不同複雜度地質模型與非線性參數對地層下陷模擬之影響 —以雲林地區為例

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摘要

地層下陷監測數據顯示，雲林地區至今仍為台灣嚴重地層下陷區，其主沉陷區已涵蓋至高鐵路段影響其結構安全。為了有效治理因超抽地下水而引發之地層下陷，確切了解雲林地區之地層下陷機制為首要目標。先前研究已表明地層下陷的行為與特徵會隨著區域地質條件與地質架構的不同而有所差異。因此，透過可靠的地質模型可以準確預測地層下陷的規模與範圍，並有助於儘早地規劃緩解之措施。考慮到地質材料分布在地層下陷行為之重要性，本研究參考雲林地層下陷區之水文地質剖面，在有限元素軟體 COMSOL MULTIPHYSICS 中建置不同複雜度的地質模型，其中以 Biot 耦合孔彈性理論為基礎，模擬飽和土體隨時間排水與壓密的過程。接著，使用相對敏感度(relative sensitivity)在假想的層狀模型中進行參數敏感性分析。最後，建立變形效應引起之非線性參數系統，探討土體特性在排水與壓密的過程中變化之情形。本研究結果顯示，層狀模型中的沉陷量主要受阻水層控制，阻水層會在水頭停止下降後持續排水與壓密。參數敏感性分析結果顯示，楊氏模數、帕松比與滲透性對沉陷量較為敏感，孔隙率則不敏感，滲透性之敏感度將隨時間變化。整體而言，阻水層參數與含水層參數相比更為敏感。在現地模型中，累積沉陷量主要來自阻水層的壓應變，而阻水層的厚度影響其排水速度。在現地模型增加複雜度後，使得地層下陷情形更為局部，並有較大的最大沉陷量。另外，在現地模型中考慮非線性參數，孔隙率與滲透性將隨土體變形而減小，楊氏模數則隨土體變形而增加。非線性參數變化在黏土材料中尤為顯著，影響其排水速度與壓縮性，使得現地模型之整體沉陷量減少。

The Influence of Geological Models with Different Complexity and Nonlinear Parameters on Land Subsidence Simulation – A Case Study in Yunlin County

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Abstract

Local geological conditions and geological structure affect the behavior and characteristics of land subsidence. For land subsidence caused by groundwater overexploitation, reliable hydrogeological models can accurately predict the scale and extent of subsidence and help the planning of mitigation measures. Considering the importance of geological material distribution, this study constructs the geological models with different complexity in a finite element software, COMSOL MULTIPHYSICS, using the hydrogeological cross section in Yunlin County, where is currently suffering serious land subsidence. Based on Biot's poroelasticity theory, the interaction of water drainage and consolidation processes in saturated soil is simulated. Parameter sensitivity analysis is performed in a synthetic model using the relative sensitivity. The nonlinear parameters are adopted in an in-situ model to explore the variations of soil properties during the deformation process. The results show that the land subsidence quantity in a synthetic model is mainly contributed by aquitards. In addition, the aquitards continue to drain and consolidate after the hydraulic head stops decreasing, causing the delay subsidence. The results of parameter sensitivity analysis show that Young's modulus, Poisson's ratio, and permeability are sensitive to land subsidence, while porosity is insensitive. Moreover, the sensitivity of permeability varies with time. Overall, the parameters in aquitard are more sensitive to land subsidence than in aquifer. For in-situ models, the accumulated subsidence is mainly caused by the compressive strain of aquitard. The aquitard thickness affects its drainage time. Adding complexity to the in-situ model makes the subsidence more localized and has a large quantity of maximum land subsidence. The drainage and compressibility of aquitards are affected by nonlinear parameters, which reduces the subsidence in the entire model.