3° C.F.P.B.

3° CONGRESO - SEMINARIO INTERNACIONAL DE FUNDACIONES PROFUNDAS DEL 27 AL 29 DE ABRIL DE 2017

SIMSG ISSMGE

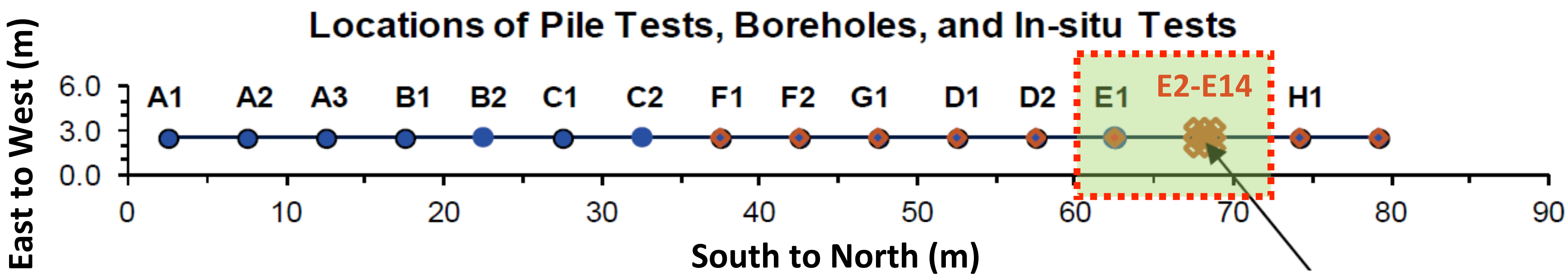
BOLIVIAN EXPERIMENTAL SITE FOR TESTING (B.E.S.T.)

SESSION 3: Experimental Results and Predictions

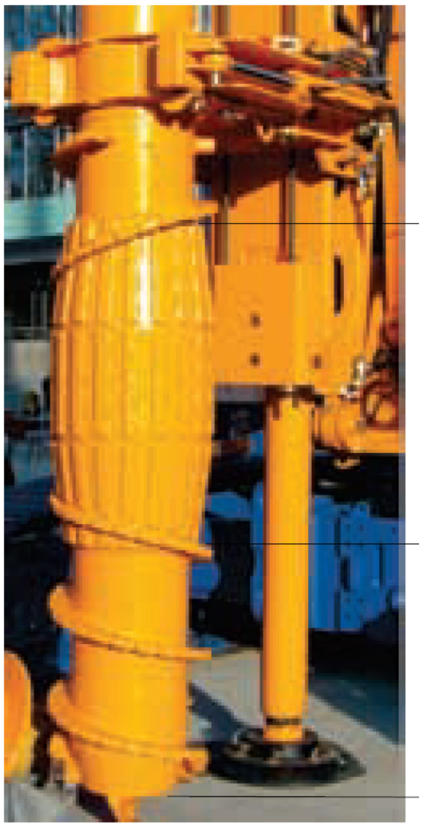
Pile Group and Piled Raft

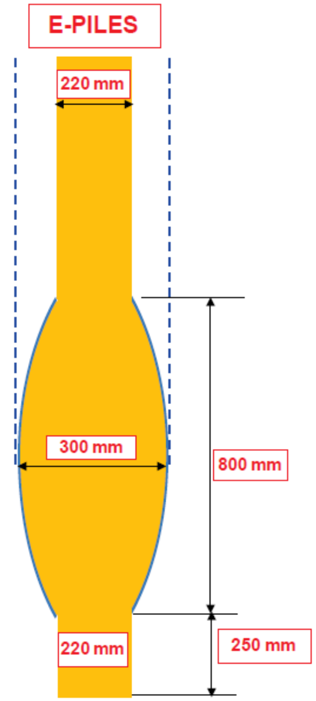
UNIVERSITÀ DEGLI STUDI DELLA CAMPANIA LUIGI VANVITELLI
SCUOLA POLITECNICA E DELLE SCIENZE DI BASE
DIPARTIMENTO DI INGEGNERIA CIVILE DESIGN EDILIZIA E AMBIENTE

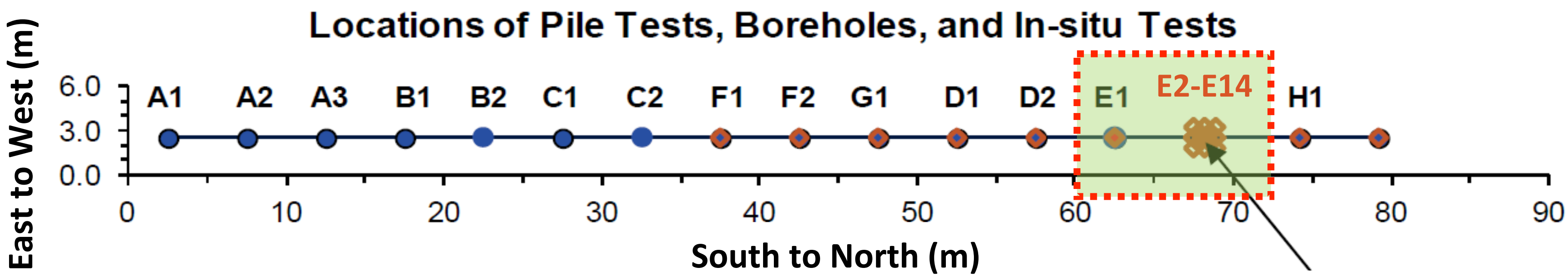
Prof. Ing. Alessandro Mandolini, Ph.D.
Chairman ISSMGE-TC212 – Deep Foundations
Email: alessandro.mandolini@unicampania.it



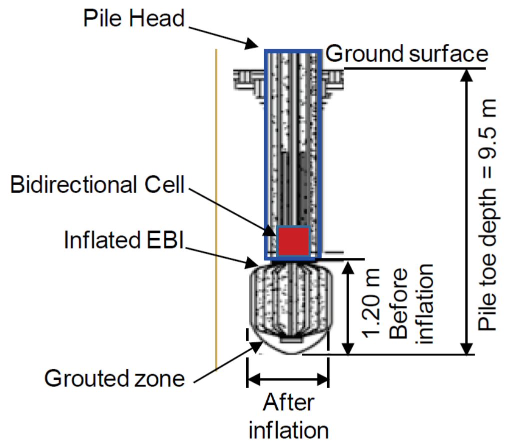
E-pile type: BAUER FDP_300



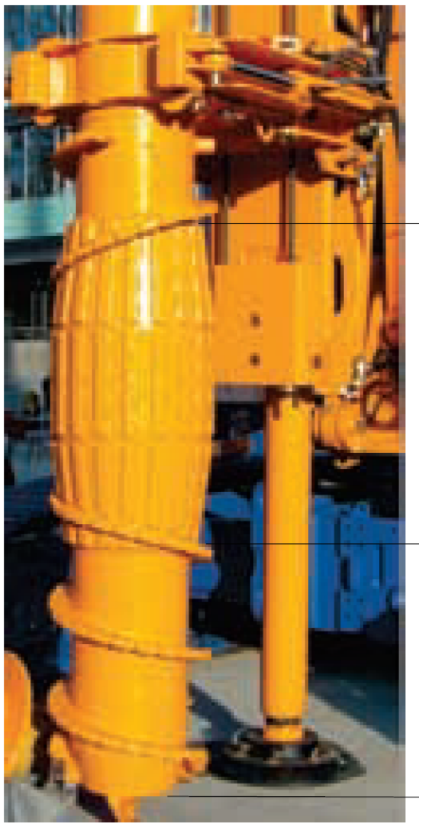


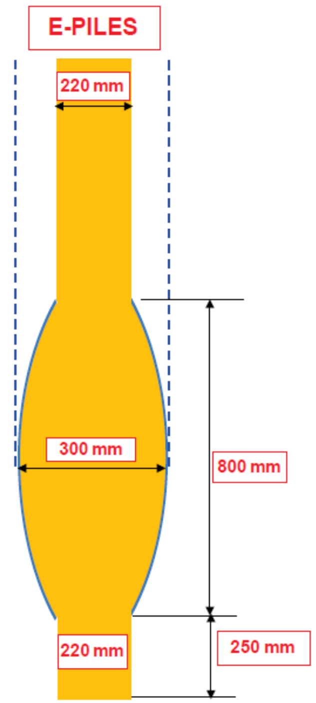


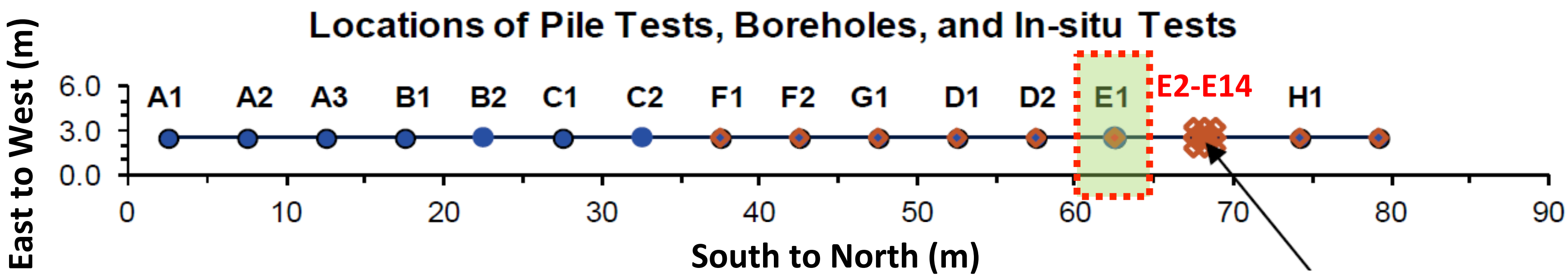
E-pile type: BAUER FDP_300 + BD + EB



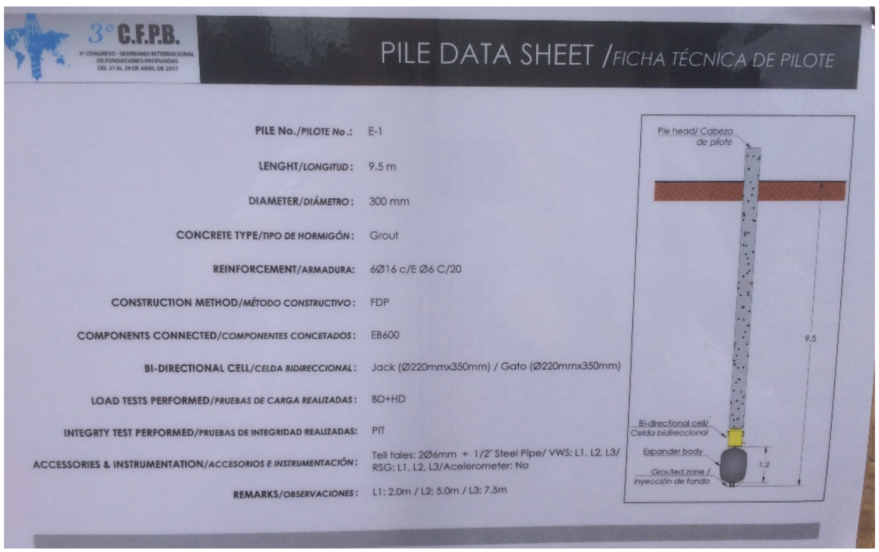
Sketch showing the EB and BD arrangement (not to scale).







