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Behavior of anchored walls during wide and deep excavations

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SYNOPSIS: A large scale earth retaining work was carried out in construction of a main pump cabin in a wastewater treatment plant using an anchor-type earth retaining system.
The monitored results of the behavior of earth retaining during the construction showed a steep rise in displacement in the earth retaining wall with a fixed anchor load value.
The analytical results of the measured data indicated that this rise is presumably due to the deformation of the anchored ground.
From the above, it can be said that anchor application methods commonly used in designing (in which an anchor is usually applied outside the active collapse angle) are not always appropriate for deep excavation.

1. OUTLINE OF THE CONSTRUCTION

1.1 Outline of earth retaining work

This paper will present a description of the earth retaining work currently carried out in Tokyo in construction of the main pump cabin in the Shingashi East wastewater treatment plant.

The scale of excavation required for constructing the main pump cabin is quite large with an area of 80m x 150m and a depth of 33m, as presented in Figure 1.

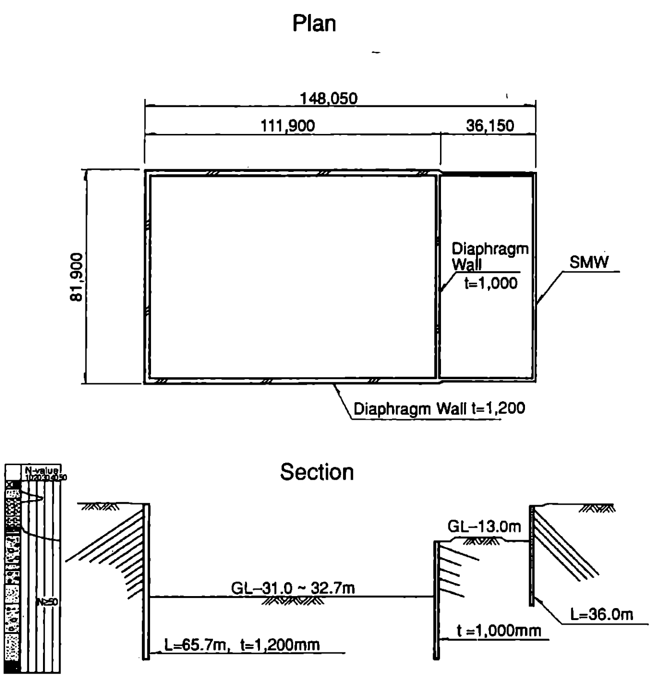

Fig. 1 Configuration of Earth Retaining Work

The RC diaphragm wall with a high stiffness (t = 1.2m) was used for earth retaining, and an anchor work of 10 to 11 steps was carried out according to the excavation depth.

1.2 Outline of geological conditions

The construction is carried out in the lower land of Tokyo. Typical soil profile is presented in Figure 2. As can be seen in the figure, the soil roughly consists of an upper weak alluvial cohesive stratum of 20m, and a lower solid diluvial gravel stratum. The lower diluvial gravel stratum has a high permeability and an artesian head of approximately GL - 9.0m. Consolidated silt is distributed in the strata deeper than GL - 65m, in which the diaphragm wall is reached as a cut-off wall.

