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**Research Article**

# Research on Direct Shear Test of Undisturbed Root-soil Composition

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**Abstract:** In order to further study the soil reinforcement of roots on the quantitative analysis of "reinforced" soil, to understand the effect of plant roots on the soil shear strength. direct shear test was employed to investigate the shear displacement and stress force relationship of the undisturbed soil and disturbed soil without root located at An Shan Kou, Ba Mao Di, Hun He Di and Duo Hua Mulan Di and the shear strength of the average root content of soil was discussed, as well. The results show that the cohesion of the undisturbed soil is significantly greater than that of the disturbed soil without root, under the condition of the average root content of 0.945% at An Shankou, 1.154% at Ba Mao Di, 0.4425% at Hun He Di, 1.1725% at Duo Hua Mulan Di. The increase of cohesion is respectively 5.05, 17.19, 36.93, 31.84%; and the increase of inner friction angle is not obvious with the increase of root content, soil cohesion increase, the shear strength thus increases. Compared with the herbaceous roots, the grass-shrub mixed plant roots system can improve the shear strength of the soil more effectively.

**Keywords:** Disturbed soil without root, direct shear test, ecology protection of slope, moisture content, undisturbed soil

## INTRODUCTION

With the fast growth of Chinese economy and the construction of highway, railway increased rapidly, there appears a large number of slope engineering. Compared with the traditional ways of slope protection, the technology of the ecological protection of slope is a new type of slope protection and greater emphasis on the harmonious development of human being and nature (Zhang, 2010). Since the 1990s, China has begun a large number of studies on the ecology protection of slope. These studies mainly concentrate on the aspects of the soil reinforcement of root, performance on the improvement of the soil shear strength (Zhang and Hu, 2009). Root-soil composite still has a quasi-cohesion (Ouyang, 1991; Wu *et al*., 2002), which explains that root-soil still accords with Mohr-Coulomb shear strength theory (Dang and Li, 2001). Compared with shear strength of root-soil and root-free soil by trials, the test results of Chen *et al*. (2006) and Liu *et al*. (2006) have shown that the root-soil composite can significantly improve the shear strength of soil.

Existing research work is mostly qualitative research, which lacks of quantitative analysis on the root-soil shear strength often can't meet the need of engineering design (Luo and Xiao, 2011). There is little research on the quantitative aspects of the roots on the soil reinforced. Hu *et al*. (2010) studied single root content and shear strength of early herb in disturbed soil with roots, but not for irrigation grass mixed plants in undisturbed soil.

Direct shear test was employed to investigate shear strength parameters of the undisturbed and disturbed soil without root located at An Shan Kou that it planted Cyperus rotundus, Ba Mao Di that planted White thatched, Hun He Di that it planted White clover and White thatched and Duo Hua Mulan Di that it planted Indigofera amblyantha-Galium aparine, Vernica and shepherd's purse, which grows along the Qingzheng expressway, the shear strength of the Root-Soil Composition was also studied.

## DIRECT SHEAR TEST

**Direct shear test on undisturbed soil**: Undisturbed soil is sampled in different sections of Qingzheng highway between Wuhan with Xianning, where the construction of ecology protection of slope was completed in 2008 and plant has been growing for 4 to 6 years and has high plant coverage rate. An Shan Kou, Ba Mao Di, Hun He Di and Duo Hua Mulan Di where plants grow well are four sites as the sampling, each site sapling there groups. In order to facilitate sampling, before sampling by a cutting ring of 5cm high, the ground stems and leaves parts are cut off, then sealing, numbering and saving.

