

# Review on the Mechanical Properties of Fractured Composite Rocks

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## Abstract

This paper primarily analyzes the recent research progress on fractured composite rocks, summarizing their mechanical properties and failure behaviors under different conditions. It introduces the research findings on fractured composite rocks under various factors, such as crack size, inclination angle, and the influence of different external loads on the rocks. Based on the existing research, the paper discusses future research directions regarding the mechanical properties and failure characteristics of defective rocks.

## Keywords

Composite Rock; Fracture; Mechanical Properties; Failure Behavior.

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## 1. Introduction

Composite rock mass refers to a rock mass composed of two or more different types of rock materials. The mechanical properties and failure behavior of composite rock masses are typically influenced by internal cracks and their constituent materials. The properties of the base rock, interlayer materials, and their proportions can significantly affect the mechanical characteristics of the composite rock mass. Under external loading conditions, it is easy for cracks within the rock mass to initiate, propagate, and even connect, leading to macroscopic fracture phenomena that affect the stability of the rock mass. Therefore, studying the influence of inherent defects on the mechanical properties of composite rocks and the crack propagation behavior is of great practical significance for the safety and reliability analysis in engineering applications.

## 2. Research Status of Mechanical Properties of Fractured Composite Rocks

Researchers have conducted experimental studies on fractured composite rocks, focusing on their mechanical properties, crack propagation behaviors, and failure mechanisms. In studies of geotechnical deformation, fracture, or local evolution, laboratory experiments attempt to simulate the real engineering geological conditions of rocks. Due to the limitations of testing methods, several advanced techniques, such as digital image correlation (DIC), acoustic emission (AE), CT scanning, and Hopkinson bar experiments, have been employed to investigate the mechanical properties and failure behaviors of defective rocks.

### 2.1 The Influence of Different Crack Lengths and Inclination Angles on the Mechanical Properties of Composite Rocks

Due to the presence of numerous microcracks with various shapes within the rock mass, researchers have analyzed the effects of different crack lengths and inclination angles on rock deformation characteristics through numerical simulations and laboratory compression tests.

Liu Bo [1] adopted the ultimate tensile strain criterion as the threshold for the initiation of rock mass damage. Based on laboratory tests, FLAC3D finite difference simulations, and PFC2D discrete element method (DEM), he conducted Brazilian splitting tests and corresponding numerical simulations on seven thick limestone specimens with different inclination angles. The study revealed that the tensile strength and peak strain of layered limestone with different inclination angles exhibit anisotropic characteristics.

Zhang Liang et al. [2], based on the energy calculation principles of rocks and laboratory uniaxial compression tests, investigated the evolution of total energy, elastic strain energy, and dissipative energy during the deformation and failure process of fractured rock masses. The study also explored how crack length affects the energy indicators at the peak point and the length effect of energy mutation in fractured rock masses.

Wang Qihu [3], considering the geometric characteristics of inherent cracks in composite rocks at the microscopic level, developed a composite rock model consisting of two types of rocks with a single crack. The study found that the failure mode and strength characteristics of the composite rock sample under external loading are more complex compared to a single rock body. In composite rock samples, the geometric characteristics of cracks influence the failure mode and strength.

Chen Yan'an [4] used the discrete fracture network (DFN), planar joint contact model, and smooth joint contact model in the particle flow software PFC2D to create numerical models of composite rock samples. By pre-creating coplanar cracks with different inclination angles and performing numerical simulations, the study analyzed the effects of crack inclination and bedding plane angles on the strength and crack propagation characteristics of composite rock samples.

Li Heng [5] used the particle flow simulation method to study the mechanical properties and crack propagation behavior of composite rock masses with double cracks. Through uniaxial compression simulations and crack analysis, the study revealed the effects of different rock bridge angles and bedding angles on the composite rock layers.

Deng Huafeng [6] conducted laboratory experiments on discontinuous jointed sandstone under various confining pressures and joint inclination angles. The study obtained deformation and strength parameters, then analyzed the results to compare the failure modes and deformation characteristics under different joint inclination angles and confining pressures, summarizing the failure modes under these conditions.

