農田排水常見生態孔入滲管湧現象之研究

A study on infiltration piping in conventional ecological holes of agricultural drainage

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摘　要

工程會為推動公共工程落實節能減碳理念，建構優質永續之公共建設，已於 111 年 8 月 31 日訂定「公共工程節能減碳檢核注意事項」，積極引導公部門落實節能減碳，進一步提升基礎建設的永續性與環境適應力。本研究以實踐永續 ESG 為導向，於農田排水路採封底及設置滲透措施（PVC 管），穩定渠床結構、減少管湧發生，並提升地下水補注與蓄水能力，提供水生生物棲息環境，促進農業永續發展。

農水路工程中，入滲管湧是農田排水路或滲水設施常面臨的問題，尤其滲水設施底部常發生此類現象，此現象係指土壤細粒料隨水流從農田底土流失，並湧出至排水路或滲水設施中，主要成因為工程位於高地下水位區域或砂質壤土等高滲透性地層，在臨界水力坡降條件下產生地下水上湧，夾帶細粒料流失至滲水孔外，進而導致渠底隆起、排水功能下降，更可能直接影響農民耕作的穩定性而造成農業損失。

管湧現象之發生機率與土壤特性及耕地類型密切相關。砂質壤土由於水力傳導係數較高，水分滲透與流動速度較快，加上砂質壤土粒料間黏著力低，細粒料易隨上升之地下水流動而流失，因而較易發生管湧現象。反之，黏質壤土或坋質壤土因水力傳導係數較低，具良好之吸水力及低滲透性，發生管湧之可能性相對較低。此外，在農田排水路內設置之生態滲水設施，於整田插秧期間因田間需水量增加、土壤含水量提高，且長期湛水導致滲透量大，致使管湧風險遠高於旱田環境。

在農田排水設計中，為兼顧生態功能及地下水補注需求，常於排水路渠底以固定間距設置 PVC 管作為滲水設施。本研究採用土壤滲流分析方法，並計算管湧安全係數（Harza, 1935），以評估滲水孔管徑及設置間距對管湧發生之影響。研究結果顯示，滲水孔管徑對管湧安全係數影響顯著，管徑愈大，安全係數愈低，管湧發生機率亦隨之提高；相較之下，設置間距對管湧影響則較小。本研究蒐集各地農地重劃區農田排水路臨田側不同土壤性質（砂質壤土、坋質壤土及黏質壤土）、排水路 PVC 管徑（60、80、100、125 及 150 mm）、渠底寬度（0.7、0.8、0.9 及 1.0 m）、渠高（0.6、0.8 及 1.0 m），並假設田間湛水深度為 20 cm，評估不同條件下 PVC 滲水管不致發生管湧現象之管徑設置門檻。結果顯示，不同土壤條件下 PVC 管之滲水孔建議最大管徑（門檻值）如下：(1) 砂質壤

土 60 mm；(2) 坋質壤土 80 mm；(3) 黏質壤土 100 mm。本研究成果可作為未來農田排水路生態滲水設施設計之參考依據。

關鍵詞：農田排水、生態孔，管湧現象

Abstract

To promote public constructions to implement the concept of energy conservation and carbon reduction, and to construct prime and sustainable public construction, Public Construction Commission (PCC) has formulated the “Public Constructions Energy Conservation and Carbon Reduction Notices” on 31 August 2022, which actively guides public departments to implement energy conservation and carbon reduction, and further enhances the sustainability and environmental resilience of infrastructures. This study is guided by the practice of sustainable ESG, and adopts bottom sealing and infiltration facilities (PVC pipes) in agricultural drainage channels to stabilize the channel structure, reduce the occurrence of piping, enhance groundwater recharge and storage capacity, provide aquatic habitat, and promote the sustainable development of agriculture.

Infiltration piping is a common problem encountered by agricultural drainage channels or infiltration facilities in Farm Road and Canal Engineering, especially at the bottom of infiltration facilities. This refers to the loss of fine soil particles from the subsoil of the farmland with flow of water, and piping into drainage channels or infiltration facilities. The major cause is that the engineering project is in high water table regions or sandy loam and other highly permeable strata, generates groundwater upwelling under the conditions of critical hydraulic gradient. At the same time, this leads to the loss of fine granular materials to the outside of the ecological holes. This leads to heaving of canal bottom and deterioration of drainage efficiency, which may directly affect the stability of farmers' cultivation and cause agricultural losses.

The probability of piping is closely related to soil characteristics and type of cultivated land. Sandy loam has a higher hydraulic conductivity, faster water infiltration and flow, and low adhesion between sandy loam particles, so fine particles are easily lost with the rising groundwater, making it more prone to piping. In contrast, clay loam or silt loam because of hydraulic conductivity is lower, has good water absorption and low permeability, the probability of piping is relatively low. In addition, the ecological infiltration facilities set up in the farmland drainage channels, in the preparing field and rice transplanting period because of the field water demand increases, soil moisture content increases, and long-term soak resulting in large permeability, resulting in probability of piping is much higher than the upland field environment.

In the design of farmland drainage, to consider the ecological function and groundwater

recharge requirements, PVC pipes are often installed at fixed intervals at the bottom of the drainage channel as water infiltration facilities. This study adopts soil infiltration analysis method and calculates the piping safety factor (Harza, 1935) to evaluate the effect for diameter and interval of PVC pipes on the occurrence of piping. The results show that diameters of PVC pipes influence the piping safety factor significantly, the larger the diameter of pipe, the lower the safety factor, and the probability of piping are therefore increasing. In contrast, the intervals of pipes have less impact on piping. In this study, different soil properties (sandy loam, silt loam, and clay loam), PVC pipe diameters (60, 80, 100, 125, and 150 mm), widths of the bottom of the drainage channel (0.7, 0.8, 0.9, and 1.0 m), and heights of the drainage channel (0.6, 0.8, and 1.0 m) were collected from different locations of the drainage channel of the agricultural field in the farmland readjustment region, and the depth of soaking in the field was assumed to be 20 cm to evaluate the thresholds for diameters that would not cause piping under different conditions. The results show that the recommended maximum diameter (threshold) of PVC pipes under different soil conditions were as follows: (1) 60 mm for sandy loam, (2) 80 mm for silt loam, and (3) 100 mm for clay loam. The results of this study can be used as a reference for the design of future ecological infiltration facilities for farmland drainage channels.

Keywords : farm drainage, ecological holes, piping phenomenon