Experimental Study on Shearing Strength of Sand Pebble in Southeast Tibet

Guangchen Liao*, Jianfei Wei, Rui Xiang and Peiqing Wang*

Water Conservancy Project & Civil Engineering College, Tibet Agriculture & Animal Husbandry University, Nyingchi Tibet, 860000, China

*Corresponding author e-mail: 497450734@qq.com, 936681077@qq.com

Abstract. In order to study the shearing strength characteristics of sandy pebble soil in southeast Tibet, this paper takes the sandy pebble packing of high road embankment of Lalain high grade highway as the research object, and conducts particle analysis test on sandy pebble soil. On the basis of natural gradation, sand pebble soil was gradated and improved. In this paper, the undisturbed sand pebble soil and sand pebble soil with improved gradation were tested by direct shear tests under different vertical pressures. The results show that the stress-strain relationship of sandy pebble soil is mostly strain softening. The sandy pebble soil shears first, dilatancy occurs after, and the whole presents obvious dilatancy. The natural sandy pebble soil all has the phenomenon of grain deficiency, the shear strength of natural sandy pebble soil was improved by gradation. With the increase of the percentage of soil particle mass with a particle size of 20mm-60mm, the shear strength of sandy pebble soil increases accordingly. The physical and mechanical properties of sandy pebble soil was analyzed in this paper, which provides technical reference for the high embankment filling project in southeast Tibet.

1. Preface

The southeastern part of Tibet is located in the southeastern part of the Qinghai-Tibet Plateau. The area is located on the western line of the Hengduan Mountains. The Indian Ocean monsoon brings a lot of rainfall every year, which makes the valleys of the area vertical and horizontal, and a large amount of sand pebble soil is accumulated due to river sedimentation. At present, the infrastructure construction in the region is in full swing. The Sichuan-Tibet Highway, the Sichuan-Tibet Railway, and the Lalain High-grade Highway pass through the region. Due to the large number of alpine valleys in the region, high-steep embankments often appear during construction. Sand pebbles have high compressive performance. Therefore, sand pebbles have broad application prospects as embankment fillers. In engineering construction, there are few studies on the physical and mechanical properties of sand pebble soil and the stability of sand pebble embankments. Research has positive practical significance.

Sand pebbles are one type of coarse-grained soil (a soil material having a particle size greater than 0.075 mm and a particle content greater than 50%). Many scholars at home and abroad have studied the physical and mechanical properties of coarse-grained soil. Taylor [1] in 1948 believed that the shear strength of coarse-grained soil consisted of the frictional force between the particles and the force generated by the external overcoming of the rolling and dilating of the particles. In 1962, Rowe [2] used...
the energy balance equation to study sand soil. It is believed that the shear strength of coarse-grained soil is caused by the friction between soil particles, the intensity of redistribution of soil particles, and the strength of soil particles rolling and dilating. The three are composed together. De Mello [3] found that the shear rate has little effect on the shear strength of non-cohesive soil. Lindquist [4] studied the shear strength of coarse-grained soils as the content of coarse particles increased. Jalili J [5] et al. Conducted orthogonal tests on two coarse and fine particles of sand, silt, clay and suspended coarse particles. Obtain the relationship between stress-strain relationship and super-void water pressure. Guo Qingguo [6] found that the engineering properties of coarse-grained soil are closely related to the content of coarse-grained soil (particle size less than 5mm) by summarizing the test data of coarse-grained soil in a large number of water conservancy projects. Yan Fuyong [7] studied the dilatancy of coarse-grained soil, and the south-water constitutive model established by Shen Zhuijiang [8] took soil dilatancy as a factor to consider. Jiang Jingshan [9] et al., Cheng Zulin [10] also studied the relationship between soil volume and shear displacement of coarse-grained soil under low confining pressure and high confining pressure. The stress-strain characteristics of coarse-grained soil have been studied by many scholars, and the stress-strain relationship shows two types of strain hardening and strain softening [11-12].

