The Effect of Moisture Content and the Freeze-thaw Cycle on Loess Tunnel Stability

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ABSTRACT
Seasonal frozen loess tunnel stability is controlled by many factors. To study the effects of water content and freeze-thaw cycles of loess tunnel stability, taking loess in Shanxi Yangqu No. 1 tunnel face as the research object, to do different moisture stability studies on loess tunnel after repeated freeze-thaw cycles. The results show that: (1) by the comprehensive structure potential and structure index concept as the theoretical basis, do uniaxial compression test on condition of different water content and different freeze-thaw cycles. The results show that: with the increase of freezing and thawing cycles and water content, the structure index and uniaxial compressive value decrease, which is due to that the structural properties of loess is damaged by water and freeze-thaw cycles. (2) With the increase in the water content of the surrounding rock, wall rock maximum and minimum principal stresses were increased, the tunnel stability coefficient decreases. (3) In condition of same moisture content, the stability factor in tunnel arch and side walls was minimum, indicating that the stress concentration after excavation, soil tends to destroy. The stability factor in tunnel dome was largest, the soil is in a stable condition. With increasing water content in the surrounding rock stability coefficient decreased substantially linear relationship. (4) With the increase of freeze-thaw cycles, the maximum principal stress surrounding rock and minimum principal stresses were increased, stable coefficient decreases. Wall and arch stability factor lower and the magnitude smaller than the dome.
end of the arch. Hope this paper can provide construction reference in loess distributed area of yangqu even in shanxi.

**KEYWORDS:** loess; freezing and thawing cycle; soil moisture; stability

**INTRODUCTION**

Loess is a special soil, widely distributed in our country, and is one of a sediments in quaternary period, mainly located in the arid and semi-arid regions, normal is non-saturated status, moisture content and temperature paly important role on physical and mechanical properties of loess. Loess is a quaternary sediments, generally has the characteristics of general definition of soil is unconsolidated reservoirs, loose, soft deposits; does not have rigid connection, physical state and changeable, low mechanical strength; located in crustal surface, is a qualitative environmental carrier main human engineering and economic activities by the soil particles, the general; water, air in a certain way etc.. At the same time, the engineering properties of loess also has the unique distinction at other soil; special connection mode between particles makes the loess has resistance to certain external force for the structural behavior of loess; water and force to the structural effects exhibited by collapsible wet certain; it was widely distributed and special engineering properties makes the majority of scholars have conducted in-depth research of loess.

factors. Qi Jilin (2003) using soil mechanics method and electron microscope assisted, compared the Tianjin powder soil and loess in Lanzhou, obtained two kind of soil mechanical properties before and after freezing thawing and microstructure changed. Song Chunxia (2007) that different dry density of soil weakening and strengthening effects of different freezing and thawing may also have an effect on the preconsolidation pressure. Lian jiang bo (2010) of Yangling loess repeated freeze-thaw cycle test, explore its structural. Dong Xiaohong (2010) to investigate the long-term freeze-thaw deterioration of loess under the strength characteristics. Zhao Shuping (2010) (2012) CT uniaxial compression test of frozen remodeling based on loess in Lanzhou carried out to study the damage dissipation potential. Gao Jianwei of Sha nxi Hequ loess of unconfined compression test of the compressive strength of loess, unconfined compressive strength, elastic modulus and water content, dry density relationship. Luo Aizhong conducted a study on the rules of the structural variation characteristics under uniaxial pressure with different initial structural loess. Chen Cunli to test the moisture content and dry density with different structural (arrangement) of the compacted loess tests were conducted on the unconfined compression test, to explore its intrinsic regularity. Fu Wei of different temperature on the northern foot of pho clay by uniaxial compression test and monitoring the entire process of frozen soil resistivity, obtains the stress - strain – resistivity curve, fast and accurate estimation of frozen soil in uniaxial compressive strength parameters. Li Xiaoyuan on the freeze of unconfined compressive strength test of modified loess soil thawing condition, discusses the influence of freeze-thaw cycles on the modified loess. Lv Qingfeng of the cycle of freezing and thawing modified loess unconfined study coefficient and the microstructure and compressive strength, permeability, puts forward the optimal ratioof Loess modifier. Du Haimin to carry out uniaxial compressive strength test system of silty sand quantity with high ice(water) content. Xiao Haibin of artificial frozen soil of the uniaxial compression test, the analysis of compressive strength and temperature and moisture relationship. Song Zhigang of Shanghai of the 4th layer of silt clay before and after cryopreservation of unconfined compressive strength tests were carried out to study the.

