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Mechanical Behavior of Temporary Braced Walls

Mouvement Mècanique des Murs de Soutènement

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SYNOPSIS. This paper presents a method of designing a temporary braced wall under the condition that the lateral pressure on the wall is known. For estimating rationally the wall stresses, wall displacements, strut loads and soil reactions, the antecedent displacement of the wall in each stage of strutting and the influence of the width of excavation are considered. Large scale field measurements on the behavior of braced walls and adjacent grounds were carried out in two deep subway excavations in Tokyo, where the subsoil is consisted of very soft alluvial soil. From the behavior of walls observed during the progress and completion of works, evidence is provided to support the present design method.

INTRODUCTION

Along with the recent development of the temporary wall, many braced excavations in soft ground have been performed, and several design methods for temporary walls were proposed based on the field measurements and investigations. However, those design calculations could not always predict the actual behavior of the wall.

In this paper the authors propose a design method for braced walls, considering the antecedent displacement of the wall in each stage of strutting and the influence of the width of excavation.

The applicability of the method was examined and confirmed, through the detailed investigations and data obtained in two deep subway excavations in soft grounds.

CALCULATION METHOD

The braced wall is regarded to be a continuous beam with a finite length, and the stresses and displacements of the wall are calculated by use of the stiffness method. The followings are assumed:

1. The external forces acting on the continuous beam are the lateral pressure on the back surface of the wall, and as shown in Fig. 1, its distribution is assumed to be a triangle in shape, above the level of excavation, and to be a trapezoid whose two legs intersect at a depth of $H + H'$ (H = depth of excavation, $H' = B$ = width of excavation), below the level of excavation.

The latter is determined by the consideration of the influence on the vertical plane of the wall, due to unloading the overburden pressure ranged over the excavated surface. This is the first approximation of the Boussinesq's Solution for such a uniformly distributed load on the excavated surface. By this assumption, effect of the width of excavation is introduced into the analysis.

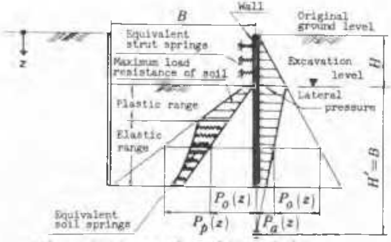

Fig. 1 Braced wall model

2. The supports of the continuous beam are represented by springs, whose elastic constants are equivalent to those of the struts or the soil in front of the wall.

a) Each strut is assumed to be a spring, whose load-deformation relationship is bilinear as shown in Fig. 2, that was determined from the actual field data.

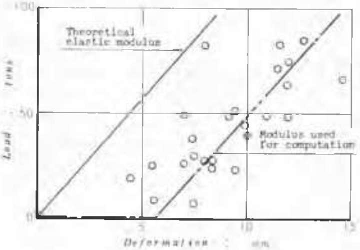

Fig. 2 Load-deformation relationship of struts

b) The soil in front of the wall is assumed to be many springs. The spring constants are determined by the coefficient of soil reaction in the lateral direction, that is a function of the soil deformation modulus as shown in Fig. 3.
Each soil spring is assumed to be an elasto-plastic spring, whose maximum allowable reaction at a depth of z is equal to the value of $P_p(z) - P_o(z)$. Herein, $P_p(z)$ is the *passive* lateral pressure at the depth, and $P_o(z)$ is the value obtained by subtracting the trapezoid shaped *effective* lateral pressure from the *active* lateral pressure $P_a(z)$.

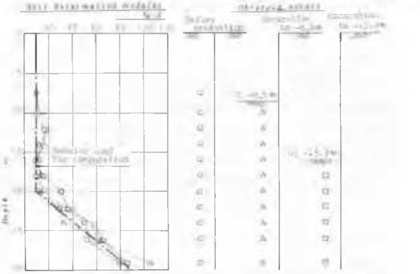

Fig. 3 Soil deformation modulus based on Pressuremeter Tests

Based on the assumptions outlined above, the stresses and displacements of the wall at each stage of excavation can be obtained by solving the following matrix equation,

$$a_i^{(n)} + b_i^{(n)} = \sum_k s_{ik}^{(n)} d_k^{(n)},$$

where n is the number of excavation stage, $a_i^{(n)}$ is the nodal force vector equivalent to the lateral pressure, $b_i^{(n)}$ is the auxiliary nodal force vector, considering the antecedent displacement of the wall in each strutting, $s_{ik}^{(n)}$ is the stiffness matrix, $d_k^{(n)}$ is the displacement vector.
The second term of the left hand side of the equation is the vector of the auxiliary nodal forces, on the consideration that each strut is installed on the previously deflected wall. The components of the vector are $P_1, P_2, \cdots, P_n$, shown in Fig. 4. Each is the product of k_i, the spring constant of the strut, and δ_i, the displacement at the strut level, that has occurred previous to the strutting.