2. Test plan
This paper takes the high embankment filling of the Linzhi-Lhasa section of the national highway 318 line (Lallin high-grade highway) as the research object, and samples the two typical sand pebble embankments in the Niyang section of the Lalin high-grade road. Based on the grading improvement. The natural sand pebble soil with a particle size larger than 5 mm is sieved according to the grain group, and then the sieved good soil sample and sand are used to prepare a sand gravel soil sample with a fine grain content of 70%. Through the large direct shear test of sand pebble soil, the shear strength characteristics, stress-strain relationship and dilatancy shearing performance of sand pebble soil were studied. Study the effect of sand pebble soil grading on shear strength.

3. Particle analysis test
The particles of the sand pebble soil are looser and the particles are less angular. The particle gradation of sand pebble soil is an important physical property. The pros and cons of gradation are directly related to the advantages and disadvantages of engineering properties of sand pebble soil. Particle grading of sand pebble soil can be obtained by particle analysis experiments. In this paper, the judgement of the fineness of the sand pebble soil is judged by the standard of China GBJ145-90. Whether the gradation of the soil is good or not, the commonly used uneven coefficient Cu and the curvature coefficient Cc are used to represent:

\[ C_u = \frac{d_{60}}{d_{10}} \]  
\[ C_c = \frac{(d_{60})^2}{d_{60}d_{10}} \]

Where: \(d_{10}\) - effective particle size, mm; \(d_{60}\) - limiting particle size, mm; \(d_{10}\) - the particle size corresponding to the horizontal coordinate of the particle grading curve is 30%, mm.

The gradation curve of the upper and lower sand pebble soil and its improved soil can be obtained by the analysis test of sand pebble soil particles as shown in Fig. 1. The high embankment of the upstream sand pebble soil sampling point is located at the river terrace slope of the Daniyang River in Gongbujiang. In the upstream sand pebble soil, the particles with a diameter of 40mm-60mm are round and non-angular; the shape of the particles with a diameter of 20mm-40mm is mostly smooth and has few strips; the particles with a particle size of 10mm-20mm are smooth and partially broken. The majority of the particles having a particle size of 2 mm to 10 mm are sharply divided particles. Particles
with a particle size of less than 2 mm are extremely irregular in shape of sand particles, and are mostly branched and flaky. The curvature coefficient $C_c$ of the sand pebble soil is 26.58>3, which indicates that the particle size distribution is discontinuous. The soil sample has less fine particles. Therefore, 7.71% of the original sand pebble soil is added to the fine sand pebble soil after passing through the 5mm sieve. Granules, obtained upstream sand pebble modified soil.

The downstream sand pebble soil sampling point is located at the east bridge bridge head in the Bayi District of Lalin High Grade Highway. The shape of the downstream sand pebble soil is similar to that of the upstream sand pebble soil, and most of the particles are round and have few edges and corners. The curvature coefficient $C_c$ is 0.22<1, which indicates that the coarse particles of the soil sample are less, so the sand pebbles with the diameter of the original sand pebble soil of 4.15% and the grain size of the original sand pebble soil are 13.77%. 40mm-60mm sand pebble particles, obtaining downstream sand pebble modified soil.

![Figure 1. Grain composition curve of natural sand pebble soil and improved soil](image)

The mass percentage of particles in natural sand pebble soil and modified soil is shown in Table 1.