For the structural index of loess, Shao Shengjun use the comprehensive structure potential ideas through undisturbed soil and remolded soil, and the saturated soil unconfined compressive strength test, undisturbed soil and remolded soil by the unconfined compressive strength of soil structure can reflect the stability, expression is coupling characteristics of soil particles, by saturated soil and undisturbed soil unconfined compressive strength compared to reflect the structural variability of soil characteristics, expression is arrangement of soil particles, the structural index defined as follows:

\[
m_u = \frac{m_1}{m_2} = \frac{(q_u)_o/(q_u)_r}{(q_u)_r/(q_u)_o} = \frac{(q_u)_o^2}{(q_u)_r(q_u)_s}
\]

Type \((q_u)_o\), \((q_u)_r\), \((q_u)_s\) respectively, undisturbed, remolded soil, saturated undisturbed soil unconfined compressive strength; \(m_1\) reflect structural stability; \(m_2\) reflect structural variability.
At present, to make some advances in the study of the stability of Loess tunnel. Zhang Wei\cite{30} of large section loess tunnel surrounding rock deformation characteristics and rock pressure forming mechanism is analyzed, analysis of the distribution of rock pressure. Yang Zhuo\cite{31} using software to study the fluid solid coupling effect on the stability of surrounding rock of Yunnan Shuanglong tunnel and the plastic zone of numerical analysis. Tang Guozhang\cite{32} by finite element simulation, temperature field monitoring and other means of Kunlun Mountains tunnel, simulated the numerical stability. Zheng Yuanzhong\cite{33} with copper Huang highway uphill arched tunnel as the background, taking the field tests and simulation studies under complex geological conditions, tunnel arch stability problem in the process of construction, in order to realize the concept of the new Austrian Tunneling Method of dynamic construction, dynamic design. Su Chunhui\cite{34} effect on the stability of the tunnel are analyzed with the help of PLAXIS software on the changes of water rich loess tunnel surrounding rock water content, numerical settlement and settlement trough width affect surface on the precipitation caused bya simulation study. Lun Peiyuan\cite{35} by field monitoring, and other means, to get the surface settlement, change law of vault settlement and horizontal convergence relationship, of large section tunnel construction process of three dimensional numerical simulation and analysis of tunnel, and analyzed the reasons of Water Leakage. Wang Wenguang\cite{36} measuring data processing based on finite element simulation analysis of construction process and the amount of double arch tunnel, discuss the bias stress distribution under. Liu Fengming\cite{37} on the background of Shanxi Lvliang tunnel, displacement of surrounding rock of the reserved time variation, the amount of deformation were studied, obtained the general rule of shallow buried bias stability of loess tunnel with small spacing. Chen Siyang\cite{38} on the background of Yongdeng Gulang tunnel, the tunnel design theory, the instability mechanism, influencing factors of stability, construct function considering the comprehensive safety coefficient. HuShimin\cite{39} adopts the method of theoretical analysis, laboratory research, numerical simulation and field engineering application of combination of surrounding rock deformation characteristics are studied, solving the key problem of the deformation of surrounding rock control etc.. Li Jian\cite{40} to Zheng west line loess tunnel groups based on the project of large section loess tunnel, the supporting mechanism and deformation characteristics of the system research. Liang Qingguo\cite{41} loess are analyzed as special soil and loess tunnel surrounding rock with water sensitivity, small strain failure properties, anisotropy and loess joints on the stability influence, put forward in the study of classification of loess tunnel test research contents and corresponding method. Zhang Hua bing\cite{42} using elastic visco-plastic constitutive model for finite element analysis of loess tunnel surrounding rock deformation law of surrounding rock, study, study the distribution of surrounding rock displacement, the results can be a reference for the construction.

