

冻融作用下含冰裂隙花岗岩动态抗拉力学特性研究

Dynamic tensile mechanical properties of ice-fractured granite under freeze-thaw cycles

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摘要: 高寒地区含天然裂隙岩体在地下水和低温作用下易形成含冰充填裂隙岩体, 严重影响岩体在爆破等动态载荷下的稳定, 研究冻融作用下含冰裂隙岩石在动载作用下的拉伸力学特性对冻融岩体破裂失稳有重要意义。以含冰裂隙花岗岩为研究对象, 采用 CT 扫描技术量化了含冰裂隙岩石的冻融损伤劣化规律, 利用摆锤驱动的分离式霍普金森压杆 (SHPB) 装置研究了不同冻融次数和加载率下含冰裂隙花岗岩的损伤特性, 利用高速摄影和扫描电子显微镜技术探讨了含冰裂隙花岗岩的断裂特征。研究表明, 在一定的加载速率下, 含冰裂隙花岗岩的动态抗拉强度随冻融次数的增加而指数级降低, 并且与纵波波速变化量和孔隙率变化量呈显著的负相关关系; 基于纵波波速变化量和孔隙率变化量, 分别建立了动态抗拉强度衰减模型, 模型均能反映动态抗拉强度的劣化规律; 以纵波波速和孔隙率作为冻融损伤参数, 以动态加载率与静态加载率的比值 (加载率敏感性) 作为动载损伤参数, 建立了冻融裂隙岩石动态抗拉强度的预测方程, 能够反映冻融循环损伤及加载率效应; 与完整试样和单裂隙试样相比, 裂隙冰起到了一定的支撑、固结作用, 但是预制裂隙的导向作用在试样断裂过程中仍占主导地位。

关键词: 冻融循环; 含冰裂隙花岗岩; 动态抗拉强度; 破坏模式

Abstract: The natural fractured rock mass in the alpine region is easy to form ice-filled fractured rock mass under the action of groundwater and low temperature, which seriously affects the stability of rock mass under dynamic loads such as blasting. Studying the tensile mechanical properties of ice-filled fractured rocks under dynamic loading is significant for understanding the fracture and instability of freeze-thaw treated rocks. This study focuses on ice-filled fractured granite, using CT scanning to quantify the degradation of freeze-thaw damage, and employing a Pendulum-driven Split Hopkinson Pressure Bar (SHPB) testing device to investigate the damage characteristics under different freeze-thaw cycles and loading rates. High-speed photography and scanning electron microscopy are utilized to explore the fracture characteristics of the granite. The study reveals that the dynamic tensile strength of ice-filled fractured granite decreases exponentially with an increase in freeze-thaw cycles at a given loading rate, showing a significant negative correlation with changes in longitudinal wave velocity and porosity. Dynamic tensile strength attenuation models are established based on these parameters, reflecting the degradation trend. A predictive equation for the dynamic tensile strength of freeze-thaw fractured rocks is developed, incorporating longitudinal wave velocity and porosity as freeze-thaw damage parameters, and the ratio of dynamic to static loading rates as a dynamic load damage parameter, capturing the effects of freeze-thaw cycles and loading rates. Compared to intact and single-fracture samples, ice in the fractures provides some support and consolidation, but the guiding effect of pre-existing fractures remains dominant in the fracture process.

Keywords: freeze-thaw cycles; ice-filled fractured granite; dynamic tensile strength; failure mode