Fifth International Conference on Geotechnique, Construction Materials and Environment, Osaka, Japan, Nov. 16-18, 2015, ISBN: 978-4-9905958-4-5 C3051

PREDICTION OF SPACE DISTRIBUTION FOR SOIL SURVEY VALUES BASED ON GEOSTATISTICS

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ABSTRACT

Recently, land subsidence and liquefaction are becoming evident. But neither the countermeasure nor research technique have not been established. In order to determine the cause, more detailed comprehension of soil properties is essential; therefore, in this research Improved Swedish Sounding Testing machine, or NSWS *1, capable of measuring more detailed physical properties of in-ground was utilized and conducted a subsurface investigation at a narrow detailed house at which land subsurface have occurred. Based on the result of the investigation presented physical properties of the in-ground in the plane manner using Kriging method, one of geostatistics methods. Also, the comparison of converted N-value measured by the NSWS and converted N-value estimated by Kriging method is presented to examine the composite capability and benefit of Kriging method and NSWS for simplified on-site verification and re-measurement for reaffirmation (diagonal measurement) in the confined detached house ground.

*1. Due to the many refinements made to the machine, the new reference name is provided.

Keywords: Geostatistics, Kriging, Method for Swedish weight sounding test, disaster prevention

1. INTRODUCTION

The vast area of Urayasu city, Chiba prefecture was liquefied when 2011 Tohoku earthquake struck and followed by the permanent displacement causing heavy damage to the buildings. Although JIS standard for a research method or countermeasure construction method for liquefaction have been around for long time, they are still being developed. A technology that correspond to fast-paced changes in the natural disaster has not been established. Especially, the detached house grounds are having difficulties because they are private properties and very small in Japan. Also, due to the reasons of time, finance, vibration, a mechanical reason for installation area, and the conventional JIS method enable a limited number of data collection when conducting in-situ soil analysis. For that, in general an estimation is carried out using some methods based on a limited number of soil analysis for un-investigated area.

In this research, the NSWS was utilized at an embankment of a sunk detached house measuring converted N-value in details at each survey point. Furthermore, based on depth distribution of measured converted N-value, Kriging method is used to predict space distribution of the unknown domain with unclear N-values within the survey ground. Also, the comparison of converted N-value measured by the NSWS and converted N-value estimated by Kriging method is presented to examine the composite capability and benefit of Kriging method and NSWS for simplified on-site verification and re-measurement for reaffirmation (diagonal measurement) in the confined detached house ground.

2. INVESTIGATION TESTING EQUIPMENT AND ON-SITE SUMMARY

The research conducted a ground survey at land subsidence occurred site. On this survey, the NSWS, was utilized as the survey testing machine. The machine has refined the conventional Swedish

Fig.1 NSWS

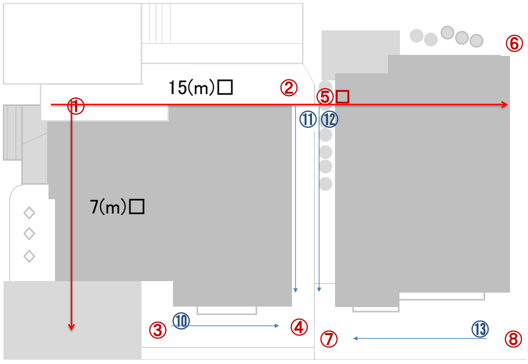

Fig.2. On-site summary

Sounding Testing machine; it evaluates soil strength by loading weight on a penetrating rod and collecting data by rotation.

The followings are the characteristics of the NSWS:

1. Maximum loading amount is 2500N possessing high penetration capability
2. It can penetrate soil layers with gravels mixed, and soft rock layers.
3. A measurement resolution is 10.8mm, very fine, enabling to collect detailed data.
4. Not only a vertical measurement but diagonal measurement are possible enabling to collect many data at the confined research area.

The next is about the venue. The venue is a detached house embankment in Nishinomiya city, Hyogo prefecture. It is a slope area with a stair-casing residential area; two two-story general detached houses are line up on the site. A part of the site caused land subsidence causing distortion on the part of the building and concrete-block wall that surround the house. These phenomenon mainly happened at the South part of the site. As depicted in Fig.2 survey locations are the vertical measurement points at the North of the site (1, 2, 5, and 6) and the vertical measurement points at the South of the site (3, 4, 7, and 8), the side of the retaining wall. Also, diagonal measurement of survey locations (10, 11, 12, and 13) are meant to comprehend the bounds of weak area and insufficiency of compaction in the vicinity of the retaining wall.

