



Missouri University of Science and Technology
Scholars' Mine

International Conference on Case Histories in
Geotechnical Engineering

(1988) - Second International Conference on
Case Histories in Geotechnical Engineering

03 Jun 1988, 10:00 am - 5:30 pm

Behavior of Ground Anchors for Taipei Sedimentary Soils

J. C. Li

Planning and Research Department, Taiwan

H. L. Yao

Planning and Research Department, Taiwan

L. P. Shi

Planning and Research Department, Taiwan

B. I. Shy

Foundation Construction Office of Taipei Main Station, Taiwan

Follow this and additional works at: <https://scholarsmine.mst.edu/icchge>

 Part of the [Geotechnical Engineering Commons](#)

Recommended Citation

Li, J. C.; Yao, H. L.; Shi, L. P.; and Shy, B. I., "Behavior of Ground Anchors for Taipei Sedimentary Soils" (1988). *International Conference on Case Histories in Geotechnical Engineering*. 9.

<https://scholarsmine.mst.edu/icchge/2icchge/2icchge-session6/9>

This Article - Conference proceedings is brought to you for free and open access by Scholars' Mine. It has been accepted for inclusion in International Conference on Case Histories in Geotechnical Engineering by an authorized administrator of Scholars' Mine. This work is protected by U. S. Copyright Law. Unauthorized use including reproduction for redistribution requires the permission of the copyright holder. For more information, please contact scholarsmine@mst.edu.

Behavior of Ground Anchors for Taipei Sedimentary Soils

J.C. Li

Director of Planning and Research Department, Taiwan

H.L. Yao

Chief of Research Sector, Planning and Research Department, Taiwan

L.P. Shi

Assistant Engineer of Research Sector, Taiwan

B.I. Shy

Chief of Foundation Construction Office of Taipei Main Station, Taiwan

SYNOPSIS: Seven ground anchors were installed for full scale field tests in Taipei Railway Underground Project. The soil at job site can generally be classified as silty clay or clayey silt. The length of the anchors was about 40 m each, including 23 m bond length. The borehole diameter was 125 mm and the designed borehole inclination was 26 degrees downward. Each of the anchors was expected to share approximately 300 to 400 kN of tie-back force to support the diaphragm wall during excavation. Investigation of the borehole inclination was carried out by using horizontal inclinometer. The distribution of skin friction along the bond anchorage was determined from strain gauges applied on the anchoring strands, and the tensile load was monitored by load cells. It was observed that the average borehole direction deviated with an angle of about 1.5 degrees. It has also been found that most of the design load was carried by the first 10 m of the bond length. For a nearest spacing of about 1.5 m between the anchors, the group effect and the stress interaction among them were negligible.

INTRODUCTION

For designing an anchor in soil, it is generally assumed that a constant skin friction distributes over grout-soil interface along bond anchor length. OSTERMAYER and SCHEELE (1977) have performed the full scale tests on anchors in non-cohesive soils. They have found that the decrease of tendon forces from the front part to the rear part of the bond length corresponds with the load transmission from the tendon into the grouted body. The maximum skin friction shifts from the front part of bond length towards the anchored end when the tensile step loadings were gradually applied. A progressive failure mechanism was used to explain the variation of skin friction with bond length. So far, as the behavior of ground anchors in silty or clayey soil is concerned, the limitations of the application of the various theoretical approaches have been discussed by Ou (1986). In this paper, a field investigation on the behavior of ground anchors in Taipei Sedimentary Soils is reported. The main objectives of this research are:

- (i) to observe the borehole inclination after it was driven.
- (ii) to understand the stress distribution along fixed anchor length and its variation with respect to time,
- (iii) to understand the group effect of anchors and its influence on stress distribution,

FIELD TESTS

Among the many anchors installed in Taipei Railway Underground Project, seven were selected for full scale tests. A schematic arrangement of the test anchors is shown in Fig. 1. According to the requirements on

this research, three instrumentation systems, i.e., horizontal inclinometer, strain gauges and load cells, were used in the testing program. The length of the anchors was about 40 m each including about 23 m bond length. The borehole diameter was 125 mm and the designed borehole inclination was 26 degrees. The simplified geotechnical profile of typical Taipei Sedimentary Soils is shown in Table I. A large part of the bond length was situated at a layer of silty clay or clayey silt with undrained shear strength (S_u) of about 60 kN/m². Some part of the bond length was located in the layers of silty fine sand with effective internal friction angle of 31 to 32 degrees. All test anchors were installed at the elevation lower than the ground water table, which is normally located at 1 to 2 m below the ground surface.

