FIRST APPLICATION OF A TOTALLY PROTECTED ANCHORAGE

Première application d'un ancrage à protection totale

by

C. MASTRANTUONO et A. TOMIOLO

Ing. G. RODIO et C.S.p.A.
Casalmaiocco, Milano - Italia

SOMMAIRE

Cet article décrit la première application d'un nouveau système d'ancrage entièrement protégé contre les dommages causés par la fissuration et la corrosion des barres d'acier.

Cet ancrage appartient à la famille des ancrages à bulbe comprimé.

La technologie d'exécution du bulbe de scellement injecté est celle utilisée dans le système bien connu IRP à injection répétée en pression.

Chaque barre est protégée sur toute sa longueur par une gaine plastique jusqu'à la plaque du fond, sur laquelle se fixe chaque ancrage.

La plaque du fond est enrobée dans un mortier de résine époxy. Ainsi, même si quelques fissures se développent dans le bulbe de scellement injecté précontraint, aucun point ne peut être attaqué par la corrosion, l'acier étant entièrement protégé par la gaine en résine époxy.

Dans cet article, on présente les résultats de prototypes réalisés dans le rocher et dans des sols alluviaux mous.

Les essais effectués dans le sol mou ont été exécutés à l'aide de dispositifs de mesure montrant la distribution de la transmission des charges au terrain. Ces distributions ont été comparées à celles de deux tirants IRP traditionnels exécutés dans le même sol.

SUMMARY

This paper describes the first experimental application of a new anchoring system thoroughly protected against dangers connected with fissuring and corrosion of the steel rods.

This anchorage is similar to the type of anchors with a compressed bulb.

The grouted bulb placing technology is the same as used in the well known IRP system, i.e., with repeated high pressure grouting.

Each rod is protected, along its entire length, by a plastic sheath down to a bottom plate on which each anchor is fixed. The steel bottom plate itself is embedded in epoxy resin mortar.

In this way even if some fissures develop in the stressed grouted bulb, no point is left open to attack by corrosion, the steel being entirely protected by the plastic sheath of epoxy resins.

This paper reports the results of prototypes in rock, and in soft alluvial soils.

The tests in a soft soil were carried out with instrumentation detecting distribution of the transferred loads to the soil. These distributions have been compared to those of two traditional IRP anchors built in the same soil.

INTRODUCTION

During the last few years the application of anchorages has become more and more widespread.

The generalized use of these systems involves problems of various types. Among them the protection of anchorages against attack by corrosion and quality control on the job sites are of particular importance.