Before the test, measuring the average moisture content and the average density of four sites of undisturbed soil, as shown in Table 1. Then, direct

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Table 1: Average moisture comparison of the undisturbed soil and disturbed soil without root

| Test soil sample | An Shan Kou/% | Ba Mao Di/% | Hun He Di/% | Duo Hua Mulan Di/% |
|---|---|---|---|---|
| Undisturbed soil | 18.58 | 18.68 | 15.22 | 17.43 |
| Disturbed soil without root | 18.42 | 18.54 | 15.13 | 17.41 |

Table 2: Measured results of the average root content

| Location | The average root weight/g | The average root content /% |
|---|---|---|
| An Shan Kou | 1.057 | 0.945 |
| Ba Mao Di | 1.195 | 1.154 |
| Hun He Di | 0.377 | 0.4425 |
| Duo Hua Mulan Di | 1.167 | 1.1725 |

Table 3: Average density comparison of the undisturbed soil and disturbed soil without root

| Test soil sample | An Shan Kou g/cm³ | Ba Mao Di g/cm³ | Hun He Di g/cm³ | Duo Hua Mulan Di g/cm³ |
|---|---|---|---|---|
| Undisturbed soil | 1.878 | 1.779 | 1.428 | 1.717 |
| Disturbed soil without root | 1.875 | 1.8781 | 1.427 | 1.715 |

shear test was employed to measure the average root content, as shown in Table 2.

**Direct shear test of the disturbed soil without roots:** In order to study the enhancement of plant roots on the shear strength, direct shear test was employed on four different sites of the undisturbed soil and disturbed soil without root. In order to have comparability between undisturbed soil and disturbed soil without root, ensuring moisture content and density of disturbed soil without root is closed to the undisturbed soil's hile sampling. Results are shown in Table 1 and 3.

Table 1 and 3 show that the difference was much smaller between the undisturbed soil and disturbed soil without root, thus the test conditions (moisture and density) of four sites are assumed to be the same.

In the preparation of specimens, numbering the specimens, direct shear test was employed on the disturbed soil without root.

## EXPERIMENT RESULTS AND ANALYSES

The relation curves of the shear displacement and shear stresses at four samples are shown from Fig. 1 to 8. Due to limited space, three specimen test results are similar, so that Fig. 2 only drawn around the point of a typical sample of the test results. The vertical pressure was of 100, 200, 300, 400 kPa, respectively. The growth of displacement and stress force relationship curve becomes faster with vertical pressure increasing. In certain vertical pressure, the shear stress increases along with the increasing of shear displacement, then achieving a peak shear stress. Stress-strain curve of the initial period is linear, showing a more obvious elastic property. With the increase of shear displacement, the tangent slop slowly decreases and the stress-strain curve gets into the plastic stage. When the shear displacement reaches a certain level, the shear stress reaches the maximum and the soil will be destroyed.

Shear strength index under different conditions are shown in Table 4.The cohesion of the undisturbed soil is significantly greater than that of the disturbed soil without root, under the condition of average root content of 0.945% at An Shan Kou, the increase of cohesion is 24.61%, shown in Table 2 and 4, which

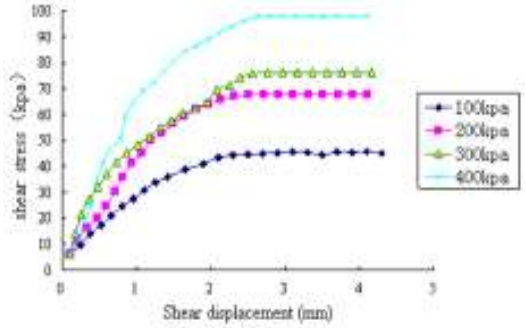


Fig. 1: Shear displacement-shear stress curves of An Shan Kou undisturbed soil

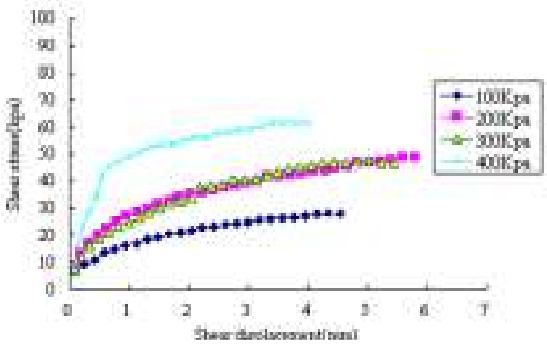


Fig. 2: Shear displacement-shear stress curves of An Shan Kou disturbed soil without root

explains the root of purple nuts edge plants and soil complex can improve the cohesion. This shows that the roots gather its surrounding soil particles together and are anchored in the ground, making the cohesion increase. The cohesion includes not only between soil particles and soil particles, but also between soil particles and root and shear stress or the anchoring force of the root by the soil particles pass to the root. At the same time, the increase of inner friction angle is 19.35%. This show the root of root-soil complex can improve the inner friction angle which is generated not only the friction between soil particles and soil particles, but also between soil particles and root.