Each of the test anchors was expected to share approximately 300 to 400 kN of tie-back forces to support the diaphragm wall during excavation. Four or five tension strands with diameter 12.7 mm each were used for anchorage. The temperature compensating strain gauges were attached to a steel bar (165 mm in length and 20 mm in diameter). They were protected by several layers of waterproof coatings and an aluminum tube to prevent from stain and damage. This assembly was then connected to one of the tension strands at the pre-selected points. All instruments were calibrated in the laboratory before the field testing. The following are the procedures of installation and measurement in the testing program:

- (i) the steel casing was driven down to the design depth,
- (ii) the plastic tubes for inclinometer were inserted into the casing and then

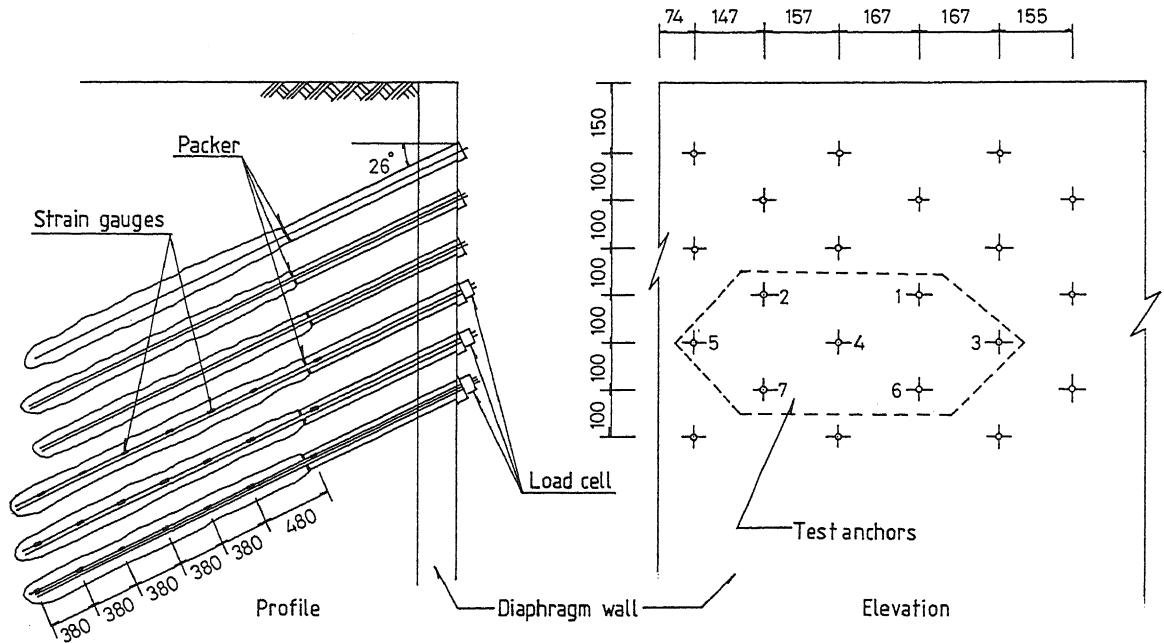


Fig. 1: Test Anchor Arrangement and Instrumentation

Table I: Simplified Soil Profile and Parameters

Elevation range, m	Soil Profile Description	N	γ kN/m ³	c kN/m ²	ϕ deg.	\bar{c} kN/m ²	$\bar{\phi}$ deg.	S_u kN/m ²
Ground Level to -2	Asphalt pavement, balast backfilled soil and silty clayey or clayey silt	5	18.6	20.6	17	0.0	23.0	24.5
-2 to -12	silty fine sand	12	19.0	-	-	-	31.0	-
-12 to -19	silty clay or clayey silt	7	18.6	30.4	15.5	0.0	28.0	58.8
-19 to -28	silty fine sand	12	19.0	-	-	-	32.0	-

Note: N: blow count of standard penetration test,
 γ : total unit weight of soil,
 c, \bar{c} : apparent, effective cohesion intercept,
 $\phi, \bar{\phi}$: apparent, effective internal angle of shearing resistance,
 S_u : undrained shear strength of soil,
 average ground surface at elevation +4.3 m,
 permanent ground water at elevation +2.0 m,
 temporary ground water at elevation +3.6 m.

