多花木兰和双荚决明分叉根拔出过程中根土界面摩擦特性

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摘 要:【意义】根系的不同分叉形态和分叉角度在拔出过程中释放的力对根系固土起重要作用，是根系固土力学性质的前置阶段。【方法】该研究以边坡绿化常用灌木多花木兰和双荚决明为研究对象，采用拉拔试验方法，研究分叉角度（0°～90°）对根系拉拔摩擦力学性质的影响。【结果】试验结果表明，分叉根有 3 种拔出破坏模式：完全拔出、主根断裂和侧根断裂，多花木兰和双荚决明破坏模式以完全拔出为主，分别占总样本的 82.61%和 86.05%。3 种破坏模式下的拉拔力与相对位移曲线（F-S 曲线）初始阶段相似，在根系相对位移为 0 时，拉拔力已经产生，且分叉角度与初始滑移荷载呈显著正相关关系（多花木兰P=0.042，双荚决明 P=0.003）。多花木兰和双荚决明分叉角度为 60°～90°时，1～2 mm 根径峰值位移分别为 19.749mm 和 17.324 mm；多花木兰和双荚决明分叉角度为 0°～30°时，>4～5mm 根径峰值位移分别为 7.253mm 和 4.891mm；根径相同时其峰值位移随分叉角度的增加而增加，根系分叉角度相同时，峰值位移随根径的增大而减小，即根径越小，分叉角度越大，峰值位移越大。多花木兰和双荚决明根土界面摩擦系数均随分叉角度的增加而增大，多花木兰平均最大拔出力从大到小的分叉角度依次为>30°～60°、>60°～90°、0°～30°，双荚决明平均最大拔出力从大到小的分叉角度依次为>60°～90°、>30°～60°、0°～30°。分叉根在受拉初始阶段释放的其中一部分力可用土压力来表示，因此可对分叉角度对摩擦力学特性的影响进行定量分析。该研究可为进一步了解根系的固土作用和锚固机理提供依据。

关键词： 破坏模式；摩擦特性；试验；根分叉角度；初始滑移荷载

Friction characteristics of root-soil interface during branches root pull-out of Indigofera amblyantha and Cassia bicapsulafis

Abstract: 【Objective】 The front stage of root system can be the root branch morphology and different angle of release in the process of pull force of root stabilization and strengthening soil in soil mechanics properties. 【Method】In this study, the pull-out experiment was carried out to clarify the effect of branch angle on the frictional mechanical properties of root pulling using SK-WDW-2 microcomputer. The experimental subjects were taken as the slope greening shrubs Indigofera amblyantha and Cassia bicapsulafis. 【Result】The results show that there were three failure modes of roots with the branches: pullout failure, breakage failure on the taproot fracture, breakage failure on the branch root. The main failure modes were the pullout failure, accounting for 82.61% and 86.05% of the total samples, respectively. The maximum pullout force increased with the increase of the root diameter. There were the similar initial stages of the pull-out force and the relative displacement curve (F-S curve) under the three failure modes. The pull-out force was generated at the zero relative displacement of roots. There was a significant positive correlation between the branch angle and the initial sliding pulling force, indicating that the root with the branch first released a part of the force during the tension. However, the correlation between the bifurcation angle and initial force was more significant in the Indigofera amblyantha than in the Cassia bicapsulafis (Indigofera amblyantha P=0.042, Cassia bicapsulafis P=0.003). Specifically, the peak displacements were 19.749, and 17.324 mm, respectively, when the root diameters was >4-5 mm, with the angle of Indigofera amblyantha of and Cassia bicapsulafis 60°-90°. Once the angle of Indigofera amblyantha and Cassia bicapsulafis was 0°-30°, and the root diameters were 1-2 mm, the peak displacements were 7.253 and 4.981 mm, respectively. Therefore, the peak displacement corresponding to the maximum pull-out force also increased with the increase of branch angle under the same root diameter range. Under the same range of branch angle, the peak displacement corresponding to the maximum pull-out force also increased with the increase of root diameter. The smaller the root diameter was, the larger the branch angle and the larger the peak displacement were. The branch angle of the average maximum pulling force for Indigofera amblyantha was ranked by >30°-60°, >60°-90°, 0°-30°, whereas, the branch angle of the average maximum pull-out force

of Cassia bicapsulafis was ranked by >60°-90°, >30°-60°, 0°-30°. The root soil interface friction coefficients of both species increased with the increase of branch angle. The mean maximum static friction coefficient increased greatly from 0°-30° to 30°-60°, while the mean maximum static friction coefficient increased slightly from >30°-60° to >60°-90°. In the same range of angles, the mean maximum static friction coefficient of Indigofera amblyantha was smaller than that of Cassia bicapsulafis. The part of the force that released by the branch root in the initial stage of tension was calculated by the soil pressure, according to the soil pressure on the branch root. When the branch angle was less than 90°, the soil pressure under the root system increased with the increase of the branch angle under the same soil depth. Therefore, the quantitative analysis was realized to determine the influence of branching angles on frictional mechanical properties. The finding can provide a strong reference to further understanding the soil fixation and anchorage mechanism of roots.

Keywords: failure mode; friction characteristics; test; root branch angle; initial sliding load