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# Fuzzy classification of soils based on Iranian standard of 2800

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**ABSTRACT:** Soil classification is a function of a region's geological conditions, which according to the Iranian earthquake standard of 2800, it is consequently a function of average shear wave velocity, as well as average SPT blow count, and average undrained shear strength of cohesive soils in different layers for up to 30 meters depth. Boundaries of these geotechnical parameters are often defined as different crisp values in the earthquake design codes. Because of the uncertainties in the mentioned parameters and also the difference between values of these parameters in the real material and values obtained from the experimental tests for the determination of these parameters, statistical and probabilistic methods is needed. Due to the computational complexity of statistical and probabilistic methods, in this research, a fuzzy inference system has been used for the decision of the classification of soil type, which can consider uncertainties without the need for complex mathematical calculations. For this purpose, after defining the effective parameters for determining the soil type, triangular membership functions were selected for them, and finally, a fuzzy inference system was designed. According to the results, the proposed model provides more accuracy than the standard in the boundaries between two successive soil classes. Also, when the values of the parameters are far from the boundaries between successive soil classes, the fuzzy inference system and the standard provide the same answers.

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## 1- Introduction

Soil classification is a function of mechanical and dynamical parameters of soil layers, which according to earthquake design codes, such as European, American and Iranian codes (earthquake Standard of 2800), it is a function of the average shear wave velocity, average SPT blow count, and the average undrained shear strength in cohesive soils in different layers is up to 30 meters from the surface [1-3]. Spatial variations of resistance parameters are considered as the most important source of uncertainty. Probabilistic analysis is a useful method for considering uncertainties and gives us a better understanding of reliability analysis than deterministic analysis [4-6], But in terms of time-consuming, it is not practical in engineering [7]. The use of probability theory, based on the classical binary-value logic, to consider uncertainties, was first challenged in 1937 by Max Black's studies and then by fuzzy sets by Lotfizadeh in 1965 [8]. Therefore, the fuzzy method was proposed as a suitable alternative to the probabilistic method [5]. The fuzzy theory represents ambiguous information and can logically be used to express uncertainties [9]. The studies have shown the effectiveness of fuzzy theory in uncertainties modeling, related to soil properties. Meidani et al., used fuzzy sets to consider the uncertainties in the soil parameters and investigated the soil slope stability. Fast calculation is the main advantage of this method compared to complex analytical techniques such as probabilistic methods and finite elements. The results of the fuzzy model are comparable in terms of accuracy with analytical and numerical methods [10]. Khademi et al, used fuzzy sets for rock classification and showed that fuzzy sets help engineers in the decision-making process. Also, the fuzzy theory has acceptable reliability for rock classification systems [11]. Bhargavi et al., using numerical code, based on some laboratory data, presented appropriate fuzzy rules by optimizing them for the fuzzy classification system [12]. Sujatha et al, Proposed a fuzzy expert system for soil engineering classification, and the results are in good agreement with the results of laboratory experiments. He proposed an engineering classification system for the soil according to the Indian Standard, using the fuzzy expert system and using quantitative parameters that include the characteristics of the soil index [13]. In this paper, first, a comparison between soil type classifications is made among the three earthquake design codes. To make an inappropriate decision to determine the soil type, a fuzzy inference system for soil classification based on the Iranian standard of 2800 is proposed. Often, boundaries are defined as crisp values, and decision-making on boundaries based

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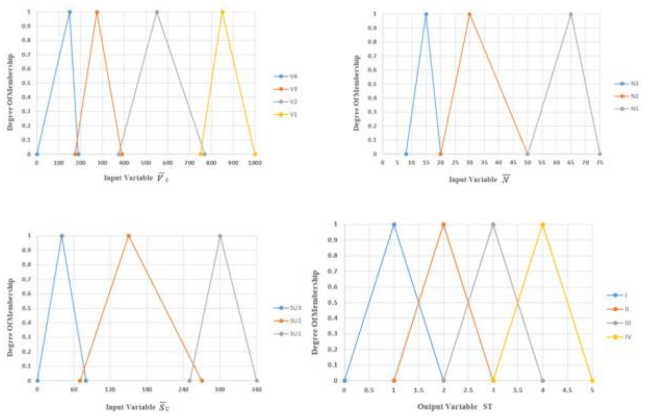

**Fig. 1. Membership functions of fuzzy model**

on classical binary-value logic is zero and one. Fuzzy logic removes the ambiguities that arise in defining boundaries. These ambiguities are due to the uncertainties in each of the effective parameters in determining the soil type. In the proposed soil type classification, based on the effective parameters in determining the soil type, first, the appropriate triangular membership functions are defined, and then, the fuzzy inference system of this classification is explained based on fuzzy rules.

## 2- Methodology

Fuzzy inference systems consist of two main parts, the first part is membership functions and the second part is fuzzy rules, which are composed of a set of if-then conditional rules. In the present study, due to the little data available from the experiments, triangular membership functions were used for the input and output parameters. According to the standard of 2800, four boundaries are defined for shear wave velocity, three boundaries for the SPT blow count, and three boundaries for the undrained shear strength. Each of these parameters overlaps with its adjacent values. The output of the membership functions must be between 0 and 1. The system output is the soil type that according to the standard of 2800, is divided into four classes I, II, III, and IV. According to “Figure 1”, the output membership function, is triangular and has overlapping in the vicinity of the boundaries. According to the inputs and outputs, 40 fuzzy rules are written for the proposed model. Fuzzy rules are usually defined based on the opinions of experts and experience. The accuracy of the model is tested in various examples. Examples include soils with different types of textures that have been extracted from geotechnical studies in different areas in Tabriz. The results of the fuzzy model are recorded in Table 1 and compared with the soil type mentioned in geotechnical reports based on the standard of 2800. The examples include soil parameters, both in the boundaries and far from the borders.

**Table 1. Prediction of Fuzzy Inference System of soil type in some case studies in Tabriz**

| soil classification according to the standard of 2800 | Soil classification is based on the fuzzy model with input membership functions according to "Figure 1" | $\overline{V}_S$ (m/s) | $N$ | $\overline{S}_U$ (kPa) |
|---|---|---|---|---|
| III | 3.29 | 300 | 45 | 70 |
| II | 2.78 | 380 | 45 | - |
| II | 2.00 | 400 | 42 | - |
| II | 2.00 | 650 | - | - |
| II | 2.50 | - | - | 300 |
| I | 1.00 | 800 | - | - |

## 3- Conclusions

The main problem in soil type classification is the precise determination of boundaries between groups. The proposed fuzzy inference system for fast and logical decision-making based on the standard of 2800 can solve this problem and determine the soil type. The most important advantages of the proposed fuzzy classification system are as follows:

- According to examples, it is observed that the proposed model provides a more accurate answer than the standard at the boundaries between two consecutive soil types. Therefore, according to conditions such as the accuracy of the tests, a more logical and accurate decision can be made than the standard. This case is the most important feature of the introduced fuzzy inference model.

- If the values of the effective parameters; average shear wave velocity, average SPT blow count, and average undrained shear strength, are in the inner parts of the ranges provided by the Iranian earthquake design code (Standard 2800), then the result of the proposed fuzzy inference model for the soil type is similar to the standard classification. But in the boundary parts of the ranges, the fuzzy inference model provides more accurate results than the standard.

- In the proposed fuzzy inference model, the input parameters can be increased. For example, soil grading and plasticity index can also be considered. It will increase the accuracy of the proposed inference system and thus make more rational and accurate decisions.

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