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# Research and Application of Geomechanical Model Test Technology

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***Abstract:*** Geomechanical model test is one of the commonly used experimental methods in the study of slope stability. It constructs the scale model of slope, simulates the geological environment and load, and carries out the corresponding load experiment to study the stability of slope and its influencing factors. This paper introduces the principles and characteristics of geomechanical model test from the aspects of similar principle, model material selection and key simulation technology.

***Keywords:*** Geomechanics; Physical simulation; Similarity principle; Model test

## Introduction

The research status of geomechanical model test presents a diversified development trend, which constantly promotes the progress and innovation in the field of geotechnical engineering.

Since the beginning of this century, some countries in Western Europe began to test with structural models and gradually established similarity theories. In the 1960s, experts led by E · Fumagalli initiated the range of elasticity to plasticity to the final destruction in Italy (ISMES). Portugal, the former Soviet Union, France, Germany, The United Kingdom and Japan. In China from the 70s the Yangtze river academy of sciences, tsinghua university, hohai university, China institute of water conservancy and hydropower, north China university of water conservancy and hydropower, Wuhan university of water conservancy and electric power and other units combined with large water conservancy project dam or dam shoulder stability successively began experimental research such as gezhouba, longyuan, three gorges, copper street engineering slippery stability problem of a lot of experimental work has obtained a large number of research results.

The main purpose of the geomechanical model test is to verify the accuracy and feasibility of the analysis method through experimental means, as well as to study the deformation, failure mechanism and stability energy of the slope under different working conditions. Geomechanical model test is a method to reasonably simulate the investigated slope by using certain similar principle and considering the geological structure of the slope and its reinforcement measures[2, 3]. The main purpose of this test is to obtain the deformation characteristics and failure pattern of the prototype by overload or strength reduction[4]. The influence of geological structure on the slope safety can provide reference for the design of reinforcement scheme.

## 1. Similar theory

The similarity theory in the geomechanical model test is based on the similarity principle, and the actual rock and soil system is transformed into a scale model, and its mechanical behavior is studied through the model test. The similarity criterion can be derived from the elastic mechanics equation or the dimensional analysis method. The basic similarity criterion of line elasticity problem can be derived from the equilibrium, geometry, physics, and boundary conditionsequations: $C_\sigma/(C_L C_\rho)=1$, $C_\delta/(C_\varepsilon C_L)=1$, $(C_\varepsilon C_E)/C_\sigma=1$, $C\mu=1$, $C_S/C_\sigma=1C_\sigma$, $C_L$, $C_\rho$, $C_\delta$, $C_\varepsilon$, $C_E$, $C_\mu$, $C_S$ are stress, geometry, physical strength, displacement, strain, elastic modulus, Poisson ratio and surface force similarity constant, respectively. For the geomechanical model, in addition to meet the above formula 5 requirements, $C_\varepsilon=1$ and the similarity constant of the strength index of the material are consistent. $C_\varepsilon=1$ requires that the prototype be similar to the stress-strain c-urve and the model.

## 2. Model materials

Model materials commonly used in geomechanical model test mainly include model soil and model rock. These materials are widely used in geomechanical model tests, which can simulate the mechanical properties and behavior of actual rock and soil mass.

Model soil is a kind of soil material which is similar to actual soil by processing natural soil or artificial soil. Common model soils include sand, clay and mixed soil. These model soils simulate the mechanical behavior of actual soil by adjusting the properties of soil particle size, water content and compactness.

Model rock is usually a scale model obtained by cutting and processing natural rock. Commonly used model rocks include materials such as gypsum, wax and ceramics. The selection of model rock should consider the mechanical properties of rock and the demand of model test, so as to simulate the mechanical behavior of actual rock better.

## 3. Simulation technology

The geomechanical model is not simply to copy the prototype, but to grasp the main problems for simulate. For the factors and parts that promote the occurrence and development of slope damage, they need to be reflected in the geological model and monitoring. The following are several typical simulation techniques[5].

### 3.1 Selection of a similar scale

(1) The principle of geometric similarity: keep the geometry and proportion between the model and the actual scale consistent. This means that the linear size (length, height, width, etc.) of the model is scaled in proportion to maintain its shape similarity.

