EXECUTION, SUPERVISION AND QUALITY CONTROL OF ANCHORS

MISE EN OEUVRE, SUPERVISION ET CONTROLE DE LA QUALITE DES ANCRAGES

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SYNOPSIS: The Active Design concept is an efficient method for monitoring and quality control of foundation structures. Supervision and quality control of soil anchor installation, using the Active Design Concept is illustrated by a case history, where the initial anchor design could be modified as a result of carefully monitored load tests. The advantages of a new type of soil anchor, using inflatable Expander Body steel bags is discussed. By measuring the inflation pressure of the Expander Body, it was possible to develop a site-specific correlation with respect to the load bearing capacity. It was thus possible to predict the load capacity of individual anchors more reliably and to increase the anchor spacing. The Active Design Concept has in the present case resulted in a more reliable design and significant savings for the project.

INTRODUCTION

Anchors can be used to solve a variety of foundation engineering problems. For example, they are frequently used to resist tension forces, such as in the case of transmission line foundations or structures subjected to uplift. Another common application, mainly for inclined anchors, is the lateral support of retaining structures, such as bulk heads.

The first group of applications is often used for permanent structures, where design is generally governed by the geotechnical conditions and structural considerations. Load testing of such anchors is usually only performed occasionally and relatively high factors of safety are therefore applied.

Anchors for retaining structures are often of temporary nature and the loading conditions can, at least to some extent, be controlled during the construction process. Loads against retaining structures depend on the method of excavation and on the resulting deflections of the wall. As excavation progresses in front, or as filling takes place behind a wall, the magnitude of deformations decides the distribution of earth pressure with depth. The actual earth pressure depends not only on the properties of the soil but also on the sequence of construction operation and on the type of bracing or anchor system. Thus, the earth pressures used for design can not be determined exclusively by theory, but must be based on experience and modified according to field observations and site monitoring.

Anchors can be classified in three basic categories according to Fig. 1, Kulhawy (1985). The behaviour of soil anchors depends to a large degree on the anchor type and the installation method, which should be taken into consideration at the design stage of a project.

Spread anchors consist of a wide structural member, which is embedded in the soil by excavation and backfill or by direct embedment. Helical anchors consist of a steel shaft to which helices are attached. Generally, these anchors are installed by applying an axial load to the shaft while rotating it into the ground. Grouted anchors contain a steel tendon,

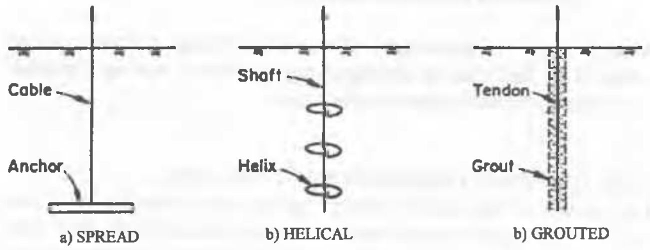

Fig. 1. Basic Anchor Types, after Kulhawy (1985)

placed into the ground inside a pre-drilled hole or by driving. Grout can be place by gravity or by pressure. The anchors may be pre-stressed after installation, which has the advantage that anchor is proof-loaded to the design value.

The supervision of the execution process is of particular importance for ground anchors. Field monitoring during anchor installation and testing of the anchors after installation can provide valuable information, which can lead to a better technical solution and also a more economical anchor design.

ACTIVE DESIGN CONCEPT

Design methods for foundation problems are inherently crude and must often be based on a limited quantity of geotechnical data, having to assume uncertain loading conditions. The Active Design Concept recognises these limitations of foundation engineering in a rational way, by gradually improving the initial design, using field measurements obtained during the actual construction process.

An important aspect of this Active Design is, that the foundation process can be modified during the project execution phase, taking advantage of the improved geotechnical information resulting from site monitoring.

This flexibility of the foundation design concept must be included already in the initial design of the project and different strategies should be developed in advance.

The Active Design Concept is especially well-suited for projects including retaining walls with soil anchors and consist of the following steps:

- initial geotechnical design, using the best available information prior to the start of the project. A parameter study is performed to identify the most important parameters which affect the project,
- selection of a preferred foundation method and development of alternative strategies,
- design of a field monitoring scheme which makes it possible to determine important geotechnical parameters in the field,
- monitoring and supervision of the foundation process during and after execution of the structure,
- revised geotechnical design of the structure, based on the field data, and
- modification of the foundation process to take into consideration the results of the field measurements.

In most cases, the advantages of the Active Design Concept can be evaluated by field trials at the beginning of a project, making it possible to compare different foundation alternatives.

CASE HISTORY - EXPANDER BODY ANCHOR

The benefits of the Active Design Concept are illustrated by a case history, where a new type of soil anchors, Expander Bodies, were used for the rehabilitation of a 600 m long quay wall, Gustavsson and Widerström (1991). A new quay wall was constructed in front of the existing quay, composed of 12,5 m long, interlocking steel sheet piles, which penetrated about 5,5 m into the sea bed, Fig. 2.