| Particle size (mm) | Upstream sand pebble soil (%) | Upstream sand pebble improved soil (%) | Downstream sand pebble soil (%) | Downstream sand pebble improved soil (%) |
|-------------------|-------------------------------|----------------------------------------|-------------------------------|----------------------------------------|
| 60-40             | 33.70                         | 31.29                                   | 10.58                         | 20.65                                  |
| 40-20             | 33.89                         | 31.47                                   | 24.35                         | 20.65                                  |
| 20-10             | 6.76                          | 6.28                                    | 15.51                         | 16.67                                  |
| 10-5              | 1.04                          | 0.97                                    | 9.10                          | 7.72                                   |
| 5-2               | 0.36                          | 0.44                                    | 6.94                          | 6.1                                    |
| 2-0.5             | 1.81                          | 2.21                                    | 8.65                          | 7.6                                    |
| 0.5-0.25          | 14.14                         | 17.24                                   | 15.7                          | 13.8                                   |
| 0.25-0.075        | 6.59                          | 8.04                                    | 7.53                          | 6.62                                   |
| <0.075            | 1.7                           | 2.08                                    | 1.64                          | 1.45                                   |

In order to study the sand pebble soil at $P_5=70\%$, the distribution of the particle size of the fine particle fraction (soil particles with particle size <5 mm) and the distribution of the particle size of the coarse particle fraction (particle particles >5 mm) to the sand pebbles the influence of soil mechanical properties. Therefore, the sifted soil particles obtained by the large-scale screening test in the Dongru Bridge sand pebbles in the Bayi District and the coarse sand from the Niyang River tributary are combined into $P_5=70\%$ well-graded sand gravel soil samples CS0, CS1, CS2, CS3, CS4, CS5, CS6. The artificially prepared $P_5=70\%$ sand pebble soil, with the decrease of the mass percentage of the particles with the particle size of 20mm-60mm, the uneven coefficient $Cu$ gradually decreases, and the curvature coefficient $C_c$ gradually increases in the range of 1-3.
4. Large direct shear test of sand pebble
The direct shear test is the simplest and most efficient test method for measuring the shear strength of soil. Since the maximum particle size of sand pebble soil sample is 60mm, a large direct shear tester is needed to meet the test requirements. The instrument used in this direct shear test is a stacked ring shear tester. The appearance of the shear test machine is shown in Figure 2.

![Figure 2. External view of shear testing machine](image)

4.1. Test plan
The retrieved soil samples were first air-dried, and the dry density and water content of each soil sample were prepared according to the results of the compaction test, and the soil was suffocated for 24 hours. According to the Test Methods of Soils for Highway Engineering (JTG E40-2007), the sample is divided into three parts on average and is divided into three layers. In order to ensure the dry density control, the dry density required by the test, each layer is struck. The solid height is 1/3 of the height of the cut box. After each layer of soil is compacted, the surface should be shaved to ensure the integrity of the soil sample. The soil test protocol is shown in Table 2.

| Sample                        | Dry density (g/cm³) | Moisture content (%) | Vertical stress (kPa) | Shear rate (mm/min) |
|-------------------------------|---------------------|----------------------|-----------------------|--------------------|
| Upstream sand pebble soil     | 2.11                | 6                    |                       |                    |
| Upstream sand pebble improved soil | 2.11                | 6                    |                       |                    |
| Downstream sand pebble soil  | 2.21                | 7                    | 200, 300, 400         | 0.7                |
| Downstream sand pebble improved soil | 2.21                | 7                    |                       |                    |
| CS0                           | 2.11                | 6                    |                       |                    |
| CS1                           | 2.11                | 6                    |                       |                    |
| CS2                           | 2.11                | 6                    |                       |                    |
| CS3                           | 2.11                | 6                    |                       |                    |
| CS4                           | 2.11                | 6                    |                       |                    |
| CS5                           | 2.11                | 6                    |                       |                    |
| CS6                           | 2.11                | 6                    |                       |                    |

4.2. Analysis of shear stress-horizontal displacement curve
Three kinds of vertical loads of 200kPa, 300kPa and 500kPa were applied to the soil samples of the upstream and downstream sand pebble soil and its improved soil. The four soil-like shear stress-horizontal displacement curves are shown in Figures 3-6. The curves of shear stress and horizontal displacement of soil samples are mostly strain-softening type. The relationship between shear stress and horizontal displacement of upstream sand pebble soil and upstream sand pebble has certain differences.