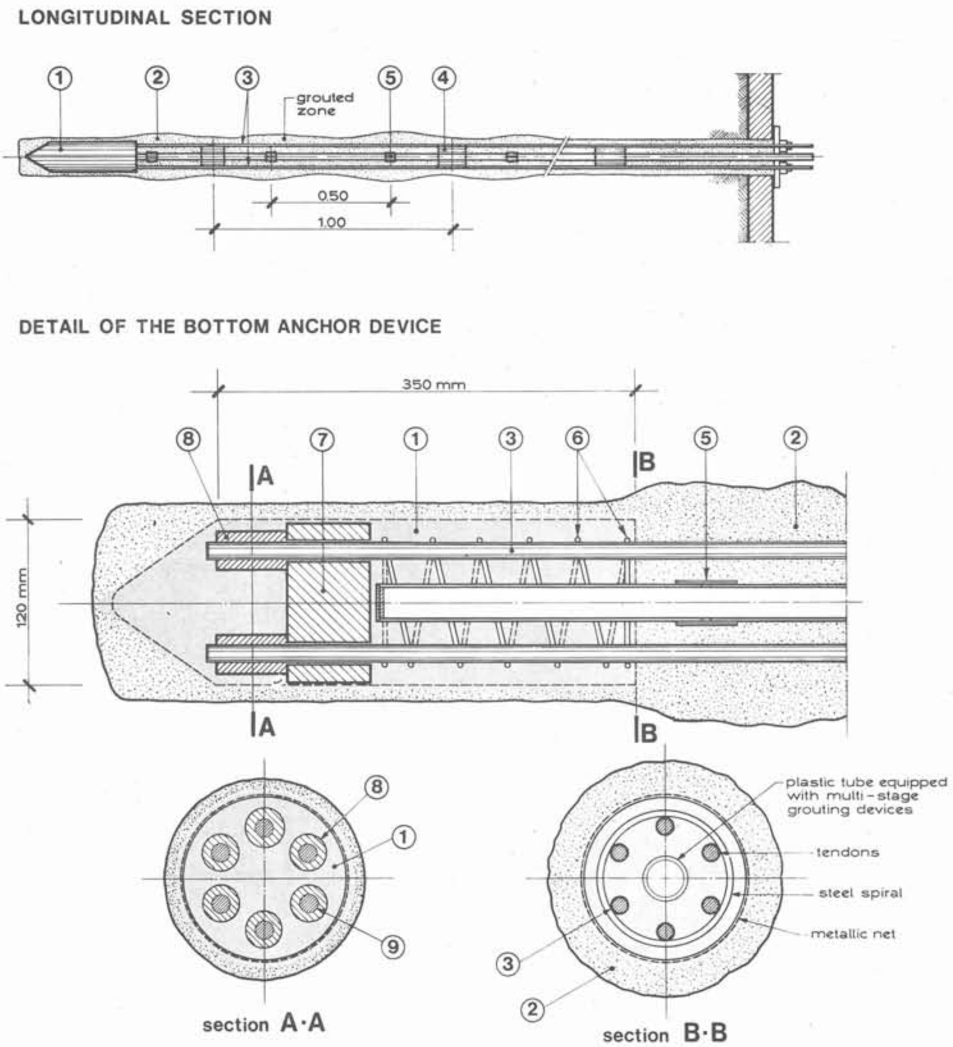
In the first part of this paper a new type of anchor called TPT, entirely protected against corrosion, is described. The results of two series of tests on prototypes of such anchor are reported. Prototypes in the first series have been installed in rock whilst those of the second series in normally consolidated clayey silts.

Anchors of the second series, in soft soils, were instrumented so as to measure distribution of stresses along the length of the grouted bulb. These measurements were also carried out on traditional anchor prototypes placed in the same soil thus allowing a comparison between the two anchoring systems.

1. DESCRIPTION OF TPT ANCHOR

As shown in figure 1 the characteristics of the TPT anchor may be summarized as follows:

- The TPT anchor consists of a number of cables placed all around a pipe equipped to perform repeated high pressure grouting.
- Each strand is protected by a plastic sheath down to the bottom plate, thus preventing any possible contact of the steel with waters present in the ground, even if fissuring of the grouted bulb occurs.



L E G E N D A

(1) mortar of epoxy resins
(2) cement grout
(3) tendons protected with a plastic sheath
(4) device for positioning the tendons
(5) tube equipped with grouting device
(6) reinforcement steel spiral
(7) terminal steel plate
(8) devices for fixing the steel tendons
(9) tendons without plastic sheath protection

Fig. 1. — **TPT anchor system.**

- The bottom plate equipped with strand fixing devices is embedded in epoxy resin mortar. In this way all the steel parts are thoroughly protected.
- The prestressing device may be any one of those employed for other traditional anchors.
- The TPT anchor belongs to the family of anchors with compressed grouted bulb in that the steel cables may run within the plastic sheaths and transfer the load to the bottom plate.
- The TPT anchor grouted bulb is carried out using the same construction method employed for the IRP anchor. (4)
- Hence it is possible to combine the advantages of repeated high pressure grouting with those relating to protection against corrosion both of cables and bottom plate.

2. STRENGTH OF GROUTING MORTARS

A particularly important problem involved in grouted anchors, especially those with compressed bulb, is that related to strength of the injected mix.

This mix undergoes a state of triaxial stresses wherein the principal stresses are due to:

a) stresses transmitted by bottom plate;
b) confining effect due to the soil surrounding the grouted bulb.

It is well known (1) that by varying the mechanical properties of the grouted bulb and surrounding soil, distribution and magnitude of stress states in the grouted mix will also vary.

The author has carried out tests with a view to determining the strength range of a grouting mix of the type commonly employed, subject to triaxial stress states.

