Panel discussion: Ground anchors in alluvial soil – What is practice today?

Débat de spécialistes: Tirants d'ancrage dans les alluvions – Les nouvelles techniques à ce jour?

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ABSTRACT: Results are presented of a random inquiry about anchor techniques used in different countries throughout the world.

RESUME: Les résultats présentés font suite a une étude des techniques employées dans de nombreux pays partout dans le monde.

Almost 40 years have passed since the first ground anchors were used for an unbraced excavation in Munich in 1958. Today the anchor has spread worldwide and has undergone various developments. A random inquiry in several countries has led to interesting results, which are summarized in table 1. The definitions are shown in Fig. 1.

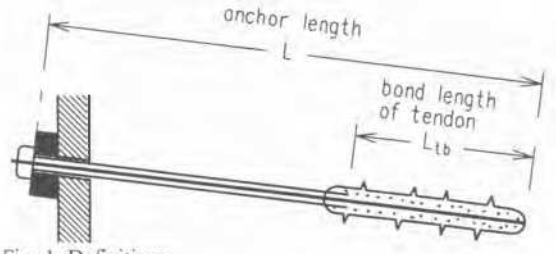

Fig. 1. Definitions

The inquiry asked for the most commonly used steel tendon, the average anchor length, the maximum anchor length installed, the average bond length of the tendon, the max. anchor design loads (not test loads) used in various soils and the estimated total anchor length carried out per year. Every answer obtained was a statement or best guess for the whole country, not for an individual company.

The following may be observed:

- The strand has taken the lead as steel tendon.
- The 0,6"-strand seems to replace the 0,5" size.
- The characteristic values of the steel strength (yield, ultimate) differ by 5 to 6,5 %.
- The average anchor length depends mostly on the geology of the country.
- The maximum anchor forces as well as the bond lengths of the steel tendons used in different countries vary by a great amount. This is partly due to the local geology and partly due to different design concepts. The maximum anchor loads used seem to

Table 1. Most common anchor practices in various countries throughout the world

Country	Steel Strand f_y / f_u	l (Ave.) (m)	l_{max} (m)	l_{tb} (m)	F_{max} -gravel/sand silt/clay (kN)	Total Anchor Length per year (km)
Austria	0,6" 1570/1770	20 (13 - 25)	80	6 (4 - 8)	1200/800 - 500/400	80
France	0,5" 1660/1860 0,6" 1570/1770	18	90	10 (5 - 20)	1700/1250 - 700/600	400
Germany	0,6" 1570/1770	16	80	5 (4 - 10)	1200/1100 - 500/400	1500
Italy	0,6" 1580/1780	20	70	8 (3 - 15)	1600/1400 - 1100/900	400
Spain	0,6" 1670/1860	15	70	7 (4 - 12)	1500/1200 - 800/500	200
Sweden	0,6" 1580/1780	12	45	6 (5 - 7)	650/500 - 400/250	50
Switzerland	0,5" 1640/1820 0,6" 1570/1770	15	65	6 (4 - 10)	950/800 - 550/500	120
United Kingdom	0,5" / 0,6"	30	70	7 (6 - 8)	1000/800 - 400/800	200
Japan	0,5" 1570/1860 0,6" 1640/1860	20	100	7 (3 - 10)	1200/1000 - 400/350	>1000
Malaysia	0,6" 1580/1780	30	50	6 / 20* (5-7) (15-25)	-/- - 1000/1000	400
USA	0,6" 1580/1860	15	30	5 (5 - 15)	1100/950 - 630/780	100