From these studies, it is clear that crack length and inclination angle significantly affect the mechanical properties of composite rocks. Furthermore, the impact of these factors varies under different conditions. Therefore, when designing and constructing rock masses, it is crucial to consider these factors to ensure the stability and safety of the rock mass.

## **2.2 Failure Behavior of Fractured Composite Rocks under Different External Loads**

Considering the actual stress characteristics of underground engineering rock masses, such as blasting and impact, researchers have investigated the failure behavior of fractured composite rocks under various loading conditions-such as impact loading, dynamic loading, and cyclic loading-through experiments like Split Hopkinson Pressure Bar (SHPB), acoustic emission (AE), and numerical simulations.

Wen Sen [7] used the Split Hopkinson Pressure Bar (SHPB) to conduct impact tests, studying the mechanical response of composite rock layers under dynamic loading. The effects of different loading rates and incident angles on the energy dissipation characteristics of composite rock samples were considered, and the energy dissipation properties of the samples were examined.

Du Chaochao [8] conducted uniaxial dynamic-static combined loading tests to investigate the dynamic mechanical properties and failure mechanisms of composite rock samples under high in-situ stress and dynamic disturbances.

Li Yang [9] used triaxial compression and dynamic impact tests to study the effects of confining pressure and loading rates on the deformation and failure characteristics of composite rocks. The

study comprehensively examined the energy dissipation and fracture characteristics of layered composite rocks under dynamic loading.

Li Xin [10], based on FLAC3D software, performed numerical simulations of unloading failure in composite coal-rock masses. By comparing the axial stress-step curves under different loading and unloading rates, the study explored the mechanical behaviors and failure characteristics of composite coal-rocks under various loading and unloading conditions.

Zuo Jianping [11] conducted uniaxial and cyclic loading-unloading tests on coal-rock composite bodies, investigating the mechanical properties and deformation behaviors of these composites under different stress levels. This study provided deeper insights into the failure mechanisms and deformation characteristics of coal-rock composites.

From the above research, it is evident that the crack propagation, evolution, and energy dissipation behaviors of composite rock masses under different external loads follow distinct patterns.

### **2.3 Mechanical Properties of Fractured Composite Rocks under Different Environmental Conditions**

Researchers have considered the performance of different layered composite rocks in deep underground environments and the periodic variations in natural conditions, such as rainfall, evaporation, and temperature changes. These studies have focused on curing rocks under various environmental conditions to evaluate their physical and chemical properties.

Liu Yongsheng [12] selected red sandstone, green sandstone, and marble with different rock properties as research subjects. Layered composite rock samples were created with different combinations and interface layer angles and then cured under acidic conditions. The study explored the effects of different rock combinations, interface layer angles, and curing conditions on the performance of layered composite rocks.

Long Chaohui [13] conducted experimental studies under wet-dry cyclic conditions to analyze the mechanical degradation characteristics of sandstone under varying confining pressures and cycle counts. The study revealed the variation patterns of peak compressive strength, internal friction angle, and cohesion, as well as the degradation of rock mechanical properties.

Chen Xinfeng [14] analyzed the effect of wet-dry cycles in acidic environments on the physical properties of rocks. The study included physical property analysis of rock samples, such as mass, water absorption, wave velocity, and uniaxial compressive strength.

## **3. Conclusion**

Researchers have employed experimental studies and numerical simulations to analyze the mechanical properties and failure characteristics of rocks containing different defects, leading to a wealth of findings that provide a foundation for future rock mass research.

1) In practical engineering, the morphology and distribution of fractures exhibit diversity and complexity. Natural fractures are often three-dimensional, with varying heights. Therefore, the impact of multiple factors on the macroscopic mechanical properties and crack propagation behavior of composite rock samples warrants further study.

2) For fractured rocks, current research focuses primarily on the mechanical mechanisms of fractured rocks without considering pore water pressure. As underground engineering progresses to greater depths, these rocks are subjected not only to high in-situ stresses but also to pore water pressure. Therefore, it is necessary to analyze the mechanical properties of rocks with pores and fractures under multiple stress conditions, considering the influence of natural fractures on hydraulic fracture propagation.

3) The conditions of engineering rock masses are extremely complex, and some theoretical models proposed based on laboratory simulations are subject to various degrees of interference when applied in engineering rock mass calculations, making them not entirely suitable.

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