The upstream sand pebble soil has obvious peak at lower vertical pressure and exhibits obvious strain softening type; the upstream sand pebble soil has less peak at higher vertical pressure and exhibits weaker strain softening type. This shear stress versus horizontal displacement curve occurs because each sample maintains the same dry density and moisture content. The soil sample is in a compact state, the particles are tightly combined, and the bite force is large. During the shearing process, the particles move,
rotate, and even climb over the adjacent particles, so that the soil sample undergoes dilatancy and deformation. In order to overcome the dilatancy, the soil particles need to do more work, so that the stress value is continuously increased, and the stress value is the largest when the shear stress peaks. After the shear stress reaches the peak value, the soil sample becomes looser due to the dilatancy deformation, so that the bite force between the soil particles decreases, the shear stress decreases, and the strain softening characteristics are exhibited. With the increase of vertical pressure, the dilatancy deformation is not easy to occur, so the peak value of shear stress is not obvious. With the increase of vertical pressure, the vertical pressure suppresses the stronger the dilatancy deformation of the soil sample and the degree of softening of the soil sample. At the lowering, the soil sample exhibits a weaker strain softening characteristic.

The upstream sand and gravel improved soil has obvious peaks at lower and higher vertical pressures, and the shear stress and horizontal displacement curves show obvious strain softening. The curves of shear stress and horizontal displacement of the upstream sand pebble modified soil and the upstream sand pebble soil under different vertical pressures show different rules. This phenomenon occurs because the upstream sand pebble modified soil is graded and improved on the basis of the natural grading of the upstream sand pebble, and the particles lacking the particle size of less than 5 mm in the upstream sand pebble are increased, so that the coarse grain content P5 is 75.40. The % becomes 70.00%, the curvature coefficient Cc changes from 26.58 to 2.94, and the gradation is optimized. The grading optimization makes the skeleton gap of the coarse particles filled, thus increasing the contact area between the particles and the particles. The soil sample is more compact and the contact between the particles is tight. As the shear stress increases, the particles gradually cross the adjacent particles and soil. The sample is more prone to dilatancy, so the upstream sand pebble modified soil exhibits strain softening characteristics. The shear stress of the upstream sand pebble modified soil under the corresponding vertical pressure is larger than that of the upstream sand pebble soil.

There is also a certain difference between the shear stress and horizontal displacement curves of the improved sand pebble soil and downstream sand pebble. The shear stress and horizontal displacement of the two soil samples show different laws under higher vertical pressure. The downstream sand pebble soil has shear stress peaks at lower and higher vertical pressures, and the relationship between shear stress and horizontal displacement is strain softening. The downstream sand pebbles improved soil has obvious peaks at lower vertical pressure, showing obvious strain softening type; there is no obvious peak at higher vertical pressure, and it is weaker strain hardening type. Under the higher vertical pressure, the downstream sand pebble modified soil is added with soil particles with particle diameters of 10mm-20mm and 40mm-60mm. After increasing the large soil particles, the soil particles turn, roll and climb more difficult, and the soil dilatancy is inhibited. Therefore, the downstream sand pebble soil is a weak strain hardening type under a high confining pressure. The peak value of the shear stress of the downstream sand pebble modified soil under the corresponding vertical pressure is larger than that of the downstream sand pebble soil.

![Figure 3. Shear stress - horizontal displacement relation curve of sand pebble soil upstream](image-url)
Figure 4. The shear stress - horizontal displacement relation curve of the upstream sand - pebble improved soil

Figure 5. The shear stress - horizontal displacement relation curve of sand and pebble downstream

Figure 6. The shear stress - horizontal displacement relation curve of sand - pebble improved soil downstream
The soil samples of CS0, CS1, CS2, CS3 and CS4 are applied with three different vertical loads of 200 kPa, 300 kPa and 500 kPa. The shear stress-horizontal displacement curves of the five soil samples are shown in Figures 7-11. The curves of shear stress and horizontal displacement of soil samples are mostly strain-softening type. This is because the five soil samples have good gradation, there are many contact points between the particles, the soil particles are easy to roll, the contact points after rolling are reduced, and the shear stress is the value is reduced. The relationship between the shear stress and horizontal displacement of each soil sample also has certain differences.

