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Session 3 on Design

Excerpts from IWM 2000 at Ube:

- Vertical loading (grouting effect, pull-out,...) (11)
- Horizontal loading (2)
- Structural capacity (2)
- Seismic (liquefaction, lateral loading,...) (5)
- Network (or cònfinement) effect (2)
- Tunneling (1)
- Corrosion

Vertical loading:

"it is…recommended to perform…load tests…as well as ang group configuration, if possible" (Mason and Kulhawy)

"…results primarily from the micropile pressure grouting installation effects…" (Kulhawy and Jeon)

"…it is important…the collection and assembly of data from tests in situ" (Hoshiya et al)

"Shaft resistance of CSG piles approximates to drilled and post-grouted micropiles" (Lehtonen)

"…the bearing capacity [of large diameter bored piles] is largely lower…of HP injected micropiles" (Pagliacci)

"It is necessary...to formulate a design standard for bearing capacity" (Oka)

"…the closer the angle to vertical, the greater the load strength" (Morikawi et al)

"…conduct tests…for…calculation methods for bearing capacity and determination of SF" (Nakata and Kishishita)

"If skin friction is to be increased…take measures such as increasing interlocking between the ground and piles" (Watanake and Sakamoto)

(Pull out…)

"For the group tests no significant difference between center and corner piles…could be observed" (Herbst)

"Although the mechanism…is not well understood…the post-grout is expected to improve the shear strength of the…interface" (Misra et al)

Horizontal loading:

"…in cases where to obtain the identical…lateral strength, enough piles to provide…diameter ratio identical…are necessary" (Fukui et al)

"…it is necessary to accumulate data obtained from field horizontal loading tests, etc." (Yamane and Togawa)

Structural capacity:

"[high capacity] steel tube core which improves load performance of axial and bending resistance…" (Murata et al)

"[it] is a function of deformation characteristics of the surrounding soil" (Korkeakoski and Eronen)

Tunneling:

"…wide recognition and realization of their safety excavation and minimized settlement with the [umbrella forepiling] methods" (Iwao Nakahara)

Seismic (liquefaction, lateral loading,…)

"…the pile should sustain the ground deformation, which requires piles with flexibility micropiles meet the requirements" (Miura)

"…the effect of the reduction of soil spring due to liquefaction on the decrease of the critical load is significant." (Zhu and Miura)

"It is therefore our responsibility to assimilate new findings for improvement of our design approach. As non linearity of structures and grounds need to be considered our design method has become very complicated" (Nishimura)

"…by dynamic response analysis…high capacity Micropiles proved to have high ductility and resistance against earthquakes" (Kishishita et al)

"…such high strength steel piles…are expected to improve the dynamic behaviors of foundations" (Kawamura and Jiang)

Network (or cònfinement) effect:

"…must be quantified and the application of micropile networks as a measure to prevent liquefaction must be studied" (Ichimura et al)

"In the case of dense ground, bearing capacity is improved remarkably,…" (Tsukada et al)

IWM 2000, Turku, Finland

Recent issues about micropile design:

1. Bearing capacity of high pressure micropiles
2. Design according to ECϕ + EC7
3. Investigation into the behaviour of groups and networks (FOREVER)
4. Calculation of group settlements (FOREVER)

FORVER

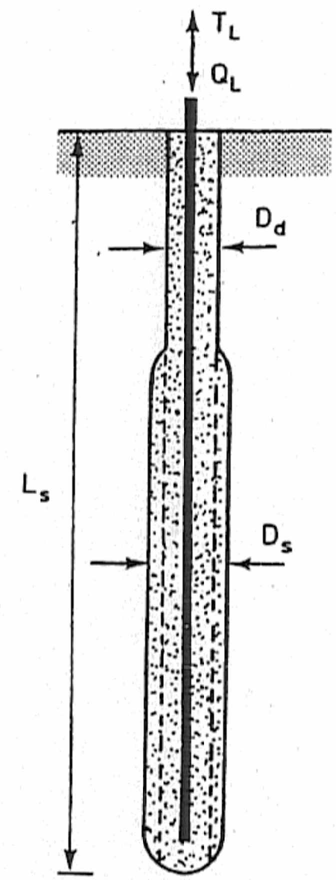
Projet National : Renforcement des sols par micropieux