Pile E1: BD test (22/03/2017)

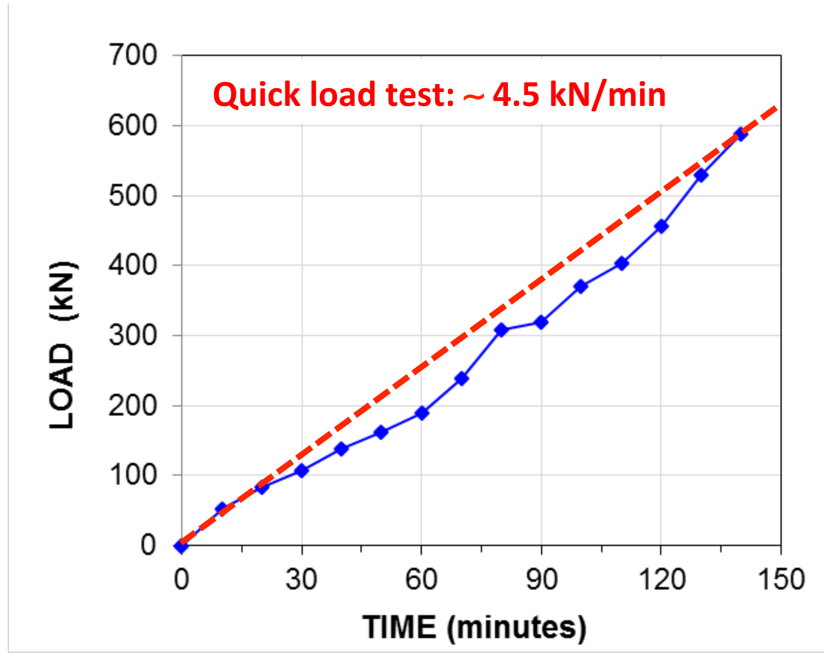


3° C.F.P.B.
3° CONGRESO - SEMINARIO INTERNACIONAL DE FUNDACIONES PROFUNDAS DEL 27 AL 29 DE ABRIL DE 2017

PILE DATA SHEET / FICHA TÉCNICA DE PILOTE

PILE No./PILOTE No.:	E-1
LENGHT/LONGITUD:	9.5 m
DIAMETER/DIÁMETRO:	300 mm
CONCRETE TYPE/TIPO DE HORMIGÓN:	Grout
REINFORCEMENT/ARMADURA:	6Ø16 c/E Ø6 C/20
CONSTRUCTION METHOD/MÉTODO CONSTRUCTIVO:	FDP
COMPONENTS CONNECTED/COMPONENTES CONCETADOS:	EB600
BI-DIRECTIONAL CELL/CELDA BIDIRECCIONAL:	Jack (Ø220mmx350mm) / Gato (Ø220mmx350mm)
LOAD TESTS PERFORMED/PRUEBAS DE CARGA REALIZADAS:	BD+HD
INTEGRTY TEST PERFORMED/PRUEBAS DE INTEGRIDAD REALIZADAS:	PIT
ACCESSORIES & INSTRUMENTATION/ACCESORIOS E INSTRUMENTACIÓN:	Tell tales: 2Ø6mm + 1/2" Steel Pipe/ VWS: L1, L2, L3/ RSG: L1, L2, L3/Accelerometer: No
REMARKS/OBSERVACIONES:	L1: 2.0m / L2: 5.0m / L3: 7.5m

Pile head/ Cabeza de pilote
9.5
Bi-directional cell/ Celda bidireccional
Expander body
1.2
Grouted zone / Inyección de fondo



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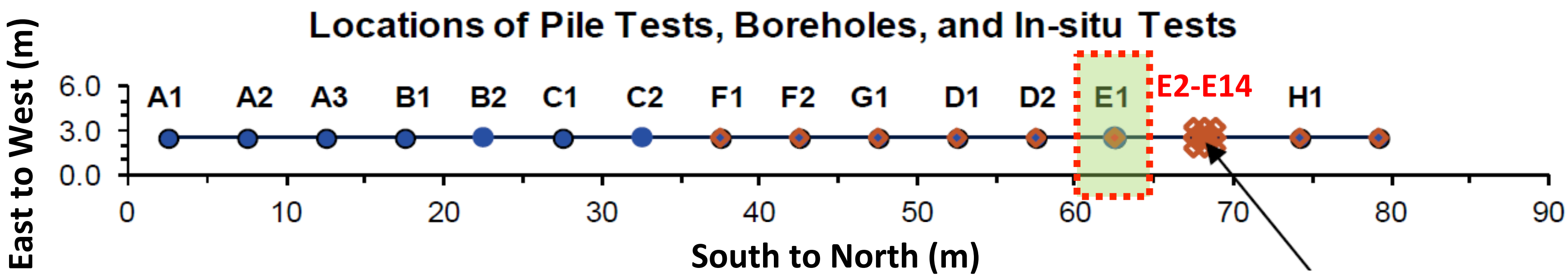
DESIGN EDILIZIA E AMBIENTE



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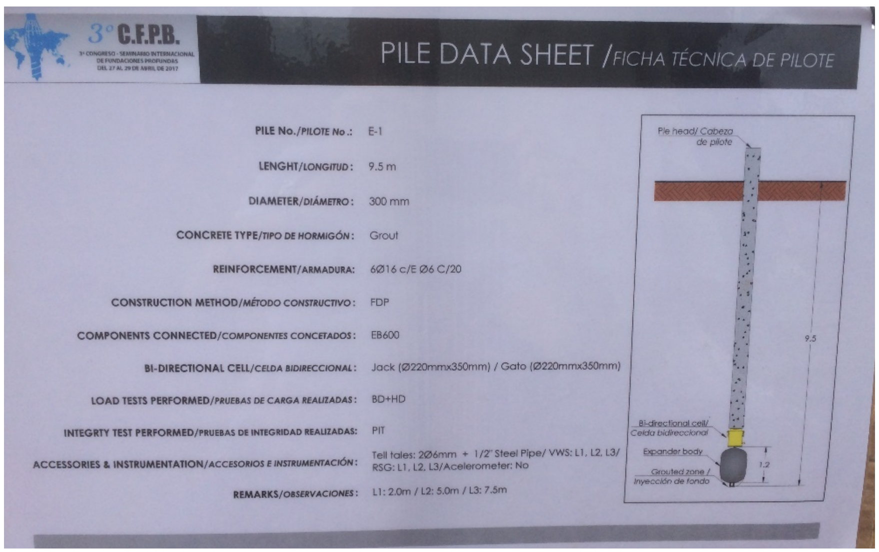

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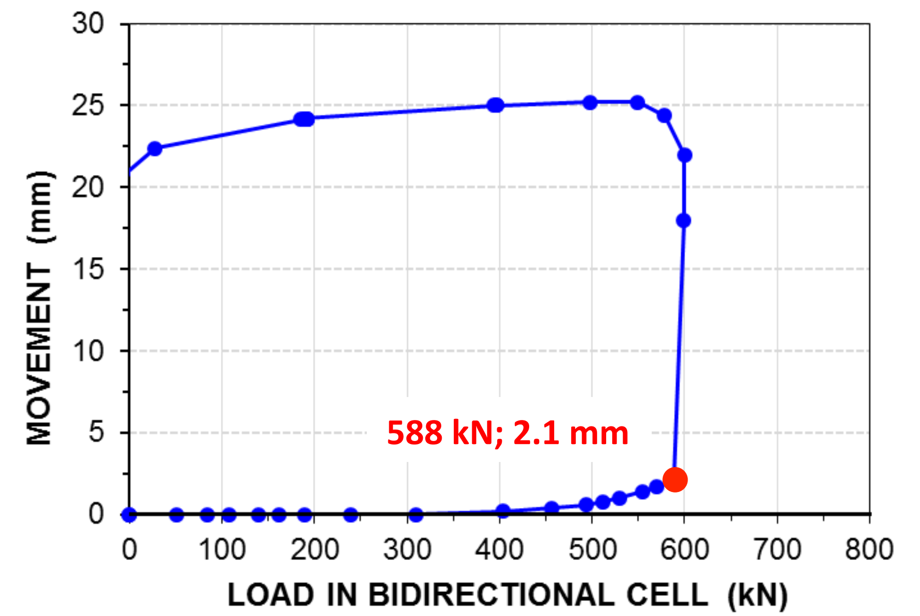
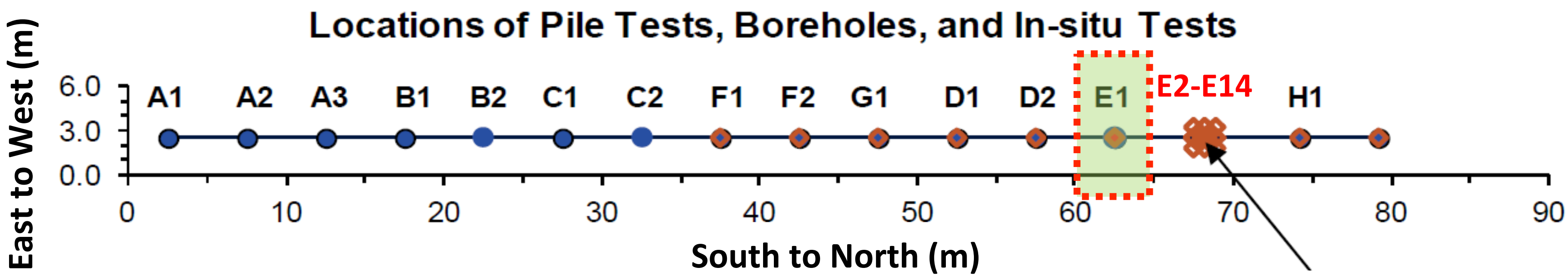


Courtesy B. Fellenius



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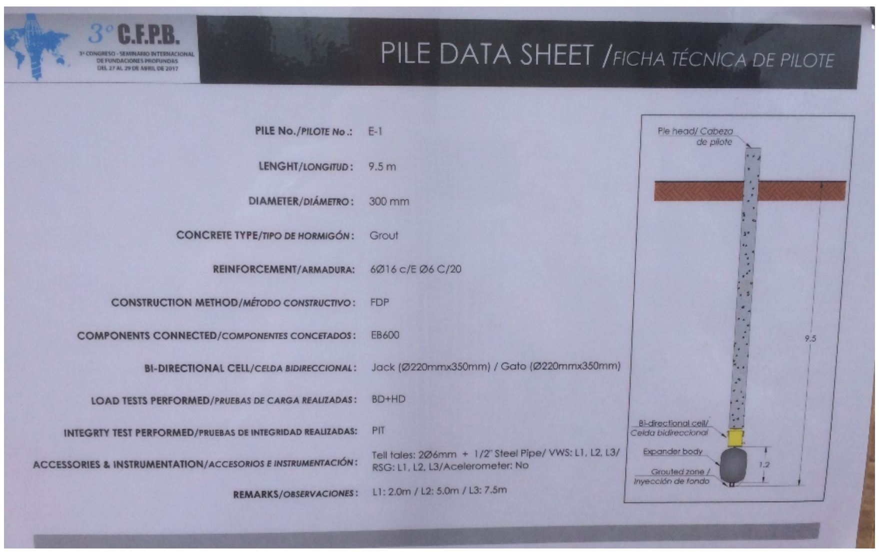

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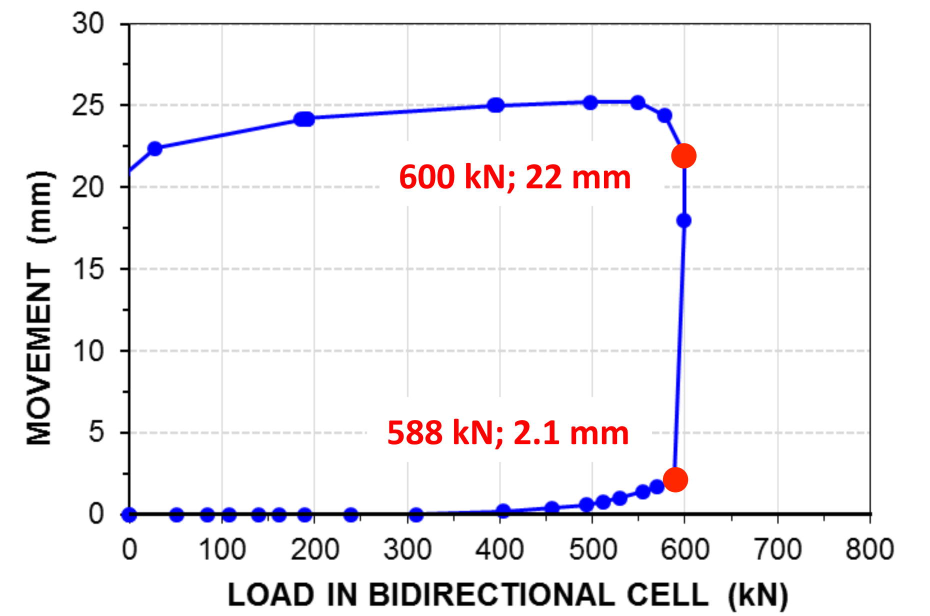
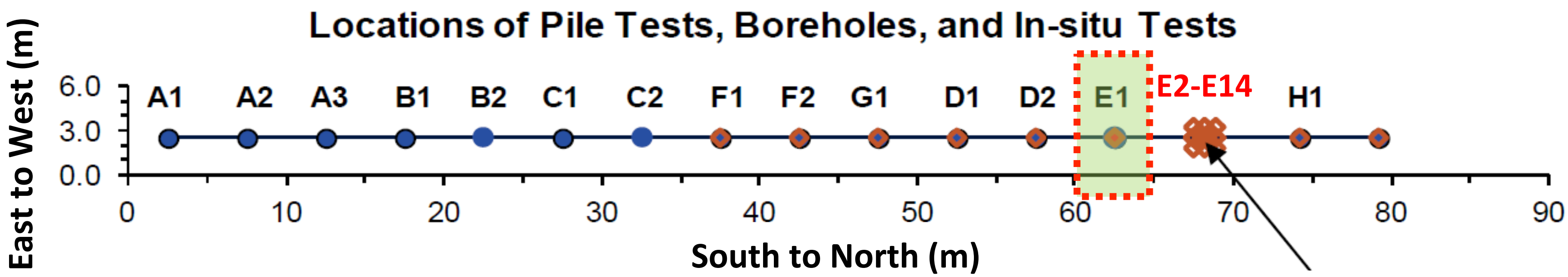