These tests were performed at ENEL (Government Electrical Agency) Laboratory at Niguarda, (Milan).

Tests were carried out on eight sets of specimens of a grouting mix with the following characteristics:

- size of specimens $10 \times 10 \times 10$ cm;
- pozzolana cement 325;
- water/cement ratio 0.55;

Results of these tests are given in figure 2 where two curves are plotted, representing, in Rendulic's plane, the strength range limits of the grouting mix subject to triaxial stress states. The maximum stresses usually acting on the mix injected near the anchor bottom plate vary from 500 to 600 kg/sq.cm. By comparing these stresses with the stresses shown in figure 2 it will be seen that these states of stress do not cause breaking of the mix when the surrounding soil is able to exert such a confining pressure that the ratio between the principal stresses is equal to 0.3.

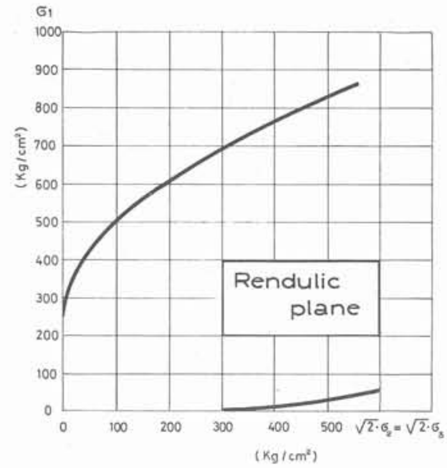


Fig. 2. — **Variation of strength of grout under triaxial state of stress.**

3. TEST ON PROTOTYPES

Tests on TPT anchor prototypes were carried out on two test sites representative of two limit conditions.

In the first case the soil consisted of rocks showing the best mechanical characteristics, while in the second case the soil was formed by clayey silts of very poor geotechnical properties. In both cases the aim of the tests was to provide information on the following points:

- verify that the TPT anchor actually worked as a compressed bulb anchor;
- verify that the strength of the injected mixes submitted to triaxial stress states was consistent with strength measured by the laboratory tests described in the preceding paragraph;
- compare the behaviour of compressed bulb TPT anchors with that of the traditional IRP anchors.

3.1. Tests of TPT anchors in rock on the Sorrento jobsite (Naples)

Six TPT anchors were built in soil consisting of calcareous rock.

The tests were carried out from July to September 1976. The characteristics of these anchors were the following:

length: 25 m
drilling diameter: 120 mm
testing load: 117 t

The test load value is determined by the yield point of the steel. The tests were performed according to the procedure described by Portier (2), i.e. the cycle method. This system offers the possibility of interpolating the free length of the anchor taking into account the loading and unloading curves measured during the tests.

Measurements taken were highly satisfactory for they showed differences of 7% from the theoretical free lengths.

As an example, we show in figure 5 the stress/strain curve measured during the test on a TPT anchor.

The tests performed led to some conclusions which may be summed up as follows:

- in practice, the measured free lengths coincide with the theoretical lengths thus showing that the anchors actually behave in the same way as anchors with compressed bulb;
- stresses transferred by the bottom plate to the grouted mix were 800 kg/sq. cm. approx. and no failure phenomenon occurred.

This confirms the validity of values found through the experimental tests referred to in paragraph 2.

Following the successful outcome of the tests, TPT anchors have been employed in general in all jobsites involving anchors in rock which required a definitive protection against corrosion.

