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Behavior of walls and ground surface settlement during braced excavation

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SYNOPSIS: The present paper is comparison between the analysis value and the measurment value for the deformation behaviour of the braced walls and the ground adjacent to caused by excavation in soft ground. It became clear that measurment values are influenced considerably by the wall stiffness, cutting depth, location and number of the struts. Especialy, it is considered that the effect of execution period in the excavation. Furthermor, it became clear that the analysis value not agree well with the measurment value.

INTRODUCTION

It is quite important for planning, design and construction of the braced walls which possibly affected to the structures, road and under-ground structures nearby job site to clarify the relation between displacement of the braced wall in excavation and deformation behavior of the surrounding ground. However, there are so many factors affected to the deformation of the braced walls and surrounding ground in excavation. Therefore, many studies have been done prediction and filed observation for the deformation of the braced walls and surrounding ground in excavation by Peck (1969), Kijima and Abe (1979) and Sugimoto (1986).

From this point of view, in this paper, in order to clarify deformation of the braced walls and settlement behavior of the surrounding ground in case of construction of drainage pipe line adjacent to the existing structures in soft ground area, relation between rigidity of braced walls, location and number of steps of strut setting, difference of depth in each excavation and construction period is studied. In this study, basic data needed for the braced walls are obtain considering the conditions of grounds, surrounding circumstances and construction methods.

OUTLINE OF BRACED WALLS AND GROUND CONDITION OF SITE

The braced walls explained in this paper was made in order to construction of drainage pipe line of the reinforced concrete with 4.7 meters in diameter in soft alluvial ground after open cut excavation with 7.0 meters wide, 6.5 meters depth from the ground surface. The results of the boring core log chart and soil test carried out at the job site are shown in Fig. 1. The braced walls ars applied in alluvial sand layer, of which thickness is 15 meters from ground surface. The results of standard penetration test carried out in the upper most alluvial clay layer and sand layer show 2 -3 in N-value, and natural water content is more than 60 %, which means soft ground. Ground water level is located at 3 meters from the ground surface at job site.

In addition to the soft ground, residential houses are adjoining to the construction site. Accordingly, possibility of settlement and movement of the surrounding ground surface and consequent trouble caused by excavation are anticipated. Furthermore, during construction stage, clearance of 5.5 meters in minimum between the lowest strut and the excavation bottom is necessary for placing concrete of reinforced concrete pipe with 4.7 meters in diameter. Therefore, minimizing the displacement of excavate soil face by increasing number of struts or close setting of strut is impossible.

Allowable settlement of the ground surface is required less than 1.5 cm caused by deformation of the braced walls at job site adjacent to the residential houses. Therefore, for the design condition to satisfy the designed deflection and the allowable stress of the braced walls, four types, from A to D as shown in Fig. 2, of the braced walls construction method are adopted. Here, the PW - pile wall (ϕ-500 mm, B-Type) is adapted for the braced walls at job site adjacent to the residential houses and the steel sheet pile (Ⅲ and Ⅳ Type) is selected for the braced walls at job site located in non-residential area.

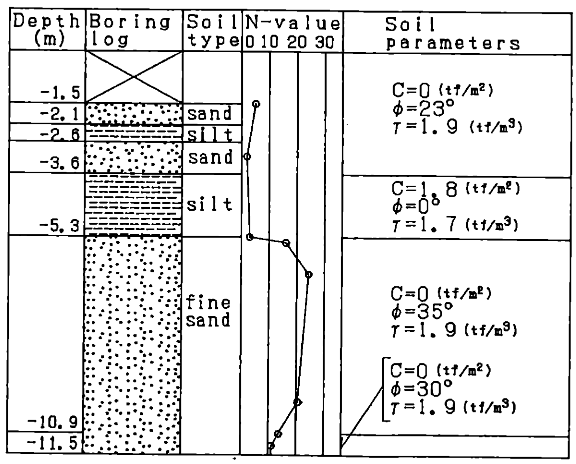

Fig.1. Boring log of the site and soil parameters

MEASUREMENT METHOD OF BEHAVIOR OF BRACED WALL AND BACK SIDE GROUND

In orde to study the displacement behavior of the braced walls and ground behind the braced walls are measured the axial force of the struts of inclination of the braced walls and settlement of ground surface behind the braced walls.

