PANAMERICANO 2019
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XVI PANAMERICAN CONFERENCE ON SOIL MECHANICS AND GEOTECHNICAL ENGINEERING

Geotechnical Engineering in the XXI century: lessons learned and future challenges

Some experiences on the effect of re-injection on the load capacity of ground anchors

Author: José GONZÁLEZ, Rogelio MONROY, Sergio VILLAR, Jose CLAVELLINA & Juan PAULÍN
Soletanche Bachy México (CIMESA)

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The load holding capacity of a ground anchor is derived from frictional resistance developed in the soil-grout interface surface of the fixed length. In theory it is possible to calculate the load capacity by multiplying frictional resistance times the interface surface. However, it is not uncommon that actual geometry of the bulb differs from the theoretical one, depending on the characteristics of the soil and the construction method (specially injection pressure). High pressure injection has a positive effect on the load capacity, however, it must be done in a controlled manner given the effects it can have on the soil and surrounding structures

- ✓ **Load capacity T_u:** Is the load that can be applied by a structure to the soil that supports it
- ✓ **Ultimate load:** Is the maximum capacity of conventional tension stress to break the bulb length seal
- ✓ **Critical load:** is the tension from which large displacements begin to occur due to the creep of the soil in the anchor seal

$$T_u = k\pi DL\sigma'_V \tan\delta$$

T_u: Ultimate load
k: Load capacity increase coefficient
D: Drilling diameter
L: Bulb Length
σ'_u: Effective stress in the middle of the bulb
$\tan\delta$: Coefficient of friction

Constructive process

1. Drilling
2. Injection
3. Post - Injection
4. Tensioning

Primary injection (gravity) - Forms the bulb and a corrosion protection barrier

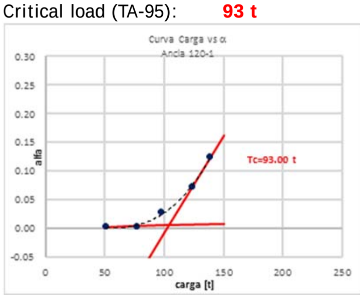
IGU (Unique global injection)

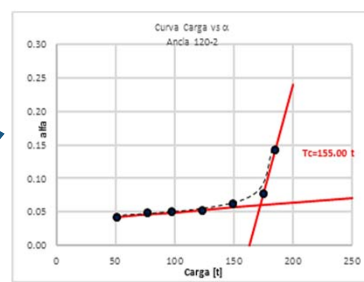
IRS (Repetitive Selective Injection)

Post-injection - Increases the frictional resistance of the bulb

Case study:

First injection (IRS): 13/05/17
Grout Consumption: 0 l
Tensioning: 17/05/17
*Maximum load not reached
Critical load (TA-95): **93 t**





second injection (IRS): 18/05/17
Consumption: 1634 l
Tensioning: 23/05/17
*The specified maximum load was not reached, but the penultimate step was reached
Critical load (TA-95): **155 t**

Conclusions:

- ✓ The construction method used affects the load capacity of the anchors, specially the injection pressure
- ✓ The IRS injection method allows to generate higher load capacities than IGU method
- ✓ Injection parameters can be determine or adjusted by performing tension tests
- ✓ The critical load allows to know the load limit value so that the creep phenomenon does not develop, preventing the anchor from losing its active force

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Philosophy of testing and tensioning of ground anchors according to international standards