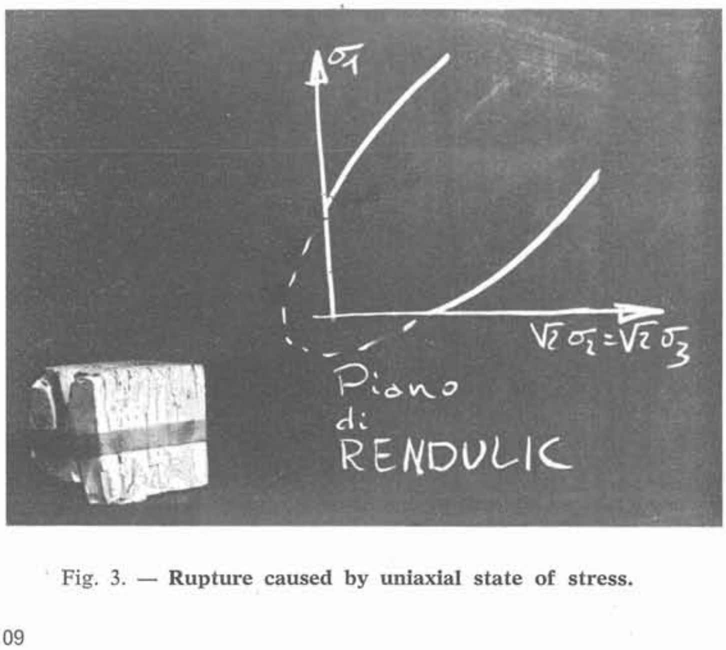


Fig. 3. — **Rupture caused by uniaxial state of stress.**

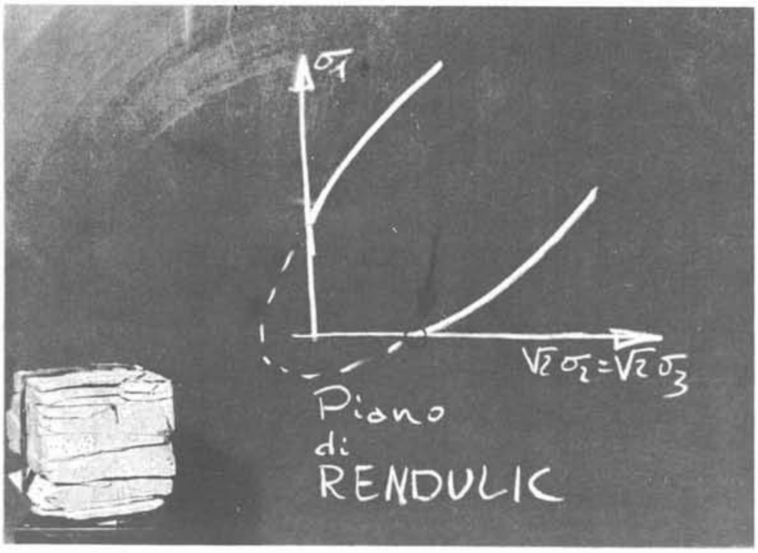


Fig. 4. — **Rupture caused biaxial state of stress.**

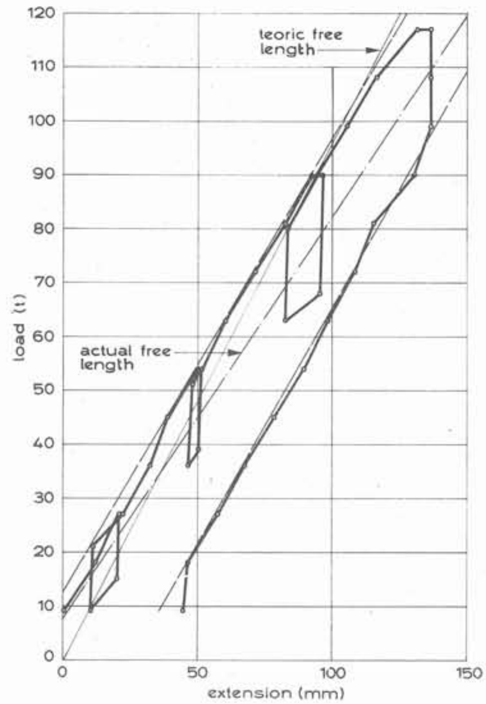


Fig. 5. — **Stress/strain curve.**

At present (March 1977) a jobsite where about 150 anchors of this type are being installed, is being set up. In this jobsite measurements of the free lengths are systematically carried out.

3.2. Tests on TPT anchor in soil of poor geotechnical characteristics

In February 1977 a series of tests were begun on TPT anchors, installed in soils of very poor geotechnical characteristics, that is alluvial clayey silt soils in the Po river delta.

The anchors were set out in the same site where traditional IRP anchors were under construction. This allowed comparison on the behaviour of the two types of anchors in the same soil.