- (iii) the borehole inclination was measured, the wire strands with strain gauges were inserted into casing,
- (iv) the borehole was grouted from bottom of the casing while retracting the casing simultaneously,
- (v) in the free length part, i.e., outside the packer of borehole, the remaining cement paste was flushed out with water,
- (vi) the load cell was installed after a waiting period of about 7 days and then the tensile force was applied.

The water/cement ratio of the grout was 0.5 and the grouting pressure was kept at about 0.2 to 0.5 MN/m². The pulling force was applied in steps (LITTLEJOHN, 1981) by a hollow ram jack.

TEST RESULTS

Borehole Inclination

Fig. 2 shows a typical borehole inclination (represented by dashed lines). According to the measurement of inclination (sensor length about 610 mm), the borehole inclination at each advancing length ranges from 23.4 to 27.6 degrees. The average deviation away from the designed inclination was about 1.5 degrees (Fig. 2). On the diaphragm wall, the minimum distance among the anchors was about 1.8 m. While along the bond length of each anchor, the minimum spacing calculated from the measured inclination was about 1.5 m.

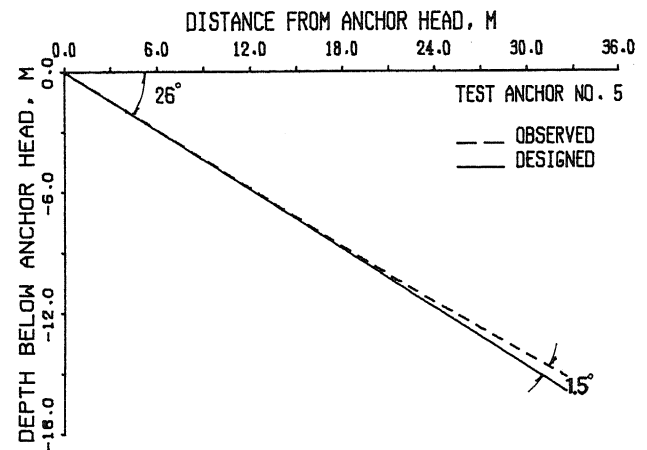


Fig. 2: Borehole Inclination after Driven

Distribution of Tensile Load

A typical distribution of tensile forces in strands and average skin friction along grout-soil interface are represented in Fig. 3. The bond length indicated on the horizontal axis refers to the position of the packer. The skin friction was obtained from the difference of forces at two neighboring points divided by the circumferential area of the grouted body. It is observed that the transmitted forces have decreased from the front to the rear part of bond length (Fig. 3A) and the distributed forces have increased when the load was kept constant for a period of time (about 5 minutes). It is also found that as the load was kept constant at high loading steps, the decrease of skin friction in the front part is accompanied by the increase of skin friction in the rear part of bond length (Fig. 3B). It must be kept in mind that the test anchors have passed through non-homogeneous soils, i.e., the first 6 m of bond length was in the layer of medium dense silty fine sand and the remaining 16 m was in the layer of silty clay or clayey silt. The behavior of test anchors shows a similar phenomenon as that disclosed in the research for non-cohesive soils (OSTERMAYER and SCHEELE, 1977).