The research results by above knowable, the existing achievements mainly aims at the normal temperature environment for a certain temperature or loess under the condition of uniaxial compression results, quantitative research mainly in the comprehensive structure potential as the basis, using the index of different amount respectively. Frozen loess in the vast areas of the short-term, is undergoing great development, but, as in the loess area of tunnel engineering lack of experience and mature, and because the special structure of the loess, the prerequisite experience the
outside temperature changes and its containing comprehensive role change of water disaster, often collapse or diseases occur, tunnel engineering construction for the Loess covering area brought great difficulties. But, on the other hand, according to the results of uniaxial compression test of loess under different freeze-thaw cycles are rare, this paper takes Shanxi Yangqu No. 1 Tunnel in loess as the object of study, by the analysis of uniaxial compression strength after different freeze-thaw cycles, using the uniaxial compression equipment for quantitative analysis by using the concept of structural comprehensive structure potential and structural index of Yangqu loess. The research results can be applied to the design and construction of engineering geology in loess area of short-term freezing.

As can be seen, the research on loess tunnel stability, main research work for the influence of water content on the stability of Loess tunnel. Considering the influence of freezing and thawing cycle and the change of water content of coupling effect on the stability of the loess tunnel is very little, based on the background of Yangqu No. 1 tunnel, considering the freeze-thaw cycle and the change of water content of loess tunnel effect, stability and freeze-thaw cycle and moisture content change rule, provides the reference for the construction of loess tunnel in seasonally frozen ground regions.

**SAMPLES**

Undisturbed soil samples used in the test are taken from the mountain west Yangqu 1 loess highway tunnel face new construction excavation. After the test, known specimen of natural water content is 22.65%, the calculation of plasticity index was the natural state for 15.5, liquid index is 0.30.

The undisturbed soil sample using the water film transfer method for humidifying and dehumidifying the natural air dry, when the water content reaches the test required moisture content control point, the soil sample in the humidor in sealed curing 24h, make the specimen surface and internal moisture distribution, to meet the water content error rate is less than 1% required rate of.

Remolded soil preparation according to GB/T50123-1999 "Standard Test Method", will be the first loess crushed, 2mm screen after the determination of moisture content after drying, and then with asoil test. Will need to add water spray to the soil material mix, slightly after standing in a plastic bag and then placed in sealed containers of at least 24h, the moisture content evenly, and then soil preparation, design of soil samples were made in 14%, 18%, 22%, 26% and saturated water content. First prepared with the water content of 14% soil samples, followed by water film transfer method to low moisture soil sample was prepared with high moisture content of soil samples, according to the number of theoretical calculation with water, with the medical syringe of 5ml at the surface of the sample around slowly and evenly dripped into the predetermined content, then put the sample placing maintenance a few days in the maintenance of a sealed cylinder, so that the water in the water film under the action of the pressure gradually transfer, finally the uniform distribution in the inside of the specimen, the specimen to the purpose of containing water preparation. Saturated specimen
preparation, pumping cylinder will be equipped with in anhydrous saturator. 14% specimens were used in pumping saturated solution of saturation.

**TEST EQUIPMENT**

The freeze-thaw test by RTP-175BU Dongguan huanrui environmental testing equipment factory production procedure of high and low temperature test box, balanced temperature control system (BTC), using P.I.D. control of SSR, make the system heat equal to the amount of heat loss, so it can be long-term stability. The parameters for the controllable temperature range of -30 DEG C ~ 50 DEG C, the temperature fluctuation is plus or minus 0.5 DEG C, the temperature deviation of less than 1 DEG C. Instrument refrigeration compressor with two sets of TECUMSEH (France Taikang) composed of refrigeration system for low temperature compressor, refrigerant used USA DuPont refrigerant R404A, the heater adopts a fin type radiating pipe nickel chromium alloy U type high-efficiency heater, a temperature measuring device with DIN specification 4.8mm SUS grade a psi#304 stainless steel PT 100 Omega 1.

![Figure 1: RTP-175BU type high low temperature test box](image)

Compression samples using soil of Nanjing Instrument Factory Company Limited production of the YYW-2 type strain controlled unconfined pressure instrument. The maximum force is 0.6kN, rate of 2.4mm/min. The uniaxial compressive strength is confining pressure equal to 0 of a kind of unconsolidated undrained test.
TEST METHOD

Each group of uniaxial compression test preparation diameter is 39.1mm, height of undisturbed soil sample 80mm, the undisturbed loess, remolded loess configuration moisture content is 14%, 20%, 22%, 26%, 5 moisture saturated sample.