A number of anchors were instrumented with removable strain gauges.

Measurement were taken by instruments and technicians of «Laboratoire Central des Ponts et Chaussées» of Saint-Brieuc (3). The tests made it possible to take measurements on stress distribution within the bulb on both TPT anchors (loaded by a bottom plate) and traditional IRP anchors where the load transfer to the bulb occurs by adhesion between steel and cement mix).

At present (March 1977) the testing programme is still under way, hence it is impossible to give general results on the behaviour of TPT anchors in soil of poor geotechnical characteristics.

Nevertheless we think it is of some interest to refer to the results of the strain gauge measurements detected along the bulb length, referred to in figure 6, 7 and 8.

In figure 6 a typical section of the work is given, showing both anchor position and points where strain gauge measurements were carried out. Measurements were taken only at the grouted bulb and strain gauges placed in the same position for all anchors.

In figures 7 and 8 strain measurements carried out both on a IRP anchor and a TPT anchor are reported.

A numerical evaluation of these results will form the subject of a future paper that will be published after completion of the present investigation programme. Here we are just making a few remarks of a qualitative character.

In figure 7 bulb deformations as a function of applied load for a TPT anchor are given. We have five load/deformation diagrams each referring to one of the points indicated in figure 6.

It should be noted how at the plate, the deformations are very high while they decrease towards the top of the bulb. This confirms the success of the anchor, from the technological point of view, in that working performance approaches theoretical performance, even in the range of the lowest loads.

In figure 8, curves relating to IRP anchor, similar to those in figure 7 are shown.

As already stated, in this type of anchor, load transfer occurs by adhesion of the strands to the grouted mix. Deformations decrease towards the end of the bulb.

It will be seen that the strain gauge placed near the inflatable packer on top of the bulb detects no deformations.

It is interesting to note that unit maximum per cent deformations, in anchors with bulb undergoing tensile stress, are much higher than those of anchors with compressed bulb. This proves the risk of bulb microfissuring, as already pointed out by various authors (Ostermayer, 1974, for instance) (5).