Courtesy B. Fellenius



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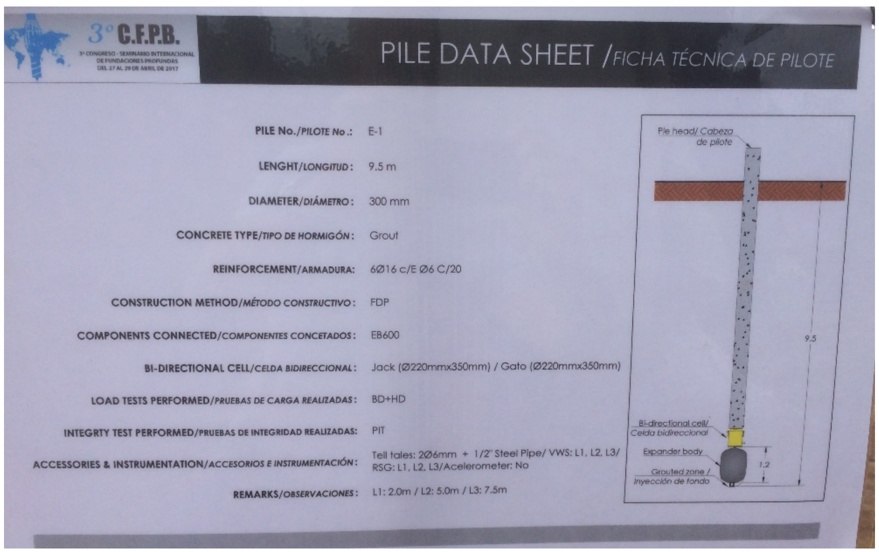
3° C.F.P.B.
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PILE DATA SHEET / *FICHA TÉCNICA DE PILOTE*

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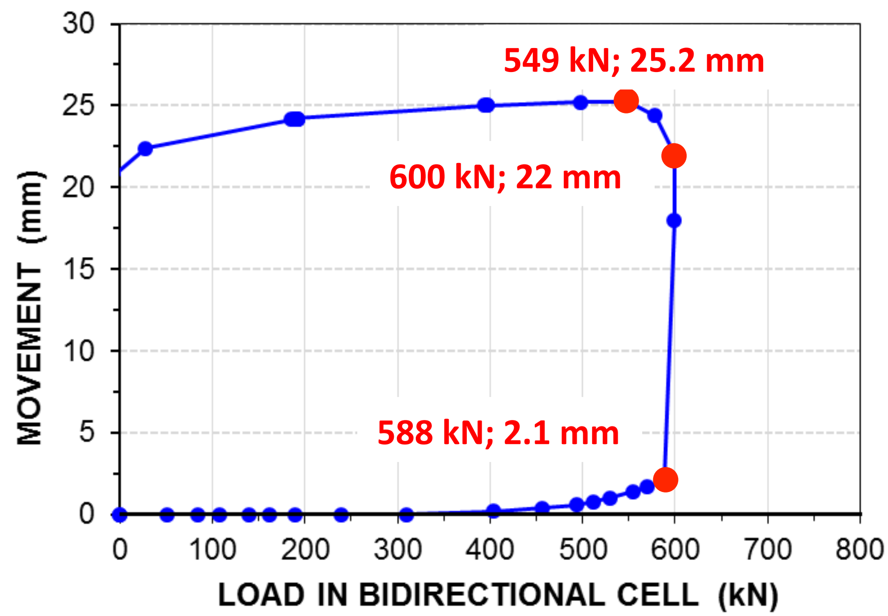
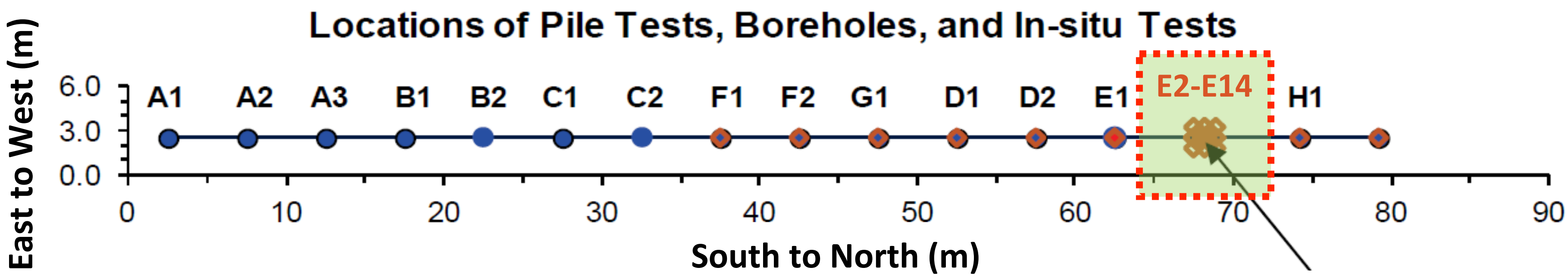
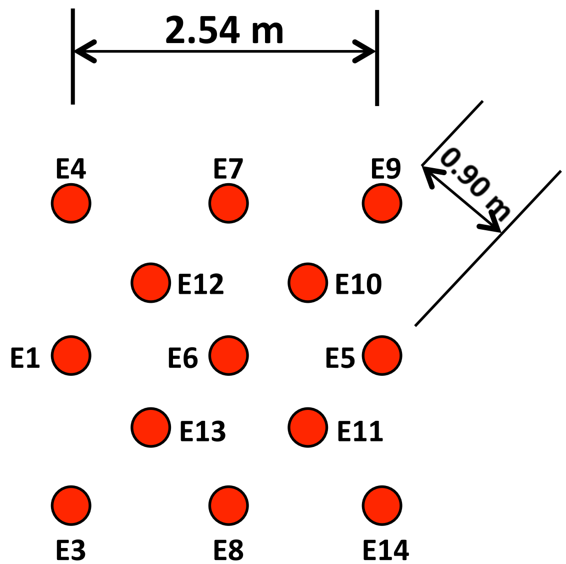
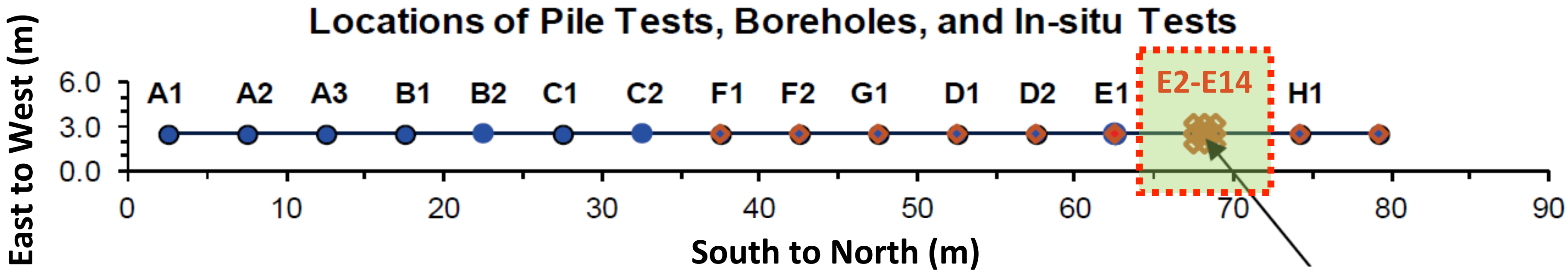


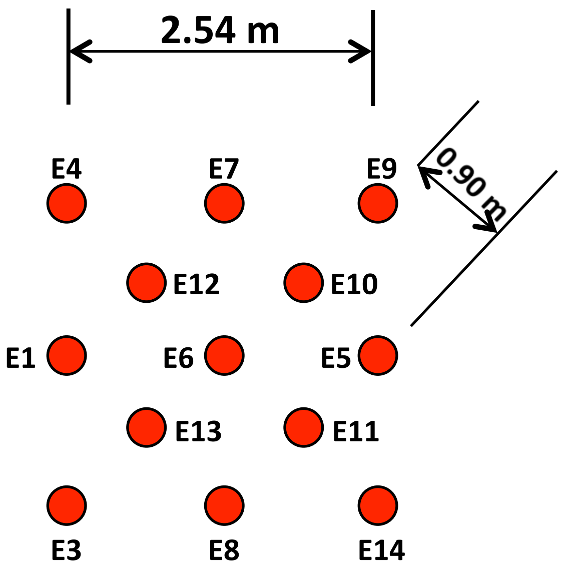
Courtesy B. Fellenius



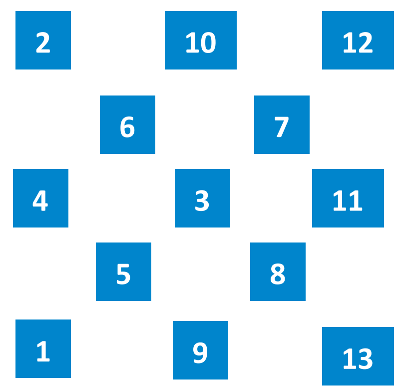


Pile group layout



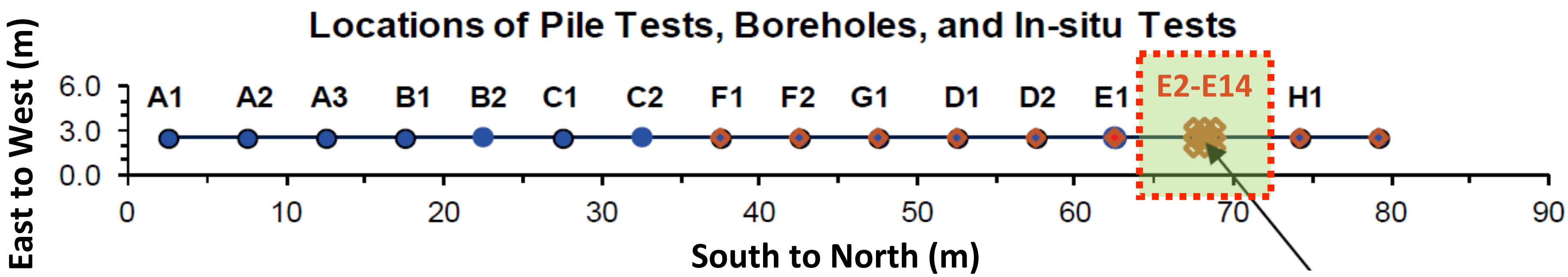


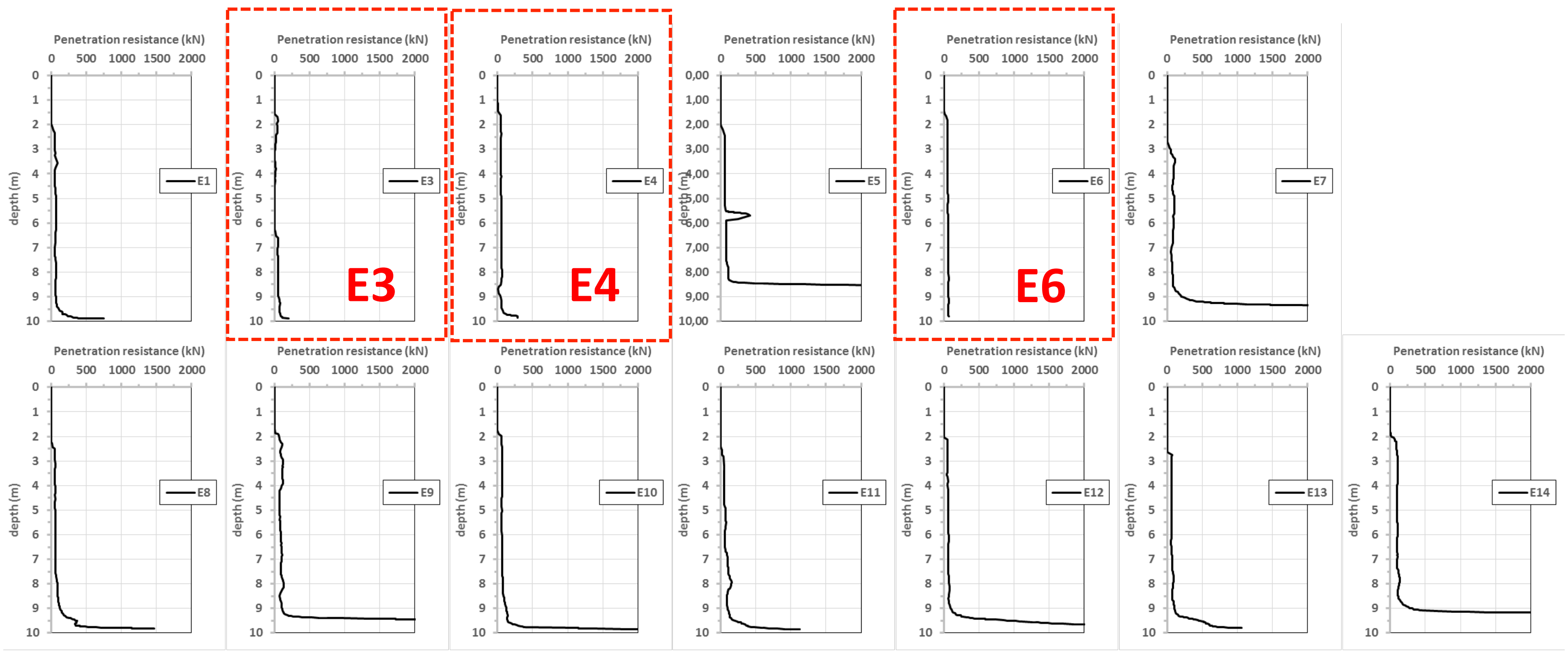
Pile group layout



Sequence of pile installation

(20 and 21 April 2017)