3. SPATIAL DISTRIBUTION PREDICTION BY ORDINARY KRIGING

In this study interpolated a cross section among survey locations using Ordinary Kriging method and estimated the distribution of converted N-value along the cross section. Ordinary Kriging method is one of Kriging methods under the assumption of fulfillment of stationary in random variables and calculates weighted mean value of the variables. In this study, random variables are converted N-values. Also, stationary means that expected values of random variables are fixed throughout the whole

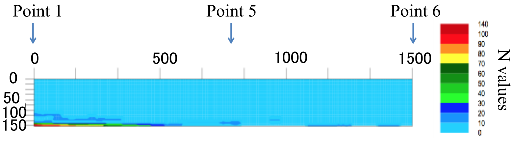

Fig.3. Result of Kriging on 1.0cm pitch

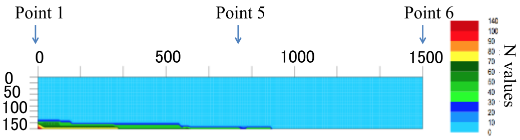

Fig.4. Result of Kriging on 25.0cm pitch

targeted area, and a covariance depends solely on distance among data and is independent of the locations of data.

A general formula of Ordinary Kriging method is as follows (1):

$$\hat{\boldsymbol{w}}(\boldsymbol{x}) = \sum_{i=1}^{n} \boldsymbol{b}_i\, \boldsymbol{w}(\boldsymbol{x}_i) \qquad (1)$$

W(x): Estimated value, W(x): Measured value, b1: Weight at each survey location

Also, formula (2) is necessary to fulfill the aforementioned stationary requirement:

$$\sum_{i=1}^{n} \boldsymbol{b}_i = \mathbf{1} \qquad (2)$$

The formula requires the sum of weights to be equal to one; under this condition, Kriging method can be applied.

In this study, Ordinary Kriging method was carried out based on converted N-value measured by the NSWS. The NSWS can collect data with 1.0cm pitch. So, with this measurement resolution, or by changing the number of data analyze the change of results of interpolation and also analyze the accuracy of the estimations by changing the number of data assuming the measured values as true values. Kriging method was carried out with 1.0cm pitch and 25cm pitch. And, besides comparing these two, the applicability of Kriging method to the detached house grounds was examined as well.

Also, in order to make estimations on different cross sections, Kriging method was utilized likewise at survey locations 3 and 7 with 1.0cm pitch. This is to judge the applicability of Kriging method at different cross sections. On the cross sections created between survey locations 3 and 7 exist survey location 4 that was measured vertically, and survey location 10 that was diagonally measured from survey point 3. Therefore, by estimating this cross section and comparing with vertically and diagonally measured data, the applicability of

Kriging method can be judged as well as judging whether it is possible for Kriging method to interpolate point data in a plane manner.

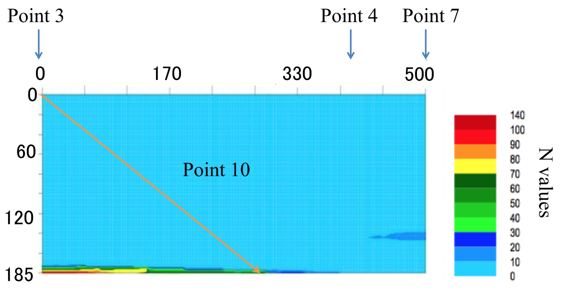

Fig.7.The result of Kriging on other section

Fig. 3 shows the results of Kriging method with 1.0cm pitch at survey points 1, 5, and 6. Fig. 4 is the results of Kriging method with 25cm pitch at survey points 1, 5, and 6. By comparing these two one can confirm that from about depth 130 cm to 150 cm Fig. 3 has a finer and more various distribution; with finer measurement resolution enables more detailed estimations. Next, Fig. 6 is a comparison of two estimations with measured converted N-value at survey point 2. One can tell that at the deep ground the estimated value with 1.0cm pitch deviates less from the measured value. From this confirmation, one can see the need to collect many data by measuring with narrow interval. Also, since both estimations have small deviations up till 140cm depth, it is safe to say the estimations have high-precision when treating measured values as true values.

Fig. 7 shows the result of Kriging method from survey point 3 to 7 with 1.0cm pitch. With Fig. 7 one can confirm the existence of weak ground down until 120 cm deep. From there, at the vicinity of survey point 7 a strong layer appears at the vicinity of 120 cm depth, and at the vicinity of 180 cm depth a wide-ranged strong layer appears. Next, Fig.9 is the comparison of the measured value to estimated value at survey point 4, and Fig.10 is the comparison of the comparison of the measured value to estimated value at survey point 10. Fig.9 has overall small deviations. Next, one can confirm that down until 180 cm depth Fig.10 has small deviations. But the deviation become bigger from there. Table 1 shows relative errors of at both survey points. According to Table 1 both points have the relative errors less than one. This means both have relatively small errors. Because of these results, it is fair to say

