40 YEARS OF MICROPILING, 20 YEARS OF SOIL NAILING WHERE DO WE STAND TODAY?

40 ANS DE MICROPIEUX, 20 ANS DE CLOUTAGE DES SOLS OU EN SOMMES NOUS AUJOUR D'HUI?

M.F. Stocker

Technical Director
Bauer Spezialtiefbau GmbH
Schrobenhausen, Germany

SYNOPSIS: This paper is an attempt to give a short summary on the present state of the art, on problems and tendencies of micropiling and soil nailing

MICROPILES

Micropiles were introduced for the first time in Italy in 1952 in the form of so called root piles. This happened approximately at the same time when the technique of bored piles was revolutionized by introducing large drilling rigs with grabs and later strong rotary drilling machines. It also happened six years before the invention of the prestressed soil anchor.

Today micropiling is a very popular and steadily increasing technique in many countries.

There is no generally valid definition of micropiles. But their characteristics may be described as follows:

- pile diameter between 90 and 300 mm
- installation by drilling, driving or vibrating with small rigs
- installation must be possible under restricted access and head room (basements). Thus, driven precast concrete piles or long steel piles do not count as micropiles, even if their diameter is less than 300 mm.

Micropiles may be divided into five major categories according to the table below. The main application is

- reinforcing or strengthening of foundation structures of old or historic buildings
- strengthening of foundations to increase their load capacity
- underpinning of structures
- lifting of structures which have settled
- foundation of structures with difficult access for heavy equipment
- using micropiles instead of prestressed anchors (e. g. against uplift)
- reinforcing of soil to form a retaining structure (Italy)
- increasing slope stabilities before, during or after landslides.

The use of micropiles in Europe seems to be rising mainly due to the facts, that more and more historic buildings have to be secured or restored and the use of anchors is often replaced by micropiles.

Micropiles have been installed to depths of more than 50 m, but the main application lies between 6 to 15 m. Although the slenderness ratio may range between 50 and 200, buckling seldom has to be considered. According to several investigations and specifications buckling of the pile has to be considered only if the undrained shear strength of the surrounding soil is less than 10 kPa, i. e. in very soft soil.

One useful development made in recent years should be mentioned. It is possible to lift buildings or parts of them after they have suffered severe settlements via prestressing devices at the pile head. The pile is not only preloaded to avoid any further settlement, but the structure (existing floor slab or foundation) is lifted against the piles. This may be carried out simultaneously on as many as 20 piles or even more by programming, controlling and monitoring the amount of lifting at each pile. After the correct elevation has been reached, the foundation is locked off versus the pile heads. The hollow space below the building is filled with grout.

A research project conducted at the Technical University of Munich between 1982 - 1988 indicates that micropiles subjected to dynamic loading in medium dense sand may lose their bearing capacity rather suddenly as late as 200 000 load cycles after the first loading. If dynamic loading is to be expected, care should be taken when the cyclic portion of the load is greater than 20 - 30 % of the creep limit load of the pile. This is valid both for cyclic loads in compression and tension (one way) and for cyclic alternating loads.