* with post-grouting

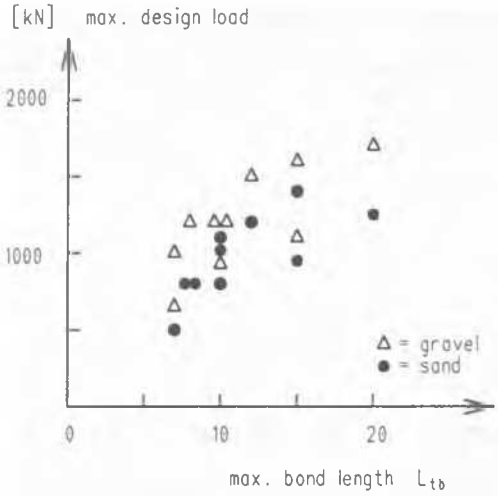

Fig. 2. Maximum design loads vs. maximum bond lengths

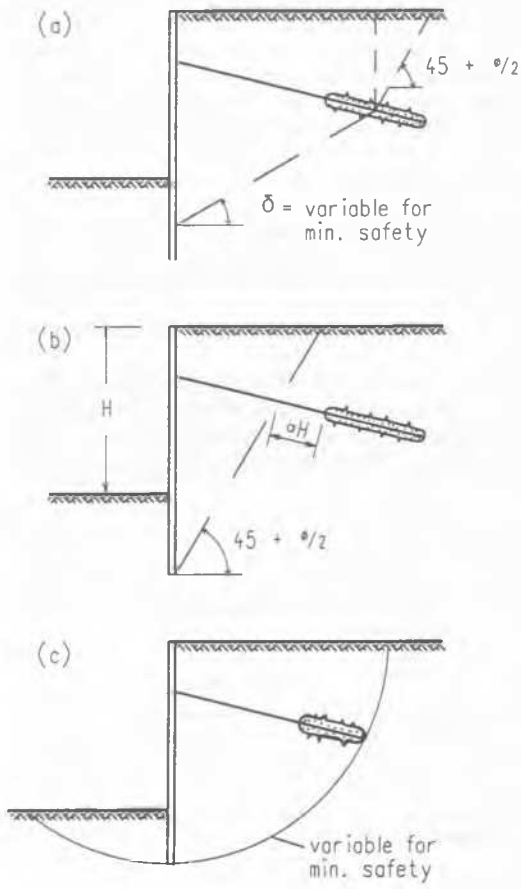

Fig. 3. Various design models for determining the anchor lengths

be proportional, though not linearly proportional, to the bond lengths of the tendon (Fig. 2). A profound evaluation was not possible due to the lack of detailed data. Some countries report of even higher maximum anchor loads when using special post-grouting techniques and drilling diameters larger than 200 mm.

Another question was raised with respect to the most common design model used in each country. The methods used, with small variations, are shown in Fig. 3 and table 2.

In table 2 retaining wall techniques are listed which are most competitive with "anchored" structures.

The methods of the corrosion protection of permanent anchors seem to become relatively similar world-wide.

Table 2. Most common design methods and competitive systems

Country	Design Model	Competitive Techniques		
		Bracing, cut and cover	Micro-Piles	Soil nailing
Austria	a	x	x	x
France	a b c	x	x	
Germany	a c	x	x	x
Italy	b	x	x	x
Spain	b	x		
Sweden	b			x
Switzerland	a c	x		x
United Kingdom	a b c	x	x	x
Japan	a b c	x		x
Malaysia	a c	x		x
USA	b			x

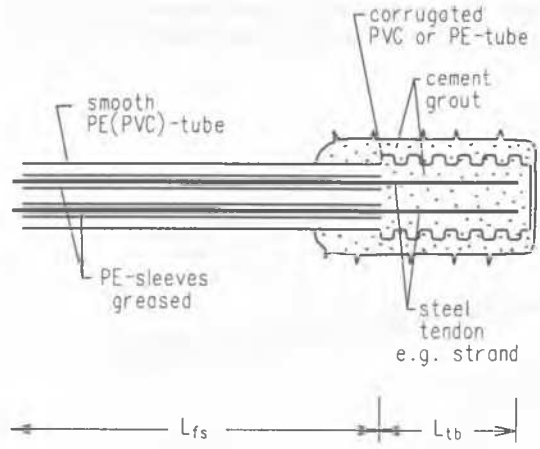

Fig. 4. Most common system of corrosion protection for permanent anchors

There are some special anchor types, as for instance compression-tube anchors in Germany or the compression-type anchor in Japan, but the majority of the corrosion protection system corresponds to Fig. 4.

The following corrosion protection within the bond length of the steel tendon is used:

- A corrugated PVC- or PE-tube surrounding the steel tendon and filled with cement mortar protects the steel.
- In the United Kingdom a double duct system, consisting of two concentric corrugated plastic tubes, both filled with cement mortar, is used frequently to increase the safety against corrosion
- In France a steel tube, deformed or smooth and equiped with post-grouting valves, often replaces the corrugated PVC- or PE-tube

The corrosion protection along the unbonded length of the steel tendon consists of:

- Corrugated, smooth or both tubes of PVC or PE guarantee the corrosion protection and the freedom of deformation along the unbonded length of the tendon. These tubes are filled with ce-

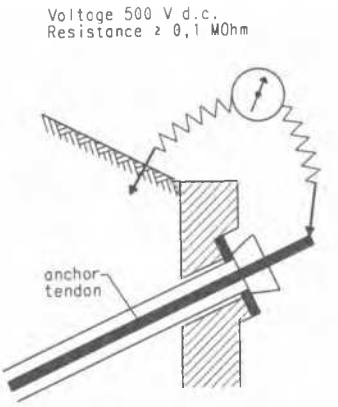

Fig. 5. Electrical resistance test for determining the effectiveness of the corrosion protection

Fig. 6. Test after prestressing the anchor

ment mortar or corrosion-protective material. In addition, the tendons, mostly strands, are encased by greased PE sleeves.

- One system which is mainly used in Switzerland should be mentioned as new development. With an electrical resistance measurement between the surrounding soil and the steel tendon, the intactness of the corrosion protection can be measured before installing the anchor tendon into the bore hole, after grouting, after testing and even years afterwards (Fig. 5 and Fig. 6). This gives an additional safety.

The ground anchor has become an almost irreplaceable structural element in foundation engineering. Its quality has reached a very high level. Therefore it was possible and desireable to produce a common European code which specifies the minimum and required standards. This code will be published as EN 1537 early in 1998 and will be available in English, French and German.