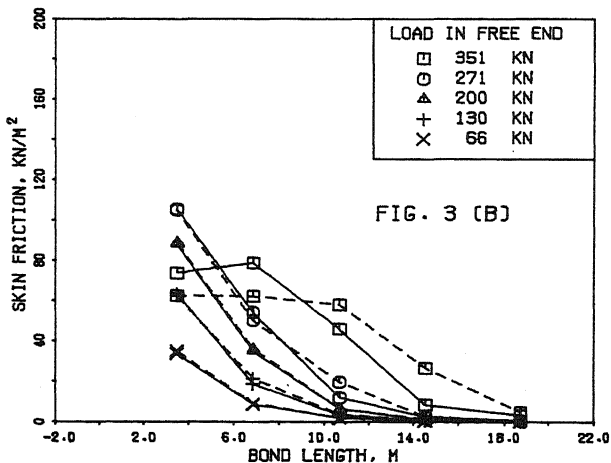
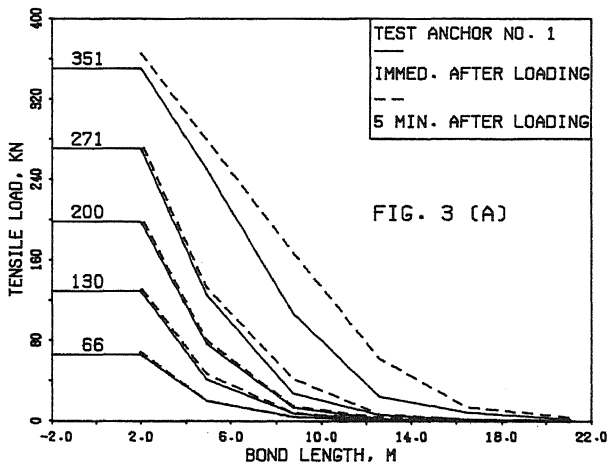
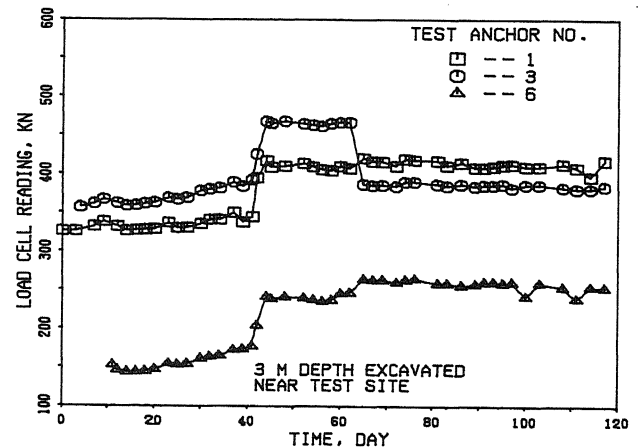


Fig. 3: Tensile Load and Skin Friction Distribution along Bond Length

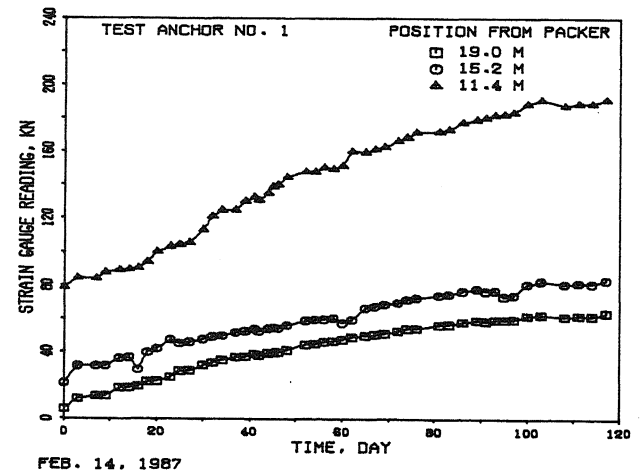
The progressive failure phenomenon was found when the load applied was approaching 300 kN. It is indicated from Fig. 3 that the first 10 m of the bond length was enough to carry most of the design load. An important issue is to maintain the grout-soil interface well bound.

Continual observations on this field test were performed from February to June, 1987. The excavation work went on until the end of April. The load cell readings with respect to time are shown in Fig. 4. There was a sudden increase of tensile force in the anchor head due to 3 m depth excavation near the test site at the end of March (40 days after February 14). The readings of strain gauges with respect to time are shown in Figs. 5, 6, and 7. It was observed that the influence of excavation can be immediately detected only in the gauges of anchor number 6 (1.8 and 4.5 m away from packer in Fig. 7). The results given by the other strain gauges (over 7 m away from packer) have shown that the tensile force increased gradually at beginning, and then became steady after the end of May (about



FEB. 14, 1987

Fig. 4: Load Cell Readings with Respect to Time



FEB. 14, 1987

Fig. 5: Strain Gauge Readings with Respect to Time (Test Anchor No. 1)

100 days after February 14). It is noted that the tensile load in anchor number 3 decreased after excavation (Fig. 4). The readings of strain gauges at 7.6 m from packer were also affected by this decrease of tensile load (Fig 6). It has also been found that most of the anchor load was taken by the first 10 m of bond length at long term condition.

Group Effect

In order to know the group effect and stress interaction among these anchors, the stress condition was recorded for all the anchors when one of the anchors was being loaded. It is worth noticing that a particular test sequence was arranged to assure meaningful comparison, i.e., the center one in test group (number 4 in Fig. 1) was loaded until all the others had been installed. Comparing the test results before and after pulling the anchor number 4 (Table II), there was a very small difference between these two test data. The maximum value of the difference was about 22 microstrains (0.5 kN). The same phenomenon was also detected in the other test cases.