MEASURED PENETRATION RESISTANCE

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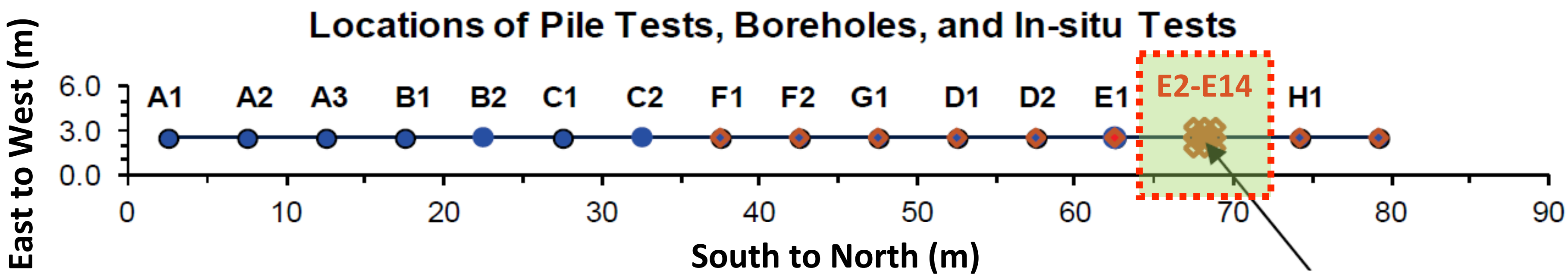
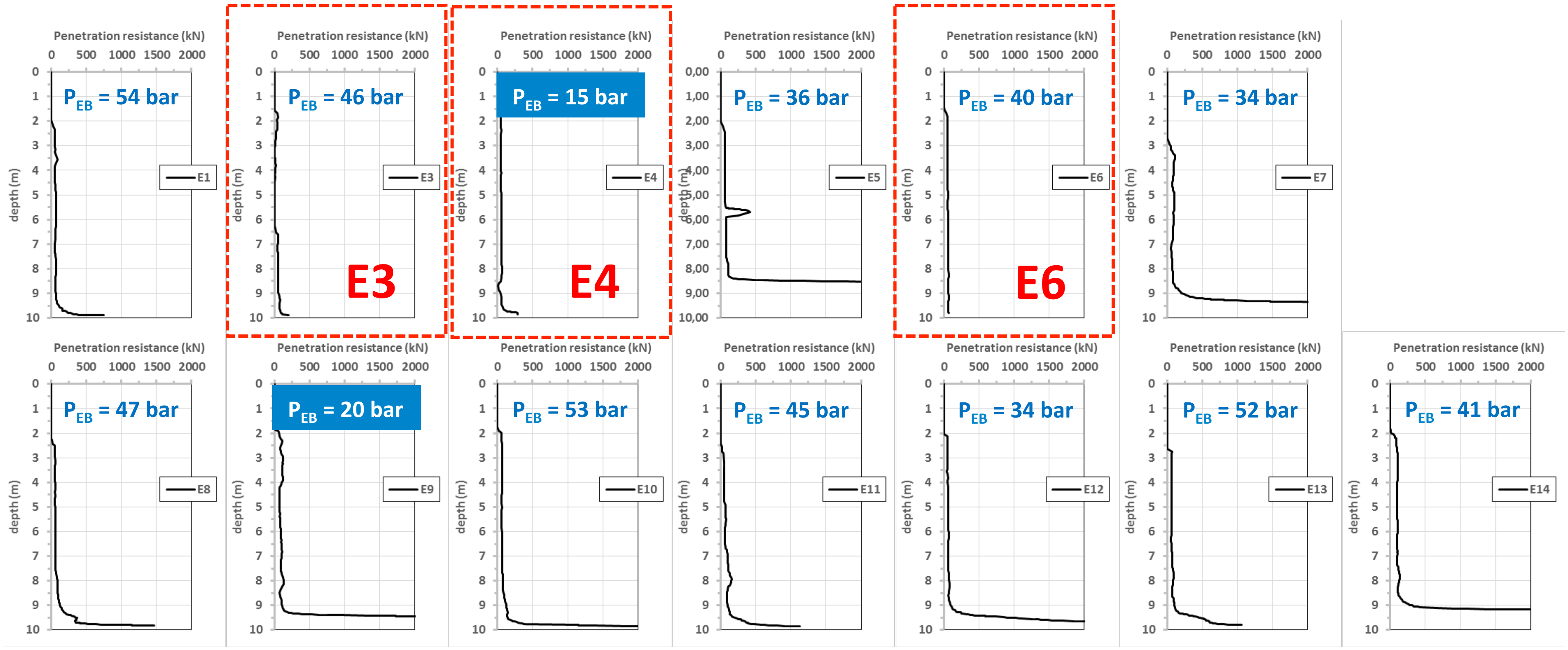
DESIGN EDILIZIA E AMBIENTE

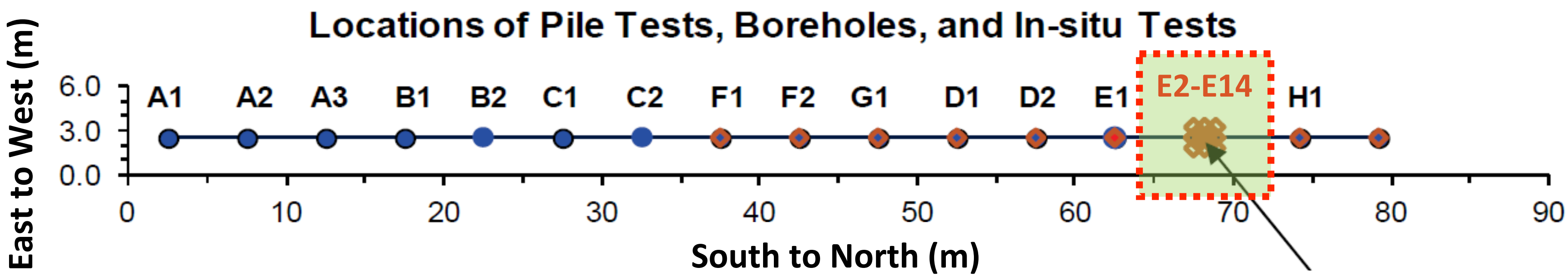
Alessandro Mandolini
BEST – Session 3
Pile Group and Piled Raft

