Abstract of PhD Thesis submitted by Col. Manish Kapil

Behaviour of Micropiles in Glacial Deposits under Axial and Lateral Loads: Field Testing and Numerical Simulations

India, as a rapidly developing nation, is undertaking extensive infrastructure projects across the Himalayan region to improve connectivity between its northern states. These initiatives primarily involve the construction of roads, railway lines, tunnels, and bridges to traverse the rugged mountainous terrain. Due to the presence of numerous rivers, valleys, and depressions, bridge construction is particularly crucial. However, the unique geological conditions in the Himalayas, especially the presence of thick glacial moraine deposits—formed by the movement and retreat of glaciers and often exceeding 100 meters in depth—pose significant challenges for foundation design. Conventional deep foundations like driven or bored piles are often impractical in such deposits due to the inaccessibility of hard strata. In this context, micropiles emerge as a promising alternative due to their small diameter (typically less than 300 mm), ability to be installed with minimal disturbance, and adaptability to a wide range of subsurface conditions.

This study focuses on the glacial deposits of the Ladakh and Uttarakhand regions, where both geomorphological mapping and geotechnical characterization are systematically carried out. Laboratory investigations classified the deposits predominantly as poorly graded gravel (GP), with gravel content varying between 36% to 57%, and high shear strength values reflected in internal friction angles exceeding 40°. Mineralogical analysis through X-ray diffraction (XRD) and scanning electron microscopy (SEM) revealed a dominance of angular particles composed mainly of quartz, feldspar, and traces of clay minerals, contributing to the high frictional resistance of the material.

A comprehensive field testing program was undertaken, comprising 28 full-scale load tests on micropiles installed in glacial deposits. It includes 9 vertical, 9 lateral, 5 group load tests, and 5 load tests on instrumented micropiles. These tests demonstrated that the actual in-situ load capacity of micropiles exceeded analytically predicted values (based on IS 14593:1998 and IS 2911 Part 1 Sec-2) by more than 2.5 times. Vertical load capacities reached up to 80 tons, with corresponding settlements ranging from 3.12 mm to 8.9 mm, while lateral capacities were significantly affected by scour depth—experiencing up to 160% reduction after 1 m of scouring and complete failure beyond 2 m.

To complement the field investigation, a parametric numerical study was performed using PLAXIS 3D. The effects of various parameters such as type of loading, elastic modulus of the glacial deposits, scouring depth, slenderness ratio (L/D), and grade of grout were evaluated. The results indicated that increasing the stiffness of the surrounding soil and using higher-grade concrete improved the micropile capacity. Conversely, increased scouring depth and L/D ratios led to reduced performance. The numerical analysis corroborated field findings and emphasized the critical role of lateral loads and scour in micropile design. Inclined micropiles and improved concrete grades were identified as viable solutions to enhance lateral resistance.

In summary, this study provides a robust understanding of the behavior of micropiles in glacial deposits through integrated geomorphological, geotechnical, in-situ, and numerical approaches. The findings not only demonstrate the viability of micropiles as a foundation solution in complex Himalayan terrain but also provide essential insights and a comprehensive field test data to develop design guidelines for micropiles in glacial deposits.