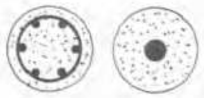
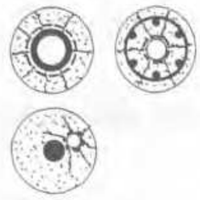
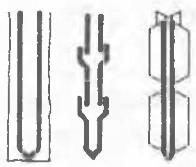
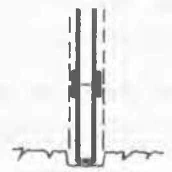
	GROUTED PILE	POST-GROUTED PILE	DRIVEN, VIBRATED STEEL PILE	EXPANDER PILE	STEEL CORE PILE
FORM OF PILES USED TODAY					
FIRST APPLICATION	1952	1970 - 1975	1970 1982	1983	1982 (?)
PILE DIAMETER [mm]	89 - 280	114 - 280	76 118 275 170	114 - 168 folded: 50/80/110 expanded: 300/500/800	168
REINFORCEMENT [mm]	16, 20, 25 GEWI 28, 32, 36 40, 50, 3 x 40/50	70/89-157/178 16,20,25 GEWI 32, 40, 50 3 x 40/50	68/76 98/118 275 148/170	Tubes 89/101 98/118 120/140 and similar	95
STEEL GRADE fy/fu [MPa]	420/500 500/550 835/1030	560/650 420/500 500/550 835/1030	420/500 340/450 270/410 ductil iron		270/530
POST-GROUTING DEVICE	—	Tube à manchettes + packer Post-grouting tubes	—	Inflation of bulb with cement grout	—
ALLOWABLE WORKING LOADS IN COMPRESSION [kn]	up to 1100 1680	up to 1100 1680	170 450 100 900 150	140 - 900	1100
USUAL INSTALLATION	rotary flush drilling, withdrawing of casings with air- or grout pressure	rotary flush drilling	driving or vibrating with or without simultaneous grouting at the tip	driving or vibrating steel pipe with expander body folded	drilling down to rock with casing. Inserting steel core, driving steel core into rock, grouting of borehole

Table 1: Classification of Micropiles with the most common types of piles.

SOIL NAILING

Soil nailing, first carried out in France in 1973 and scientifically investigated in Germany from 1975 to 1979, is used more or less worldwide today as an economic method of building retaining walls.
By the end of 1992 approximately 100 000 m^2 have been constructed in France, 140 000 m^2 in Germany, 8 000 m^2 in Great Britain, 55 000 m^2 in Switzerland, 100 000 m^2 in Japan and 250 000 m^2 in USA.
Although the American, French and German design methods still differ, an agreement has been reached after a long scientific dispute in so far, that the nails in a retaining structure carry primarily by axial tension and not by shear. The shear capacities of the nails in a possible failure (slip) plane are activated only after much larger deformations than the tensile forces. Therefore, they should not be considered in design.
The various design methods have proven to be adequate. Only very few local failures or larger deformations have been reported, and these were caused mostly by bad workmanship or by careless soil investigation.
The future trend will go towards a wider spacing of the nails with increasing heights of the walls, more economic design of the concrete facing and more aesthetic appearance of the wall face. The fairly simple design and production method with little expenditure of equipment makes soil nailing an ideal method for technically less developed countries.
Although nails with lengths up to 26 m have been carried out, the usual length varies between 2 and 8 m. The spacing of the nails ranges normally from 1 to 3 m.

Combinations of prestressed anchors and nails are used frequently, especially when underpinning buildings with heavy loads.
Walls up to 20 m in height have sucessfully been carried out in alluvial soils. The wall faces have withstood strong frost-thaw changes during the wintertime without damage (North America, Switzerland), although horizontal movements (breathing) of the walls up to 20 mm have been recorded.

Vibrations caused by traffic loads on top of a nailed wall do not decrease the stability of the wall. This could be shown in a large-scale test in sand of medium density.
During the Loma Prieta earthquake in San Francisco on October 1989, eight soil nailed walls were in existence in this region, with wall heights between 2,7 and 9,8 m. None of them was damaged. The magnitude of the earthquake was 7,1. The maximum horizontal ground acceleration was in the order of 0,47 g.
Soil nailing is used successfully today in securing historic walls. It can be done by setting plugs behind the existing wall, so that the appearance of the historic wall face does not suffer.
The name of soil nailing is sometimes applied for a more or less vertical reinforcement of the soil in the way micropiles are installed for slope stabilizations or the increase of the bearing capacity of foundations. This has little to do with the original soil nailing, in which the nails have been designed for tensile forces only, and not for shear forces. If the nails are designed for shear or dowelling effects, the method should be called soil reinforcement as this is done, when micropiles are used for such cases.