The prepared with different water content of soil sample is placed in the RTP-175BU programmable high low temperature test box, set the temperature of -15 DEG C after freezing 12h, set the temperature of 15 DEG C melting 12h, 1 times of freeze-thaw cycle. Repeated many times can get 0(including 0 times without freezing and thawing cycles), 1, 3, 5, 10 times the cycle of freezing and thawing soil sample. The specimen is removed after separately carried on the uniaxial compression test.

EXPERIMENTAL RESULTS AND ANALYSIS

In the loess mechanical properties test of different water content, the actual preparation compared the rate of soil water as the moisture content control point of 14.05%, 18.07%, 22.03%, 26.08%, 35.03%, to ensure that all the dry density of specimen were 1.45g/cm3. The undisturbed soil sample using the water film transfer method for humidifying and dehumidifying the natural air dry, when the water content reaches the test required moisture content control point, the soil sample in the humidor in sealed curing 24h, make the specimen surface and internal moisture distribution, to meet
the water content error rate is less than 1% required rate of. In order to compare the samemoisture content conditions, different influence of freeze thaw cycles on physical mechanical properties of loess, in this paper, error of water cut are omitted sample preparation of moisture content, using the ideal value as the moisture content control points were compared.

Figure 3: stress-strain curve of intact loess with different water content

Figure 4: stress-strain curve of remolded loess with different water content

From Figure 3 and Figure 4 can get the following characteristics:

① The undisturbed and remolded samples in moisture content becomes large in the process of uniaxial compressive strength decreased, showing the same trend, the uniaxial compressive strength and the uniaxial compressive strength of undisturbed soil samples were higher than that of remolded soil with water content, show obvious structural strength.

② For the undisturbed and remolded samples, when the moisture content is 14%, 18%, 22%, has the obvious peak intensity, belongs to brittle failure. The stress-strain curve has a rising stage, when in the rising stage, soil structure stability, small deformation, non slip among soil particles, soil unit basically is in the stage of elastic deformation. When the structure of soil is not enough to resist the axial compression load, the soil skeleton suffered damage, the axial stress peak, between the soil grains appear slip deformation, microcrack connecting part particles after damage. This shows that compared with the undisturbed soil remolded soil water content, has the obvious structural, stress drop is undisturbed soil structural damaged points.
③ In undisturbed and remolded samples, when the moisture content is higher than 26%, the stress strain curve was basically a straight line, showing a strain hardening characteristics. That the larger water content, soil water and soil structural impact on the larger.

④ The sample in the saturation process, water sensitivity of undisturbed and remolded loess structural potential is fully released, the water film entry will change the original mineral intergranular binding, secondary clay mineral particles to form grain cementation decomposition, so that the soil structure changed significantly, the uniaxial compression strength of structure show significantly reduced; arranged evenly loss and particle skeleton particles cemented the secondary structure, the formation of a new stable.

With water content of 22% loess freeze-thaw compressive strength curve after the cycle as an example, the analysis of effects of freezing and thawing cycles on the compressive strength of loess.

![Figure 5: moisture content 22% of intact loess after freeze-thaw cycle stress-strain curve](image_url)

![Figure 6: moisture content 22% of remolded loess after freeze-thaw cycle stress-strain curve](image_url)

From Figure 5, Figure 6 can get the following characteristics:
Along with the increase of freezing and thawing cycles, the uniaxial compressive strength with the water content of 22% of the undisturbed loess and remolded loess decrease, this is because the cycle of freezing and thawing soil water damage by coupling of soil particles, resulting in reduced soil sample strength's sake. Experience the same cycles of freezing and thawing, the uniaxial compressive strength of undisturbed soil sample is always greater than the uniaxial compressive strength of remolded soil samples.

With the increase of freezing and thawing cycles of structure strength of undisturbed and remolded soil samples showed a decreasing trend, and the compressive strength of the peak decreases.

**SIMULATION ANALYSIS**

Loess has strong water sensitivity, the shear strength with water content variation and significant changes in loess tunnel surrounding rock, as the change of shear strength, will also affect the stability of the tunnel itself. In order to study the influence of water content on the stability of loess in loess tunnel, select No. 1 Yangqu loess highway tunnel ZK94+810 section for typical section, geotechnical engineering using Midas/Gts software, numerical simulation is carried out by using the finite element method for the changes of morphology with different water content of Loess tunnel. In the same way of tunnel excavation conditions, the relationship between water content of loess and the tunnel between the maximum displacement of different parts, the relationship between water content of loess and rock stability coefficient. Numerical simulation of the moisture content of loess is selected four cases 8%, 14%, 20%, 26% of the numerical simulation, comes after the soil water content is 8.03%, 14.1%, 20.08%, 26.11%.