For measuring the displacement of the braced walls, measurement pipe fixed to the braced walls is used. By insert type inclinometer installed in pipe, the angle of inclination at every 0.5m interval from top of the braced walls are measured and displacement at every measured points are computed. Axial force is measured by strut axial meter using soil pressur meter. On the other hand, observation piles are driven at constant interval on the cross section line of the observation pile is measured by using level the braced walls.

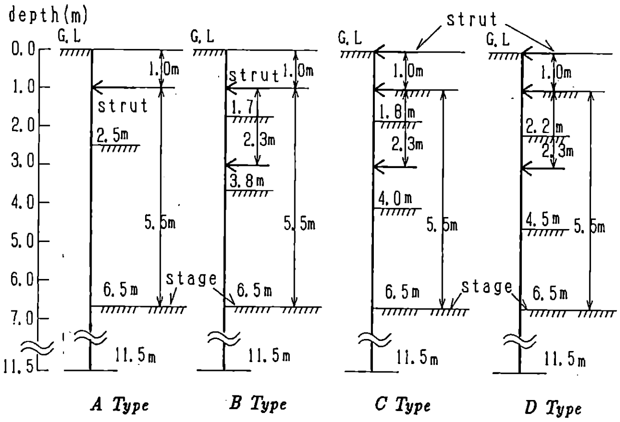

Fig.2. Types of struts and cutting stages in excavation

MEASUREMENT RESULT

1. Deformation behavior in the excavation

Fig. 3 is showing the distribution of the lateral displacement of the braced walls and distribution of settlement of the ground surface behind the braced walls at the stages of the excavation of each excavation types. In this figure, first stage of the excavation is measured at the immediately before first setting of the strut, in other word, case of self - standing state. Displacement from secondary excavation to the each final stage of the excavation are measured at the immediately after the final excavation. The braced walls of A and D type correspond to the steel sheet pile wall and the PW - pile wall, respectively. The braced walls of B and C correspond to the PW - pile wall.

It can be understood from these figures that displacement of the braced walls using struts is changed by rigidity of the braced walls, depth of the excavation in each excavation steps and setting condition of the struts. Maximum displacement of the PW - pile walls is about 2.0 cm which is quite small compared with the steel sheet pile.

It is remarkable that the shape of the displacement behavior of the PW - pile wall is similar to that of the self-standing state. In other word, shape of the behavior of the displacement is gradually increased at the point below the excavation bottom, and showing tendency of swelling of the braced walls by

