Quantitative analysis of spatial variability of geotechnical parameters

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Quantitative Analysis of Spatial Variability of Geotechnical Parameters

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Abstract. Geotechnical parameters are the basic parameters of geotechnical engineering design, while the geotechnical parameters have strong regional characteristics. At the same time, the spatial variability of geotechnical parameters has been recognized. It is gradually introduced into the reliability analysis of geotechnical engineering. Based on the statistical theory of geostatistical spatial information, the spatial variability of geotechnical parameters is quantitatively analyzed. At the same time, the evaluation of geotechnical parameters and the correlation coefficient between geotechnical parameters are calculated. A residential district of Tianjin Survey Institute was selected as the research object. There are 68 boreholes in this area and 9 layers of mechanical stratification. The parameters are water content, natural gravity, void ratio, liquid limit, plasticity index, liquidity index, compressibility coefficient, compressive modulus, internal friction angle, cohesion and SP index. According to the principle of statistical correlation, the correlation coefficient of geotechnical parameters is calculated. According to the correlation coefficient, the law of geotechnical parameters is obtained.

Key words: Geostatistics; Geotechnical parameters; Variogram; Kriging estimation; Relativity.

INTRODUCTION

Geotechnical engineering is a great variability of engineering materials. During its formation, it has undergone many natural and human factors [1-2].Therefore, the nature of rock and soil is very complicated. Natural rock and soil body is not uniform and anisotropic, which determines the various properties of rock and soil with spatial variability. The variability of geotechnical parameters is both structural and random. It is the root cause of the uncertainty of geotechnical parameters. Geostatistics is the study of regional variables. Geostatistics is not only the theoretical foundation for the study of spatial variability of rock and soil mass, but also a rapidly developing subject with broad application prospects in the field of mathematical geology [3-5].The study of geotechnical characteristics of spatial variability provides technical support for the design and construction of construction engineering. At the same time, it can also reveal the variation phenomenon and regularity of spatial characteristics of regional rock and soil, and describe its variation characteristics by mathematical method. The spatial statistical characteristics of rock and soil parameters are used in the design and study of the reliability of geotechnical engineering [6].Therefore, it is of great significance to study the characteristics of spatial variability of geotechnical parameters.

GEOSTATISTICAL ANALYSIS OF GEOTECHNICAL PARAMETERS

Introduction of kriging

In mining terminology, according to some characteristic data of some information samples, a method of linear unbiased and minimum variance estimation for unknown data of similar features of the block is proposed. From a mathematical point of view, it is a method for finding the optimal and unbiased interpolated estimators. More specifically, Kriging is in consideration of the information of the sample and the shape and size of the blocks to be

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estimated between the spatial distribution of the geometry features, and variables such as spatial structure, ore grade and thickness of coal seam, in order to achieve linear, unbiased and minimum variance estimation and estimation considering. Each sample values were given the right coefficient, method for estimation of unknown quantities to estimate the last block or panel with weighted average method. It is also said that Kriging is a specific sliding weighted mean method [7].

Kriging is constantly developing and perfecting. Different Kriging methods can be used for different situations and purposes. At present, Kriging method is roughly as follows: First, ordinary kriging can be used to satisfy second-order stationary or intrinsic assumptions. Second, the pan Kriging method can be used in the nonstationary or drifting existence. Third, when the recoverable reserves are calculated, the Kriging method can be obtained by using the nonlinear estimators. Fourth, when the regionalization variable obeys the lognormal distribution, the logarithmic Kriging method can be used. Fifth, the random Kriging method can be used when the data is less, the distribution is not large, and the accuracy of the estimation is not too high. In recent years, there are also newly developed factor Kriging method, indicating Kriging method and so on. Geostatistics mainly uses various Kriging methods on the basis of structural analysis to evaluate and solve practical problems. Thus, geostatistics is often said to be kriging.In fact, geostatistics also contains many other important elements such as conditional simulations. This shows that Kriging plays an important role in geostatistics.

Let Z (x) be a regionalized variable, and Z (x) is determined on a point - supported set. It is second-order smooth. Among them:

Expected value: $E\{Z(x)\} = m$, m is an unknown constant.

Variation function: $E\{[Z(x+h) - Z(x)]^2\} = \gamma(h)$

The linear estimator Z_γ^* used is a linear combination of n numbers:

$$Z_K^* = \sum_{i=1}^{n} \lambda_i Z_i \tag{1}$$

n weight coefficients λ_i are calculated, to ensure that the estimator Z_γ^* is unbiased. The estimation error is the smallest.