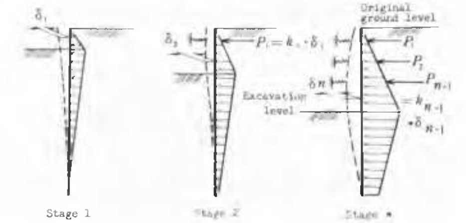

Fig. 4 Auxiliary nodal forces at various stages of excavation

The summary flow diagram of the computational process is shown in Fig. 5.

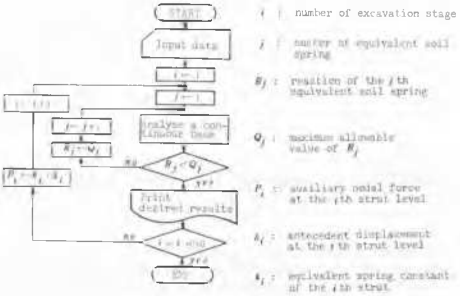

Fig. 5 Summary flow diagram of the computational process

FIELD MEASUREMENTS

Large scale field measurements were carried out in two deep excavations for construction of stations of the Tokyo Municipal Subway, Line No. 10.
Typical cross sections of the excavations and instrumentations are shown in Fig. 6, together with the significant soil properties. Steel concrete diaphragm walls with good impermeability were used in the site A, and steel pipe pile walls in the site B.
Field measurements were carried out on the following items; (1) the earth and water pressure on both surfaces of the wall, (2) stresses and deflection of the wall, (3) axial loads of the struts, (4) horizontal and vertical displacements of the adjacent ground, (5) heave of the excavated surface.
Data obtained from the measurements were served for safety control of the constructions, over a period of two years, during excavation and during construction of the subway structures.
Observed performances are the followings:
1. Distributions of the lateral pressure on the back surface of the wall at various stages of excavation are given in Fig. 7. Shape of the distribution diagram may be considered a triangle, above the level of excavation.
2. As shown in Fig. 8, the value of K, the coefficient of mean lateral pressure, decreased from 0.88 to 0.71 in the site A, and from 0.67 to 0.56 in the site B, with the progress of excavation.
3. Throughout the period of excavation, the *passive* lateral pressure on the wall had remained almost unchanged, except near the excavated surface. The distribution diagrams are also given in Fig. 7.
4. The resultant of *active* lateral pressure envelope and the total of *passive* lateral forces including the strut loads, made an exact agreement in the observation, indicating the accuracy of the measurement.

