Logistics of Transition from Working Stress to Limit States Design in Foundations Engineering

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ABSTRACT

The paper considers transition from Working Stress Design (WSD) using a single Global Safety Factor (GSF) to Limit States Design (LSD) using differentiated load and resistance factors in one specific aspect of foundations engineering – design of pile foundations for vertical compressive loads. Conversion to LSD format in Canadian design codes in 2005, based on works by Becker [1, 2], did not assure consistency of designs with the earlier WSD paradigm, sacrificing it in favour of direct probabilistic considerations. As a result, the new LSD methodology ended up more conservative than the previous WSD designs; the equivalent GSF has increased from 2.5 to 3.6. Due to it, the piles for the same loads became longer or larger than before, and consequently more expensive. In revamp projects where existing piles are being reused, they fail the capacity checks even for unmodified original loads. This undermines credibility of the LSD paradigm in the eyes of the practitioner since the existing WSD designs have performed adequately.

Using this case as an example, the paper examines a more general question of probabilistic calibration of load and resistance factors in LSD and similar methods. It is shown analytically and confirmed numerically by Monte Carlo simulation that uniform level of reliability is not achieved in these methods. The imposed reliability of resistance is generally much higher than the reliability of load calculation, which limits usefulness of these methods for direct probability-of-failure-based design. Published data on "averaged" foundations' probability of failure (10^{-2} to 10^{-3} per year) correspond to the reliability index β = 2.3 to 3.1, which is substantially lower than the target value of 3.4 in the 2010 National Building Code of Canada. Therefore, the new load and resistance factors are deliberately set to increase the level of design reliability (and therefore the cost), despite the absence of evidence against the WSD-designed legacy foundations.

The results of probabilistic calculations critically depend on the assumed coefficient of variation of both the load and the resistance, which can only be back-calculated from data for existing designs. It is argued that uncertainties that abound in geotechnical problems do not allow any more refined quantification of design reliability than that afforded by the single number of GSF.

In the process of transition from WSD to LSD, it is suggested to maintain the compatibility condition GSF = α / ϕ ($\alpha > 1$ – load factor, $\phi < 1$ – resistance factor) in all cases, using probabilistic considerations only for information and control. A procedure of Bayesian update is proposed for development of improved code provisions based on new research data. Within its framework, code modification will only occur if the results of new tests deviate significantly from the existing data, or the amount of the new test data becomes comparable with the tremendous number of foundations designed under WSD and performing adequately.

REFERENCES

[1] D.E. Becker, "Eighteenth Canadian Geotechnical Colloquium: Limit states design for foundations. Part I. An overview of the foundation design process", *Can. Geotech. J.*, **33**, 956-983 (1996).

[2] D.E. Becker, "Eighteenth Canadian Geotechnical Colloquium: Limit states design for foundations. Part II. Development for the National Building Code of Canada", *Can. Geotech. J.*, **33**, 984-1007 (1996).