The overview of the site

The site is located in the Tianjin peace zone, Fu'an street, Xingan Road, Huaan street and Duolun Road. These are the old urban areas. The surface geology is complicated. A large number of holes and trench pits are distributed in large quantities.During the exploration, the original ground buildings have been demolished and the underground obstacles have not been cleared. The west side of Heping Road has more dismantling soil and high terrain, which is about 1.00~1.70m of high difference with the current road section of peace road. The rest of the land is slightly undulating, and the high difference between the road and the peaceful road is less than 1.00m.There are 68 holes in the site, and the height of the orifice of each hole is between 4.70~2.95m.According to the survey data, the site is buried deep in the depth of 55.50m. The foundation soil can be divided into 9 lower layers according to the genetic age. It can be further divided into 12 sublayers according to the mechanical properties. It is distributed all over the field, with a thickness of 2.60~5.60m. The floor elevation is 0.83~2.50m. The top layer can be divided into 2 sub layers. In the first sublayer, the thickness of the clutter is 0.80~4.00m, which is variegated and loose. It is mainly composed of the surface dismantling soil, the lower waste soil, the brick and the stone. The thickness of the soil is 1.00~4.20m, which is composed of silty clay and silt soil, including brick slag, rot plant, organic matter and so on.

CORRELATION ANALYSIS OF GEOTECHNICAL PARAMETERS

Correlation coefficients are used to describe the degree of correlation between variables. The correlation coefficient between the ith variable and the jth variable is:

$$r_{ij} = \frac{\sum_{k=1}^{p}(x_{ik} - \overline{x_i})(x_{jk} - \overline{x_j})}{\sqrt{\sum_{k=1}^{p}(x_{ik} - \overline{x_i})^2 \sum_{k=1}^{p}(x_{jk} - \overline{x_j})^2}} \tag{2}$$

In the equation, $-1 \le r_{ij} \le 1$, $\overline{x_i} = \frac{1}{p}\sum_{k=1}^{p} x_{ik}$, $\overline{x_j} = \frac{1}{p}\sum_{k=1}^{p} x_{jk}$.

Physical indicators of rock and soil include water content, severity, porosity ratio, liquid limit, plasticity index and other test indicators. Geomechanics indicators include the compressibility, compressive modulus, cohesion, internal friction angle and so on. The physical property index of rock and soil is the basic qualitative data for evaluating the foundation of the engineering. To a large extent, it reflects the deformation and strength characteristics of rock and soil. The mechanical property index of rock and soil is to evaluate the performance of the foundation rock and soil to resist external force, and the rock and soil body will be deformed and destroyed by external force. Physical and mechanical properties of rock and soil are different in physical meaning. However, there is an intrinsic and closely related relationship between them. The correlation coefficients between second, third, and fourth layers of common parameters are calculated. Correlation coefficient of the second layers of soil parameters is shown in Table 1.Correlation coefficient of the fourth layers of soil parameters is shown in Table 2.

TABLE 1. Correlation Coefficient of the Second Layers of Soil Parameters

Water content	Natural density	Voidratio	Liquid limit	Plastic index	Liquid index	Compression coefficient	Compression modulus	internal friction angle	Cohesive force	Standard penetration index
1.0000										
-0.6368	1.0000									
0.8777	-0.9181	1.0000								
0.2479	0.1752	0.0350	1.0000							
0.4423	0.0479	0.2218	0.9166	1.0000						
-0.4489	0.1685	-0.3346	-0.3061	-0.2838	1.0000					
0.3203	0.0050	0.2498	0.3105	0.5207	-0.2270	1.0000				
0.0607	-0.2990	0.1215	-0.4115	-0.4586	0.0118	-0.8566	1.0000			
-0.7634	0.2780	-0.5794	-0.4019	-0.5560	0.3581	-0.5395	0.2382	1.0000		
0.5975	-0.3703	0.5310	0.1719	0.3408	0.1210	0.3647	-0.1431	-0.6852	1.0000	
-0.0748	0.2144	-0.1727	-0.0016	0.1629	0.4623	0.2137	-0.3033	0.1174	0.3192	1.0000

TABLE 2. Correlation Coefficient of the Fourth Layers of Soil Parameters

Water content	Natural density	Voidratio	Liquid limit	Plastic index	Liquid index	Compression coefficient	Compression modulus	internal friction angle	Cohesive force	Standard penetration index
1.0000										
-0.5296	1.0000									
0.5508	-0.9929	1.0000								
0.3231	-0.0298	0.0637	1.0000							
0.3265	-0.0321	0.0652	0.9974	1.0000						
0.3858	-0.7495	0.7258	-0.4110	-0.3920	1.0000					
0.1144	0.1795	-0.1689	0.4761	0.4399	-0.4199	1.0000				
-0.0574	-0.2930	0.2980	-0.5121	-0.4871	0.5229	-0.9502	1.0000			
-0.6158	0.4080	-0.4553	-0.0561	-0.0589	-0.5033	-0.1435	-0.0259	1.0000		
-0.0538	-0.0257	0.0343	0.1783	0.1450	-0.2590	0.7514	-0.6780	-0.2574	1.0000	
-0.1820	0.1142	-0.1584	0.0576	0.0732	0.0633	-0.3836	0.2703	0.4457	-0.4537	1.0000

