彈性與非彈性變形的影響因素與機制：濁水溪沖積扇地層下陷現象相關文獻回顧與見解

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摘要

地下水是濁水溪沖積扇地區的重要水資源，根據臺灣經濟部水利署（Water Resources Agency, WRA）2023 年紀錄，該地區因為長期超抽地下水，成為臺灣曾經下陷面積最大的區域，當年最大下陷速率達 6.4 公分。本研究結合兩篇相關文章，探討造成地層下陷之非彈性變形的影響因素與機制。研究利用 Terzaghi 有效應力原理，探討抽水行為下孔隙水壓與有效應力的關係，並與預壓密應力比較。同時，透過應變應力曲線特徵，區分彈性、彈性-非彈性與非彈性變形。進一步使用空間回歸(Spatial Regression)與快速獨立成分分析(Fast Independent Component Analysis, Fast-ICA)對彈性與非彈性儲水係數、比儲水係數及其比值進行量化分析。結果顯示，應力-應變曲線中的滯後回線和殘餘變形可區分彈性變形和非彈性變形。並提出時間、深度和地質材料粒徑大小為影響變形的重要因素。基於文獻回顧，本研究進一步應用全球導航衛星系統(Global Navigation Satellite System, GNSS)、磁環分層式地層下陷監測井(Multi-layer compaction monitoring Well, MLCW)與地下水水位監測井(Groundwater Level Well)資料，繪製應力-應變曲線。初步將宏崙國小第一含水層數據歸類為彈性-非彈性變形。根據 2016 年至 2020 水文年間 MLCW 資料，計算各含水層與阻水層之下陷量平均值占比與層厚，結果顯示層厚會影響各層下陷量占比。未來將進一步探討相關數學模型，並結合相關參數以闡述物理現象機制，為地層下陷管理提供更具體建議。

關鍵字： 地層下陷、預壓密應力、儲水係數、滯後回線、殘餘變形。

Factors and Mechanisms of Elastic and Inelastic Deformation: A Literature Review and Insights on Land Subsidence in the Choushui River Alluvial Fan

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Abstract

Groundwater is a crucial water resource in the Choushui River Alluvial Fan. According to the 2023 records from Taiwan's Water Resources Agency (WRA), this region became the area with the largest land subsidence in Taiwan due to groundwater overdraft, with the maximum subsidence rate reaching 6.4 cm/yr. This study combines two relevant articles to explore the factors and mechanisms for inelastic deformation. Baesd on Terzaghi's principle of effective stress, previous study examines the relationship between pore water pressure and effective stress and compares with preconsolidation stress. It differentiates elastic, elastic-inelastic, and inelastic deformations using stress-strain curves. Spatial regression and Fast Independent Component Analysis (Fast-ICA) are employed to analyze elastic and inelastic storage coefficients, specific storage coefficients, and their ratios. The results show that hysteresis loops and residual deformation can distinguish between elastic and inelastic deformation. Time, depth, and the particle size are identified as factors influencing deformation. Through a literature review, this study utilizes the Global Navigation Satellite System (GNSS), Multi-layer Compaction Monitoring Wells (MLCW), and groundwater level data to construct stress-strain curves. Preliminary data of the first aquifer of HLES is classified as elastic-inelastic deformation. Analysis of the thickness and MLCW data from 2016 to 2020 reveals the average compaction ratio for each aquifer and aquitard. The results indicate that layer thickness influences the compaction ratio. Future research will investigate mathematical models and parameters to understand physical mechanisms, providing insights for land subsidence management.

Keywords: Land subsidence, Preconsolidation stress, storage coefficient, Hysteresis loop, residual deformation.