The mass percentage of soil particles with particle size of 20mm-60mm in the four soil samples of CS1, CS2, CS3 and CS4 were 56%, 42%, 35% and 14%, respectively. In the case of ensuring good soil sample grading and P5 is 70%, the peak value of shear stress corresponding to vertical pressure decreases continuously as the relative content of coarser particles in sand pebble soil decreases.
Figure 9. The shear stress - horizontal displacement relation curve of CS2

Figure 10. The shear stress - horizontal displacement relation curve of CS3

Figure 11. The shear stress - horizontal displacement relation curve of CS4
Both CS5 and CS6 soil samples have three different vertical loads of 200 kPa, 300 kPa, and 500 kPa. The shear stress-horizontal displacement relationship ($\tau$-$\Delta L$) curves of the two soil samples are shown in Fig. 12 and Fig. 13. The relationship between shear stress and horizontal displacement of soil samples shows strain softening, and the relationship between shear stress and horizontal displacement of soil samples has certain differences.

The shear stress and horizontal displacement curves of CS5 soil samples have shear stress peaks at both lower and higher vertical stresses, showing strain softening. When the vertical stress is 200 kPa, the shear stress peak of CS5 is 17 kPa larger than that of CS3. When the vertical stress is 300 kPa, the shear stress peak of CS5 is 3 kPa smaller than that of CS3. When the vertical stress is 500 kPa, the shear stress peak of CS5 is 22 kPa smaller than that of CS3.

The shear stress and horizontal displacement curves of CS6 soil samples have shear stress peaks at both lower and higher vertical stresses, showing strain softening. When the vertical stress is 200 kPa, the peak value of shear stress of CS6 is 7 kPa less than that of CS3. When the vertical stress is 300 kPa, the peak value of shear stress of CS6 is 23 kPa less than that of CS3. When the vertical stress is 500 kPa, the peak value of shear stress of CS6 is 36 kPa less than that of CS3. The peak value of shear stress of CS6 soil sample is smaller than that of CS3 soil sample. The peak value of shear stress decreases with the increase of vertical pressure.

**Figure 12.** The shear stress - horizontal displacement relation curve of CS5

**Figure 13.** The shear stress - horizontal displacement relation curve of CS6
The shear stress-shear displacement curves of the above 11 kinds of sand pebble soil samples have basically experienced four stages of elastic deformation, strain hardening, strain softening and residual deformation. The elastic deformation is generally completed within a short shear displacement, and then the shear strength of the sand pebble soil sample further increases, and begins to soften after increasing to the peak value, and finally the shear stress is maintained at a stable value. The shear stress-horizontal displacement curve of the specimen is relatively smooth at the initial stage of the test because the specimen is continuously deformed at the initial stage of shearing and the curve is smoother. After the soil particles are bite, embedded, rotated, and turned over, the indirect contact of the particles is reduced, and the pressure at the contact point of the particles is increased. After the pressure is increased to a certain value (limit value), the soil particles with lower strength are broken, and the shearing is performed. The stress will decrease instantaneously. After the particles are broken, the reorganization will occur immediately, and the shear stress will increase. Therefore, the shear stress-horizontal displacement curve fluctuates.

### 4.3 Study on Shear Strength of Sandy Cobble Soil

The shear strength of sand pebble soil consists of fine grain strength, coarse grain strength and strength between coarse and fine particles. The adhesion between the particles of sand pebble soil is low or even zero, so the shear strength of sand pebble is provided by the friction between the soil particles and the bite force generated by the dilatancy.