Table 4: Shear strength index under different conditions

| Location | The average cohesion cohesion c | | | The average internal friction angle φ | | |
|---|---|---|---|---|---|---|
| | Undisturbed soil /kPa | Disturbed soil without roots/kPa | Relative increment/% | Undisturbed soil /kPa | Disturbed soil without roots/kPa | Relative increment/% |
| An Shan Kou | 24.837 | 19.931 | 24.61 | 10.36 | 8.68 | 19.35 |
| Ba Mao | 12.526 | 9.542 | 31.27 | 9.41 | 8.17 | 15.18 |
| Hun He | 18.247 | 15.401 | 18.48 | 6.83 | 5.96 | 14.6 |
| Duo Hua Mulan | 31.639 | 20 | 58.2 | 8.74 | 6.84 | 27.78 |

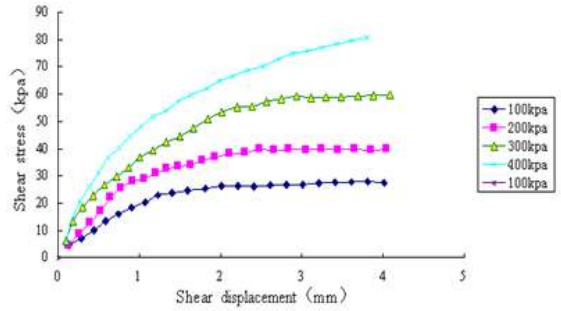


Fig. 3: Shear displacement-shear stress curves of Ba Mao Di undisturbed soil

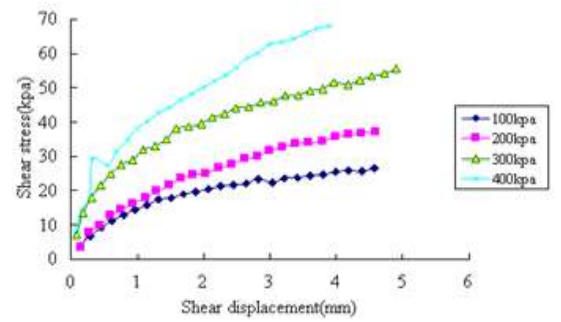


Fig. 4: Shear displacement-shear stress curves of Ba Mao Di disturbed soil without root

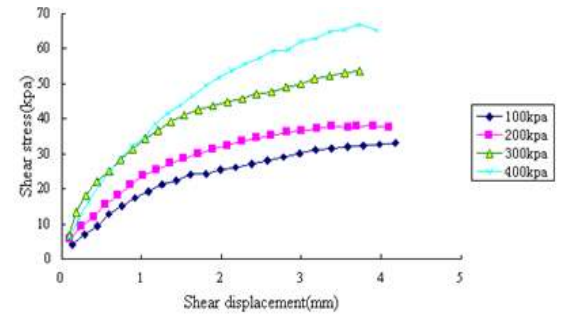


Fig. 5: Shear displacement-shear stress curves of Hun He Di undisturbed soil

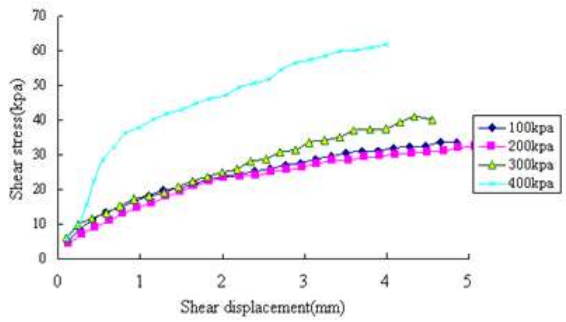


Fig. 6: Shear displacement-shear stress curves of Hun He Di disturbed soil without root