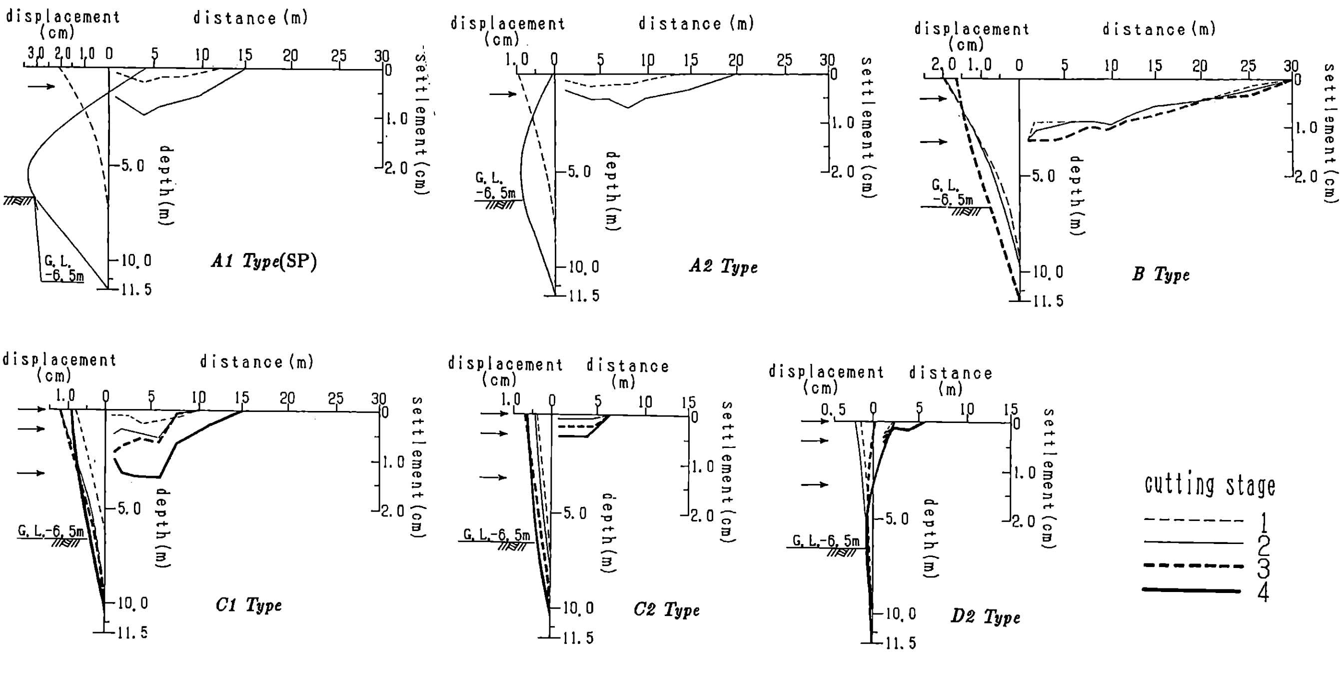

Fig.3. Deformation of walls and ground for each cutting stages

increasing depth of the excavation in every type caused by the fix mode of struts at the top of the braced walls. Specially, A type shows remarkable example and is similar shape of displacement to the steel sheet pile walls.

Fig. 3 shows also that settlement behavior of the ground surface behind the braced walls has a close relation with deformation of the braced walls. The shape of the settlement behavior curve is similar to the shape that the deformation curve of the braced walls when it turns 90 degree. The area affected by the settlement of the ground behind the braced walls spreads far from the braced walls depending upon the depth of the excavation. In case that the displacement of the braced walls is big, the settlement affected area reaches up to 4 - 5 times of the excavation depth. Furthermore, location of the maximum settlement of the ground behind the braced walls shows the behavior as if the location of the maximum settlement moves to the swelling part of the braced walls, namely maximum settlement point apart from the braced walls and finally appears at the point of about 1/2 to 1.0 of the excavation depth. The maximum amount becomes approximately 0.2 - 0.3 % of the excavation depth.

2. Comparison between analized and measured value in the excavation

The analyzed value and measured value of the displacement of the braced walls and measured value of the ground surface settlement behind the braced walls in each type are illustrated in Fig. 4. Shown together in the chart of the ground surface settlement behind the braced walls of Fig. 4 is the distribution curve of the displacement of the braced walls at the stage of the final excavation which is rotated 90 degree (hatched area) when it is assumed that the distribution chart of the ground settlement is equal to that of the braced wall displacement. Also showing together is the 45 and 30 degree line from bottom of the excavation as one of the mode to predict the affected area.