#### 4.3.1 Analysis of Shear Strength of Two Undisturbed Sandy Cobble Roadbed Soils and Their Improved Soils

In order to study the shear strength of two undisturbed sand pebble soils and their improved soils, the curves of the shear strength and vertical stress of the two sand pebble soils and their improved soils are shown in Fig. 14.

![Figure 14. Relationship curve between shear strength and vertical stress of natural sand pebble soil and improved soil](image)

The natural sand pebble soil and its modified soil internal friction angle $\phi$ and cohesion $c$ (provided by the bite force between the particles) are shown in Table 5 below:

| Sample               | Upstream sand pebble soil | Upstream sand pebble improved soil | Downstream sand pebble soil | Downstream sand pebble improved soil |
|----------------------|---------------------------|-----------------------------------|----------------------------|-------------------------------------|
| Internal friction angle $\phi$ (°) | 46.80                     | 51.17                             | 44.35                      | 46.10                               |
| Cohesion (kPa)       | 90.96                     | 87.82                             | 104.01                     | 106.58                              |
As a kind of coarse-grained soil, sand pebble soil has no cohesive force between the soil particles, and the force transmission is point-to-point contact. The cohesive force of the sand pebble soil is provided by the bite force between the particles.

After the grading of the upstream sand pebble soil, the internal friction angle increased by 4.37°, the cohesive force decreased by 3.14 kPa, and the shear strength increased remarkably. Because the curvature coefficient $C_c$ of the upstream sand pebble soil is $26.58 > 3$, the fine particles are not filled, and the gap between the coarse particle skeletons cannot be filled. After the fine gradation is added to improve the gradation, the soil changes from the skeleton void structure to the skeleton dense structure, so the sand pebbles improve the shear strength of the soil.

After the grading of the downstream sand pebble soil, the internal friction angle increased by 1.75°, the cohesion increased by 2.57 kPa, and the shear strength increased remarkably. Because the curvature coefficient $C_c$ of the upstream sand pebble soil is $0.22 < 1$, the coarse grain content of the upstream sand pebble soil is lacking, and the skeleton of the coarse grain is not completely formed. After the coarse granules are added to improve the gradation, the skeleton action of the coarse particles is strengthened, so the upstream the sand pebbles improve the shear strength of the soil.

The shear strength of the improved sand pebble improved soil is higher than that of the downstream sand pebble. This is because the soil unevenness coefficient $Cu$ of the upstream sand pebble is 139.13, and the non-uniform coefficient $Cu$ of the downstream sand pebble is 72.9. The distribution of the particles is about uneven, thereby increasing the coefficient of friction between the particles and increasing the internal friction angle of the soil.

The $P_5$ of the downstream sand pebble soil, the downstream sand pebble modified soil, the upstream sand pebble modified soil and the upstream sand pebble soil were 59.535%, 65.683%, 70%, 75.4%, respectively, and the shear strength reached the maximum at $P_5=70\%$. The above change rule of shear strength is due to the change of $P_5$ from 59.535% to 70%. At this time, the skeleton effect of sand pebbles is gradually strengthened, and the shear strength is gradually enhanced. When $P_5=70\%$, the skeleton of coarse particles is completely The shear strength reaches the maximum; after $P_5$ exceeds 70%, the sand pebble soil transitions from the dense structure of the skeleton to the void structure of the skeleton, and the shear strength decreases.