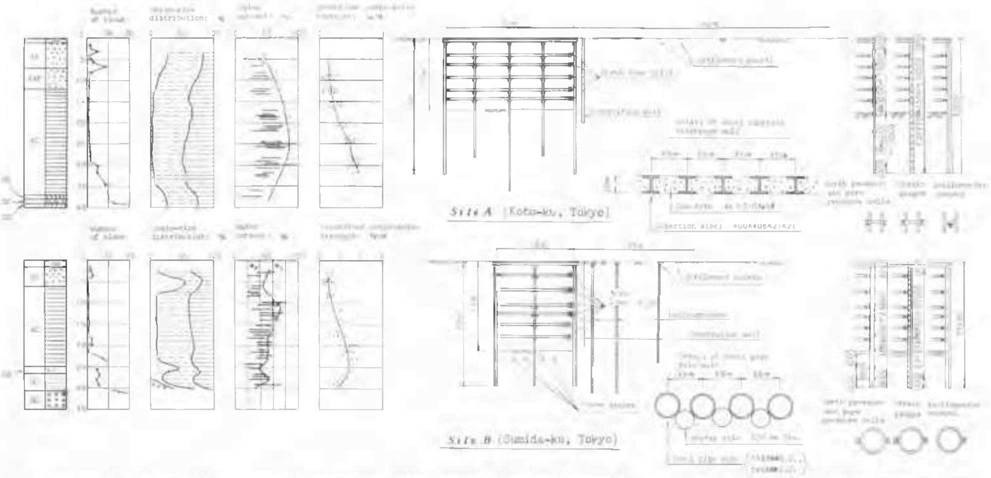

Fig. 6 Significant soil properties, cross sections of sites and instrumentations

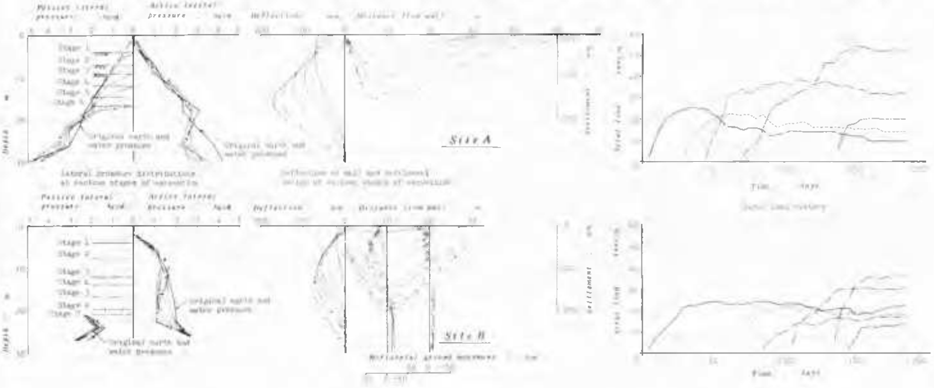

Fig. 7 Lateral pressure distributions, settlement behind and strut load history

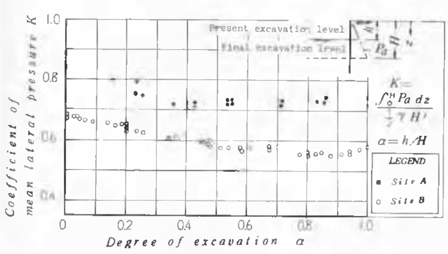

Fig. 8 Coefficient of mean lateral pressure *versus* degree of excavation

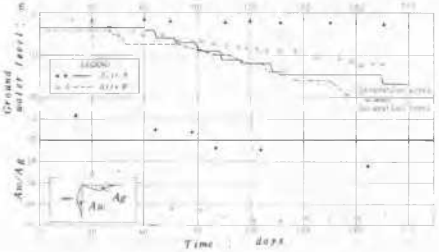

Fig. 9 Ratio of inward lateral displacement volume to settlement volume as a function of time and ground water level

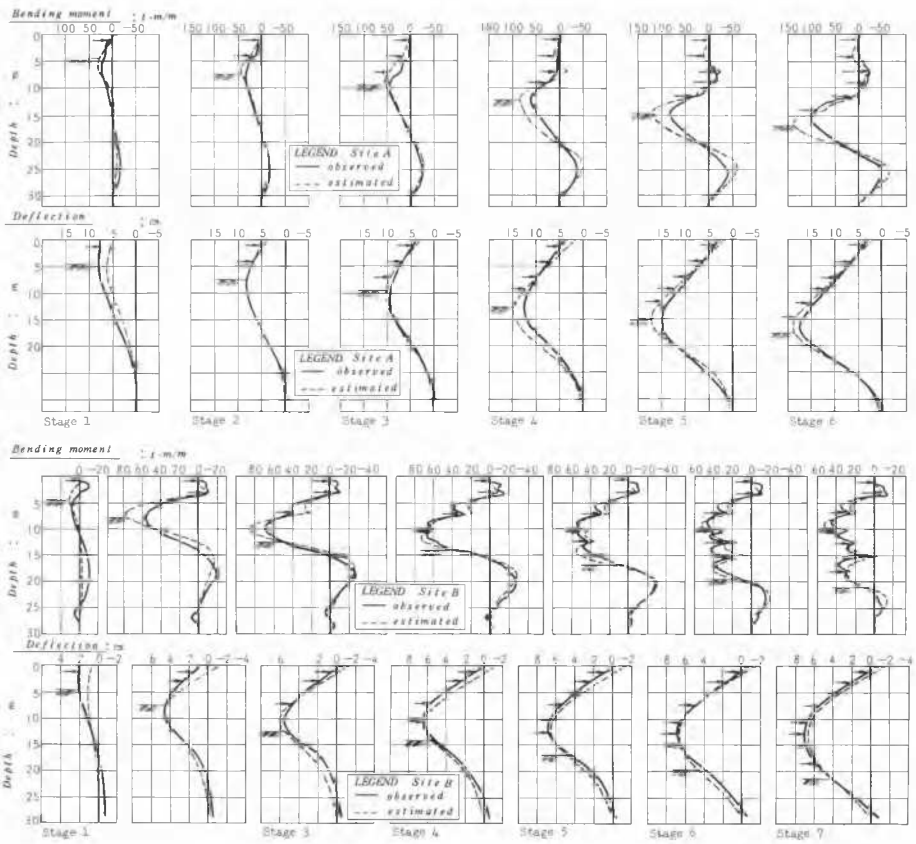

Fig. 10 Comparison between observed and estimated bending moments and deflections at various stages of excavation

5. Fig. 9 illustrates the relationship between the volume of inward movement of the wall and the volume of settlement, as a function of time. In the site A, where the walls with good impermeability were used, the ratios were nearly equal to one.
6. The bending moment and deflection of the wall at various stages of excavation are shown in Fig. 10. The figure shows a remarkable agreement between observed and estimated values.

CONCLUSION

A design method for the braced wall is presented. This method is simple to perform and accurate enough to estimate the actual behavior of the wall in a deep excavation in soft ground, and may be considered applicable for the designs of future excavations.

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REFERENCE

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