Postprint: Finite Discrete Element Numerical Study on Flexural Toppling Failure of Rock Slopes

Authors: Ma Bin, Zheng Yun

Date: 2025-07-21T00:00:00+00:00

Abstract

Flexural toppling is a rather complex and common failure mode of anti-dip rock slopes (ABRS), as it involves not only deformation of intact rock, but also sliding or opening of joints and fracturing of rock layers. In this work, the flexural toppling of ABRS was investigated using the Finite-Discrete Element Method (FDEM). The feasibility of FDEM for simulating flexural toppling was first verified through model tests. Then, a parametric study was conducted using FDEM to examine the effects of joint angle, slope angle, and rock layer thickness on flexural toppling. Furthermore, the failure surface of slopes undergoing flexural toppling was discussed. The results indicate that the failure surface can be a simple plane inclined at 9° to 23° from the joint normal, or a complex stepped configuration, and the depth of the failure surface gradually increases with increasing rock layer angle. For slopes with poor stability against flexural toppling, two failure surfaces develop within the slope, with the deep failure surface being approximately parallel to the shallow one. The failure surface does not necessarily intersect the slope toe, and may be located above it.

Full Text

Preamble

Numerical Study on Flexural Toppling Failure of Rock Slopes Using Finite-Discrete Element Method

Bin Ma[1,2], Yun Zheng[1,2]

[1] State Key Laboratory of Geomechanics and Geotechnical Engineering, Institute of Rock and Soil Mechanics, Chinese Academy of Sciences, Wuhan 430071, China
[2] University of Chinese Academy of Sciences, Wuhan 100049, China

Abstract

Flexural toppling represents a highly complex and common failure mode in anti-dip rock slopes (ABRS), as it involves not only deformation of intact rock but also sliding or opening of joints and fracturing of rock layers. This study investigates the flexural toppling of ABRS using the finite-discrete element method (FDEM). The feasibility of FDEM for simulating flexural toppling is first validated through model tests. Parametric studies are then conducted using FDEM to examine the effects of joint angle, slope angle, and rock layer thickness on flexural toppling. Furthermore, the failure surfaces of slopes undergoing flexural toppling are discussed. The results show that failure surfaces may be simple planes oriented at 9° to 23° from the joint normal, or complex step-like configurations. The depth of the failure surface gradually increases with the rock layer angle. For slopes with poor stability against flexural toppling, two failure surfaces develop within the slope, with the deep failure surface being approximately parallel to the shallow one. The failure surface does not necessarily pass through the toe of the slope and may be located above it.

Keywords: rock slope; toppling failure; finite-discrete element method; failure surface

Note: Figure translations are in progress. See original paper for figures.