### 4.3.2. Analysis of shear strength of sand pebbles with different grades

The effect of sand-pebble grade on the shear strength of sand-pebble soil when $P_5=70\%$ of sand pebble soil is studied. The internal friction angle and cohesion of different grades of sand and gravel are shown in Table 4.

| Sample     | CS0     | CS1     | CS2     | CS3     | CS4     |
|------------|---------|---------|---------|---------|---------|
| Internal friction angle (°) | 51.52   | 47.93   | 49.25   | 48.03   | 44.47   |
| Cohesion c (kPa)      | 84.225  | 105.860 | 65.253  | 59.737  | 75.561  |

The internal friction angle and cohesion of the shear strength parameters of the upstream sand pebble modified soil and CS0 are basically the same, indicating that the particle size distribution of the fine particle fraction is similar when the particle size distribution of the coarse particle fraction in $P_5=70\%$ sand pebble soil is similar. The impact of sand pebble shear strength is minimal.

The particle sizes of CS0, CS1, CS2, CS3 and CS4 are 20mm-60mm, the mass percentage of particles is 63%, 56%, 42%, 35%, 14%, and the curvature coefficient $C_c$ is 1.27, 1.4, 2, respectively. 2.56, 2.98, the uneven coefficient $Cu$ is 60.78, 55.2, 38.45, 30.11, and 25.81, respectively. When $P_5=70\%$, the shear strength of sand pebble soil decreases with the decrease of particle mass percentage of 20mm-60mm, and the decrease of shear strength increases with the increase of normal stress. This shows that when $P_5=70\%$, the larger the larger particle size in the sand pebble soil, the greater the shear strength of the sand pebble. This rule occurs because the sand pebble soil is in $P_5=70\%$, the curvature coefficient $C_c$ is in the range of 1-3, and the continuity of the particle size distribution of the soil is good. The larger the
larger particles in the sand pebble soil, the more the skeleton effect of the coarse particles. The better, the better the shear strength.

Study P5=70%, particle size 20mm-60mm particle mass percentage is 35%, particle size 10mm-40mm particle content difference on sand pebble soil shear strength, CS3, CS5, CS6 internal friction angle and cohesion. The force is shown in Table 5 below:

| Sample  | Internal friction angle $\phi$ ($^\circ$) | Cohesion c (kPa) |
|---------|------------------------------------------|-----------------|
| CS6     | 45.46                                    | 69.637          |
| CS3     | 48.03                                    | 59.737          |
| CS5     | 44.50                                    | 100.34          |

When the above sand grit soil sample is P5=70%, the particle size is 20mm-60mm, the particle mass percentage is 35%, the CS6, CS3, CS5 three soil samples have a particle size of 10mm-40mm, and the mass percentage is 30%, 50 respectively. 70%, curvature coefficient Cc are 2.88, 2.56, 2.46, respectively, and the unevenness coefficient Cu is 26.77, 30.11, and 31.55, respectively. Compared with CS3, CS5 has a lower internal friction angle and increased cohesive force. When the normal stress is around 300 kPa, the shear strength is the same. Compared with CS3, CS6 has a smaller internal friction angle and increased cohesive force. When the normal stress is around 100 kPa, the shear strength is the same. After the normal stress is greater than 300 kPa, CS3 has the highest shear strength.

5. Conclusion

In this paper, according to the "Technical Regulations for Highway Geotechnical Engineering" JTG E40-2007, the physical properties and mechanical properties of the soil samples of the gravel high embankment were tested. The contents of this paper are summarized as follows:

(1) It is found through the analysis of particle gradation of sand pebble soil that the curvature coefficient of upstream sand pebble soil is Cc>3, lacking fine particles, adding 7.71% of the quality of the original sand pebble soil in the upstream sand pebble soil and the fine sand pebble soil. The fine particles of the same grade of the particles obtained the curvature coefficient Cc of the improved soil of the upstream sand pebbles became 2.94, and the improved gradation was excellent. The curvature coefficient of downstream sand pebble soil is Cc<1, which indicates that the coarse particle content of the soil sample is less. The particle size of the original sand pebble soil is 4.15%, the particle size of 10mm-20mm and the original sand pebble soil mass is 13.77%. The particles of 40mm-60mm obtained the Cc of the downstream sand pebble modified soil became 1.26, and the improved gradation was good.