**CALCULATING ASSUMPTION**

1. all materials are continuous, homogeneous, isotropic;
2. rock used to meet Mohr yield condition simulation of Kulun materials, concrete, steel framebeam element to simulate jet, with implantable orange frame anchor (bar element) simulation;
3. the stress and deformation of tunnel is a plane strain problem, does not consider the spatial effect, using a two-dimensional plane model;
4. initial rock stress field without considering the tectonic stress, considering only the self weight stress.

**MODEL ESTABLISHMENT**

Tunnel excavation method for double side heading method. In the tunnel construction process, the model adopts each excavation footage cycle 1m, a total of 10 cycles, in accordance with the left-right-middle construction drift heading heading, while the observation section selected in the first cycle section excavation.
THE SELECTION OF PARAMETERS

In order to determine the changes of loess water content influence on the stability of loess tunnel, selected four kinds of different water content of Loess by numerical simulation. In the numerical simulation are considered in the process of moisture content on the loess, the influence value and bulk density.
The following parameters used are used in actual engineering design parameters and test parameters, to ensure the consistency of the results of numerical simulation and actual situation. According to the test results, the calculation model of parameters as shown in table 1.

**Table 1: calculation of the model parameters**

<table>
<thead>
<tr>
<th>Name</th>
<th>Density (kN/m³)</th>
<th>Modulus of elasticity (MPa)</th>
<th>Cohesion (kPa)</th>
<th>Angle of internal friction (°)</th>
<th>Poisson's ratio</th>
<th>The layer thickness (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>loess (water content 8.03%)</td>
<td>16.70</td>
<td>100</td>
<td>107.54</td>
<td>34.80</td>
<td>0.27</td>
<td>62</td>
</tr>
<tr>
<td>loess (water content 14.1%)</td>
<td>17.68</td>
<td>70</td>
<td>65.29</td>
<td>34.73</td>
<td>0.30</td>
<td>62</td>
</tr>
<tr>
<td>loess (water content 20.08%)</td>
<td>18.58</td>
<td>50</td>
<td>41.27</td>
<td>26.10</td>
<td>0.34</td>
<td>62</td>
</tr>
<tr>
<td>loess (water content 26.11%)</td>
<td>19.50</td>
<td>43</td>
<td>29.92</td>
<td>22.70</td>
<td>0.36</td>
<td>62</td>
</tr>
<tr>
<td>Sprayed concrete</td>
<td>24.00</td>
<td>15000</td>
<td>-</td>
<td>-</td>
<td>0.2</td>
<td>0.6</td>
</tr>
<tr>
<td>Bolt</td>
<td>78.50</td>
<td>20000</td>
<td>-</td>
<td>-</td>
<td>0.3</td>
<td>3.5</td>
</tr>
</tbody>
</table>

**SIMULATION RESULTS AND ANALYSIS**

*Figure 9:* the maximum principal stress cloud when moisture content was 8.03%
Figure 10: the maximum principal stress cloud when moisture content was 14.1%

Figure 11: the maximum principal stress cloud when moisture content was 20.08%

Figure 12: the maximum principal stress cloud when moisture content was 26.11%
As Figure 9 through Figure 12 show, in different moisture conditions, due to tunneling induced maximum principal stress direction change of tunnel surrounding rock and stress concentration trend is consistent, symmetrical distribution. Four kinds of moisture conditions, in the temporary support at the upper and lower ends have the phenomenon of stress concentration around, temporary support on both sides of the stress distribution is symmetrical about, the maximum principal stress value is basically the same. The water content was 8.03%, 14.1%, 20.08%, 26.11%, the maximum principal stress of temporary supporting the upper part are respectively -357.02 kPa, -371.20 kPa, -401.75 kPa, -414.28 kPa; with the increasing of water content, pressure increases, the stress concentration phenomenon aggravate.

