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# FINITE ELEMENT NUMERICAL SIMULATION OF LAND SUBSIDENCE AND GROUNDWATER EXPLOITATION BASED ON VISCO-ELASTIC-PLASTIC BIOT'S CONSOLIDATION THEORY*

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**Abstract:** The land subsidence due to groundwater exploitation has an obvious hysteretic nature with respect to the decrease of the under groundwater level, and the uneven settlement often causes ground fissures. To study these important features, a visco-elastic-plastic constitutive relationship with consideration of the coupling of seepage and soil deformation is proposed, and a finite element model with variable coefficients based on the Biot's consolidation theory is built. With the groundwater exploitation and the land subsidence control in Cangzhou City, Hebei Province as an example, the variations of the under groundwater level and the development of the land subsidence due to the groundwater exploitation are simulated and ground fissures are predicted by the horizontal displacement calculation. The results show that the lag time between the land subsidence and the under groundwater level descent is about a month, and the simulated results of fissures agree well with the observed data. The model can well reveal the characterization of the interaction between the land subsidence and the groundwater exploitation.

**Key words:** hysteretic property, land subsidence, visco-elastic-plastic constitutive relationship, finite element model

## Introduction

Since the eighties of the last century, the land subsidence due to the groundwater exploitation becomes more and more a research issue. During the process of consolidation, the soil shows apparent hysteretic property[1] because of time effect in the process of the clay compression. It is why the land subsidence always occurs later than the groundwater level descent. Moreover, the ground fissures caused by the groundwater exploitation go always hand in hand with the land subsidence in the temporal and spatial distributions and show a synchronism in activities and aggravations. This kind of symbiosis and consistency has the same source: the water head is decreased due to groundwater exploitation[2].

The models describing land subsidence due to groundwater exploitation are all well based on theoretical considerations. For example, in 1989, China's first model of land subsidence was built in Shanghai[3]. Afterward, the third model was built in the late 20th century and now is still under study with respect to nonlinear deformation[4]. Tianjin in 1995 built a first coupled model of land subsidence of three-dimensional seepage and one-dimensional consolidation[5]. However, because of the complexity of the problem, the rheological characteristics of aquifer and horizontal displacement were not considered in these models[6]. And constant hydraulic parameters were often assumed with respect to the permeability that varies with soil deformations, which would make great differences for practical deformation features[7]. So they can not be used to simulate the hysteretic property and more studies and improvements are required.

Therefore, in the study of land subsidence and ground fissures, one should take full account of the interaction between rheological features of soils and seepage[8]. To do so, a three-dimensional coupling model, based on the Biot's consolidation theory, is built, then according to the visco-elastic-plastic constitutive relationship and the rheological theory, the dynamic responses of the permeability coefficient and the rheological factors are considered. The comparison of calculated and observed results in the model of Cangzhou city shows that, the lag time of the land subsidence with respect to the water level descent is about one month and the intensive areas of the horizontal displacement are the high risk areas of ground fissures, The simulated results agree with the observed data.

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