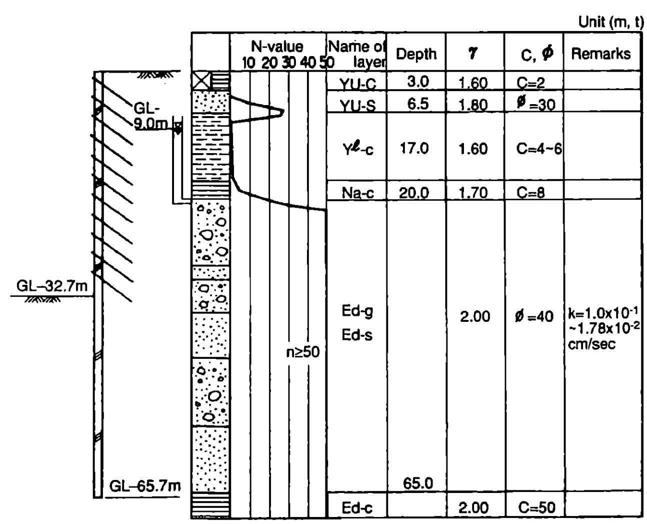

Fig. 2 Typical Soil Profile

1.3 Outline of design

The earth retaining was designed using an elasto-plastic earth retaining analytical method, in which the Rankine and Resal's earth pressure theory was employed for both active and passive pressures.

An anchor was designed to be applied to the gravel bed below the level of GL-20m with an internal friction angle of $\phi = 40°$. Since the active collapse angle is at 65° from the bottom surface, the anchor close to the bottom was eventually applied quite near to the retaining wall.

1.4 Monitoring plan

Since this construction required an unprecedented large-scale excavation using an anchor-type earth retaining method, safe execution was the ultimate goal. For that purpose, the following measurement method was selected.

Items to be measured and the objective of measurements, as well as the location of measurement devices are presented in Table 1 and Figure 3 respectively.

Table 1 List of Monitoring Parameters

Monitoring Parameter	Type of Gauges	Monitoring Target	Number of Points
Earth Retaining Wall Displacement	Borehole Inclinometer	Wall displacement monitoring	6
Stress of Earth Retaining Wall	Transducer	· Stress monitoring for retaining wall reinforcement · Major data for daily control	3
Anchor Load	Anchor Loadcell	· Anchor load monitoring · Major data for daily control	4

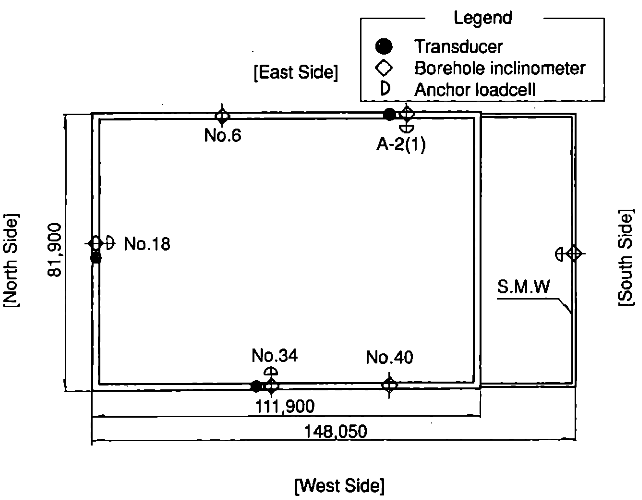

Fig. 3 Monitoring Points

2. THE MEASUREMENT RESULTS OF THE EARTH RETAINING WORK

The displacement in the wall stayed within a low level of approximately 20 mm until completion of the 9th phase excavation (GL - 25.0 m) in spite of the existence of the upper weak cohesive soil. However, with the subsequent 10th and 11th excavations, a steep rise in displacement was observed, reaching the maximum value of 115 mm after completion of 11th excavation (GL - 31.0 m).

2.1 The characteristics of the monitored results and measured values

The distribution of the displacement in a depth direction in the earth retaining wall on the north side (No.18 measurement point) where the maximum displacement was observed, as well as the variation in the displacement at the depth where the maximum displacement occurred are presented in Figure 4 and 5 respectively. The variation in the anchor load is also presented in Figure 6.

The values shown in the above figures indicate the characteristic features of the displacement observed in the earth retaining work as follows:

(1) Despite the large increase in the displacement in the retaining wall, the measured values of anchor load show almost no fluctuations.

(2) The increase in the creep-like displacement (1 mm/day) is observed even in the solid gravel ground after completion of excavation.

