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Analysis of a High Railway Slope Formed By Highly Jointed Rock Mass

Asli Can[1], Yasin Baskose[2], Candan Gokceoglu[3]
[1,2]Progeo Project Company
Ankara, Türkiye
a.can@progeo.com.tr; y.baskose@progeo.com.tr
[3]Hacettepe University
Ankara, Türkiye
cgokce@hacettepe.edu.tr

Plane, wedge, toppling, and rock falls are the main failure types for rock slopes. Investigating the endangered areas with such potential slope failure mechanisms is essential for constructing infra and superstructures. This study investigates and presents kinematic analyses of a high railway slope formed by highly jointed rock mass.

A cut slope design was necessary between Km: 166+000-166+600 within the scope of the Karaman - Ulukışla Highspeed Railway Project in Türkiye. The aerial extent of the cut slope area is approximately 205 m wide and 600 m long. The stratified limestone layers of the Meydan Formation (Jkme) are clearly visible in the outcrop and the bedding thicknesses range from 10 to 40 cm. Two boreholes with depths of 50 m and 92 m were performed in the study area. According to the borehole data, limestone layers were defined as gray-colored, weak to moderately strong, slightly weathered, containing thin to medium claystone layers, weak to medium quality, highly fractured, and the joints filled with clay, calcite, and quartz. No groundwater level was observed.

Plane failure generally occurs in slopes formed by stratified sedimentary rock formations such as limestones, especially when a structural discontinuity plane dips towards the valley at an angle smaller than the slope face angle [1]. More specifically, the potential discontinuity surface must be nearly parallel to the slope face to ensure this condition. There must be release surfaces on either side of the sliding mass which provides the least resistance during the sliding event, with a tension crack on the upper portion of the slope. The rock mass that rests on the discontinuity plane slides down the slope when shearing stresses become more than the resisting forces [2, 3]. Due to the low in situ stresses at shallow depths, the instabilities are controlled by discontinuities in the rock masses. Hence, the shear strength of discontinuities comes to the fore in the analysis of slope failures. Barton's criterion [4] was used to determine the peak shear strength of rough surfaces. Joint Wall Roughness Coefficient (JRC) was selected as 5, from the impression of joint wall roughness [5] and compared with Barton standard profiles. Uniaxial Compressive Strength (UCS) was used as Joint Wall Compressive Strength (JCS), which is 35 MPa, and friction angle (ϕ) was determined as 32 degrees.

Using proper software, the kinematic analysis of failures was investigated by employing the discontinuity measurements taken from the limestone layers. Especially on the right side, there was a plane failure possibility since the limestone layers dip in the same direction as the cut slope. In addition, although the desired safety coefficients are provided in terms of mass, rockfall may occur locally due to the frequently folding and highly jointed layers. The right and left sides of the cut slope were designed in the ratio of 3/2 (H/V) with a maximum total depth of 75 m. Due to the plane failure possibility on the cut slope's right side, the shoring system was designed with rock bolts. The stability of the cut slope design was modeled and controlled by the finite element method (FEM) for long-term stability evaluation. Wire mesh was applied to prevent adverse effects on the line operation such as rock breaking and falling from the slope surfaces of the limestone layers. Cut slope constructions were completed in 2017 and the railway system still runs safely. As a result of this study, it is concluded the high rock slopes should be designed considering all possible failure conditions.

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