It can be seen from the figure, four different moisture conditions, the maximum principal stress of soil around the tunnel and the minimum principal stress change tendency is consistent. Surrounding the minimum principal stress was compressive stress. The minimum principal stress the absolute value of the maximum value appeared at the arch at the end, and with the increase of water content of the surrounding rock, invert the minimum principal stress in the absolute value increase. The moisture content is 8.03%, 14.1%, 20.08%, 26.11%, temporary support the upper part of the minimum principal stress were -736.10 kPa, -771.37 kPa, -846.75 kPa, -857.45 kPa; arch bottom and temporary support point of contact with the minimum principal stress were -1083.76 kPa, -1108.89 kPa, -1177.42 kPa, -1176.27 kPa. The water content was 8.03%, 14.1%, 20.08%, 26.11%, respectively, -986.33 stress kPa, -968.89 kPa, -925.38 kPa, -902.05 kPa the minimum main arch angle.

Based on the shear strength theory, the relationship between soil damage depends on whether the combination of maximum principal stress in soil mass and the minimum principal stress, and a single analysis of a value of maximum principal stress or the minimum principal stress is unable to determine soil damage.

By the water content and the maximum principal stress in surrounding rock, the minimum principal stress can be drawn into the form, into the formula (5) to calculate the stability coefficient of surrounding rock. Draw the different moisture conditions of surrounding rock stability coefficient in Table 2.

<table>
<thead>
<tr>
<th></th>
<th>Water content 8.03%</th>
<th>Water content 14.1%</th>
<th>Water content 20.08%</th>
<th>Water content 26.11%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vault</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The maximum principal stress</td>
<td>-357.02</td>
<td>-371.20</td>
<td>-401.75</td>
<td>-414.28</td>
</tr>
<tr>
<td>The minimum principal stress</td>
<td>-736.10</td>
<td>-771.37</td>
<td>-846.75</td>
<td>-857.45</td>
</tr>
<tr>
<td>The stability coefficient</td>
<td>2.12</td>
<td>1.70</td>
<td>1.38</td>
<td>1.24</td>
</tr>
<tr>
<td><strong>Side wall</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The maximum principal stress</td>
<td>-176.15</td>
<td>-192.95</td>
<td>-211.28</td>
<td>-213.66</td>
</tr>
</tbody>
</table>
### Table

<table>
<thead>
<tr>
<th>Location</th>
<th>Minimum Principal Stress</th>
<th>Maximum Principal Stress</th>
<th>Stability Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arch bottom</td>
<td>-1083.76</td>
<td>-519.08</td>
<td>1.72</td>
</tr>
<tr>
<td>Arch foot</td>
<td>-986.33</td>
<td>-357.76</td>
<td>1.27</td>
</tr>
<tr>
<td>Side wall</td>
<td>-740.97</td>
<td>-564.53</td>
<td>1.21</td>
</tr>
<tr>
<td>Loess</td>
<td>-741.55</td>
<td>-570.85</td>
<td>1.03</td>
</tr>
<tr>
<td>Loess</td>
<td>-665.66</td>
<td>-519.08</td>
<td>1.01</td>
</tr>
<tr>
<td>Loess</td>
<td>-564.53</td>
<td>-519.08</td>
<td>0.98</td>
</tr>
<tr>
<td>Loess</td>
<td>-1176.27</td>
<td>-1176.27</td>
<td>0.97</td>
</tr>
<tr>
<td>Loess</td>
<td>-1177.42</td>
<td>-1176.27</td>
<td>1.08</td>
</tr>
<tr>
<td>Loess</td>
<td>-1108.89</td>
<td>-1176.27</td>
<td>1.20</td>
</tr>
<tr>
<td>Loess</td>
<td>-1108.89</td>
<td>-1176.27</td>
<td>1.43</td>
</tr>
</tbody>
</table>

**Figure 13:** relationship between wall rock stability and moisture content

The analysis of Figure 13 shows that, under the same moisture content condition, the arch and the side wall stability coefficient is the smallest, which of soil excavation stress concentration, soil stress to failure state development. The largest dome stability coefficient, the soil is in a stable state. With the increasing of water content, the stability coefficient of the surrounding rocks are reduced, basically linear relation.

