Moment propagation versus design-point search: the stochastic perturbation method convergence in tunnel reliability

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The stochastic perturbation method (SPM) [1] is applied to the reliability assessment of tunnel convergence, a problem so far addressed almost exclusively by design-point search techniques. The mechanical model is the classical plane-strain solution [4] for a circular opening in a Mohr-Coulomb elastic-perfectly plastic medium under hydrostatic in situ stress, which yields the wall convergence in closed form as a strongly non-linear function of four uncorrelated Gaussian variables: friction angle, cohesion, elastic modulus and in situ stress. Because the response is explicit, the perturbation expansion is carried out with exact symbolic derivatives, and the first two probabilistic moments of the convergence are obtained at negligible cost through a mixed second-order-mean / first-order-variance scheme. The resulting moments feed a Cornell reliability index, which we compare with the first-order reliability method (FORM) results of Liu and Low [2] on the same limit state and at the same operating point. The two indices differ substantially ($\beta = 5.02$ against $\beta = 3.00$). The Monte Carlo simulation confirms the SPM moments, thereby identifying the discrepancy in the index rather than in the propagation: the two-moment index, which is not invariant with respect to the algebraic form of the limit state [3] and does not account for the asymmetry induced by the nonlinear response, represents the limiting factor. However, both approaches agree on the classification of input variables based on sensitivity. These results form the basis for the higher-order perturbation schemes discussed in the presentation.

References

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