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# A Soil-Water Coupled Finite Element Analysis of Open-cut Excavation for Soft Clay Deposit by an Elasto-viscoplasctic Model

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ABSTRACT:

A case study of open-cut excavation in soft clay deposit has been performed by a soil-water coupled finite element analysis with an elasto-viscoplastic model. As a part of the construction of the new subway line called Nakanoshima line in Osaka, large and deep excavation has been carried out by the open-cut excavation method with earth retaining wall through the thick alluvial Nakanoshima clay deposit Nakanoshima clay is soft and sensitive and the thickness is about 10 meters. Since the construction site is located at the center of Osaka city and is surrounded by many civil structures, it was necessary to minimize the deformation of ground behind the earth retaining walls. One of the earth retaining wall is very close to the big buildings and the other is also very close to the revetment of river. The excavation has been successfully performed. In the present study, a case history of the excavation in the construction of subway station mentioned above is numerically back analyzed. In the analysis, a finite element method based on a Biot's type of two phase mixture theory [1] is adopted and an elasto-viscoplastic model considering structural changes [2] is used. Comparison between numerical analysis results and the measured results shows that the simulations method can well reproduce the deformation of earth retaining wall by incorporating the proposed compensation method of measurement data. In addition, it is confirmed that the construction has been successfully executed without significant damage of earth retaining wall and the alluvial clay deposit. Furthermore, the effect of time-dependent behaviors of clay during the excavation such as creep and consolidation are discussed.

REFERENCES

[1] Y. Higo, F. Oka, T. Kodaka, S. Kimoto, Three dimensional strain localization of water-saturated clay and numerical simulation using an elasto-viscoplastic model, Philosophical Magazine, Structure and Properties of Condensed Matter, 86, 21-22, (2006), 3205-3240.

[2] S. Kimoto, F. Oka, An elasto-viscoplastic model for clay considering destructuralization and consolidation analysis of unstable behavior, Soils and Foundations, 45, 2, (2005), 29-42.

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# A soil-water coupled finite element analysis of open-cut excavation for soft clay deposit by an elasto-viscoplasctic model

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## Introduction

### "Nakanoshima Line"

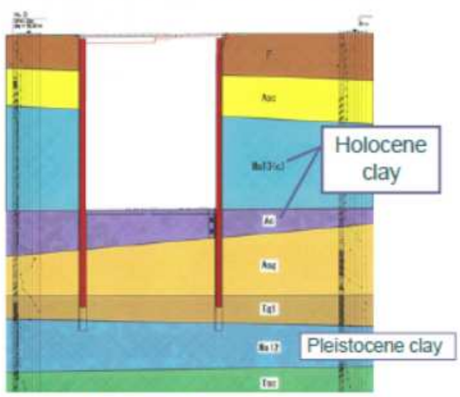
- New subway line in Osaka
- Large and deep excavation has been carried out by the open-cut excavation method for the construction of stations

- Soil excavated is thick holocene Nakanoshima clay deposit: Soft and sensitive
- Construction site is located at the center of Osaka City: Surrounded by many civil structures

⇓

**It was necessary to minimize the deformation of the ground behind the earth retaining walls**

Nakanoshima line(4 new stations. 2.9km)




Soil condition of Nakanoshima

## Scope & Objectives

- **Soil-water coupled FEM using an elasto-viscoplastic model**

  Biot's type of two-phase mixture theory (Oka et al. 1994, Higo et al. 2006)

  Elasto-viscoplastic model considering structural changes (Kimoto and Oka 2005)

↓

**A case history:**
**excavation for the construction of one subway station**
**is numerically back analyzed**

Comparison of the results of the numerical analysis and the measurements

→

- **The behavior of the retaining walls**
- **The performance of the excavation work**

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## Elasto-viscoplastic model considering structural changes

- Overstress type of viscoplastic flow rule

$$D_{ij}^{vp} = C_{ijkl} \exp\left\{ m' \left( \bar{\eta}^* + \tilde{M}^* \ln \frac{\sigma'_m}{\sigma'_{mb}} \right) \right\} \frac{\partial f_p}{\partial \sigma'_{kl}}$$

$$C_{ijkl} = a\delta_{ij}\delta_{kl} + b\left(\delta_{ik}\delta_{jl} + \delta_{il}\delta_{jk}\right) \quad C_{01} = 2b \quad C_{02} = 3a + 2b$$

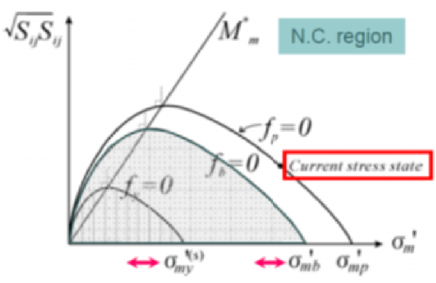
$D_{ij}^{vp}$: viscoplastic stretching tensor
$m'$ $C_{01}$ $C_{02}$: viscoplastic parameters
$\bar{\eta}^*$ : relative stress ratio $\tilde{M}^*$: dilatancy coefficient
$\sigma'_{ij}$ Terzaghi's effective sress $\sigma'_m$: mean effective stress
$f_p$: viscoplastic potential $\delta_{ij}$: Kronecker's delta

