Title: Reliability based robust design in geotechnical engineering

Abstract: Traditional reliability based design methods are receiving considerable attention among the geotechnical practitioners and researchers. Selection of a geotechnical design by traditional reliability methods involves evaluation of reliability index or probability of failure of the structure and cost evaluation. The design which satisfies target probability of failure \( \left( P_f \right) \) and is of lowest cost is often selected. However, this design is sensitive to variations in statistical parameters of input variables (noise parameters). This is often the case in geotechnical investigation where limited samples are available for characterization of the input random variables. This leads to type of epistemic uncertainty known as estimation uncertainty which describes the uncertainty associated with selection of probabilistic distribution and its parameters. For selecting a design in these situations, a relatively new design methodology - reliability based robust geotechnical design (RGD) is demonstrated. This design approach ensures cost effective as well as safe design which is less sensitive to the variation in noise parameters. Finally, a bi-objective optimization is performed to obtain an optimal design among the candidate designs, which is cost effective as well as robust.

The design approach is demonstrated through the case of reinforcement of a typical jointed rock slope using end anchored rock bolts and liner support in circular tunnels under hydrostatic in-situ stress. The design parameters to be optimized for bolt design are bolt length, bolt diameter and bolt in-plane spacing. For evaluating the \( P_f \) of the slope which is solved numerically in plane strain finite element method, an augmented radial basis function (RBF) response surface is constructed. This response surface acts as a surrogate to finite element code for evaluating factor of safety of the slope, which is computationally expensive while performing Monte Carlo simulation. The design parameters in case of rock tunnel analysis are compressive strength of concrete of liner, thickness of liner, length of the rock bolt and distance from the tunnel face where supports are to be installed. Convergence confinement analysis solutions, proposed by Carranza-Torres and Fairhurst (2000) were used, and involve determining longitudinal deformation profile (LDP), Ground reaction curve (GRC) and support characteristic curve (SCC). Three performance functions are defined to assess the tunnel – support system They are 1) rock bolt length should not be less than plastic zone of rockmass formed around the tunnel and it should be embedded 1.2m in the intact rockmass, 2) the displacement at the tunnel wall should not exceed a certain threshold and 3) the equilibrium pressure should not exceed the ultimate support capacity of the liner. Probability of failure associated with these performance functions is estimated using First order reliability method (FORM) by applying Improved HL-RF (Hasofer Lind – Rackwitz Fiessler) algorithm.

Keywords: Robust geotechnical design, probability of failure, rock bolt design, convergence confinement analysis, Tunnel support design