The analyzed values of the displacement of the braced walls are calculated by elasto-plastic analysis method and cumulative simple beam method. Rankine-Lesal formul are used for the active and passive earth pressure of the designed earth pressure in the elasto-plastic analysis. The earth pressure formular of sandy soil discribed in the design criteria, earth work issued by Japan Road

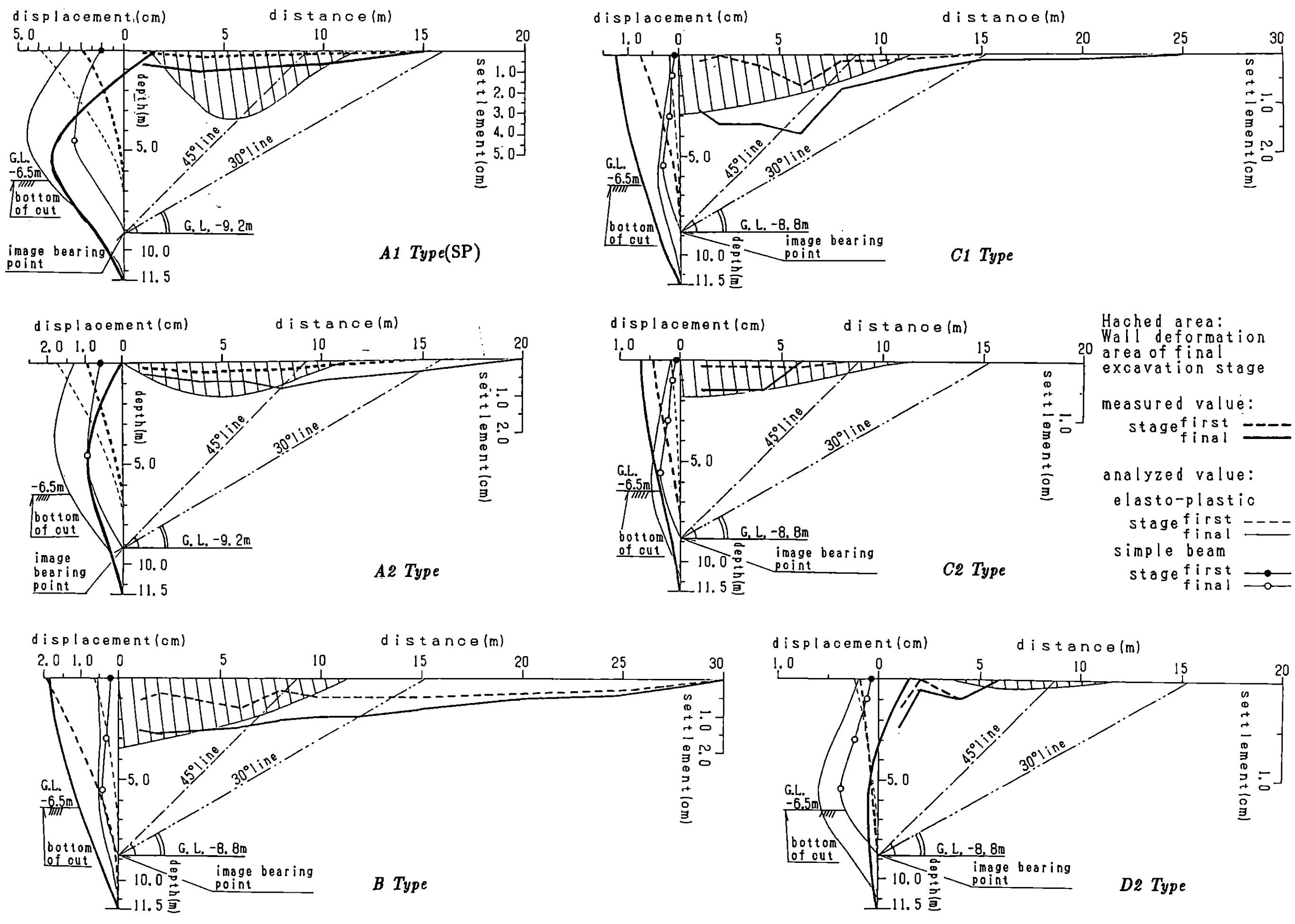

Fig. 4. Comparison between analized and measured displacement in excavation stage

Association (1987) is used for the design earth pressure in the cumulative simple beam method.
It is understood from the Fig. 4 taht the shape of measured value is quite similar to that of the analyzed in the displacement of the braced walls. However, the measured value itself is different from the analyzed value. Paying attention to the maximum displacement in measured value and analyzed value,

(1) In A type, the analyzed value is about 1.5 times bigger than the measured value in case of the steel sheet pile and the PW - pile wall.