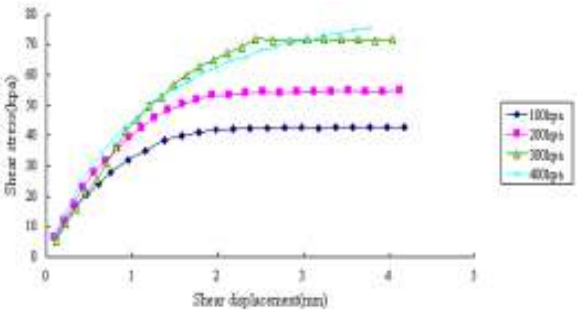


Fig. 7: Shear displacement-shear stress curves of Duo Hua Mulan Di undisturbed soil

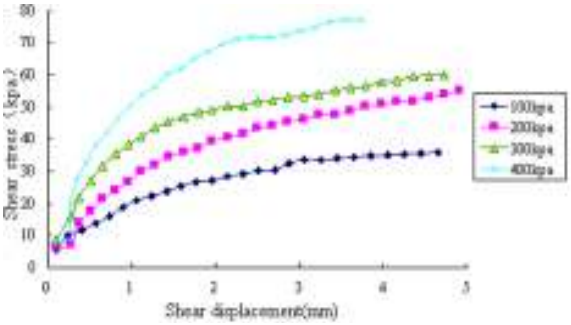


Fig. 8: Shear displacement-shear stress curves of Duo Hua Mulan Di disturbed soil without root

The results are the same with the plant root at Ba Mao Di, Hun He Di and Duo Hua Mulan Di.

Meanwhile, from Table 2 and 4, we know that the growth of soil cohesion and internal friction angle is minimum in the sample of least root content, while maximum in the sample of most root content. This shows that the anchoring force of roots content increases significantly with the increase of root content, namely soil cohesion increases significantly and the shear strength of the soil is improved with the increasing in contact area and internal friction angle.

Ba Mao Di plant Thatched white, which is belongs to the herb. Duo Hua Mulan Di planted Indigofera amblyantha-Galium aparine, Vernica and shepherd's

purse. Indigofera amblyantha belongs to the shrub, Galium aparine, Vernica and shepherd's purse belong to the herb .So it is the grass-shrub mixed. From Table 2 and 4, we know that the growth of soil cohesion and internal friction angle for the sample at Duo Hua Mulan Di is significantly greater than Ba Mao Di, showing that herb plant can enhance soil cohesion and internal friction angle more effectively, compared to the combination of herbs and bushes. This explain that the anchoring force of roots and soil cohesion are increased significantly with the increase of root diameter and tensile strength, increasing in internal friction angle with the increase of the contact area between the roots and soil. In summary, the plant roots can enhance the shear strength of soil.

## CONCLUSION

Through direct shear test in the laboratory, we study on the effect of root content on the shear strength and the main conclusions are obtained as the follows.

- The soil with plant root can improve the soil cohesion and internal friction angle, thereby increasing the shear strength of soil. The cohesion and internal friction angle of the undisturbed soil is significantly greater than that of the disturbed soil without root, under the condition of the average root content of 0.945% at An Shankou, 1.154% at Ba Mao Di, 0.4425% at Hun He Di, 1.1725% at Duo Hua Mulan Di. The increase of cohesion is 24.61, 31.27, 18.48, 58.24%, respectively; and the increase of inner friction angle is 19.35, 15.18, 14.60, 27.78%, respectively.
- With the increase of root content, soil cohesion and internal friction angle increase, the shear strength thus increases.
- Compared with the herbaceous roots, the grass-shrub mixed plant roots system can improve the shear strength of the soil more effectively, thereby increasing the shear strength of soil.

## ACKNOWLEDGMENT

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