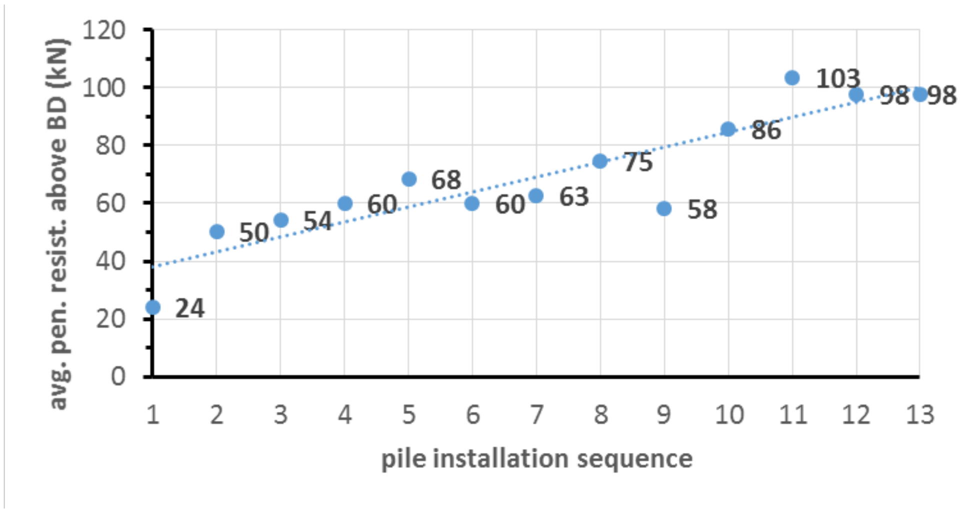




MEASURED PENETRATION RESISTANCE

EB LIMIT PRESSURE





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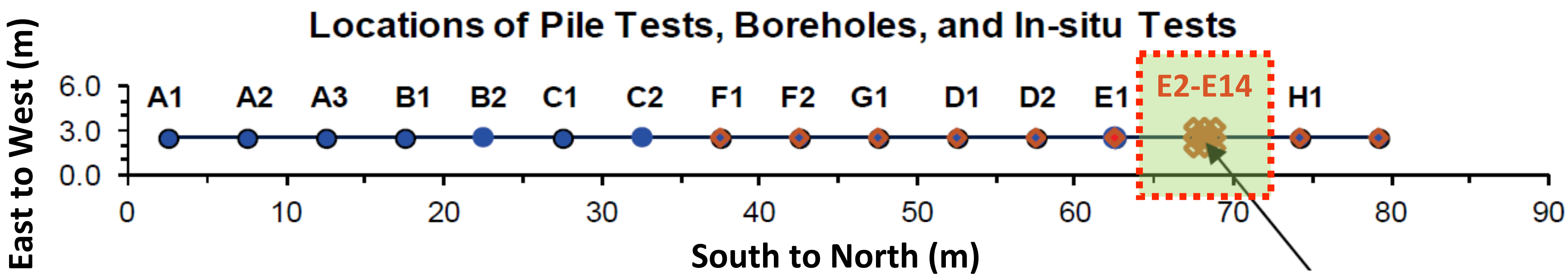
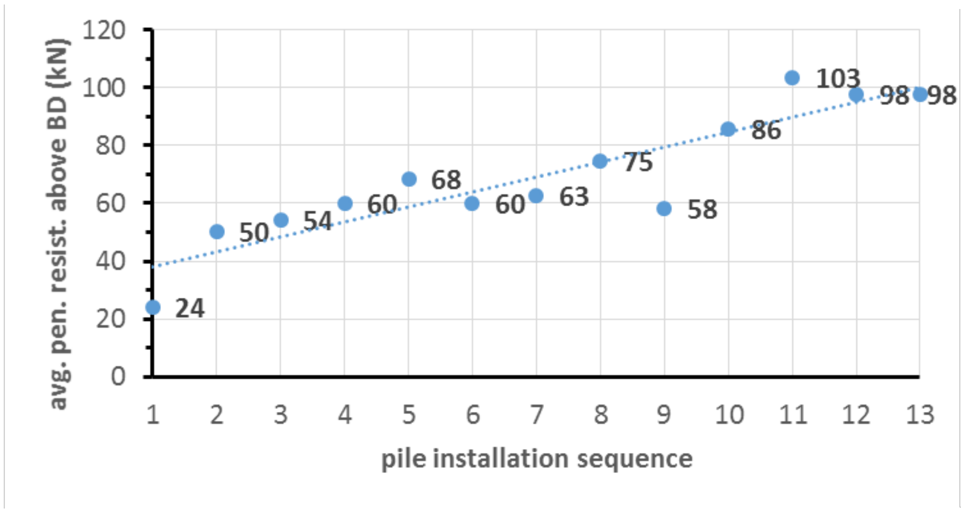
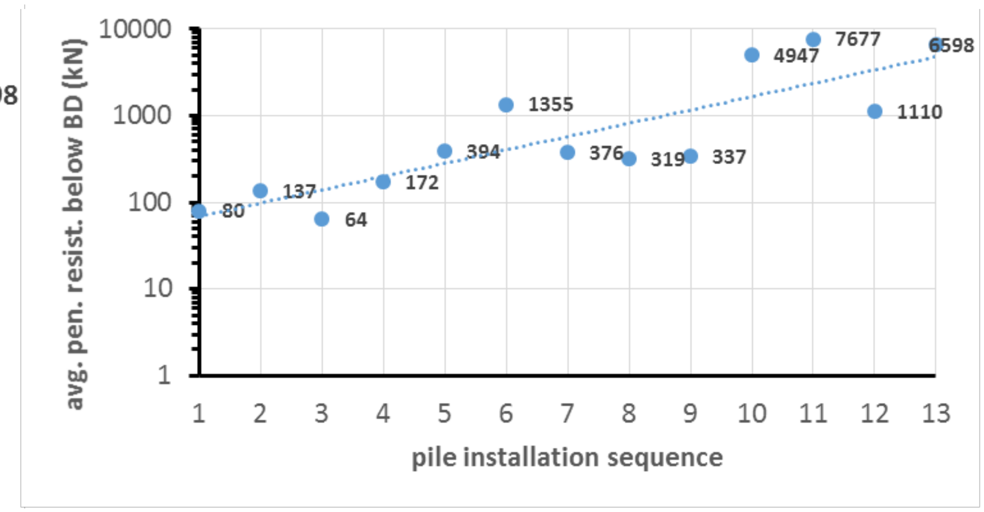
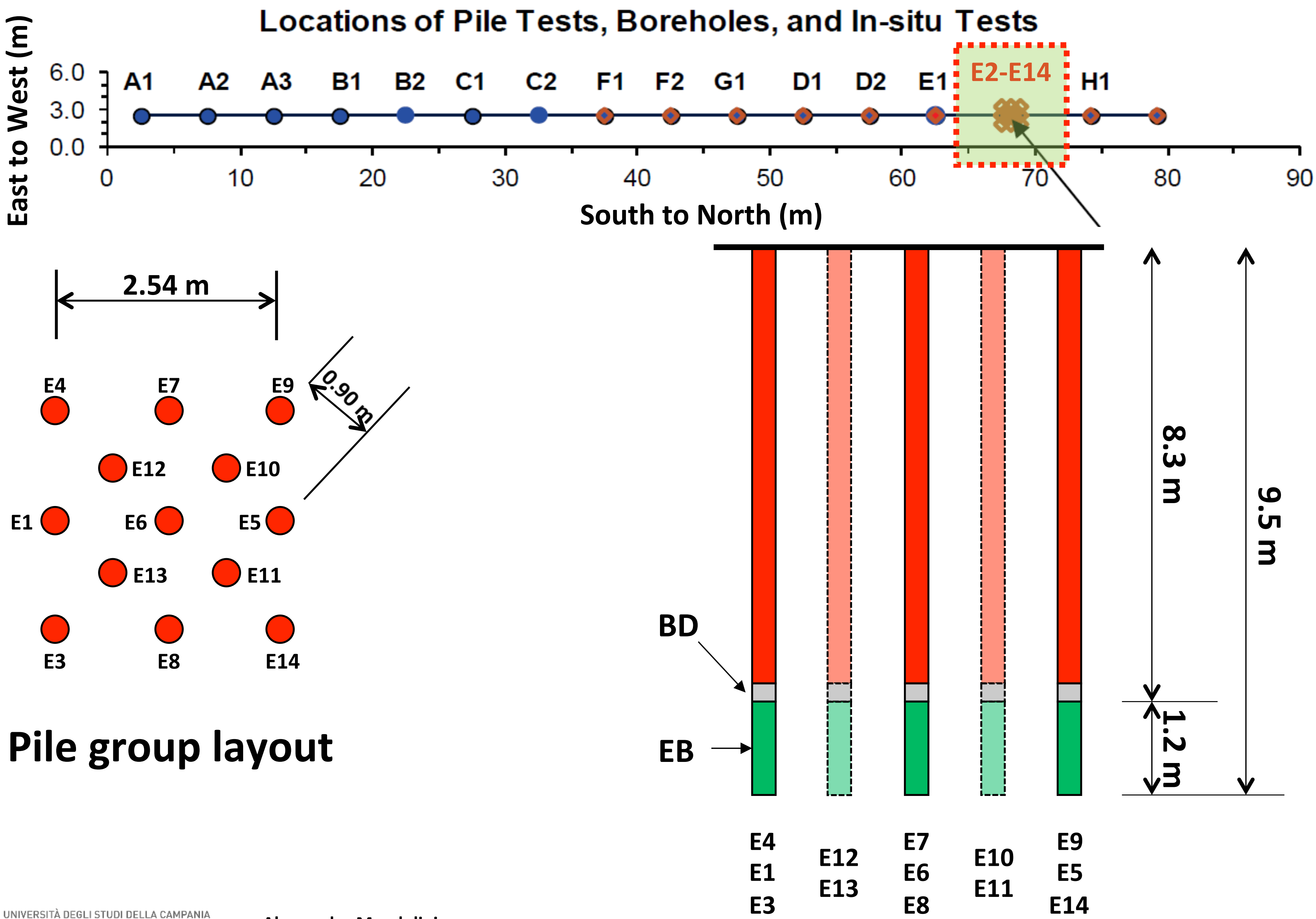

Locations of Pile Tests, Boreholes, and In-situ Tests
East to West (m)
6.0
3.0
0.0
A1
A2
A3
B1
B2
C1
C2
F1
F2
G1
D1
D2
E1
E2-E14
H1
0
10
20
30
40
50
60
70
80
90
South to North (m)


avg. pen. resist. above BD (kN)
120
100
80
60
40
20
0
24
50
54
60
68
60
63
75
58
86
103
98
98
1 2 3 4 5 6 7 8 9 10 11 12 13
pile installation sequence

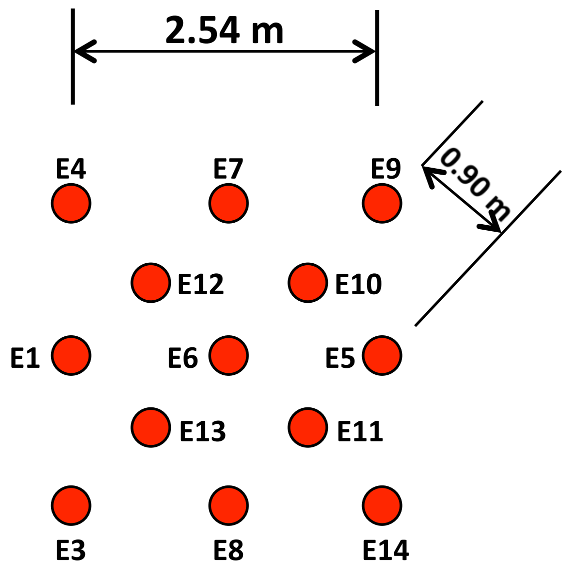

avg. pen. resist. below BD (kN)
10000
1000
100
10
1
80
137
64
172
394
1355
376
319
337
4947
7677
6598
1110
1 2 3 4 5 6 7 8 9 10 11 12 13
pile installation sequence

Log scale !!!!

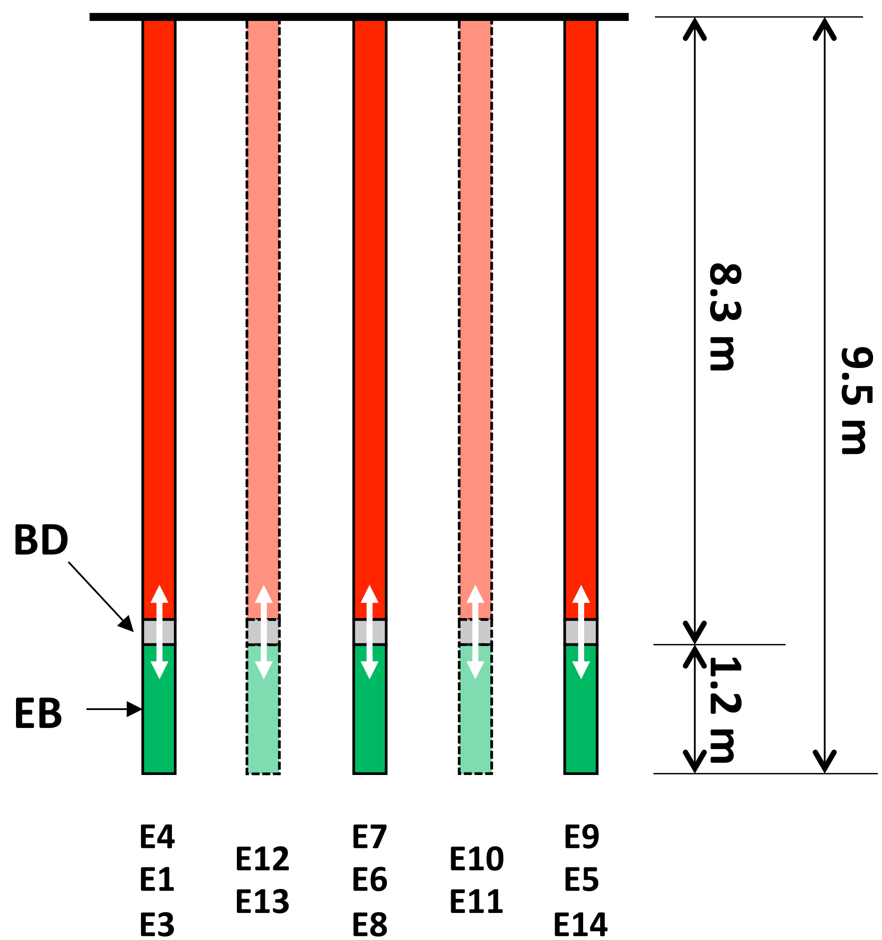


Pile group layout

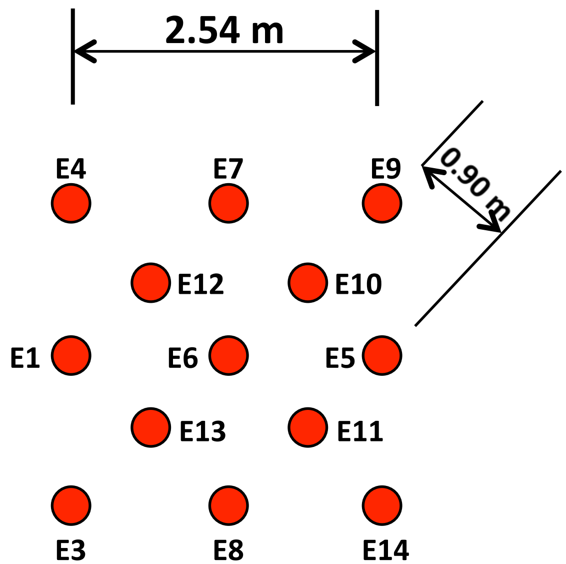
PHASE 1 – BIDIRECTIONAL TEST
(all 13 piles)