(2) In B type, the measured value is 2 - 3 times bigger than the analyzed value in case of the steel sheet pile and the Pw - pile wall.

(3) In C and D type, measured value of the maximum displacement in the steel sheet pile and the PW - pile wall is 2 - 5 times bigger than the analyzed value.

On the other hand, settlement distribution of ground surface behind the braced wall and the measured value of settlement in affected area have high correration with the displacement of the braced wall. However, the displacement values of the settlement are similar to that of the braced wall in some case, but some of them are quite different. This relation can be clarified when the settlement distribution is put on the displacement distribution curve which rotates 90 degree from its original position. In other words, the amount of the ground settlement behind the braced wall and affected area of the settlement is big when the displacement value of the braced wall is big.

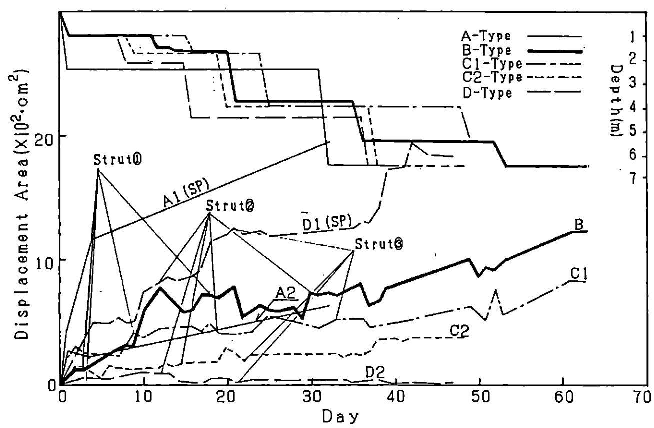

Fig.5. Relationships of deformation area and execution work days

Daily behaviours of the deformation area of the braced wall during period from beginning to completion of the excavation are shown in Fig. 5. From this figure, deformation area of the braced wall in case of the steel sheet pile is bigger than that in case of the PW - pile wall in same type of excavation. Especially the difference is remakablly big in case of A and D type equivalent to the steel sheet pile and the PW - pile wall. Deformation a area of C2 is smaller than that of C1. The diffrence is caused by short execution period from beginning to completion of the excavation. In relation between A and D type equivalent to the PW - pile wall and the steel sheet pile, deformation area of the PW - pile wall is quite smaller than that of C type. This seems to be caused by eccentric earth load.

CONCLUSION

In this paper, the deformation behavior of the braced wall and subsequent settlement behavior of the ground behind the braced wall considering the constraint of the execution method and environmental condition are studied. Furthermore, the results of the displacement analysis of the braced wall is compared with the measured value of the displacement of the braced wall and ground settlement of behind the braced wall. The main results obteind are summarized as follows;

(1) It is clarified quantitatively that displacement of the braced wall and settlement behavior of the ground surface behind the braced wall is very much affected by rigidity of the braced wall, setting position and number of the struts, excavation depth in each excavation stage and construction period from beginning to completion of the excavation in each excavation stage.

(2) It is also clarified that there is some problem in carrying out analysis to meet the analyzed displacement value to the measured displacement value by simple comparison of both values.

(3) For item to be studied in future, it is pointed out in this report that applicability of the elasto-plastic analysis method to the displacement analysis of the braced wall used in case of relatively shallow excavation with less than 10 meters deep should be examined.

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