2.2 Discussions

Considered from the fact that anchor load showed only a slight fluctuation, it is presumably least likely that the displacement in earth retaining was due to a shortage of tension load or coming-off of the anchor. Instead, it is presumed to be due to the deformation of the anchored ground.

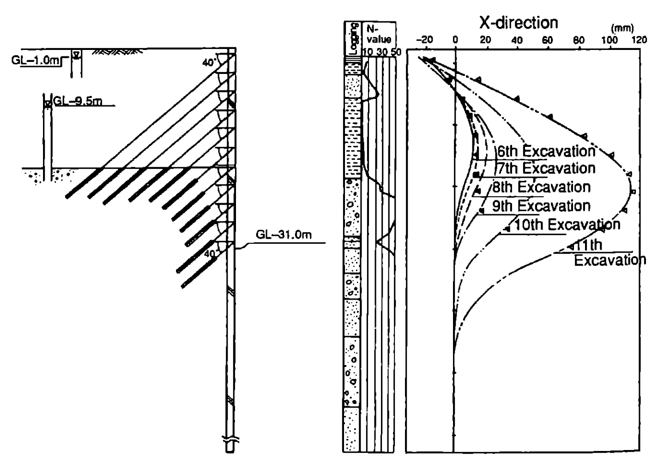

Fig. 4 Displacement Distribution in Depth of Earth Retaining Wall (North Side: No. 18 Point)

A shortage of tension load may cause increase in anchor load with increase in displacement. Whereas coming-off of an anchor causes a sudden drop in anchor load. The both cases, however, are not applicable to this specific situation.

As shown in Figure 7, the anchor location was determined with an assumption that outside the active collapse angle is fixed; however, the results indicate that the the anchor location was presumably within the range experiencing the influence caused by displacement, which was far larger than expected.

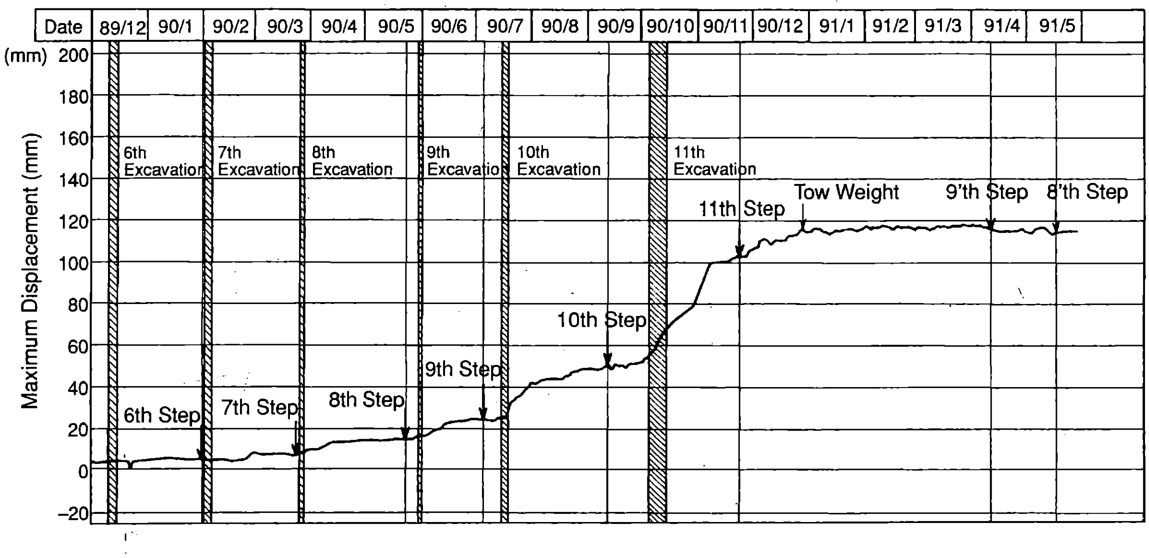

Fig. 5 Maximum Displacement Changes (No. 18 Point, GL-20m)