(2) In order to study the distribution of fine particle fraction (soil particles with particle size <5mm) and the distribution of coarse particle fraction (soil particles with particle size >5mm) at the P5=70% For the influence of physical and mechanical properties of sand pebble soil, CS0, CS1, CS2, CS3, CS4 were prepared by using the sieved soil particles obtained by large-scale screening test in the Dongru Bridge sand pebbles in Bayi District and the coarse sand of the Niyang River tributary. Seven grades of CS5 and CS6 are excellent sand and gravel soil samples. The artificially prepared P5=70% sand pebble soil, with the decrease of the mass percentage of the particles with the particle size of 20mm-60mm, the uneven coefficient Cu gradually decreases, and the curvature coefficient Cc gradually increases in the range of 1-3.

(3) The relationship between shear stress and horizontal displacement of most sand pebble soils obtained by large direct shear test is strain softening; from the relationship between the soil and the horizontal displacement of each sand pebble, it can be seen that each soil sample is smaller first. After the degree of shearing, it exhibits significant dilatancy. The shear strength of the upstream sand pebble modified soil and the downstream sand pebble modified soil is improved compared with the original soil sample. The pebbly soil with good gradation and P5=70%, with the decrease of the mass percentage of the particles with the diameter of 20mm-60mm, the shear strength of the sand ash is reduced.
Acknowledgments
Fund project: Major project of Department of Science and Technology Tibet (particle mixing) Fund project: key project of science and technology department of Tibet autonomous region of China (XZ2019ZRG-56(Z))

About the author: Liao Guangchen (1993 - ), male, master, mainly engaged in geotechnical engineering experimental research. E-mail: 936681077@qq.com

Corresponding author: WANG Peiqing* (1972 --), male, professor, doctor, mainly engaged in geotechnical engineering and civil engineering experimental research. E-mail: 497450734@qq.com

References
[1] Taylor D W. Fundamentals of soil mechanics [J]. Soil Science, 1948, 66 (2): 161
[2] Rowe P W. The Stress-dilatancy relation for static equilibrium of an assembly of particles in contact [J]. Proceedings of the Royal Society of London, 1962, 269 (1339): 500-527.
[3] De Mello, V B B . Reflection on decisions of practical significance to embankment dam construction [J]. Géotechnique, 1977, 27 (3): 281-355.
[4] Lindquist E S .The strength and deformation properties of melange [D]. University of California at Berkeley, 1994.
[5] Jalili J, Jafari M K, Shafiee A, et al. An investigation on effect of inclusions on heterogeneity of stress, excess pore pressure and strain distribution in composite soils [J]. International Journal of Civil Engineering, 2012, 10 (2): 124-138.
[6] Guo qingguo. Engineering characteristics and application of coarse-grained soils [M]. Zhengzhou: The Yellow River conservancy press, 1998, 98-106.
[7] Chu fuyong, zhu jungao, Yin jianhua. Dilatancy of coarse-grained soils based on triaxial test [J]. Rock and Soil Mechanics, 2013 (8).
[8] Shen zhujiang. Theoretical soil mechanics [M]. Beijing: China Water & Power Press, 2000.
[9] Jiang jingshan, cheng zhanlin, zuo yongzhen, et al. Triaxial experimental study on dilatancy of coarse soil [J]. Geotechnical mechanics, 2014, 35 (11): 3129-3138.
[10] Cheng c l, jiang J s, ding h s, et al. Nonlinear dilatancy model of coarse soil [J]. Chinese Journal of Geotechnical Engineering, 2010, 32 (3): 460-467.
[11] Li g x. advanced soil mechanics [M]. Beijing: Tsinghua University Press. 2004. 7
[12] Qin shanglin. Research on compaction control and mechanical properties of embankment with macrogained soil [D]. Institute of Rock and Soil Mechanics, Chinese Academy of sciences, 2007.