4. APPLICABLE EXAMINATION BY ORDINARY KRIGING

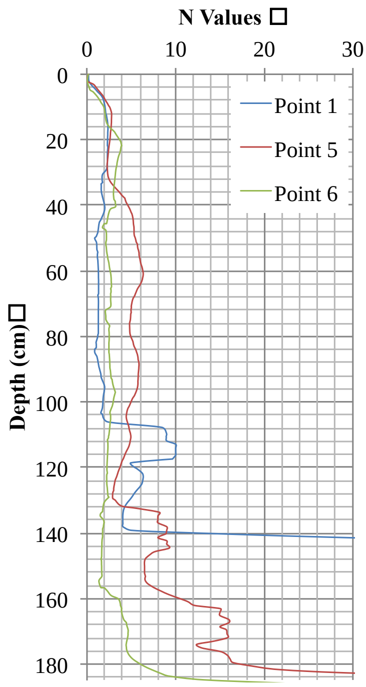

Fig.5. actual values on Point1,2 and 3

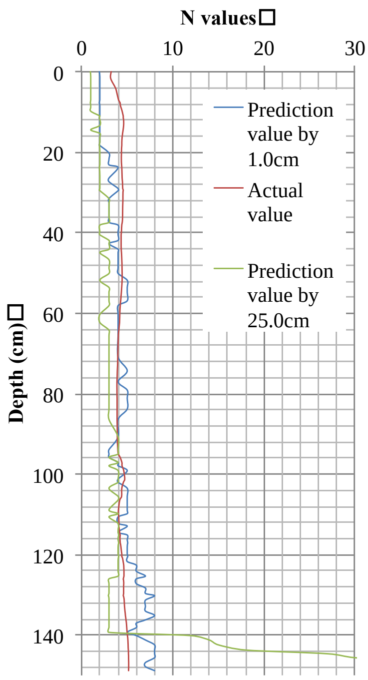

Fig.6 Compare to actual and prediction on point 2

that the estimations for vertical and diagonal measurements are highly precise.

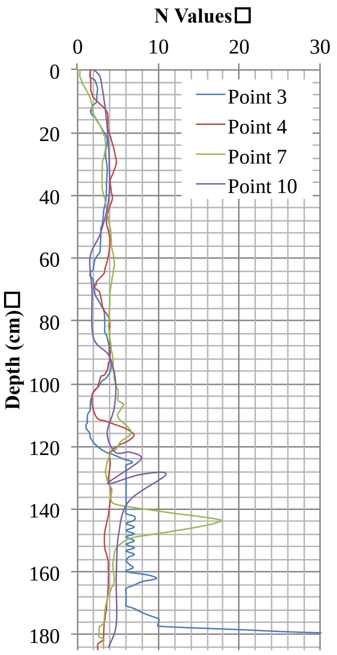

Fig.8. Measured Value at Survey Pts 3, 4, 7, 10

5. CONCLUSION

In this study, the followings were examined:
1. Applicability of Kriging method to the detached house grounds with a small area for installation of the machine,
2. Whether it is possible for Kriging method to interpolate point data in a plane manner.
3. The change in the estimation accuracy by changing the number of data

Kriging method was carried out by changing measurement data pitch; one could confirm that the increase in number of data leads to higher accuracy. Also, Kriging method was applied at two cross sections, and relative errors with estimated values were small; one could support the applicability of Kriging method to the vertical measurement. Lastly, the applicability of Kriging method was tested against the diagonal measurement; Kriging method was applied at the cross section of survey point 3 and 7. The result supports Kriging method for the diagonal measurement. Therefore, it is fair to say Kriging method is capable of interpolating in a plane manner.

This means if estimated value by Kriging method has small deviation to measured value of additional search for verification, the soil survey can be finished; this helps financially as well, but if the deviation was big, additional survey needs to be conducted to find the cause.

Table 1. Relative error with the real value

Items	Relative error
Point 4	0.284210892
Point 10	0.595928736

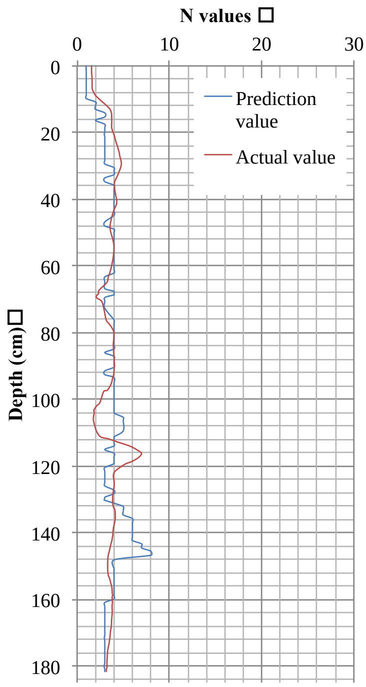

Fig.9. Compare to prediction and real on Point4

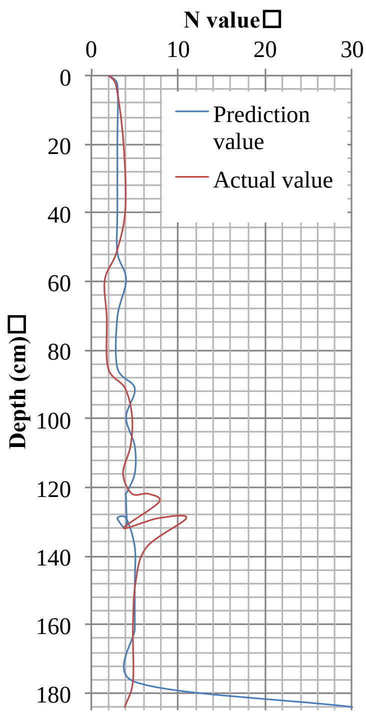

Fig.10. Compare to prediction and real on Point10

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