Loess surrounding rock water content is 8.03%, the arch foot stability coefficient is 1.27; the water content is increased to 14%, the stability coefficient is reduced to 1.01, at the arch footrock will in the limit equilibrium state; in the surrounding water content is 20%, the stability coefficient is reduced to 0.99, now the shear stress exceeds the shear strength of soil, the soiloccurs damage. Tunnel wall rock stability coefficient in the water content of 26% reduced to 0.98, strength failure. As the water content increases the strength index reduce loess shear, so in the process of tunnel excavation of soil strength. Therefore, the surrounding rock water content are important factors to the stability of surrounding rock in Loess tunnel.
Surrounding rock water content change with the same effects on the stability coefficient of wall rock and surrounding rock. When the moisture content is 8.03%, the simulation shows that displacement is less than Un/3, the stability of surrounding rock; when the water content is 14%–20%, the displacement is larger, should be strengthened to support. The water content of 26.11%, simulation results show that the deformation of surrounding rock is big, should stop driving, so as to avoid the instability of the surrounding rock failure. That the increase in water content of surrounding rock deformation of the surrounding rocks stability coefficient increase, decrease, the water content decreased the stability of surrounding rock.

Due to the arch of the foot and the side wall stability was the worst, can use setting locking anchor pipe, amplifying arch foot and the wall, increase the longitudinal connecting duct and enhance the bearing capacity of such measures in the construction, in order to effectively prevent the initial support the overall settlement.

According to the above research results, will be in Yangqu in high water content water content of loess on stability of surrounding rock, deformation value of influence is divided into four grades is shown in table 3.

<table>
<thead>
<tr>
<th>Water content (%)</th>
<th>Characteristic of Loess</th>
<th>The stability influence</th>
</tr>
</thead>
<tbody>
<tr>
<td>( w &lt; 8% )</td>
<td>Low water content, high strength</td>
<td>The stability of surrounding rock, deformation of small, generally support</td>
</tr>
<tr>
<td>( 8% &lt; w &lt; 14% )</td>
<td>Low water content, high strength</td>
<td>The stability of the surrounding rock deformation is small, good, moderate support</td>
</tr>
<tr>
<td>( 14% \leq w \leq 20% )</td>
<td>The natural water content, low strength</td>
<td>The surrounding rock is stable, large deformation, strengthening support</td>
</tr>
<tr>
<td>( w &gt; 20% )</td>
<td>The high water content of loess, very low intensity</td>
<td>Poor rock stability, deformation is large, special support</td>
</tr>
</tbody>
</table>

ANALYSIS OF FREEZING THAWING CYCLE EFFECT ON THE STABILITY OF SURROUNDING ROCK

No. 1 Yangqu loess highway tunnel in March 1, 2010 face not construction case of left lineroof collapse, the survey found that the caving zone of surrounding rock moisture content as high as 27%, high water content and meet the freezing and thawing period leading to rock soil strength greatly weakened, the soil from poor stability, resulting in the left line soil instability roof roof. Analysis of main causes of accidents is Shanxi No. 1 Yangqu loess highway tunnel located in the seasonal frozen soil area, and the Loess Tunnel with high water content, freezing and thawing cycle has a strong deterioration effect on the engineering properties of high water content of the loess, tunnel in the
construction, operation period of freezing thawing action makes the stability of surrounding rock of lower.

In order to study the cyclic degradation effect on stability of Tunnel No. 1 Yangqu loess highway loess freeze-thaw high moisture content, section selection No. 1 Yangqu loess highway tunnel outlet at ZK94+810 for numerical simulation model. Because of the higher water content of loess in the cycles of freezing and thawing deterioration effect of intense, selecting the water content of 26% parameters of the different cycles of freezing and thawing for numerical simulation. Assumption of calculation, model building were done on the same day.

Loess surrounding rock water content is 26.11%, the surrounding rock after different freeze-thaw circulation situation of tunnel surrounding rock in the maximum and minimum principal stress, surrounding rock stability coefficient in table 4.