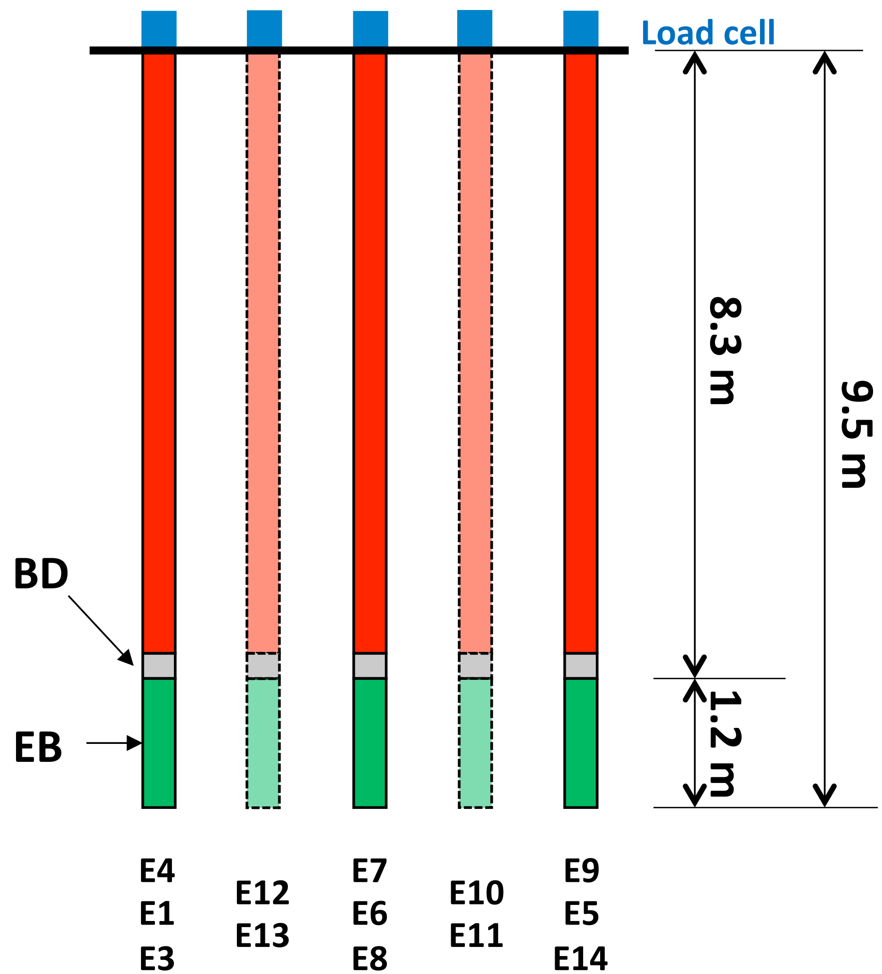
Pile group layout



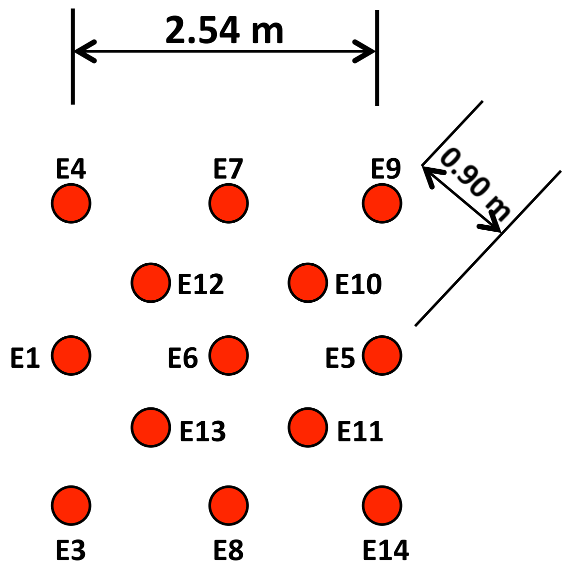
PREPARATION FOR PHASE 2 – HEAD-DOWN LOAD TEST (all BD open)



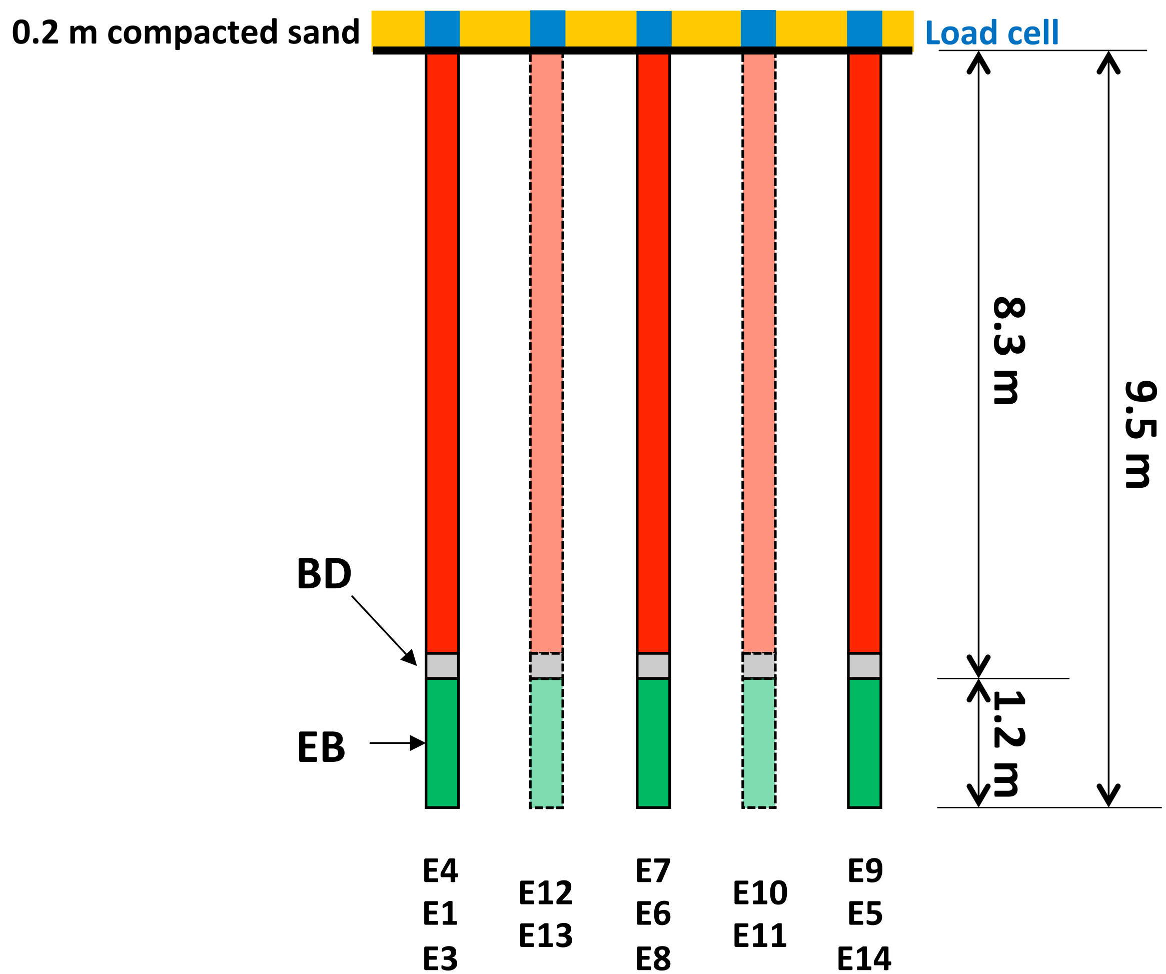
Pile group layout



PREPARATION FOR PHASE 2 – HEAD-DOWN LOAD TEST (all BD open)



Pile group layout



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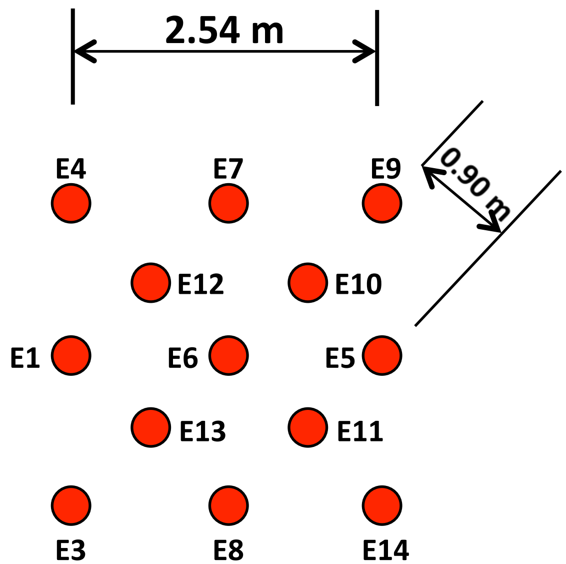
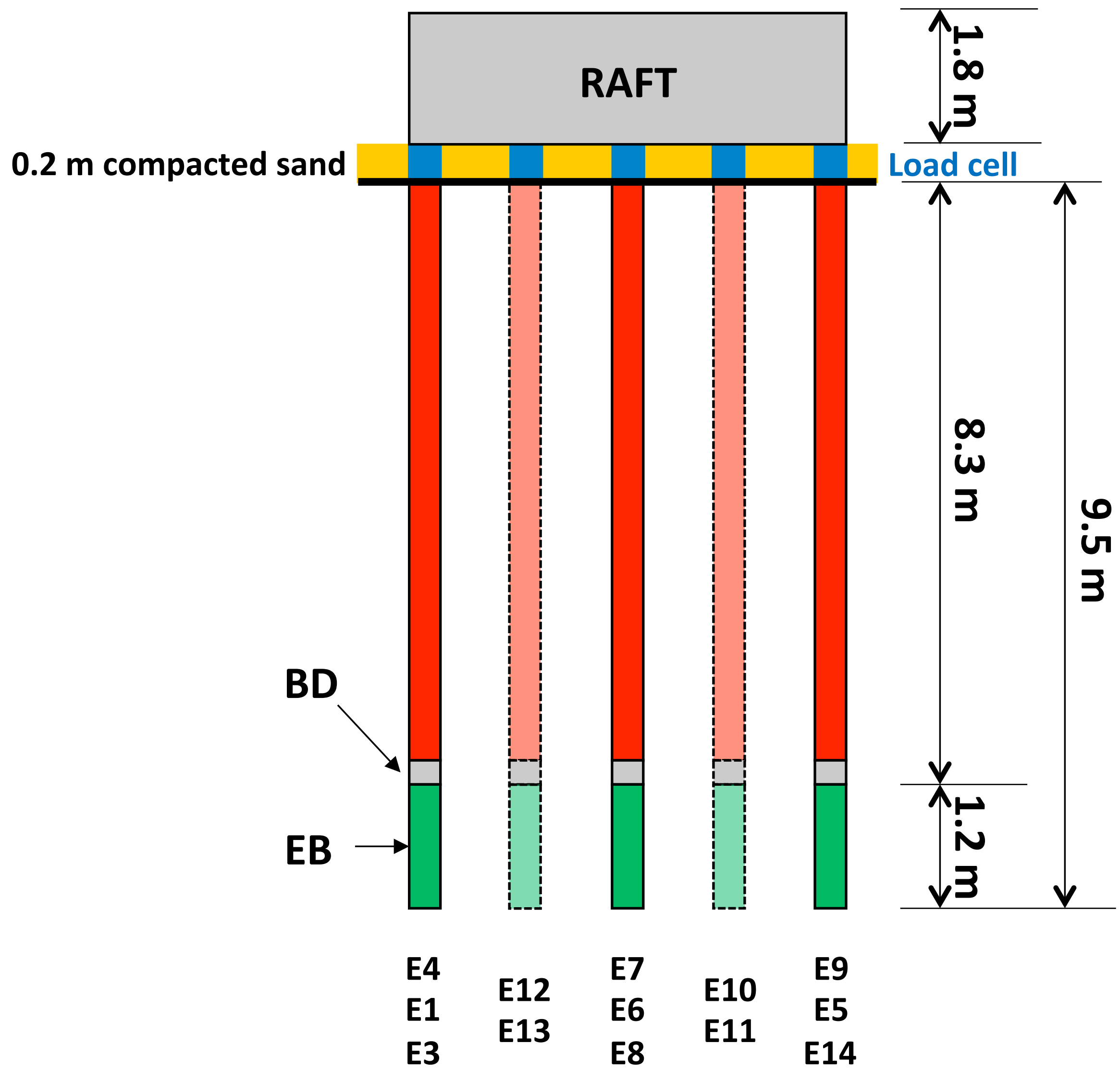
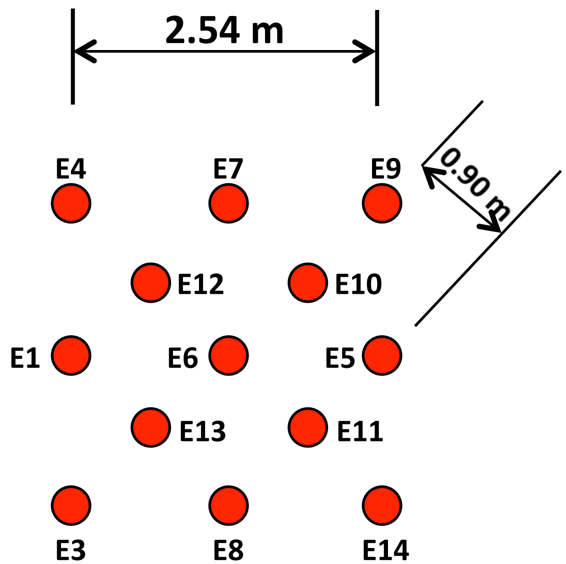