$$D_s = \alpha \, . \, D_d$$

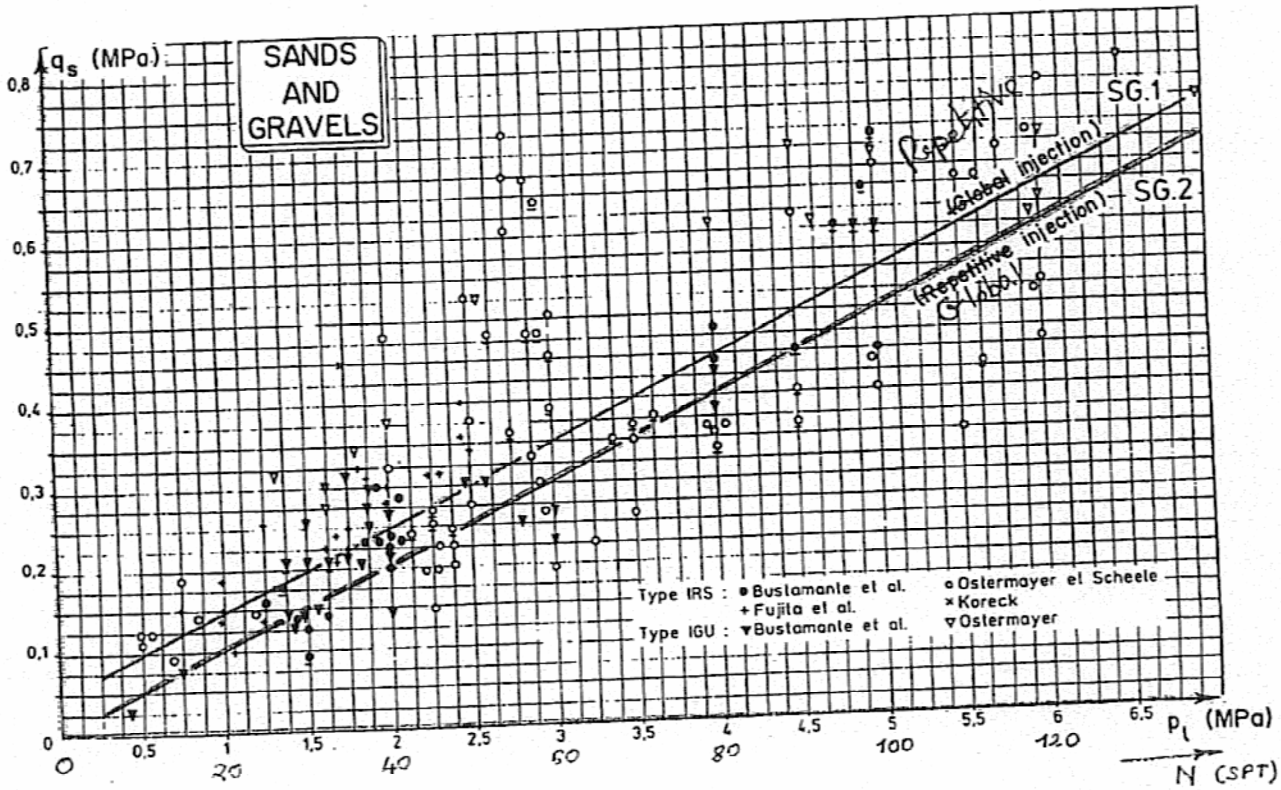
SOILS	α Coefficient	
	Repetitive injection	Global injection
ravel	1.8	1.3 to 1.4
andy gravel	1.6 to 1.8	1.2 to 1.4
ravely sand	1.5 to 1.6	1.2 to 1.3
oarse sand	1.4 to 1.5	1.1 to 1.2
ledium sand	1.4 to 1.5	1.1 to 1.2
ine sand	1.4 to 1.5	1.1 to 1.2
ilty sand	1.4 to 1.2	1.1 to 1.2
ilt	1.4 to 1.6	1.1 to 1.2
lay	1.8 to 2	1.2
Marl	1.8	1.1 to 1.2
Marly limestone	1.8	1.1 to 1.2
halk	1.8	1.1 to 1.2
Altered rock	1.2	1.1