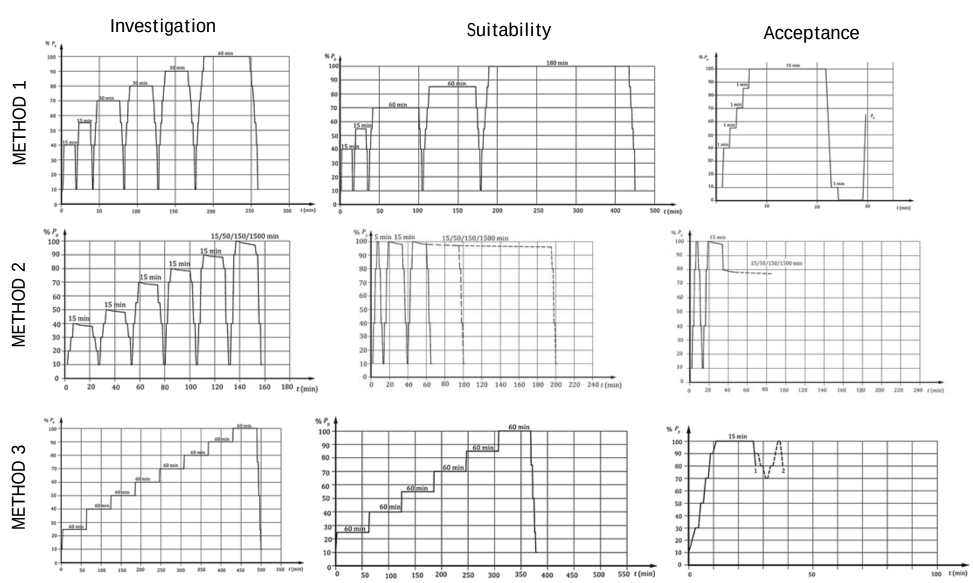
Author: Rogelio MONROY, José GONZÁLEZ, Sergio VILLAR & Juan PAULÍN
Soletanche Bachy México (CIMESA)

Ground anchors are geotechnical-structural elements with a unique characteristic: Their load capacity and ability to hold it in time without appreciable lost must be verified individually by testing it before going into service. By doing so, a good performance during service life can be expected, despite ground variability and construction method changes. Among the existing standards, those of Europe and the United States are highlighted. Regardless of the differences between them, they point to similar objectives, that is why strictly following any of them will generally lead to reliable results in practice.

Designation of different test kinds according to relevant standards and recommendations

DIN 4125 (1990)	TA 95 (1995)	FHWA (1999)	EN 1537 (2013)	PTI DC35.1 (2014)	BS 8081 (2015)
Proof	Rupture	-	Investigación	Pre-production	Investigation
Suitability	Control	Performance	Suitability	Performance	Suitability
Acceptance	Reception	Proof	Acceptance	Proof	Acceptance
In service	-	Lift-off	-	Lift-off	-

Test methods according to EN 1537:2013 / ISO 22477-5:2018



Remarks

- ✓ Every single production anchor must be tested with any of the foregoing methodologies in order to guarantee its load holding capacity during service life
- ✓ During testing it is important not to exceed the elastic limit of the tendon, so the plastic deformation of the steel does not get intermixed with that of the bulb, making it difficult to interpret the ground creep behavior
- ✓ Construction method directly incides upon load capacity (mainly injection pressure). If an important change is done a suitability test has to be made in order to verify that the anchor will continue to comply with the expected load capacity and creep behavior
- ✓ Knowing the critical load allows to establish in an accurate way the load value which must not be exceeded so the creep phenomena does not develop in such a way that the anchor loses its tension and capacity to exercise an active force

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Geotechnical Engineering in the XXI century: lessons learned and future challenges

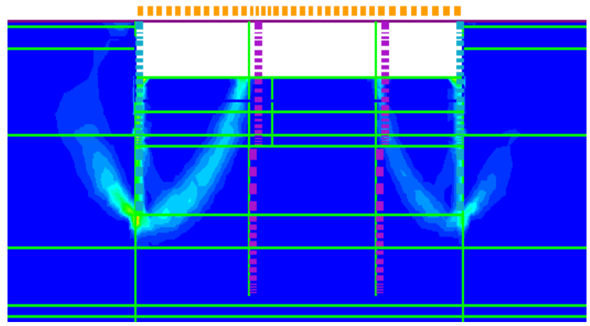
Propuesta de solución para resolver la excavación de un túnel somero de sección rectangular en suelos blandos

Autores: Sergio D. VILLAR SOLARES, Juan PAULÍN AGUIRRE
Soletanche-Bachy, México (CIMESA)

1) Problemática

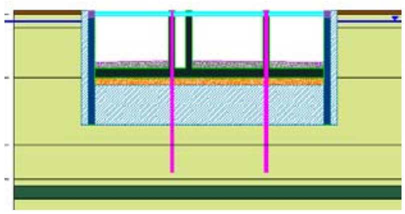
Mantener estable la construcción de un túnel somero, de sección rectangular, ubicado en suelos arcillosos blandos, evitando:

- Inestabilidad del fondo de la excavación por expansión.
- Falla por resistencia al esfuerzo cortante del suelo.
- Desplazamientos horizontales importantes en el muro.