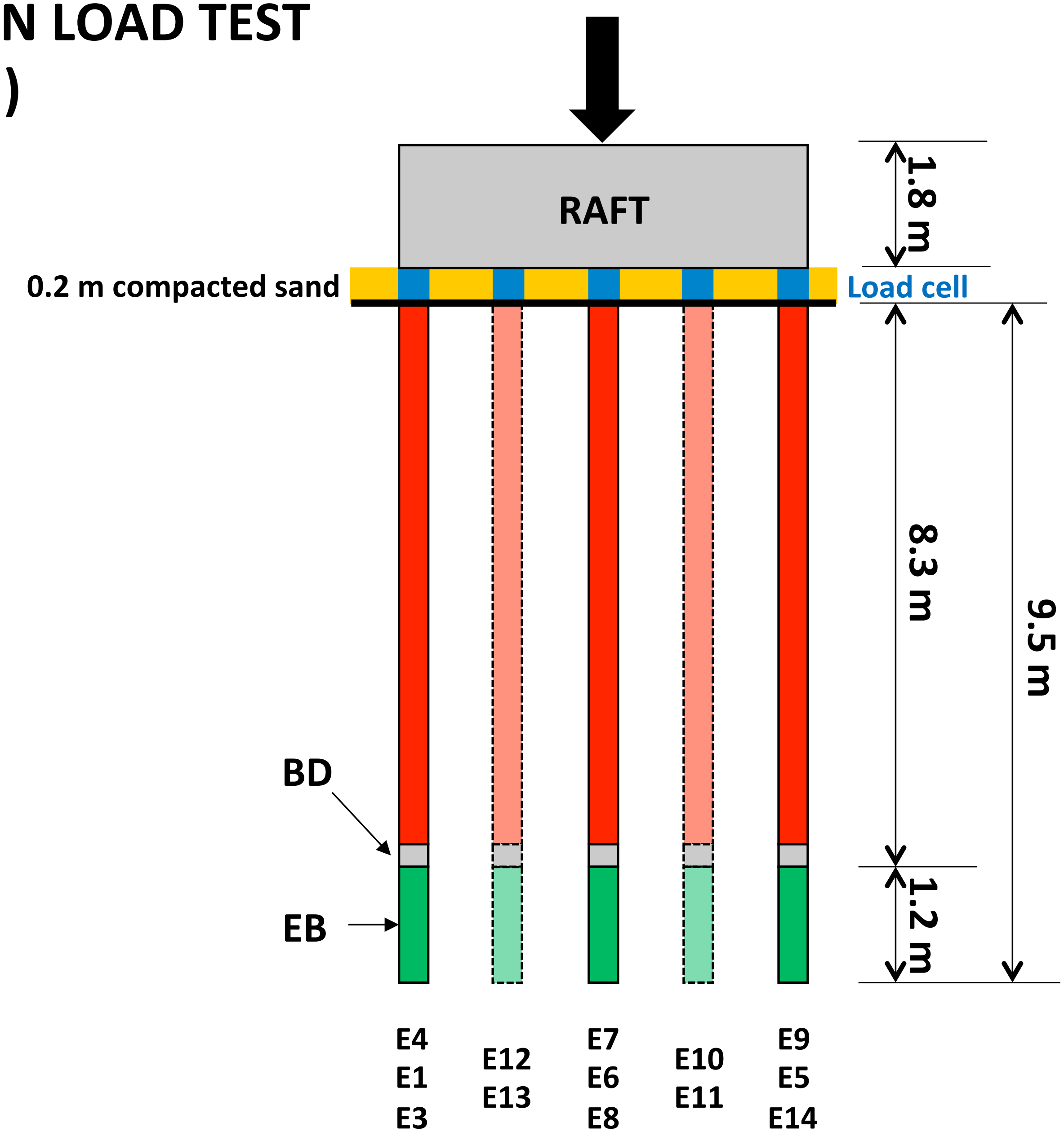
Pile group layout



PHASE 2 – HEAD-DOWN LOAD TEST
(all BD open)



Pile group layout



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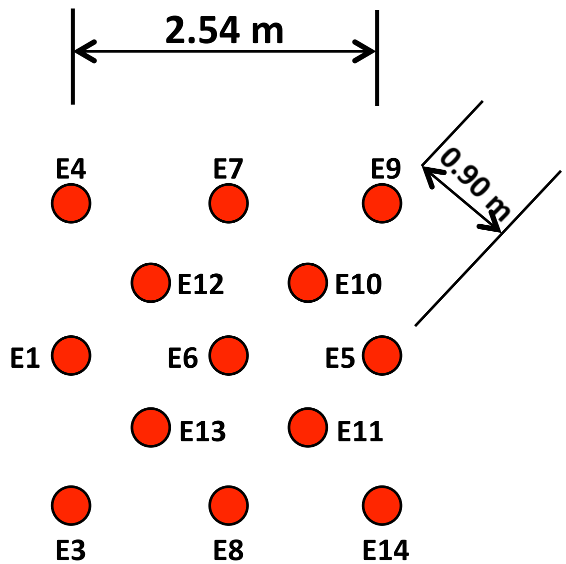
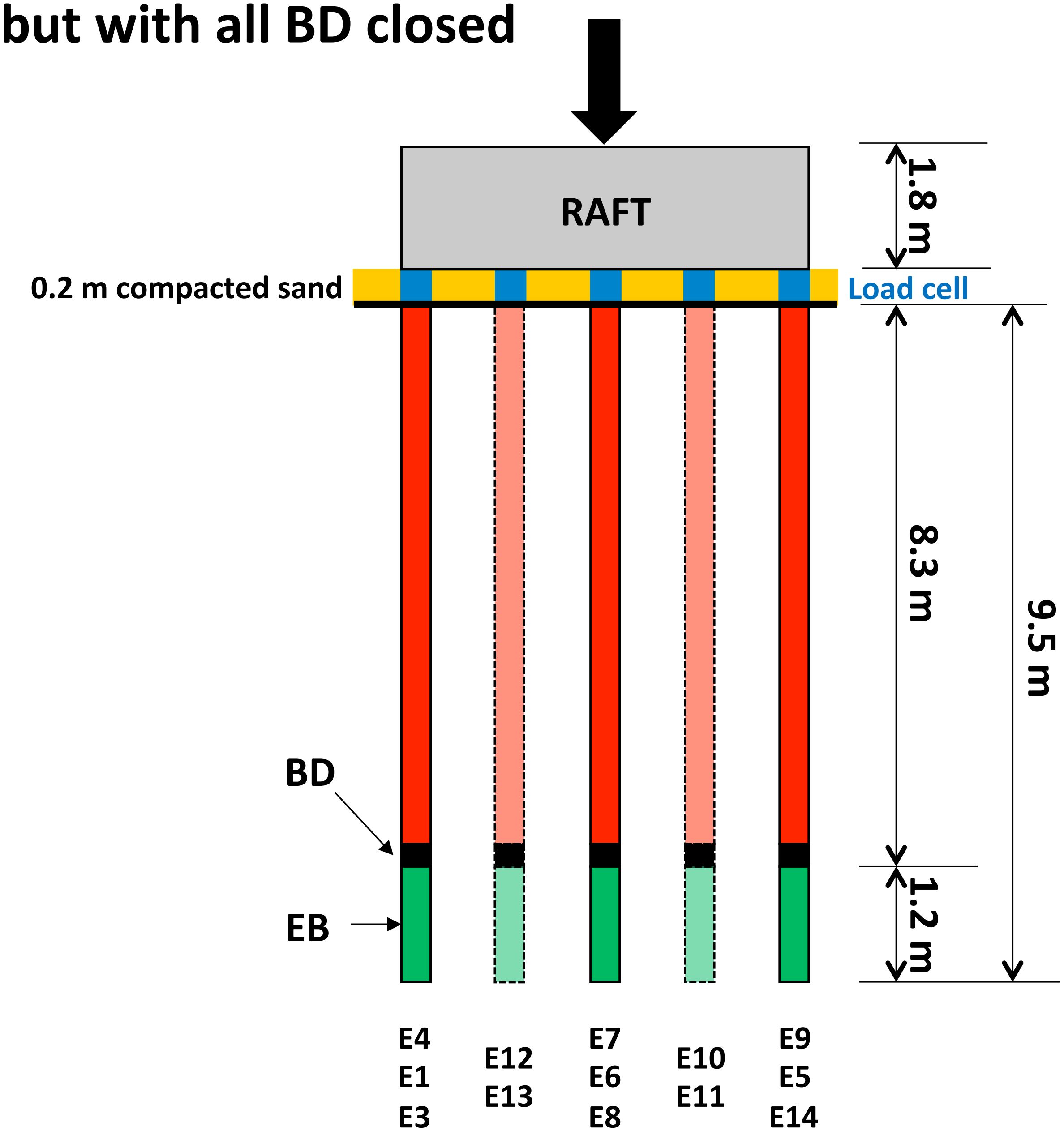
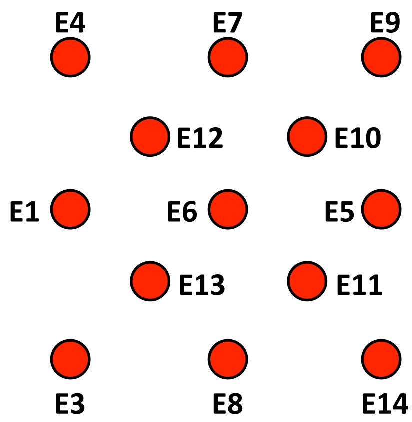
PHASE 3 – as PHASE 2 but with all BD closed



Pile group layout

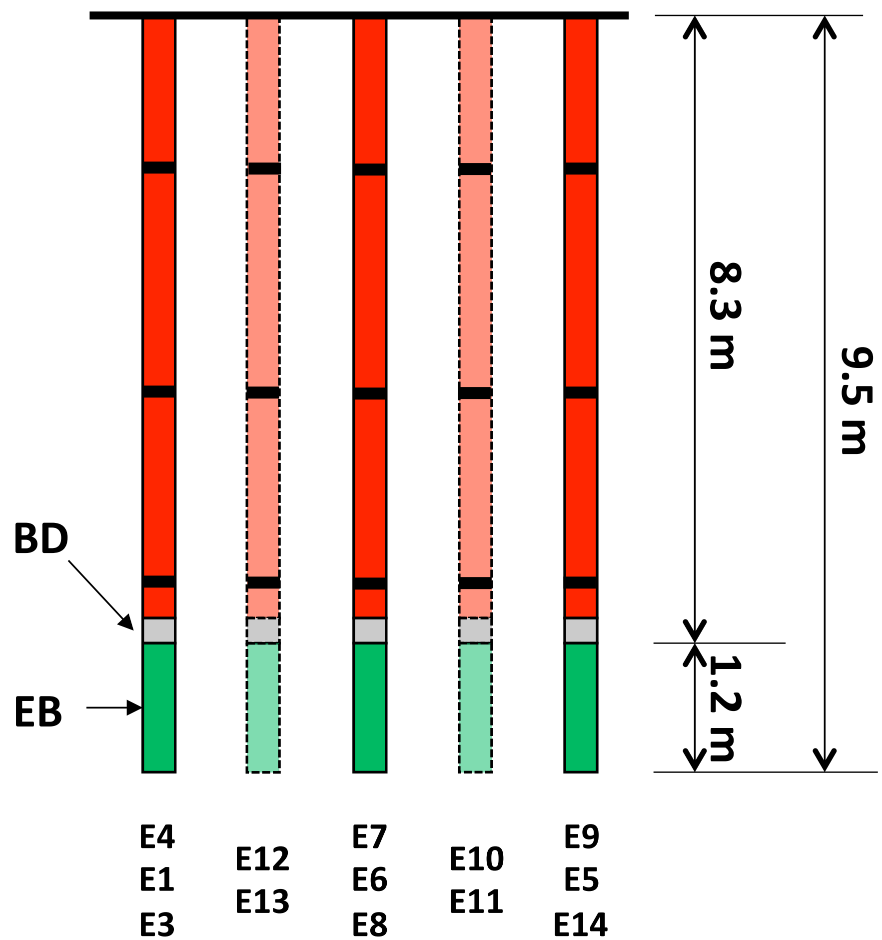


PHASE 1 – BIDIRECTIONAL TEST (all 13 piles)

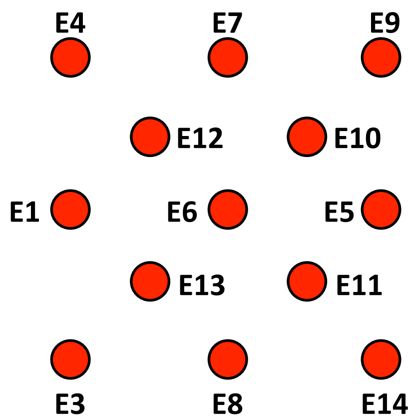


Pile instrumentation (any pile)

- n. 3 strain gages (2.0 m; 5.0 m; 7.5 m)