The correlation coefficient of second layers of soil is greater than 0.8: the ratio of water content to void ratio: 0.8777, void ratio and gravity: -0.9181, compression coefficient and compression modulus -0.8566, liquid limit and plasticity index: 0.9166.The fourth layer soil correlation coefficient is greater than 0.8: pore ratio and severe: -0.9929, compression coefficient and compression modulus -0.9502, liquid limit and plastic index: 0.9974.The following conclusions can be drawn from the data: The water bearing capacity of the soil is directly controlled by the pores in the soil. The size of the pore determines the size of the void ratio and the amount of water. For the same soil, the more pores in the soil, the larger the pore ratio, the more water in the pores, and the less the soil particles. The water content

depends on the ratio of the quality of the water to the mass of the soil particles. The pore ratio has a good positive correlation with the water content. There is a strong correlation between liquid limit and plasticity index. There is a strong negative correlation between compressibility and compression modulus. Besides, there is a certain correlation between compressibility and liquid index and water content. Both the strength index and the compression coefficient have a good correlation with the water content and the pore ratio. There is a good negative correlation between the internal friction angle and cohesive force index of soil. Therefore, the internal friction angle and cohesive force cannot be regarded as independent random variables in geotechnical analysis, and the interrelated influence between them must be considered.

The shear strength of soil is essentially a comprehensive embodiment of various forces between soil particles, which is closely related to the properties and state of the soil. With the compaction of soil, the pore ratio becomes smaller. Water content is reduced. The thickness of the combined water film around the soil particles is thinner and the spacing of the soil particles is reduced. The interaction of water and glue with water film increases gradually, and the interaction force between particles increases and the shear strength of soil increases. Therefore, the shear strength index is negatively correlated with water content and pore ratio. The correlation between soil properties is determined by the mineral composition, sedimentary conditions, stress history, water content and other aspects. The composition and origin of soil, and its existing conditions determine the relevance of soil properties. In most projects, due to the limitation of equipment conditions, it is impossible to conduct comprehensive engineering geological investigation and comprehensive engineering geological testing in all engineering geological surveys. Therefore, the index of the bearing capacity of the stratum can only be judged according to the geological quality and the limited semi quantitative index. The correlation analysis of physical and mechanical properties of rock and soil is to deduce another unknown variable from one known random variable and meet the engineering requirements. This will greatly reduce the work of engineering geological exploration and comprehensive engineering geological testing. The error of the test results is verified, and the accuracy of the test work and the utilization of the results is improved, which is favorable for the whole project design.

CONCLUSION

This paper mainly introduces the application of geo statistics theory in geotechnical engineering. The model parameters of geotechnical parameters were calculated, and the spatial variation of geotechnical parameters was analyzed. The Kriging method was used to find the unknown points and draw the contour of each geotechnical parameter. The correlation coefficient between rock and soil parameters is calculated and their correlation is analyzed. Correlation coefficient values can be derived from the degree of geotechnical parameters. By using the correlation between parameters, the workload of engineering exploration will be greatly reduced. The test results are verified, which is beneficial to the whole engineering design.

REFERENCES

1. Oliver, M. A., & Webster, R. (2014). A tutorial guide to geostatistics: Computing and modelling variograms and kriging. Catena, 113, 56-69.
2. Aidoo, E. N., Mueller, U., Goovaerts, P., &Hyndes, G. A. (2015). Evaluation of geostatistical estimators and their applicability to characterise the spatial patterns of recreational fishing catch rates. Fisheries research, 168, 20-32.
3. Lebrenz, H., &Bárdossy, A. (2017). Estimation of the Variogram Using Kendall's Tau for a Robust Geostatistical Interpolation. Journal of Hydrologic Engineering, 22(9), 04017038.
4. Du, D., Wang, C., Du, X., Yan, S., Ren, X., Shi, X., & Hein, J. R. (2017). Distance-gradient-based variogram and Kriging to evaluate cobalt-rich crust deposits on seamounts. Ore Geology Reviews, 84, 218-227.
5. Delrieu, G., Wijbrans, A., Boudevillain, B., Faure, D., Bonnifait, L., &Kirstetter, P. E. (2014). Geostatistical radar-raingauge merging: A novel method for the quantification of rain estimation accuracy. Advances in Water Resources, 71, 110-124.
6. Liang, X., Schilling, K., Zhang, Y. K., & Jones, C. (2016). Co-kriging estimation of nitrate-nitrogen loads in an agricultural river. Water resources management, 30(5), 1771-1784.
7. Xu, W., Collingsworth, P., Bailey, B., Mazur, M. C., Schaeffer, J., & Minsker, B. (2017). Detecting spatial patterns of rivermouth processes using a geostatistical framework for near-real-time analysis. Environmental Modelling & Software, 97, 72-85.