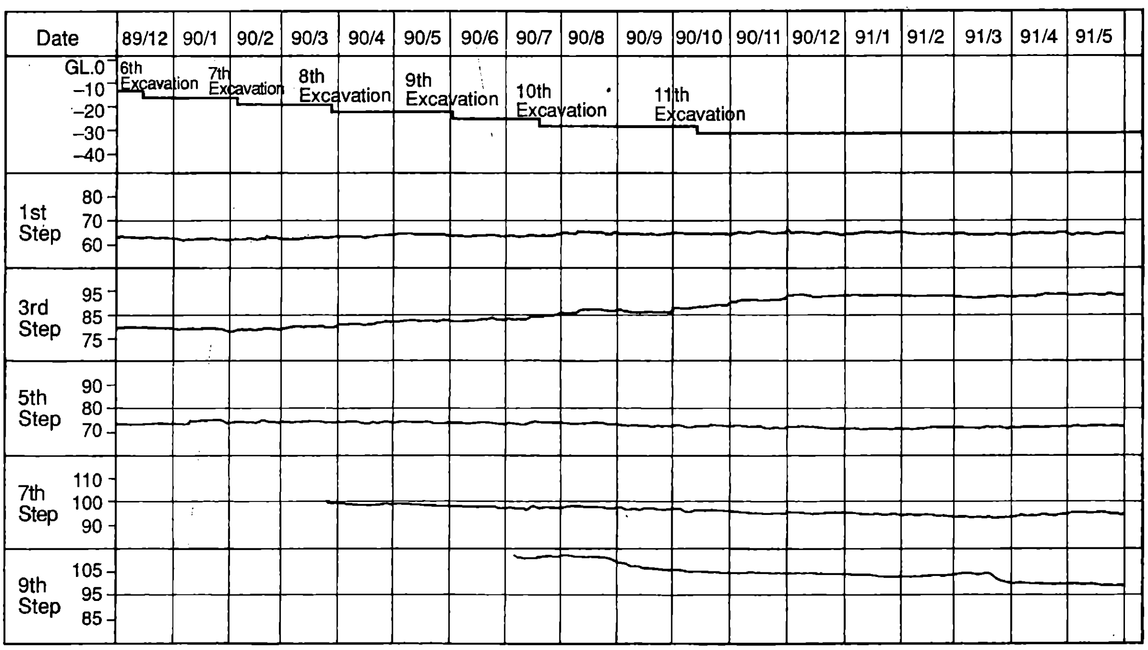

Fig. 6 Anchor Load Changes (No. 18 Point)

