strain $\Delta \varepsilon^w_1$.

$$\Delta \varepsilon^w_1 = \varepsilon^w_1 - \varepsilon^d_1$$

(2.1)

Where $\varepsilon^w_1$ is the strain of the specimen in the saturated state (%), $\varepsilon^d_1$ is the strain of the specimen in the dry state (%).

![Figure 3. Relationship between vertical deviator stress and wetting strain under different confining pressures.](image)

In figure 3, when the wetting strain is constant, the deviator stress increases with the increase of the confining pressure, which shows that confining pressure affect the amount of wetting settlement of metamorphic soft rock filler in a certain extent. Wetting strain are increased with the increase of deviator stress under different confining pressures, the curves deformation show the strain hardening type. In the beginning, the slope of the curve is larger, and the slope is gradually decreased, after the deviation stress exceeds a certain value, the strain amplitude increases greatly.

There are turning points on the $\Delta \varepsilon^w_1 - (\sigma_1 - \sigma_3)$ curve under different confining pressures. The turning point is located at about 70% of the maximum deviator stress. The rate of increase of wetting strain is smaller before turning point and is increased after turning point, with the increase of confining pressure, the turning points on the curve move backward. At lower confining pressures (200kPa, 300kPa), the turning point is more obvious, at the higher confining pressures (400kPa, 600kpa), the radian of transition is larger. In the late stage, the slope of the curve decrease gradually, the turning point is not obvious. So, the confining pressure not only affects the size of the wetting deformation, but also affects the rules of the change.

In order to analyze the influence of confining pressure on the wet deposition, the corresponding strain of the turning point is defined as the critical wetting strain, which is expressed by $\Delta \varepsilon^w_{1,u}$, the corresponding deviator stress is expressed by $(\sigma_1 - \sigma_3)_u$.  

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In figure 4, when the confining pressures are 200kpa, 300kpa, 400kpa, 600kpa, the critical wetting strain are 1.57%, 1.97%, 2.51%, 2.82%, and the corresponding values of deviator stress are 651.2kpa, 898.6kpa, 1143.2kpa, 1717.5kpa. The ratio of the axial deviator stress to the corresponding confining pressure is expressed by $\alpha$, which is

$$\alpha = \frac{(\sigma_1 - \sigma_3)}{\sigma_3}$$

(2.2)

![Figure 4. Relationship between $\alpha$ and wetting strain under the different confining pressures.](image)

In the figure 4, under different confining pressures, the wetting strain increases with the increase of confining pressures. The curve starts with a small slope, and the slope increases after the turning point, it suggests that the wetting settlement is not apparent before the turning point. The settlement caused by wet always occurs after the turning point, and the greater the confining pressure is, the greater the wetting settlement is. Under larger confining pressure, the broken rate of soft rock particles increases, the particles would rearrangement, so that the bond strength between particles reduced significantly, which produce a large wet deposition. The critical wetting strain corresponding to $\alpha$ is expressed by $\alpha_u$. When the confining pressure is 200kpa, 300kpa, 400kpa, 600kpa, the corresponding values of $\alpha_u$ are 3.24, 3.3, 2.84, 3.3, and it can be seen that the values of $\alpha_u$ near the turning point ranges from 2.8 to 3.3.

When $\alpha < \alpha_u$, the amplitude of the wetting strain $\Delta \varepsilon_1^w$ that increases with $\alpha$ becomes small, it means that the filler’s settlement caused by wetting is not the bigger when the embankment was saturated and the upper load doesn’t reach the critical value. When $\alpha > \alpha_u$, the slope of the wetting strain $\Delta \varepsilon_1^w$ increases greatly, the increment of $\alpha$ is smaller and then tend to be stable. When the filler is saturated and upper embankment load or additional load is greater than the critical state, the settlement caused by wetting increases rapidly and has certain influence on the settlement of the embankment. Contrast $\alpha$ and $\alpha_u$ at the actual working condition of the soft rock embankment, then we can analyze the regularity of development of the wetting deformation.
CONCLUSIONS

(1) The strain of the metamorphic soft rock filler under different confining pressures increases with the increase of the vertical deviator stress. There is a peak when the filler is under the dry state, the curve of stress-strain is softening. When it is under the saturated state, the curve of stress-strain behaves hardening type and there is no peak. The filler’s elastic modulus increases with the increase of the confining pressures. The dry condition of the filler shows the characteristics of elasticity at the first and plasticity after. It implies that confining pressures can affect the mechanical properties of the filler.

(2) When the confining pressure is 200kpa, the deformation caused by the saturated state is greater than the dry state with the same axial deviator stress. It shows that the strength and the bite force between the particles are reduced, the grain softening and the load carrying capacity decrease when the filler is saturated with water. The deformation caused by the wetting increases gradually with the increasing of the axial deviator stress \((\sigma_1 - \sigma_3)\). Under the dry state, a turning point of axial deviator stress appears when the strain is from 2% to 4%, at this point, it has the biggest differences from the deviator stress of saturated state, and the gap increase with the increase of confining pressure gradually. Similarly, confining pressures for 300kpa, 400kpa, 600kpa, can get a similar law.

(3) The wetting strain \(\Delta e_i^w\) increases with the increase of the deviator stress \((\sigma_1 - \sigma_3)\) under the different confining pressures, and the curve behaves weak hardening. There always is a turning point under the different confining pressures, the turning point is located at about 70% of the maximum deviator stress. The wetting strain increases slowly before the turning point, but becomes faster after the turning point, and the position of the turning point pushed back with the increase of the confining pressures. It implies that the confining pressure not only affects the size of the wetting deformation, but also affects the change of the law.

(4) The values of \(\alpha_u\) range from 2.8 to 3.3. When \(\alpha < \alpha_u\), the amplitude of the wetting strain becomes small with the \(\alpha\) increased, it means that the filler’s settlement caused by wetting is not the bigger when the embankment was saturated and the upper load doesn’t reach the critical value. When \(\alpha > \alpha_u\), the slope of the wetting strain increases greatly, the increment of \(\alpha\) is smaller and then tend to be stable. When the filler is saturated and upper embankment load or additional load is greater than the critical state, the settlement caused by wetting increases rapidly and has certain influence on the settlement of the embankment. Contrasting \(\alpha\) and \(\alpha_u\) at the actual
working condition of the soft rock embankment, then the regularity of development of the wetting deformation is analyzed.

REFERENCES
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