2) Descripción del proyecto

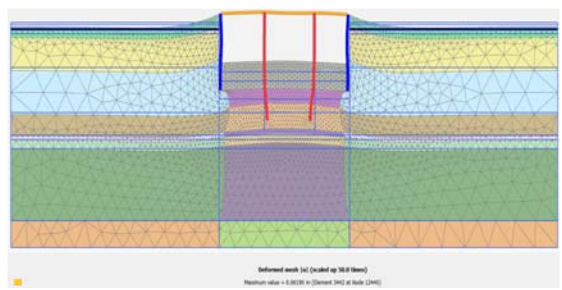
Construcción de Túnel de sección rectangular mediante muro Milán, Contrafuertes y Barrettes.



- Contrafuerte; l=38m, e=0.6m y s=@ 7m
- Prof. Máx. de desplante = 17m

3) Análisis del proceso constructivo con MEF

Modelo constitutivo (Mohr – Coulomb), análisis 2D, 3D



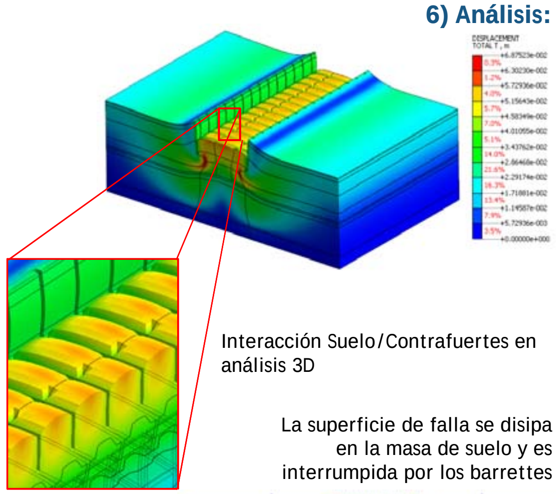
4) Proceso constructivo:

- Condición inicial
- Construcción de contrafuertes, muro Milán y barrettes interiores
- Excavación a la -2m y colocación puntales
- Nivel Máximo Excavación -11m
- Construcción de losa de fondo
- Muros divisorios (obra civil)
- Construcción de losa tapa

5) Idealización de contrafuerte en análisis 2D

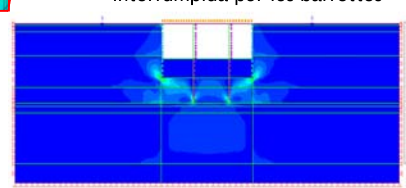
Ponderación de propiedades Contrafuerte-Suelo / 7m

6) Análisis:



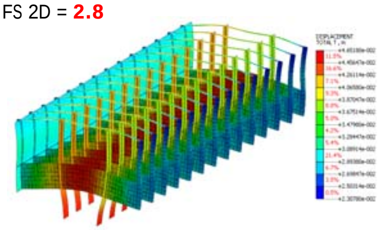
Interacción Suelo/Contrafuertes en análisis 3D

La superficie de falla se disipa en la masa de suelo y es interrumpida por los barrettes



7) Resultados

FS 2D = **2.8**



Desplazamiento Máximo en el Contrafuerte = 4.7cm

Desplazamiento de los barrettes al interior de la excavación de 4.6cm

8) Conclusión

La propuesta de contrafuertes garantiza la estabilidad de la excavación minimizando las expansiones del subsuelo, evitando la falla por resistencia al esfuerzo cortante del suelo y reduciendo los desplazamientos horizontales del muro Milán.