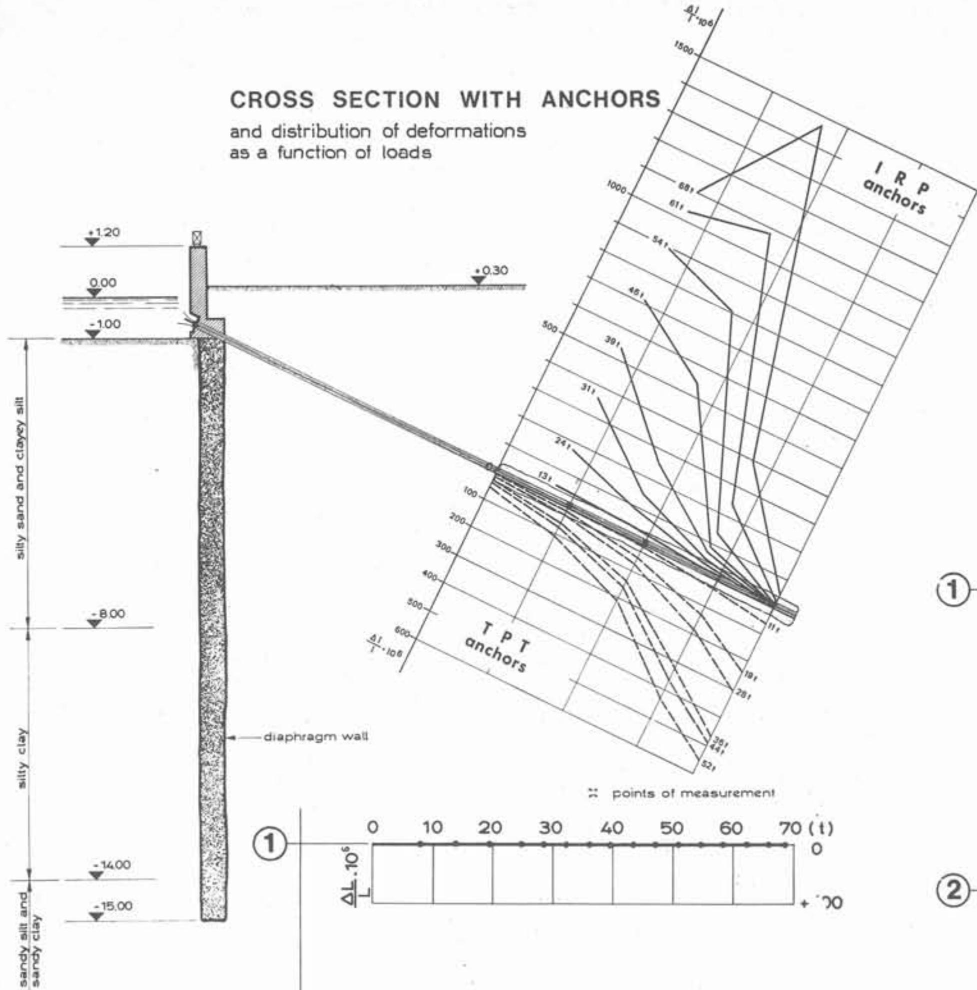


Fig. 6. — **Cross section with anchors. Position of points of measurements.**

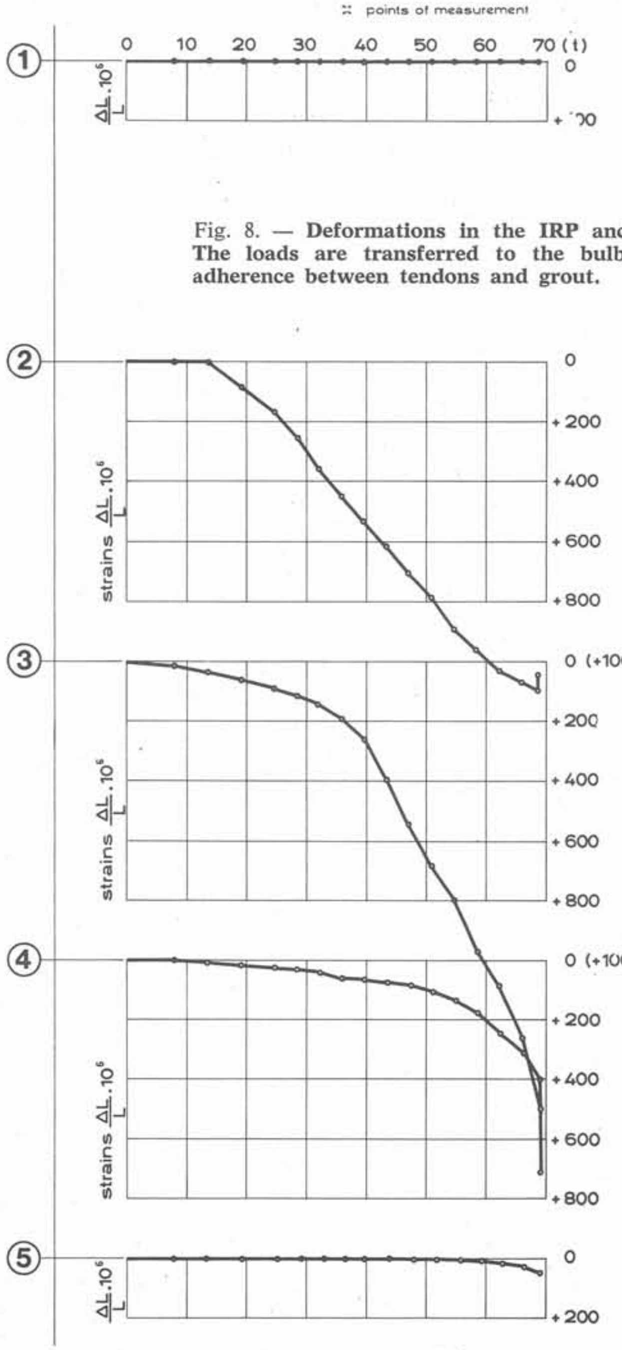


Fig. 8. — **Deformations in the IRP anchor. The loads are transferred to the bulb by adherence between tendons and grout.**