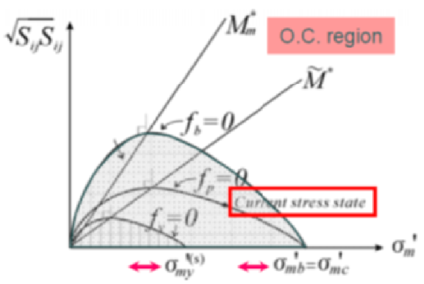
- Hardening-softening rule due to structural changes

$$\sigma'_{mb} = \left\{ \sigma'_{maf} + \left( \sigma'_{mai} - \sigma'_{maf} \right) \exp(-\beta z) \right\} \exp\left( \frac{1+e}{\lambda - \kappa} \varepsilon_{kk}^{vp} \right)$$

$$z = \int_0^t \sqrt{D_{ij}^{vp} D_{ij}^{vp}}\, dt$$

$e$: void ratio $\lambda$ Compression index $\kappa$: swelling index
$\sigma'_{maf}$: structural parameter (amount of strain softening)
$\beta$: structural parameter (rate of softening)
$\sigma'_{mai}$: initial value of $\sigma'_{ma}$ $\varepsilon_{kk}^{vp}$: viscoplastic volumetric strain




↔ : hardening and softening due to structural changes

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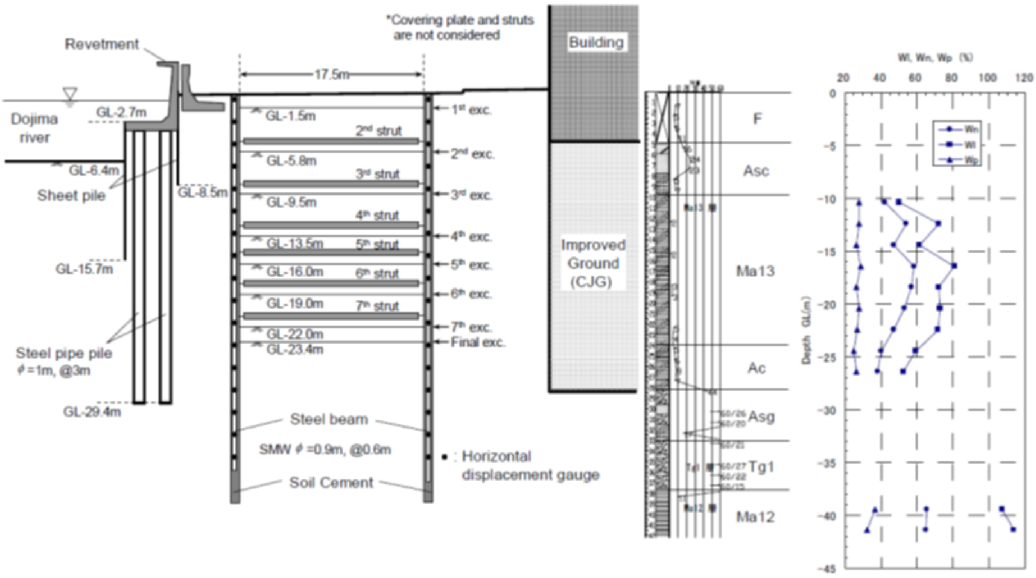
## Cross Section and Soil Conditions




- Excavation Pit: Width 17.5 m, Depth 23.4 m
- Earth retaining wall: Soil Mixing Wall, Height 38 m
- Soft Holocene clay layer: Thickness of 20 m,.
- Left-hand side of the excavation pit: Dojima River, 5.6 m away from the earth retaining wall
- Right-hand side of the excavation pit: Tall building stands 10 m behind the earth retaining wall
- Clay deposit under the building: Improved by the CJG method

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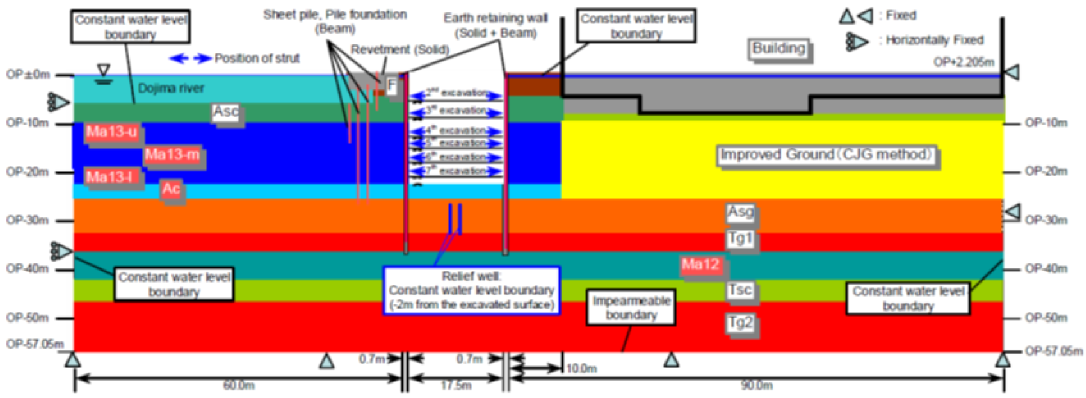
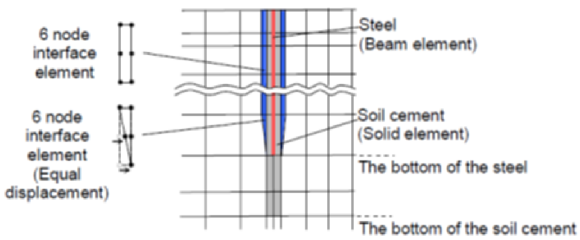
## Finite Element Mesh and Boundary Conditions




