Stochastic consideration of consolidation settlement of Holocene clay layer in Osaka Bay

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- Background & Purpose
- Analysis
  - Artificial Neural Network
  - Monte Carlo Simulation
- Results
  - Accuracy of $e^{-\log p}$
  - Frequency distribution of consolidation settlements
- Conclusion

Background

- Many manmade islands have been built in Osaka Bay
- The settlement of man-made islands in Osaka Bay is almost dependent on the consolidation behavior of Holocene clay layer
Background

➤ It is necessary to estimate the consolidation settlement accurately to control the construction work
➤ The e-logp relationship must be required to estimate the consolidation settlement

The e-logp relationship must be estimated accurately

Purpose

The purpose of this study is to discuss the effects of errors of e-logp relationship on consolidation settlement

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Artificial Neural Network

Neurons in the human brain are reproduced mathematically.

INPUT

THINK

OUTPUT

Artificial Neural Network

Deciding Subject area and estimated item

Extracting data and dividing it

To train 70% To evaluate 30%

Constructing model

Evaluating estimated value

Comparing

Estimated value

INPUT

THINK

OUTPUT

Indexes for Judging accuracy of model

• Relative error: \( r_i \)
  \( r_i = \frac{e_{NNi} - e_{DBni}}{e_{DBni}} \times 100 \)

• Standard deviation of relative error: \( \sigma \)
  \[ \sigma = \sqrt{\frac{1}{n} \sum_{i=1}^{n} (r_i - \bar{r})^2} \]

\( e_{NNi} \): estimated values by ANN

\( e_{DBni} \): target values

\( n \): number of data to evaluate

Monte Carlo Simulation

10,000 times

Generating random numbers

Calculating relative error

Calculating void ratio including the errors

Calculating settlement

Distribution of settlements

\( \bar{r} \): relative error of estimated value

\( e_{DBni} \): relative error of target value

\( e_{NNi} \), \( e_{DBni} \): estimated values by ANN

\( e_{NNi} \), \( e_{DBni} \): relative errors
Monte Carlo Simulation

- 10,000 times
- Generating random numbers
- Calculating relative error
- Calculating void ratio including the errors
- Calculating settlement

\[
\Delta e' = e_0' - e_f'
\]

\[
S_f = \frac{\sum_{i=1}^{N} \Delta e'}{1 + e_0'} H^f
\]

Subject area

Holocene clays: Kansai International Airport

Locations of soil investigations

Subject area

Holocene clays: Kansai International Airport

Number of boring: 184
Number of data: 947
Input data:
- Longitude
- Latitude
- Depth
- Consolidation pressure
Output data: Void ratio

Thickness of clay layer: 22m

Location of estimation of consolidation settlement
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Accuracy of e-logp

◎ One-dimensionial consolidation curves

![Graph showing consolidation curves for different samples.](image)

The agreement between the target value and estimated value is excellent.

Accuracy of e-logp

◎ Indexes for Judging accuracy of model

<table>
<thead>
<tr>
<th>μ</th>
<th>σ</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0061</td>
<td>0.0971</td>
</tr>
</tbody>
</table>

data to train: 663
data to evaluate: 284

The relationship between void ratio and consolidation pressure could be estimated with high accuracy.

Probability density applied to Monte Carlo Simulation

◎ Relationship between frequency and relative errors

![Graph showing frequency and relative errors.](image)

The probability density applied to Monte Carlo Simulation is obtained from the relationship between frequency and relative errors.
**Frequency distribution of consolidation settlements**

- **Less than** 7.68m: 85%
  - 7.79m: 90%
  - 7.95m: 95%

\[
\frac{7.95}{7.26} = 1.10
\]

The probability in case where the consolidation settlements less than

Consolidation settlement applied practically might be estimated about 1.1 times of the average

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**Conclusions**

- The relationship between void ratio and consolidation pressure could be estimated through an artificial neural network with high accuracy.
- The consolidation settlement could be estimated stochastically by using the relationship between probability distribution and relative error through an artificial neural network.
- The consolidation settlement within 1.1 times of that the average will occur with 95% of probability in subject area.

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Thank you for your kind attention