FOREVER

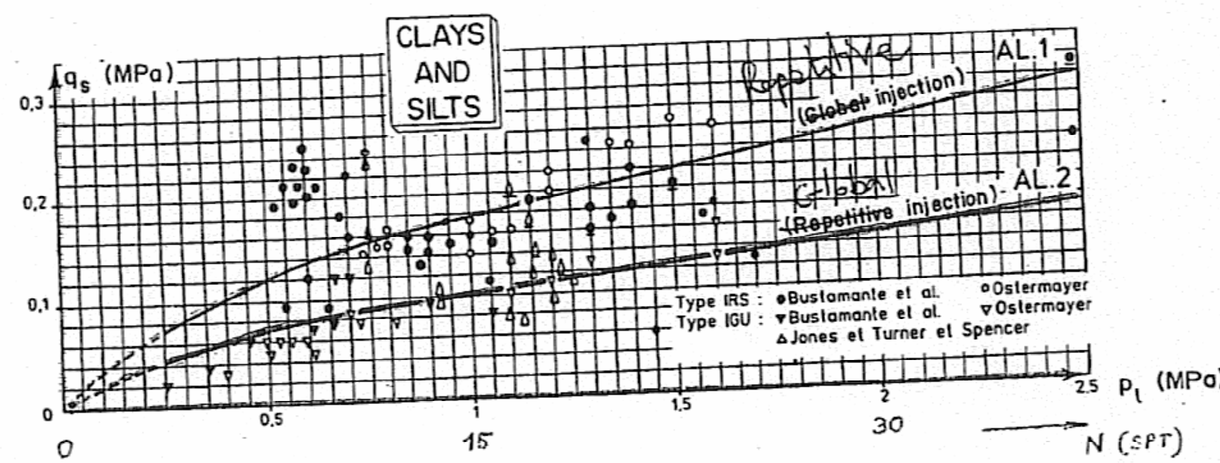
Projet National : Renforcement des sols par micropieux



GEOMETRICAL FEATURES OF A MICROPILE

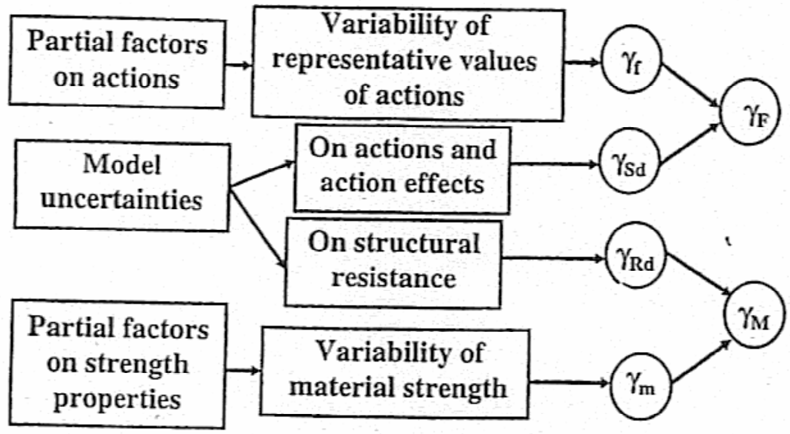


FOREVER
Projet National : Renforcement des sols par micropieux



EN1990 - Basis of Design

Partial factors



Ultimate limit states

Axial capacity of piles

Partial factors on actions :

$F_d = \gamma_F F$

Partial factors on ground property :

$R_d = R_k/\gamma_t$

(or $R_d = R_{bk}/\gamma_b + R_{sk}/\gamma_s$)