**Cohesive soils:** elasto-viscoplastic solid elements, **Other soils:** elastic solid elements




**Earth retaining wall:**

Beam elements and elastic solid elements to model the steel and the soil cement

**Interface element:**

Thin layer element (0.05m)

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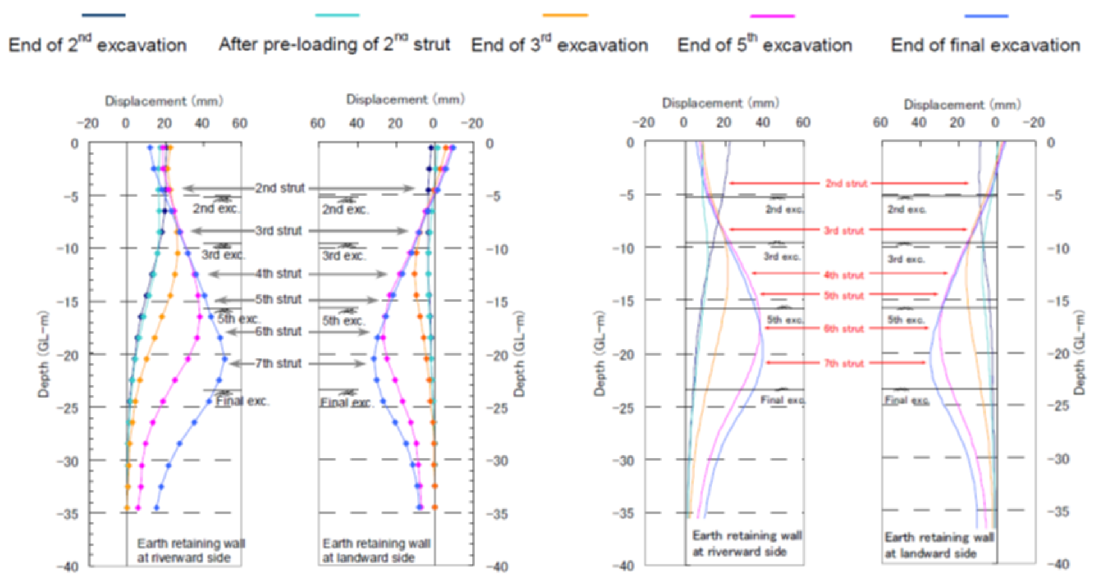
## Horizontal Deflection of Earth Retaining Wall (corrected)

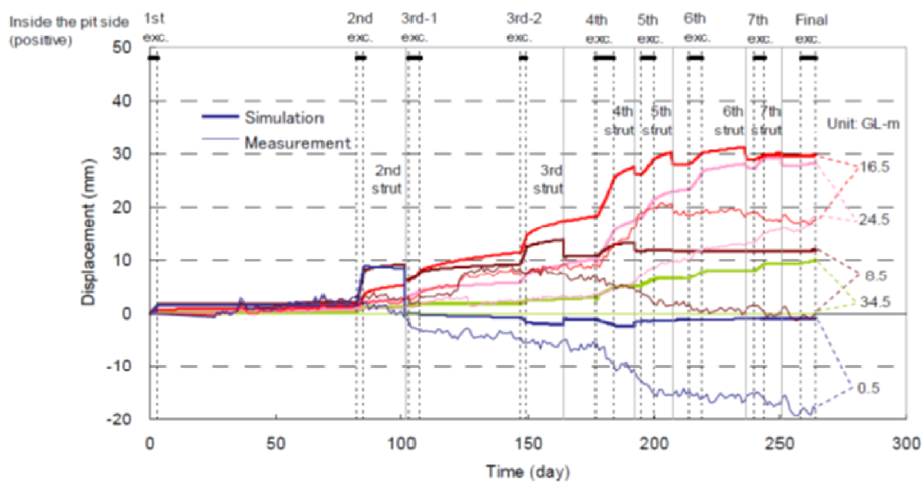



Measurement (corrected) Simulation

Deflection of the numerical results is larger than that of the measurements
Deformation modes of the retaining walls are similar



## Time history of the horizontal deflection (riverward side)




Thick lines: simulation, Thin lines: measurement

The retaining wall deforms even between the excavations due to pore water migration and creep.