

加载速率效应影响下硬岩失稳破坏试验及前兆分析研究

Study on the instability failure test and precursor analysis of hard rock under the influence of loading rate effect

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摘要: 为研究受加载速率效应影响硬岩隧道围岩失稳破坏机制, 对花岗岩进行了五组不同加载速率的单轴压缩-声发射试验。研究了各加载速率下试件的破裂演化过程及破坏模式、试件的强度变化特性、试件各应力阶段的声发射参数分布特征, 并基于振幅集中度曲线的变化规律提出一种判别花岗岩失稳破坏前兆的方法。研究表明, 加载速率越大, 试件破坏的全过程持续时间越短, 破坏程度越剧烈, 破坏后试件完整度越差; 峰值强度与弹性模量表现出明显的加速效应, 但当加载速率超过 0.1kN/s 时二者增幅下降, 峰值强度的增幅由 26% (0.02kN/s-0.05kN/s) 下降至 6.5% (0.2kN/s-0.5kN/s), 弹性模量的增幅由 35.6% 下降至 12%, 峰值应变与加载速率呈现出负相关性; AE 振铃计数的高频信号出现的时间越提前, 破坏时仅有少量超高频信号; AE 能量由“孤震型”向“群震型”转变; 试件破坏时 b 值越小, 由 0.46767 (0.02kN/s) 减小至 0.30212 (0.5kN/s); RA-AF 散点在各阶段分布特征表明, 加载速率越大, 剪切裂纹发育越好; 振幅集中度曲线 Γ 的震荡阶段与骤然上升阶段间的斜率突变点可作为不同加载速率下花岗岩失稳破坏前兆信息, 加载速率越大, 该突变点对应的强度越小, 由 $0.95\sigma_c$ (0.02kN/s) 降低至 $0.68\sigma_c$ (0.5kN/s), 且出现时间越提前, 由 4831s 降低至 186s。

关键词: 加载速率效应; 破裂演化特征; 声发射; 破坏前兆

Abstract: In order to study the destabilization and damage mechanism of hard rock tunnel peripheral rock affected by loading rate effect, five sets of uniaxial compression-acoustic emission tests with different loading rates were carried out on granite. The rupture evolution process and damage mode of the specimen under each loading rate, the strength change characteristics of the specimen, the distribution characteristics of the acoustic emission parameters of the specimen at each stress stage were studied, and a method of identifying the destructive precursor of granite instability was proposed on the basis of the change rule of the amplitude concentration curve. The study shows that the larger the loading rate is, the shorter the duration of the whole process of specimen damage is, the more intense the damage is, and the worse the integrity of the specimen is after the damage; the peak strength and modulus of elasticity show obvious accelerating effect, but the increase of both of them decreases when the loading rate is more than 0.1kN/s, and the increase of the peak strength decreases from 26% (0.02kN/s-0.05kN/s) to 6.5% (0.2kN/s-0.5kN/s), the increase of modulus of elasticity decreased from 35.6% to 12%, and the peak strain showed a negative correlation with the loading rate; the middle and high frequency signals of the AE ringing counts appeared earlier and earlier, and only a small amount of ultra-high frequency signals were present at the time of damage; the energy of AE was changed from the “lone-type” to the “group-type”; The b-value is smaller when the specimen is damaged, from 0.46767 (0.02kN/s) to 0.30212 (0.5kN/s); The distribution of RA-AF scattering points at each stage shows that the larger the loading rate is, the better the

shear crack development is; The slope mutation point between the oscillation stage and the sudden rise stage of the amplitude concentration curve Γ can be used as the precursor information of the destabilization damage of the granite under different loading rates, and the larger the loading rate is, the smaller the intensity corresponding to this mutation point is, from $0.95\sigma_c$ (0.02kN/s) to $0.68\sigma_c$ (0.5kN/s), and the time of appearance is earlier, from 4831s to 186s.

Keywords: Loading rate effects; rupture evolution characteristics; acoustic emission; damage precursors;