Characteristic value from pile load tests :

$R_k = R_m/\xi$

Thus : $F_{d(ULS)} < R_d$

leads to :

$F < R_m/\gamma_F.\gamma_t.\xi = R_m/FS$

Table A.1 Partial factors (γ_F) on actions or effects of actions for STR and GEO

Parameter	Symbol	set S1(B)	set S1(C)[1]	S2[2]	S3[3]
Permanent, unfavourable	γ_G	1.35	1.00	1.35	1.35
Variable, unfavourable	γ_Q	1.50	1.30	1.50	1.50
Permanent, favourable	$\gamma_{G;fav}$	1.00	1.00	1.00	1.00
Variable, favourable	$\gamma_{Q;fav}$	0	0	0	0

[1] See also Table A.3

[2] These factors are applied to all actions or effects of actions .

[3] Applying S3 to the actions on/from the structure, simultaneously, S1(C) for actions from the ground.

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Table A.5 Partial factors for pile foundations

Partial factors for actions and effects of actions: see Table A.1

Model factors: see Tables A.2

Partial material factors (γ_M): not applicable for calculation method given in Section 7.

Partial resistance factors (γ_R)

Pile system	Resistance parameter	Symbol	~~G1~~ S1(B)	~~G1~~ S1(C)	~~G2~~S2	~~G3~~S3
Driven	base	γ_b	1.00	1.30	1.10	1.10
	shaft	γ_s	1.00	1.30	1.10	1.10
	total	γ_t	1.00	1.30	1.10	1.10
	tensile	$\gamma_{s;t}$	1.25	1.60	1.15	1.15
Bored.	base	γ_b	1.25	1.60	1.10	1.10
	shaft	γ_s	1.00	1.30	1.10	1.10
	total	γ_t	1.15	1.50	1.10	1.10
	tensile	$\gamma_{s;t}$	1.25	1.60	1.15	1.15
CFA	base	γ_b	1.10	1.45	1.10	1.10
	shaft	γ_s	1.00	1.30	1.10	1.10
	total	γ_t	1.10	1.40	1.10	1.10
	tensile	$\gamma_{s;t}$	1.25	1.60	1.15	1.15

draft prEN1997-1

Labo 35

Table A.6a Correlation factors ξ to derive characteristic values from static pile load tests (N - number of tested piles)

ξ for N =	1	2	3	4	≥ 5
ξ_1	1.40	1.30	1.20	1.10	1.00
ξ_2	1.40	1.20	1.05	1.00	1.00

Table A.6b Correlation factors ξ to derive characteristic values from dynamic impact tests[1,2,3,4,5]

ξ for N =	≥ 2	≥ 5	≥ 10	≥ 15	≥ 20
ξ_3	1.60	1.50	1.45	1.42	1.40
ξ_4	1.50	1.35	1.30	1.25	1.25

