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# Control of rock joint parameters on deformation of tunnel opening

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ABSTRACT

Tunneling in complex rock mass conditions is a challenging task, especially in the Himalayan terrain, where a number of unpredicted conditions are reported. Rock joint parameters such as persistence, spacing and shear strength are the factors which significantly modify the working environments in the vicinity of the openings. Therefore, a detailed tunnel stability assessment is critically important based on the field data collection on the excavated tunnel's face. In this context, intact as well as rock mass strength and deformation modulus is obtained from laboratory tests for each rock type encountered in the study area. Finite element method (FEM) is used for stability analysis purpose by parametrically varying rock joint persistence, spacing and shear strength parameters, until the condition of overbreak is reached. Another case of marginally stable condition is also obtained based on the same parameters. The results show that stability of tunnels is highly influenced by these parameters and the size of overbreak is controlled by joint persistence and spacing. Garnetiferous schist and slate characterized using high persistence show the development of large plastic zones but small block size, depending upon joint spacing; whereas low persistence, low spacing and low shear strength in marble and quartzite create rock block fall condition.

## 1. Introduction

Construction and stabilization of underground openings in complex geological terrain are a challenging work. Opening created for any purpose provides avenues for the release of large amount of pre-existing stress and causes the material to deform elastically. Further, if the stresses are sufficiently high, rocks start to behave inelastically, causing fractures in rock mass and overall reduction in the bearing capacity (Ewy and Cook, 1990). Analysis of in-situ measurements and analytical modeling of excavations show that an area of $2D$ ($D$ is the diameter) is mostly affected in terms of stress redistribution and resulting strain (Brown et al., 1983; Kontogianni et al., 2008). Singh et al. (2004) observed that anisotropy in deformational behaviors of rocks is induced if the number of joint set is not very large, and modeling such behaviors of intact rocks as well as joint properties should be incorporated. The deformation and failure of surrounding rocks are widespread and the associated deformation mechanism has been a matter of great concern to researchers (Singh et al., 2011; Kainthola, 2015; Zou and Yan, 2015).

Schubert and Schubert (1993), Schubert (1996), and Steindorfer (1998) have studied the effect of geological structure on deformational behavior of rocks surrounding tunnel using Alpine tunnels' data. The deformation behaviors of rocks surrounding tunnels in varying conditions have been also studied, and different opinions and classifications are proposed accordingly. Five geomechanical modes of classes of rock deformation and failure were proposed by Zhang et al. (1981). The classes were creep–crack, slip-pressure-induced crack, bending-crack, plastic flow–crack, and slip–bending. Furthermore, Wang et al. (1984) analyzed and summarized the proposed classification in actual underground engineering basis and discussed rock deformation mechanisms, structures, methods and characteristics of the classification. Hu and Zhao (2004) recommended three types (roof falling stones, dome transverse tensile collapse and sidewall tangential squeeze slide) of deformation and failure of caverns in low stress condition. Variation of block sizes and shapes not only changes the failure mode, but also leads to considerable changes in the stress distribution around the tunnel (Solak and Schubert, 2004). Pan and Brown (1996) carried out research on the effects of out-of-plane stress and dilation on the convergence and stability of the surrounding rocks and found these parameters to be the major parameters for understanding the failure mechanism around tunnel surroundings. The size of underground excavation and types of rocks also influence

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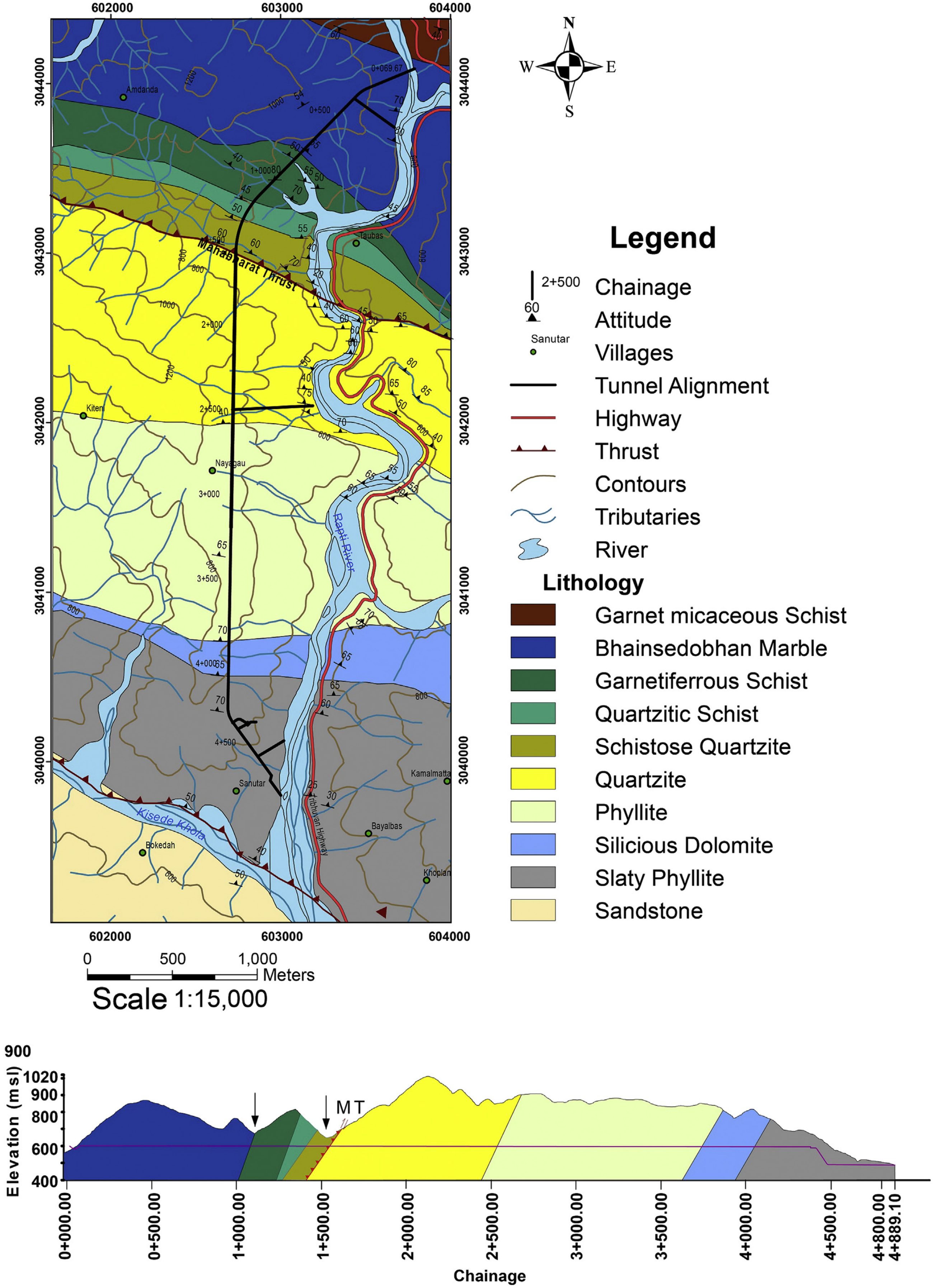

**Fig. 1.** Geological map of the study area showing tunnel alignment and L-section along the tunnel.