<table>
<thead>
<tr>
<th></th>
<th>Freeze-thaw 1 times</th>
<th>Freeze-thaw 3 times</th>
<th>Freeze-thaw 5 times</th>
<th>Freeze-thaw 10 times</th>
</tr>
</thead>
<tbody>
<tr>
<td>** Vault**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The maximum principal stress</td>
<td>-417.97</td>
<td>-423.20</td>
<td>-429.93</td>
<td>-441.61</td>
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<tr>
<td>The minimum principal stress</td>
<td>-871.19</td>
<td>-938.72</td>
<td>-996.08</td>
<td>-1114.09</td>
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<tr>
<td>The stability coefficient</td>
<td>1.13</td>
<td>1.03</td>
<td>0.98</td>
<td>0.87</td>
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<tr>
<td>** Side wall**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The maximum principal stress</td>
<td>-219.61</td>
<td>-222.92</td>
<td>-231.16</td>
<td>-237.27</td>
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<tr>
<td>The minimum principal stress</td>
<td>-596.54</td>
<td>-616.21</td>
<td>-647.71</td>
<td>-675.47</td>
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<tr>
<td>The stability coefficient</td>
<td>0.96</td>
<td>0.94</td>
<td>0.93</td>
<td>0.90</td>
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<tr>
<td>** Arch bottom**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The maximum principal stress</td>
<td>-520.83</td>
<td>-528.43</td>
<td>-533.15</td>
<td>-543.09</td>
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<tr>
<td>The minimum principal stress</td>
<td>-1230.08</td>
<td>-1277.07</td>
<td>-1374.27</td>
<td>-1390.35</td>
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<tr>
<td>The stability coefficient</td>
<td>1.04</td>
<td>1.02</td>
<td>0.97</td>
<td>0.96</td>
</tr>
<tr>
<td>** Arch foot**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The maximum principal stress</td>
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<td>-371.33</td>
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<td>-391.02</td>
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<tr>
<td>The minimum principal stress</td>
<td>-960.09</td>
<td>-989.32</td>
<td>-1058.44</td>
<td>-1167.49</td>
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<tr>
<td>The stability coefficient</td>
<td>0.95</td>
<td>0.94</td>
<td>0.90</td>
<td>0.86</td>
</tr>
</tbody>
</table>

Table 4: the main stress and stability factor under different freeze-thaw cycles
Analysis Table 4 shows, the surrounding rock after freeze-thaw cycles, the maximum principal stress of the surrounding rock and the minimum principal stress increases with the increase of freeze-thaw cycles. The water content of loess surrounding rock in the same circumstances, with the rock through the increase of freeze-thaw cycles, the stability coefficient of each part of the tunnel surrounding rock is reduced gradually. Side wall and arch foot rock without freeze-thaw stability factor has been less than 1, with freeze-thaw cycles increases, reducing the stability coefficient is smaller than the value of the vault and arch bottom.

![Figure 14: relationship between wall rock stability and freeze-thaw cycles](image)

Analysis of figure 14, shows that the surrounding rock water content is 26.11%, in the cycle of freezing and thawing 3 times before, the arch and the side wall stability coefficient is less than 1, soil excavation stress concentration, the arch and the side wall soil mechanical failure. The largest dome stability coefficient, the soil is in a stable state. With the increase of freeze-thaw cycles, the stability coefficient of each part of the surrounding rock are reduced, linearly decreasing relationship, vault the stability coefficient of maximum slope, reducing the fastest rate. In the freeze-thaw cycle after the 5 time, the vault stability coefficient decreased to 0.87, the stability coefficient is lower than other parts of the. Shows that with the increase of freeze-thaw cycles, the greatest impact on the vault. Due to the destruction of forms often occur in practical engineering is to produce large displacement in the loess tunnel top, at the top of the surrounding rock loose collapse, so vault displacement of rapid growth, the stability coefficient decreases too fast, show that the vault surrounding rock in a dangerous state, in the construction process should pay close attention to vault displacement, strengthen the supporting measures. The arch of the foot, side wall stability coefficient in freezing and thawing cycle has been less than 1, the freezing thawing cycles change stability coefficient value is small, that cycle of freezing and thawing on arch effect of small feet and side wall stability.

CONCLUSION

(1) with the increase of water content of surrounding rock, the maximum and minimum principal stress were increased, the stability coefficient decreases.
(2) under the same moisture content condition, the arch and the side wall stability coefficient is the smallest, that of soil excavation stress concentration, soil stress to failure state development. The largest dome stability coefficient, the soil is in a stable state. With the increasing of water content, the stability coefficient of the surrounding rocks are reduced, basically linear relation.

(3) with the increase of freeze-thaw cycles, the maximum principal stress in surrounding rock and the minimum principal stress was increased, the stability coefficient decrease. Side wall and arch foot stability coefficient reduce the rate is less than the value of the vault and arch bottom.

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