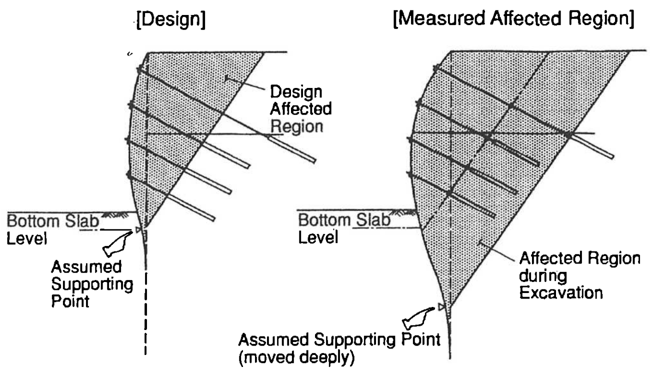

Fig. 7 Affected Region

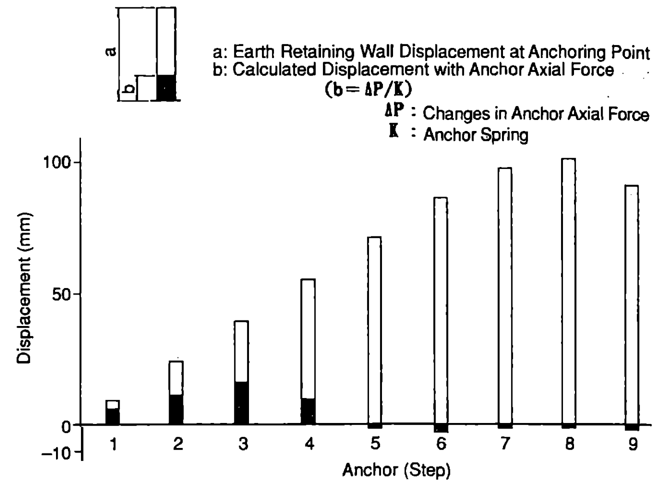

Fig. 8 Comparison between Anchor Displacement Changes

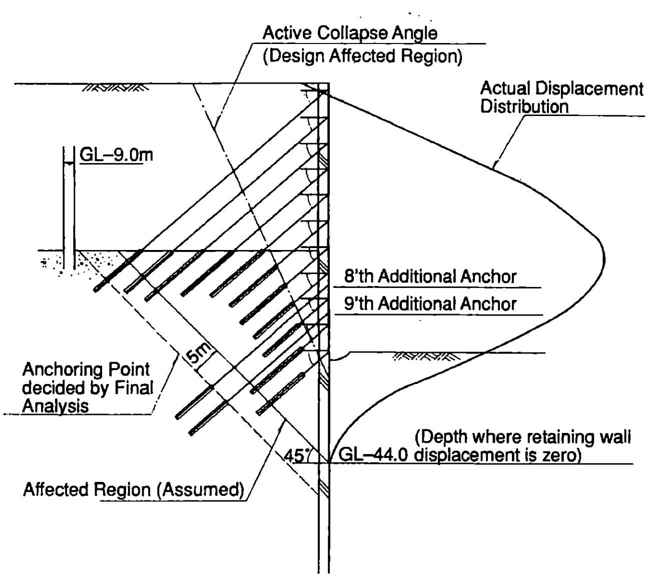

Fig. 9 Additional Anchoring Points

3. COUNTERMEASURES

3.1 Review of Countermeasures

Although the excavation was in its final phase with a remaining depth of 3m, the creep-like displacement (1 mm/day) continued even after the 11th excavation. Under such condition, securing stable earth retaining for a long construction period of 2 years covering building of the main structure seemed impossible. In view of the above, the following countermeasure was taken.

Counter load (H = 3.0 m) was constructed in front of the wall as an first available emergency countermeasure and then additional anchors of two steps were applied. The additional anchors were applied on the following basis.

(1) As can be seen in the Figure 8, comparison between the displacement at the anchored point with that computed from anchor load indicates that the point of the 1st-step anchor can be considered as the fixed point.

(2) As shown in Figure 9, the estimated line showing the area in which the influence due to displacement is anticipated, that is, the area inside the angle of $\theta = 45°$ from the depth where the displacement in the earth retaining wall becomes zero, coincides with the estimation as described in (1).

From (1) and (2), the additional anchors were eventually applied in the outside area of the line determined with allowance of 5m to that described in (2).

3.2 The measured values obtained after completion of the countermeasure work

After application of the additional anchors, the counter load was removed and bottom excavation was finally performed, during which the measurement values obtained from the earth retaining work showed no fluctuations.

From the above, it can be thus concluded that the countermeasure taken in this excavation was appropriate. The main structure is currently under construction after slab base concrete placement.

4. CONCLUSION

Most anchors are applied outside the active collapse angle; however, it was proved that this design practice is not always appropriate for deep excavation like this case.

It has also become clear that in employing anchor-type earth retaining method for deep excavation, anchor location should be determined after thorough considerations. Establishing a rational determination method of anchoring point requiring an enormous volume of in-situ measurement data and analysis is a future subject.