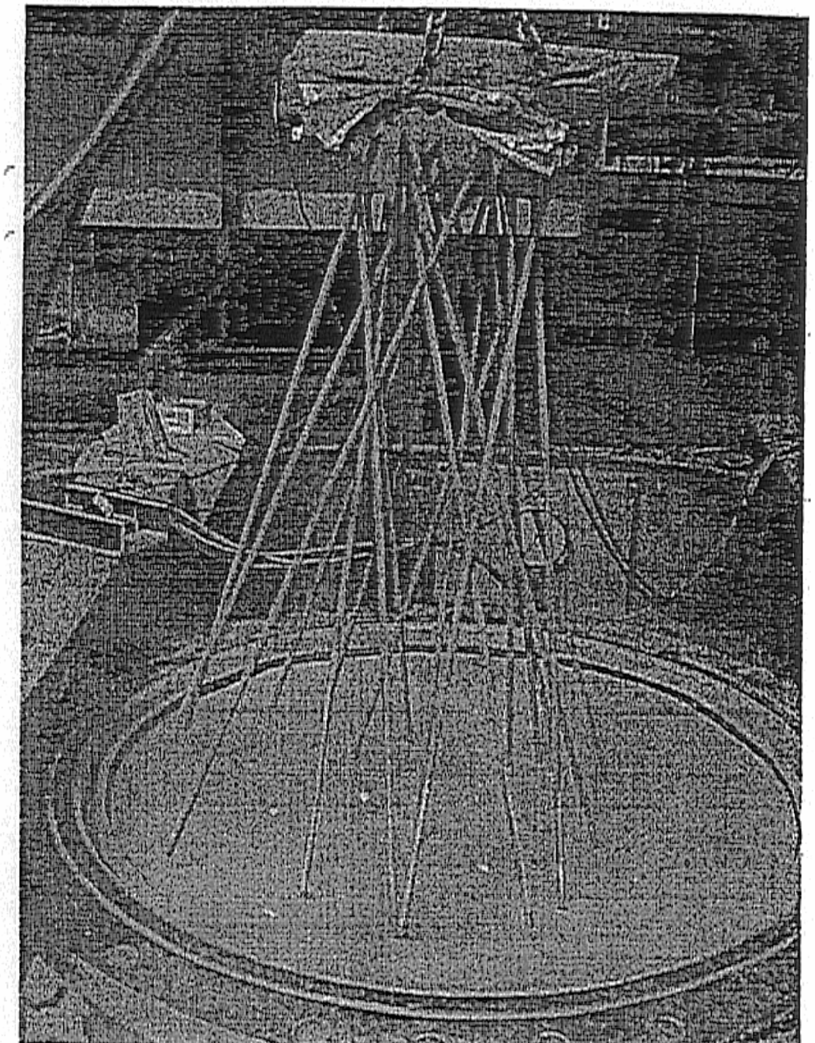
1 The ξ-values in the table are valid for dynamic impact tests.

2 The ξ-values may be multiplied with a model factor = 0.85 when using dynamic impact tests with signal matching.

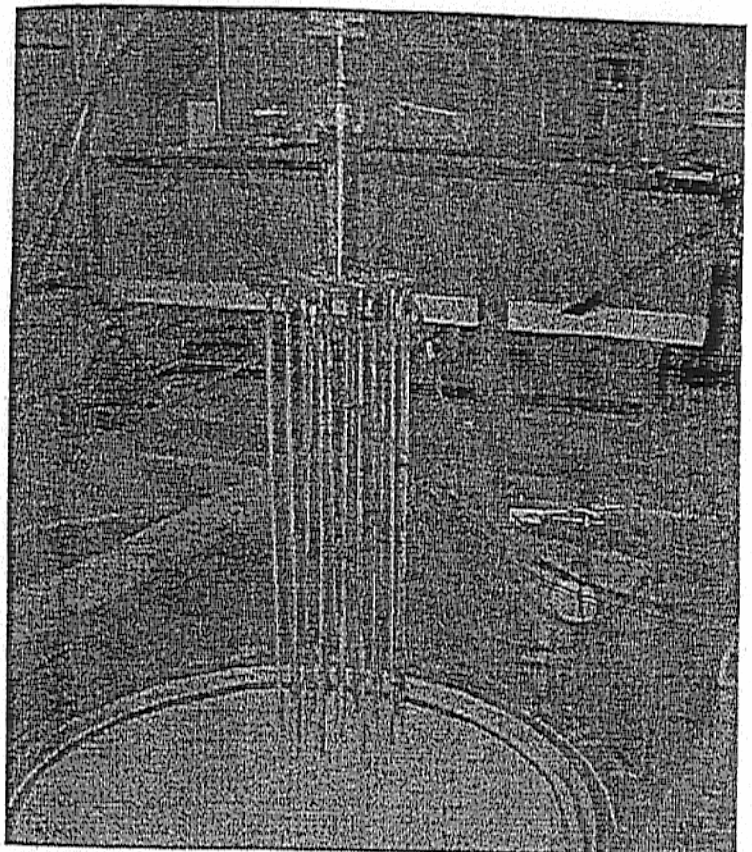
3 The ξ- values should be multiplied with a model factor 1.10 when using a pile driving formula with measurement of the quasi-elastic pile head displacement during the impact.