(2) Principle of physical and mechanical similarity: keep the physical and mechanical properties of the model similar to the actual rock and soil mass. This includes the strength, stiffness, deformation characteristics of the materials, etc. Usually, the physical properties of the model material are similar to the actual rock and soil mass, for example, by choosing similar density, water content, particle size, etc.

(3) The principle of boundary condition similarity: keep the boundary conditions of the model similar to the actual engineering. This includes the soil boundary constraint, loading mode, stress state, etc. The boundary conditions should consider the boundary state in the actual engineering to simulate the real engineering situation as much as possible.

It should be noted that the selection of similar scales has no fixed standard, but is determined according to the specific test purpose and conditions. Different trials may need to adopt different similar scales, so various factors are needed to make the most appropriate decision. In general, the scale of similar geometry should be selected at 1 / 50~1 / 200[6, 7, 8].

### 3.2 Simulation of structural surface mechanical parameters

In the geomechanical model test, the structural surface is a weak surface or crack with a certain inclination existing in the geological body. In order to simulate the mechanical parameters of the structural surface, a material similar to the actual structural surface can be selected to simulate the mechanical behavior of the weak surfaces. For example, thin film, film, or other materials that can form weak surfaces can be used as structural surfaces in the model. According to the experimental requirements, the material parameters such as stiffness, strength and friction can be adjusted to simulate different types of structural surfaces. The arrangement of materials can also be changed, and the structural surface can be simulated by adjusting the arrangement of materials. For example, the arrangement of the particles can be changed to form weak connections or sliding conditions at the structural surface, thus simulating the characteristics of the structural surface.

It is necessary to select the appropriate simulation method according to the actual situation and the purpose of the laboratory test, and to verify and adjust it according to the test results.

### 3.3 Simulation of ground stress

In geomechanical model test, ground stress is a very important parameter, which has an important effect on the behavior and failure mode of rock and soil mass in the model. The simulation of ground stress can be achieved by the stress-applying stress device and the gravity of the model material, using the appropriate centrifuge device to apply the simulated ground stress.

The commonly used test methods of ground stress are mainly divided into direct measurement method and indirect measurement method. The direct measurement method includes flat jack method, hydraulic pressure cracking method, rigid envelope stress meter method and acoustic emission method. Indirect measurement method: sleeve hole stress relief method, aperture deformation method, hole bottom should be (hollow and solid) envelope body variable method, etc.

### 3.4 Data monitoring

Data monitoring is an indispensable and important link in the geomechanical model test. Common monitoring methods include strain measurement (strain gauge, strain gauge), displacement and force measurement (displacement gauge, rangefinder, etc.), image recording (camera, three-dimensional scanning), etc. These monitoring methods can capture the key information such as stress, strain, displacement, fracture and failure form of the model during the test, and provide important data support for analyzing the mechanical behavior of the model[9]. Common data monitoring methods include: ① Strain measurement: Use a strain gauge or strain gauge to measure the strain in the test material. ② Displacement and force measurement: Use devices such as displacement meters or distance meters to measure displacement and pressure in test devices and models. ③ Image recording: Visual monitoring of the model using cameras or laser scanners and other equipment. It can be combined according to the purpose and needs of the experiment to ensure comprehensive and accurate data monitoring results.

## 4. Discussion

With the increasing scale of geotechnical engineering, the engineering problems are more complex and diverse, and the geomechanical model test has become a common method in the study of slope stability. It constructs the scale model of slope, simulates the geological environment and load, and carries out the corresponding load experiment to study the stability of slope and its influencing factors. Through the geomechanical model test, the mechanical behavior, deformation law and destruction mechanism of the slope can be deeply understood. At the same time, because the test is conducted under control conditions, the influencing factors can be better controlled, so as to provide more reliable data and conclusions, and provide an important reference basis for slope stability analysis and engineering design.

In the geomechanical model test, the appropriate model materials should be selected first, usually using the model materials with the actual rock and soil similarity, such as model soil or model rock. Then, the corresponding slope model was established according to the design requirements, and the experimental device and loading method were determined. Experimental devices usually include a loading system, displacement measuring equipment, strain gauge, etc.

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