RELIABILITY ANALYSIS OF M5-GP PREDICTION MODELS FOR UPLIFT CAPACITY OF SUCTION CAISSONS

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1. Introduction

Different models for predicting the uplift capacity are available in the technical literature. The recommended models for uplift capacity prediction do not account for the input uncertainties affecting the results.

Generally, uncertainty in the inputs, is effective on the reliability of the system responses. Suction caisson is among the widely used engineering systems that its uplift capacity is influenced by uncertainties.

To improve the reliability of the designs, the input uncertainties need to be considered directly [1]. For this purpose, various approaches have been used for analyzing the engineering systems ranging from engineering judgments to the complicated statistical and intelligent methods.

The fuzzy sets theory can be considered as the most general method to be used for uncertainty analysis in engineering [2]. Examples of successful civil engineering studies that utilized the fuzzy sets theory include the uncertainty analyses in water pipeline networks [3, 4], structural engineering [5, 6] and geotechnical engineering [7].

2. Methodology

The uncertainties in the inputs can influence the estimated suction caisson uplift capacity. For the reliable design, analysis of the possible uncertainties and their influence on the uplift capacity is necessary. In this paper, the uncertainty analysis of the suction caisson uplift capacity is done based on the Fuzzy sets theory using fuzzy numbers.

First, the uplift capacity of the suction caisson is estimated using the various approaches without consideration of uncertainty of input parameters. Then the suction caisson uplift capacity is evaluated considering the input uncertainties using the suggested fuzzy approach. Comparison of the results of different models shows that how the input uncertainties are spread out over their relationships.

3. Data

The governing parameters with considerable influence on the uplift capacity of suction caissons (*Q*) are shown in Figure 1. The database used in this study consists of the experimental test results reported by Rahman, Wang [8]. This database has been employed in different researches conducted to develop models for predicting the uplift capacity of suction caissons. One recent approach is to employ M5 model tree together with GP (M5-GP) as used by Derakhshani [9] to propose two robust methods (Table 1).

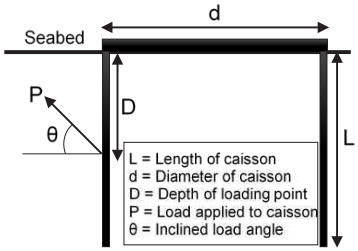

Figure 1. Suction caisson geometry.

Table 1. M5GP models [9].

M5GP1
$for\ \ S_u \le 12.28 : Q = 1.105 \dfrac{\left(\frac{D}{L}+1\right)\left(\frac{\pi}{2}+\theta\right)^{0.8} S_u^{0.9}}{T_k^{0.1}}$
$for\ \ S_u > 12.28 : Q = 0.083 \dfrac{\left(\frac{D}{L}+1\right)^{3.7}\left(\frac{\pi}{2}+\theta\right)^{2.8} S_u^{1.6}}{\left(\frac{L}{d}\right)^{0.2}(10^5 T_k)^{13.1}}$
M5GP2
$for\ \ S_u \le 12.28 :$ $Q = 0.272 \dfrac{\left(\frac{\pi}{2}+\theta\right)^{1.2} S_u}{T_k^{0.1}} \exp\left[1.2\left(\frac{D}{L}+1\right) + 2.23T_k - 0.0004S_u^{2} \exp\left(\frac{L}{d}\right)\right.$
$for\ \ S_u > 12.28 :$ $Q = 11.964 \dfrac{\left(\frac{D}{L}+1\right)^{0.2}\left(\frac{\pi}{2}+\theta\right)^{4.1}(10^5 T_k)^{1.4}}{\left(\frac{L}{d}\right)^{1.6} S_u^{2.8}} \exp\left[0.36\left(\frac{L}{d}\right) + 0.18S_u + 1.69\exp\left(\left(\frac{L}{d}\right)\Big/\left(\frac{\pi}{2}+\theta\right)\right)\right.$

4. Results and Discussion

Membership functions of M5GP models for CC and RMSE statistical measures are provided in Figure 2. Based on the results given in this Figure, it can be found that although the performance of the two M5GP models is good regarding the crisp (most likely) values, the responses are vulnerable to the input uncertainties.

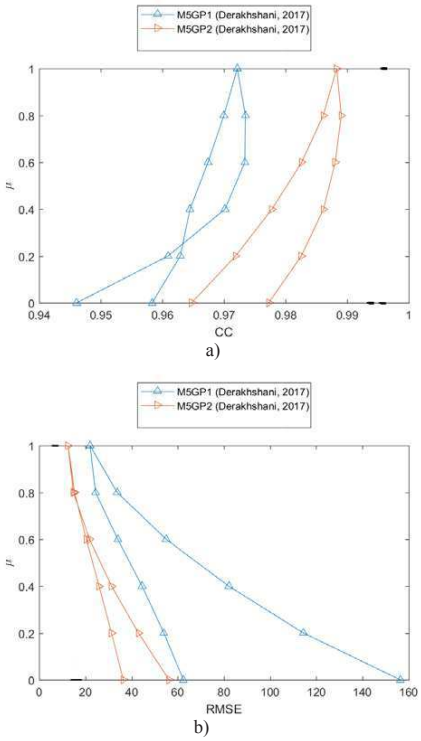

Figure 2. Membership functions of M5GP models: a) CC, b) RMSE.

5. Conclusions

Among different prediction models recommended for the uplift capacity of suction caissons, the recent hybrid M5GP models were investigated regarding the influence of input uncertainties. Reliability of the predictions made by these two methods was evaluated and compared by the fuzzy statistical indices including correlation coefficient (CC) and root mean squared error (RMSE). It is inferred that, although these models are remarkably accurate, they may be vulnerable to uncertainties of predictors.

6. References

[1] Verhoosel CV, Scholcz TP, Hulshoff SJ, Gutiérrez MA. Uncertainty and reliability analysis of fluid-structure stability boundaries. AIAA Journal. 2009;47:91-104.

[2] Liu Q, Rao SS. Fuzzy finite element approach for analysis of fiber-reinforced laminated composite beams. AIAA journal. 2005;43:651-61.

[3] Haghighi A, Asl AZ. Uncertainty analysis of water supply networks using the fuzzy set theory and NSGA-II. Engineering Applications of Artificial Intelligence. 2014;32:270-82.

[4] Sabzkouhi AM, Haghighi A. Uncertainty Analysis of Pipe-Network Hydraulics Using a Many-Objective Particle Swarm Optimization. Journal of Hydraulic Engineering. 2016;142:04016030.

[5] Valdebenito M, Jensen H, Beer M, Pérez C. Approximation concepts for fuzzy structural analysis. Vulnerability, Uncertainty, and Risk: Quantification, Mitigation, and Management2014. p. 135-44.

[6] Haghighi A, Ayati AH. Stability analysis of gravity dams under uncertainty using the fuzzy sets theory and a many-objective GA. Journal of Intelligent & Fuzzy Systems. 2016;30:1857-68.

[7] Cheng M-Y, Tsai H-C, Ko C-H, Chang W-T. Evolutionary fuzzy neural inference system for decision making in geotechnical engineering. Journal of Computing in Civil Engineering. 2008;22:272-80.

[8] Rahman MS, Wang J, Deng W, Carter JP. A neural network model for the uplift capacity of suction caissons. Computers and Geotechnics. 2001;28:269-87.

[9] Derakhshani A. Estimating uplift capacity of suction caissons in soft clay: A hybrid computational approach based on model tree and GP. Ocean Engineering. 2017;146:1-8.