4 The ξ-values shall be multiplied with a model factor = 1.20 when using a pile driving formula without measurement of the quasi-elastic pile head displacement during the impact.

5 The number N of test piles should be determined among similar piles in the foundations of similar structures in similar ground conditions.Note: The numbers in the subscripts above are informative and should be checked by national experience.



Labo 3S



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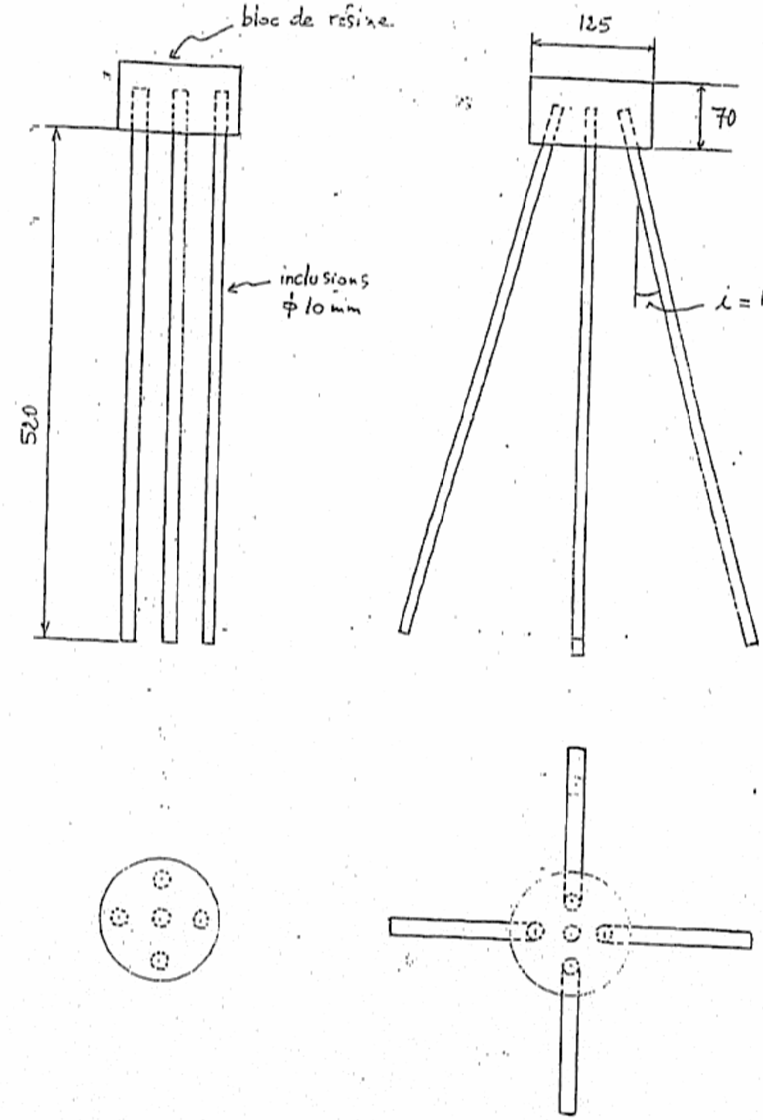