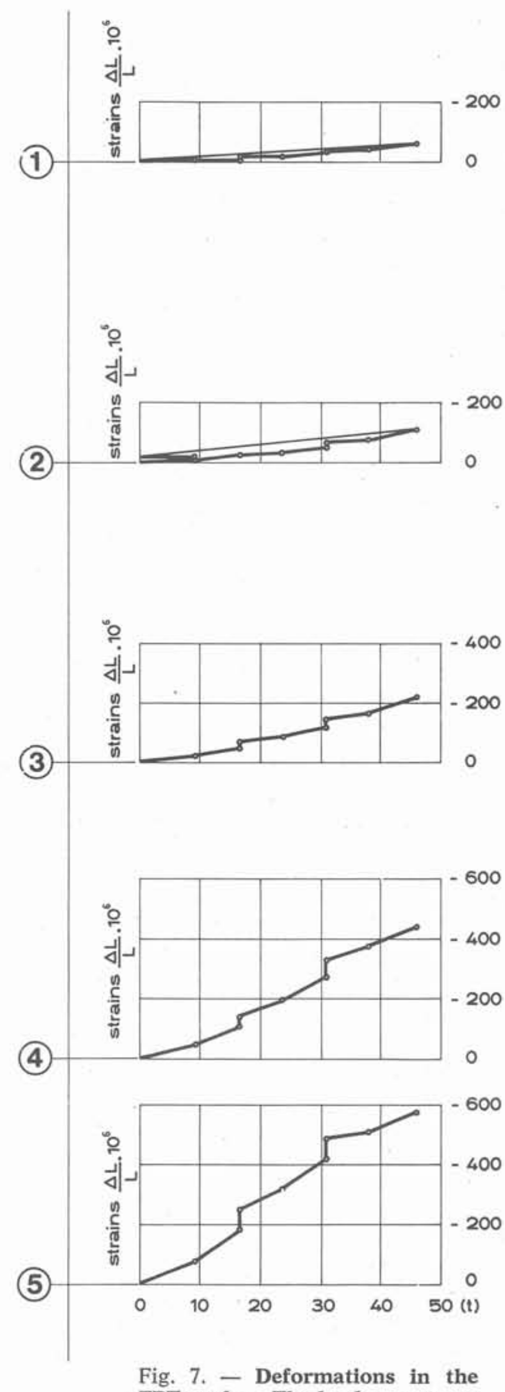


Fig. 7. — **Deformations in the TPT anchor. The loads are transferred to the bulb by a bottom steel plate. The measurement points are referred to those of fig. 6.**

AKNOWLEDGEMENTS

The authors wish to express their gratitude to Mr. Bellotti of the ENEL Laboratory of Niguarda for his research on triaxial stress states in grouting mixes, and to Mr. Jézéquel of Laboratoire des Ponts et Chaussées of Saint-Brieuc, for measurements taken by means of removable strain gauges.

REFERENCES

[1] COATES (D.F.) and YU (Y.S.). — «Three-dimensional stress distribution around a cylindrical hole and anchor», *Proc. 2nd Congress IRSM,* Beograd, vol. 3, Theme 6-7 (1970).

[2] FENOUX (G.Y.) and PORTIER (J.-L.). — «La mise en précontrainte des tirants», *Travaux,* n. 449/450, 33-43 (1972).

[3] JEZEQUEL (J.-F.), HERVE (G.) and LIBERGE (P.). — «Extensomètres amovibles pour la mesure des relations contraintes-déformations des pieux chargés verticalement», *Rapport interne Laboratoire Régional des Ponts et Chaussées* de Saint-Brieuc (1973).

[4] JORGE (G.R.). — «Le tirant IRP réinjectable spécial pour terrains meubles, karstiques ou à faible caractéristiques géotechniques», *Proc. 7th ICSMFE, Mexico,* Spec. Session 15, 159-163 (1969).

[5] OSTERMAYER (H.). — «Construction, carrying behaviour and creep characteristics of ground anchors», *Proc. Conference on Diaphragm Walls and Anchorages,* London, Sept. Paper 18, 141-151 (1974).