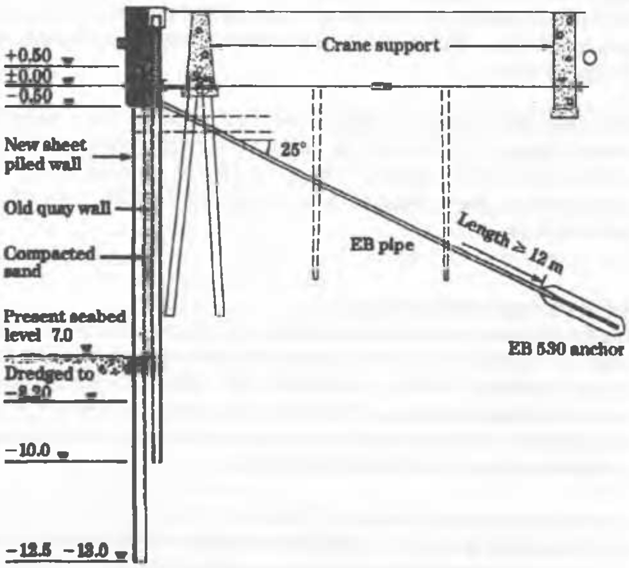

Fig. 2. Cross-section of quay wall with Expander Body anchors at Åhus, Sweden

The soil behind the existing quay wall consisted of an about 2 m thick stony fill on top of a natural soil deposit of medium dense sand and silt. Extensive soil investigations were carried out to establish the variation of soil conditions along the quay wall. At the start of the project, several design alternatives were evaluated, considering different anchor types, i.e. anchor plates, grout-injected anchors and the Expander Body anchor.

The Expander Body consists of a thin-walled, folded steel bag. After installation in the ground by drilling, driving or vibrating, the Expander Body can be inflated by injection of concrete or grout, Fig. 3. A solid, concrete-filled steel body with pre-determined shape and volume can in this way be created at any depth in the ground. During the expansion phase, as a result of the high expansion pressure, the Expander Body creates a densified soil zone, which extends to a distance of about two pile diameters. The expansion process increases the density of loose and medium dense granular soils. In cohesive soils, re-compression results in a pre-consolidation effect and improves soil strength and stiffness.

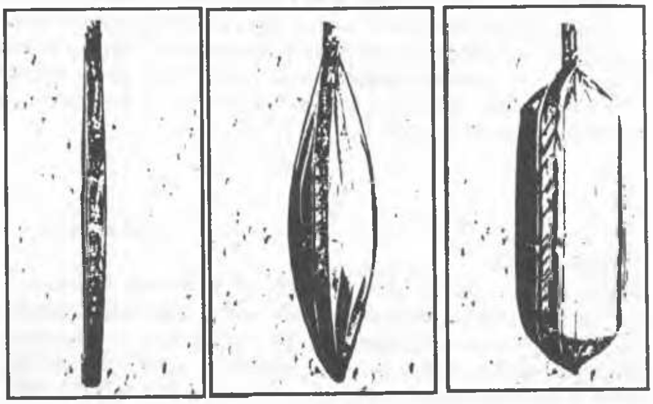

Fig. 3. Inflation phases of the Expander Body

The inflation process of the Expander Body is similar to that of a pressure meter test. thus, by recording the inflation pressure and the injected grout/concrete volume of the Expander Body, information concerning the in situ stiffness and soil strength can be obtained. Fig. 4 shows a typical diagram of the variation of grouting pressure as a function of time.

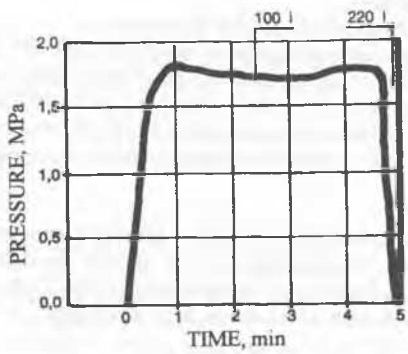

Fig. 3. Variation of grouting pressure as a function of time during expansion of the Expander Body

In order to compare the load capacity of different anchor types, a test programme was carried out, using conventional pressure-grouted anchors and Expander Body anchors. The geometry of the inflated Expander Body, type EB 530 was: 0,5 m diameter, 2,8 m expanded length. In Table 1, the results of the load tests are summarised.

Table 1. Results of testing programme for grout-injected and Expander Body anchors

Anchor Type	Length (m)	Number of Strands	Grout Volume (m^3)	Grouting Pressure (MPa)	Failure Load (kN)
EB 530	12	7	650	1,6	> 950
Grouted	13	7	-	-	550
EB 530	12	7	500	1,6	> 950
EB 530	10	9	500	2,1	> 1 350
Grouted	13	7	-	-	700

The test loads for the Expander Body anchors were significantly higher than expected and their load-deformation performance superior to conventional pressure-grouted anchors.

A site-specific correlation could be obtained between the load capacity of the anchors and the expansion pressure of the Expander Bodies. The length of conventional anchors would have been on the order of 22 - 24 m, compared to the 12 m long Expander Body anchors. The spacing of the anchors, which during the initial design phase was estimated to 1,6 m, could be increased to 2,4 m.

CONCLUSIONS

The Active Design Concept was used successfully to design anchors for a quay retaining wall. By field tests it was possible to develop a site-specific correlation between the expansion pressure and the bearing capacity of Expander Body anchors. In this way, major savings could be achieved at a site with difficult foundation conditions.

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