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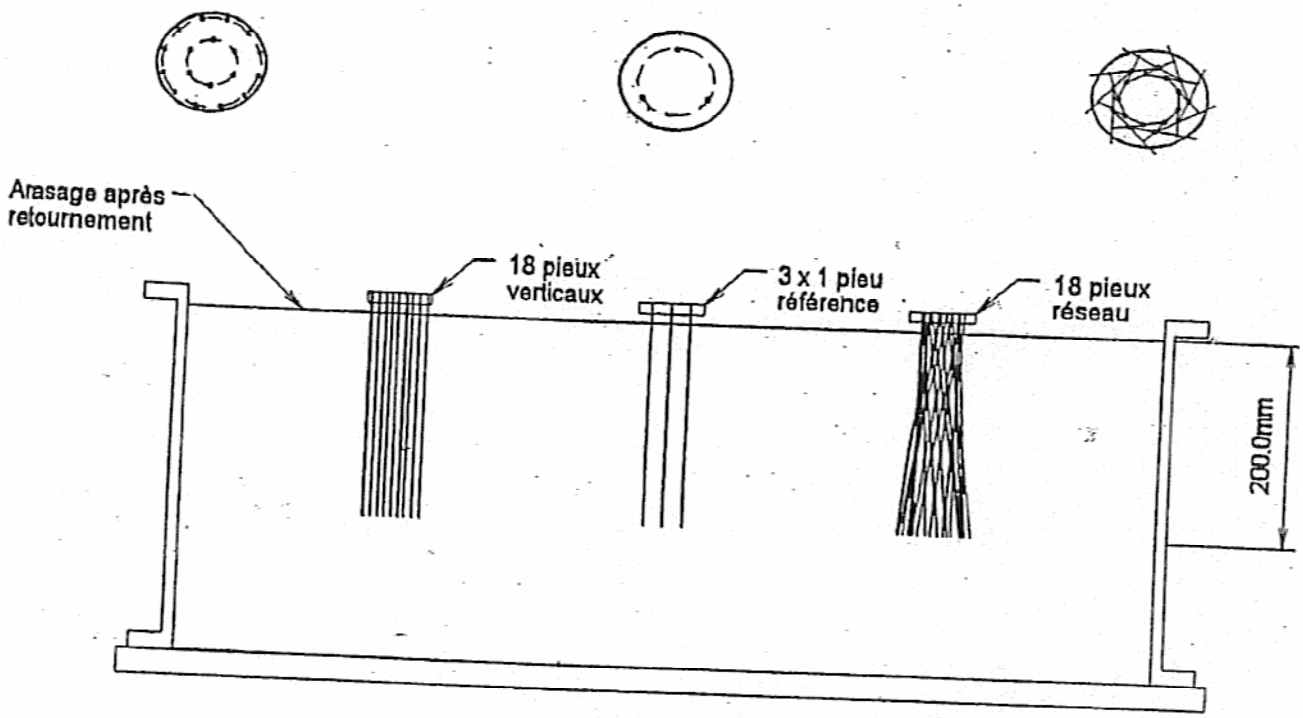


GROUPES

Coefficients d'efficacité

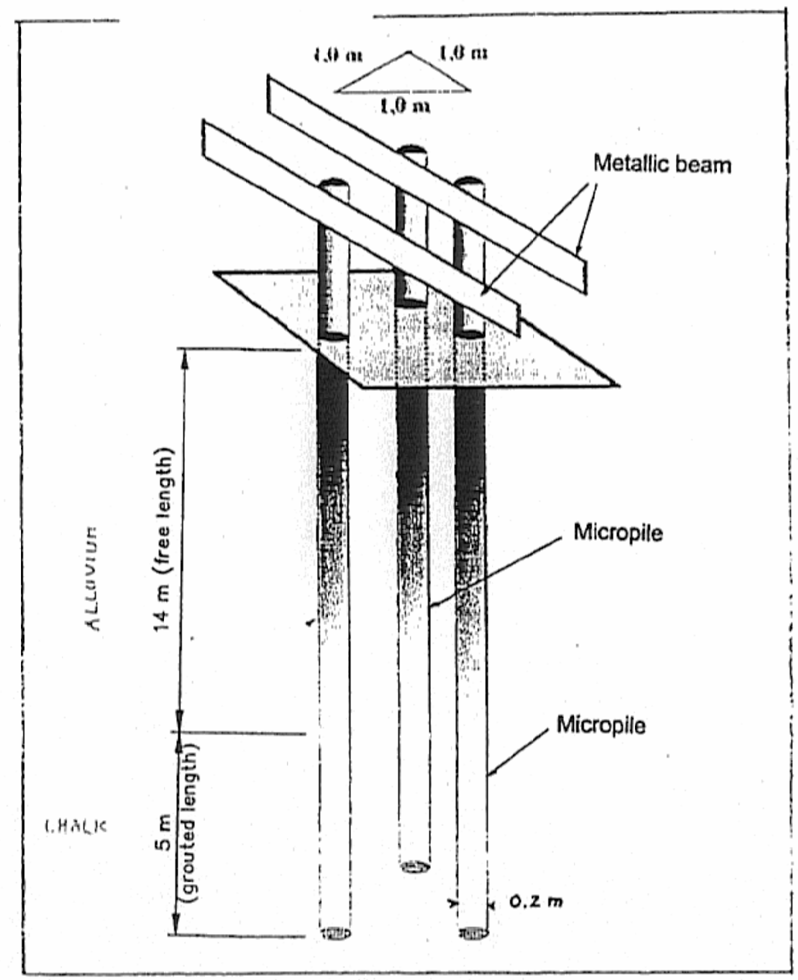
	e	C_T	C_P	C_S
Elément de base	2 à 4 d	0,8 à 1,1	0,6 à 1	1,4 à 3
Groupes	3,5 d	1,6 à 1,9	< 1	2,6
LIZZI	3,5 d	1,68		