Table II: Strain Gauge Readings (microstrain) Before and After Pulling Test Anchor Number 4

Test Anchor No.	Strain Gauge Position measured from Packer, m				
	3.8	7.6	11.4	15.2	19.0
1	-	938(932)	346(341)	200(205)	-
2	-	593(598)	349(335)	122(139)	347(325)
3	-	2376(2378)	-	-	1581(1583)
5	-	2162(2144)	1688(1676)	-	329(347)
6	-20(-14)	58(58)	-29(-27)	-45(-45)	-107(-104)
7	39(36)	6(5)	19(19)	-19(-17)	-46(-44)

Note: (): reading after pulling test anchor 4.

For a nearest spacing of about 1.5 m along bond length, the stress interaction among the test anchors was very small when loading and unloading each one of them. Therefore, the influence of group effect was negligible.

CONCLUSIONS

After investigating the behavior of ground anchors in Taipei Sedimentary Soil, similar phenomenon was observed as that in non-cohesive soil (OSTERMAYER and SCHEELE, 1977). The average deviation away from the designed inclination was about 1.5 degrees. The first 10 m of bond length can carry most of the maximum tensile load if the grout-soil interface was well bound. For a nearest spacing of about 1.5 m along bond length between testing anchors, the stress interaction among them was very small and the influence of group effect was negligible. After five month observation, it is expected that these long term instrumentation results will help in understanding the behavior of ground anchors due to excavation effect. Because of the limited monitoring period, the influence of soil creep to the behavior of ground anchors was not fully understood and a further study is recommended.

ACKNOWLEDGEMENTS

The authors are grateful to Dr. Chin-Der Ou, Shyr Chyang and Gin-Min Wei for their helpful suggestions and contributions.

REFERENCES

LITTLEJOHN, G. S. (1981) "Acceptance Criteria for the Service Behavior of Ground Anchorages", Ground Engineering Vol. 14, No. 3.

OSTERMAYER, H. and SCHEELE, F. (1977) "Research on Ground Anchors in Non-cohesive Soils", Special Session No. 4, 9th International Conf. on Soil Mechanics and Foundation Engineering., Tokyo.

OU, C. D. (1986) "Design Consideration and Test of Ground Anchor", Sino-Geotechnics, No. 14, April 1986 (in Chinese).

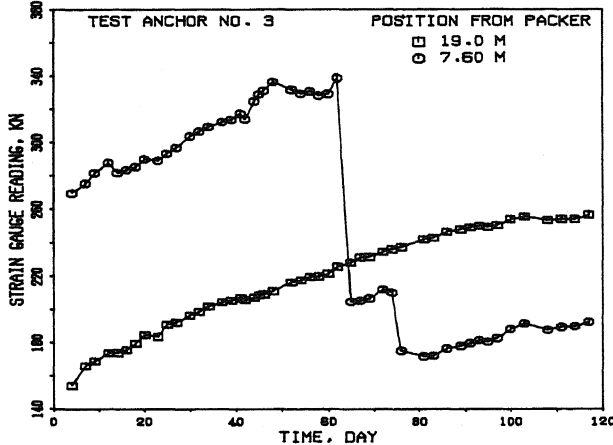


Fig. 6: Strain Gauge Readings with Respect to Time (Test Anchor No. 3)

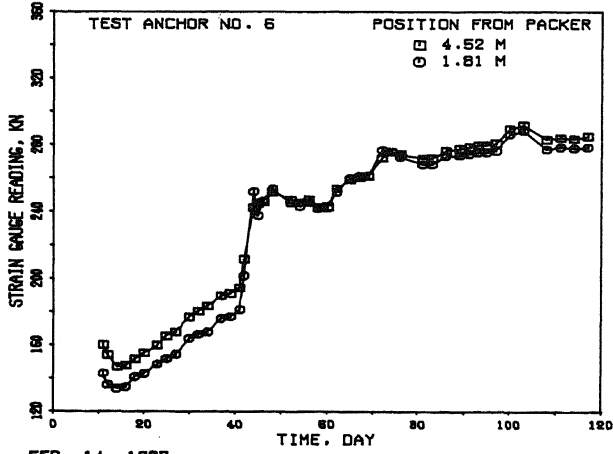


Fig. 7: Strain Gauge Readings with Respect to Time (Test Anchor No. 6)