Réseaux

Coefficients d'efficacité

	CEBTP	LCPC	L3S	LIZZI
Elément de base	0.69	0,86		
Réseau de 18 micropieux		1,31	1,74 *2,55*	2,22

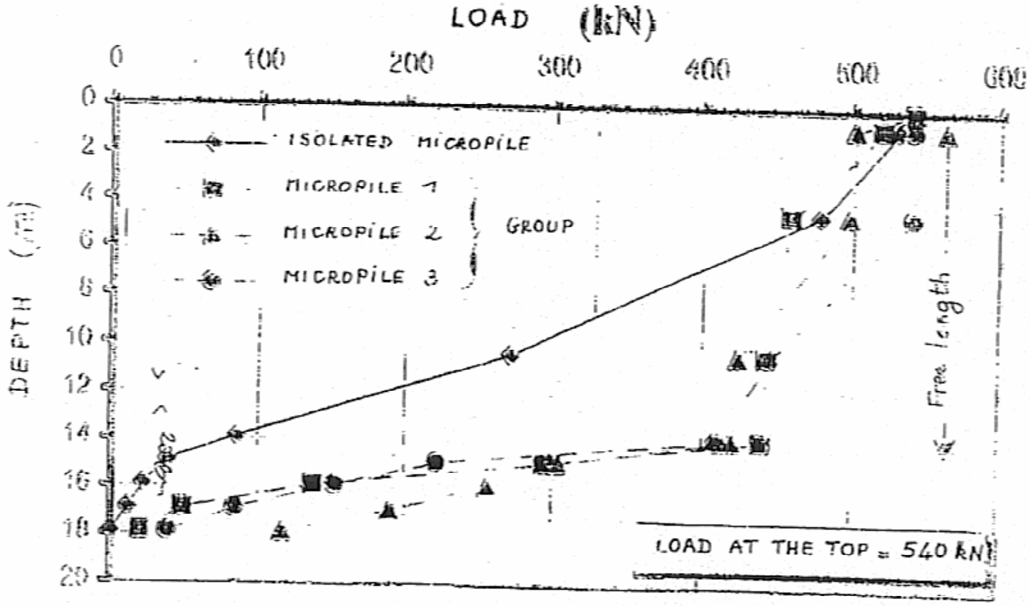
LOAD TEST ON A GROUP OF 3 MICROPILES RUEIL-MALMAISON



LOAD ON EACH PILE = 540 kN

3 MICROPILE GROUP

BEHAVIOUR OF THE FREE LENGTH



MICROPILE GROUP ANALYSIS (Goupeg code)

- FRANK and ZHAO side function
- $G_o/G_H = 10$ for micropile interaction (Frank, 1985)