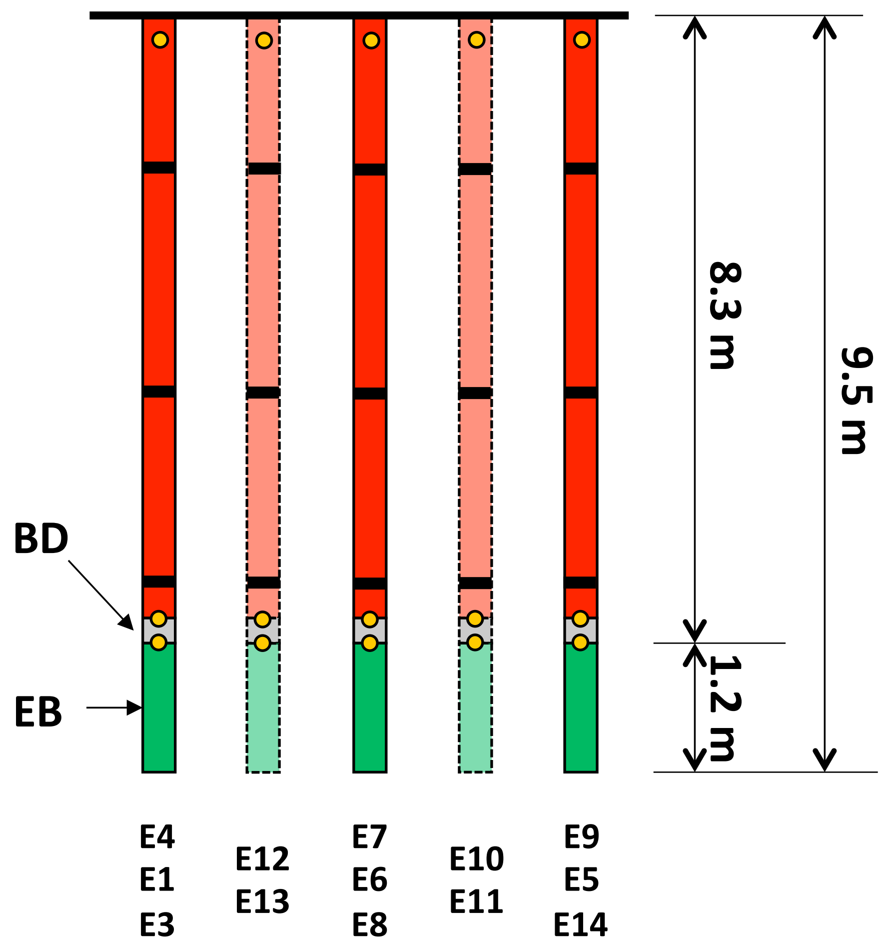


PHASE 1 – BIDIRECTIONAL TEST (all 13 piles)

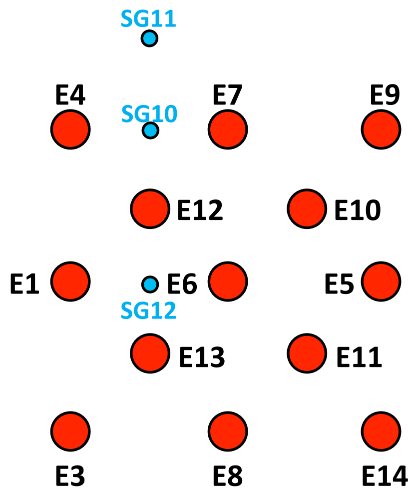


Pile instrumentation (any pile)

- n. 3 strain gages (2.0 m; 5.0 m; 7.5 m)
- n. 3 tell tales (0.5 m; 8.1 m; 8.3 m)



PHASE 1 – BIDIRECTIONAL TEST (all 13 piles)

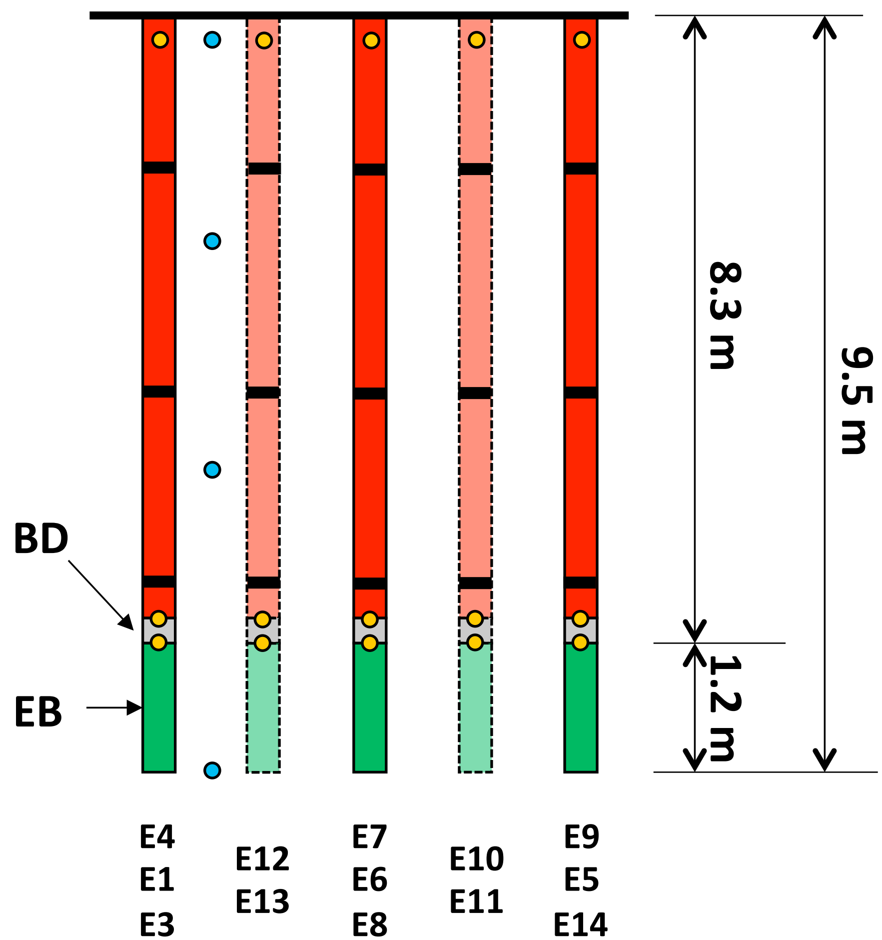


Pile instrumentation (any pile)

- n. 3 strain gages (2.0 m; 5.0 m; 7.5 m)
- n. 3 tell tales (0.5 m; 8.1 m; 8.3 m)

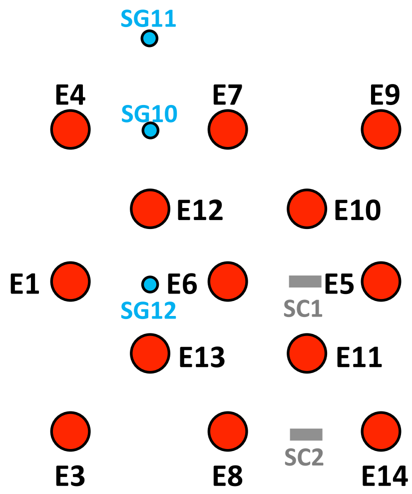
Soil instrumentation (3 verticals)

- n. 4 strain gages (0.5 m; 3.0 m; 6.0 m; 9.5 m)



UNIVERSITÀ DEGLI STUDI DELLA CAMPANIA LUIGI VANVITELLI
SCUOLA POLITECNICA E DELLE SCIENZE DI BASE
DIPARTIMENTO DI INGEGNERIA CIVILE DESIGN EDILIZIA E AMBIENTE
Alessandro Mandolini

PHASE 2 & 3 – HEAD-DOWN LOAD TESTS



Pile instrumentation (any pile)

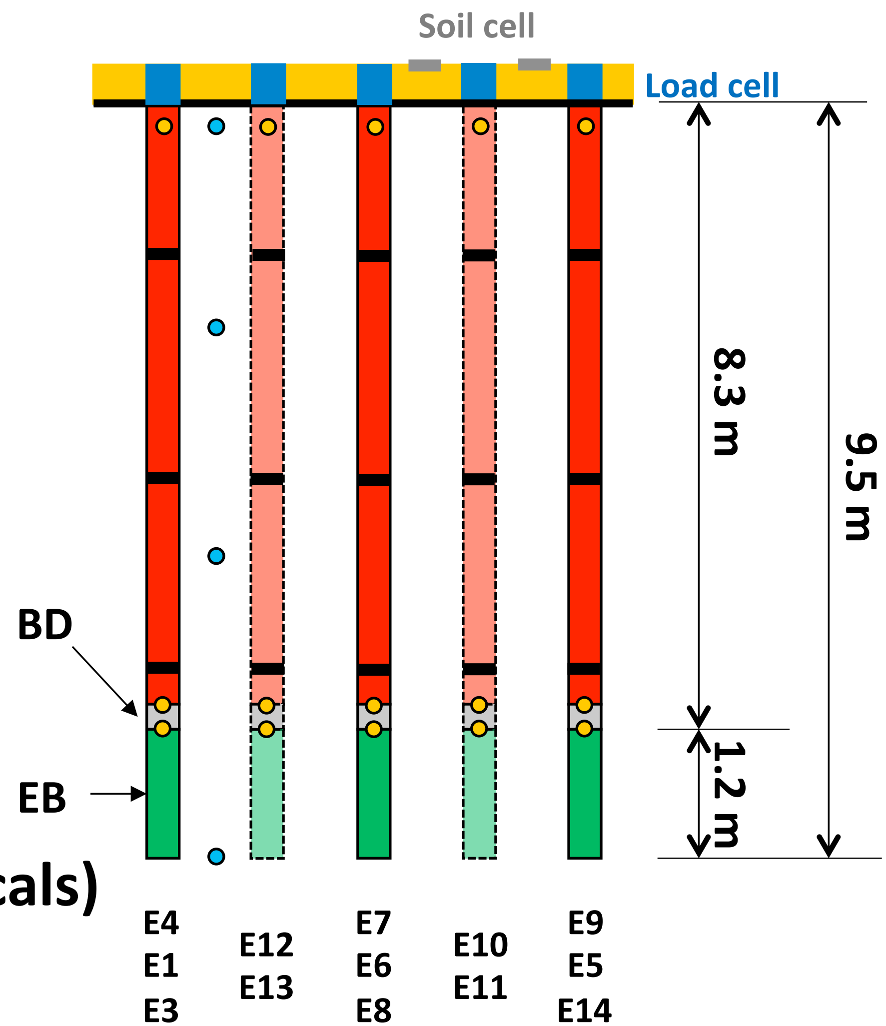
- n. 3 strain gages (2.0 m; 5.0 m; 7.5 m)
- n. 3 tell tales (0.5 m; 8.1 m; 8.3 m)
- n. 1 load cell (at pile head)

Soil instrumentation (3 verticals)

- n. 4 strain gages (0.5 m; 3.0 m; 6.0 m; 9.5 m)

Raft-soil instrumentation (2 verticals)

- n. 2 pressure cells at raft-soil contact



PHASE 1 – BIDIRECTIONAL TEST (all 13 piles)

PHASE 2 – HEAD-DOWN LOAD TEST (all BD cells open)

PHASE 3 – HEAD-DOWN LOAD TEST (all BD cells closed)

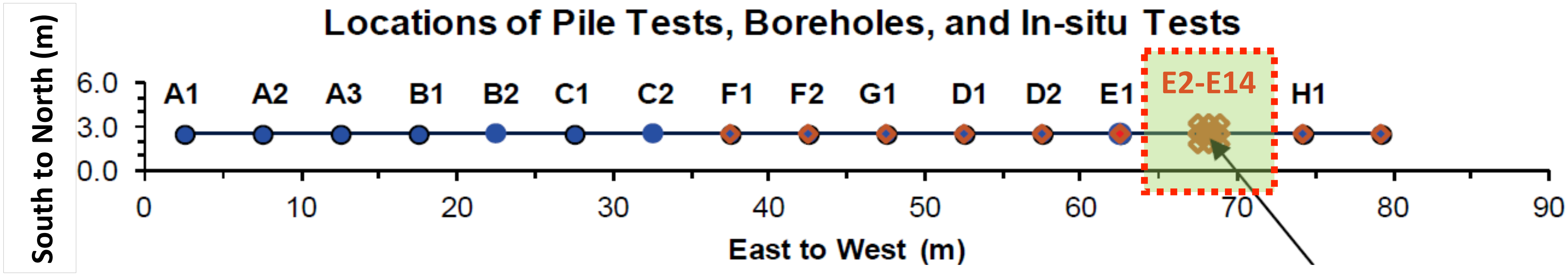
WHAT UNTIL NOW ??

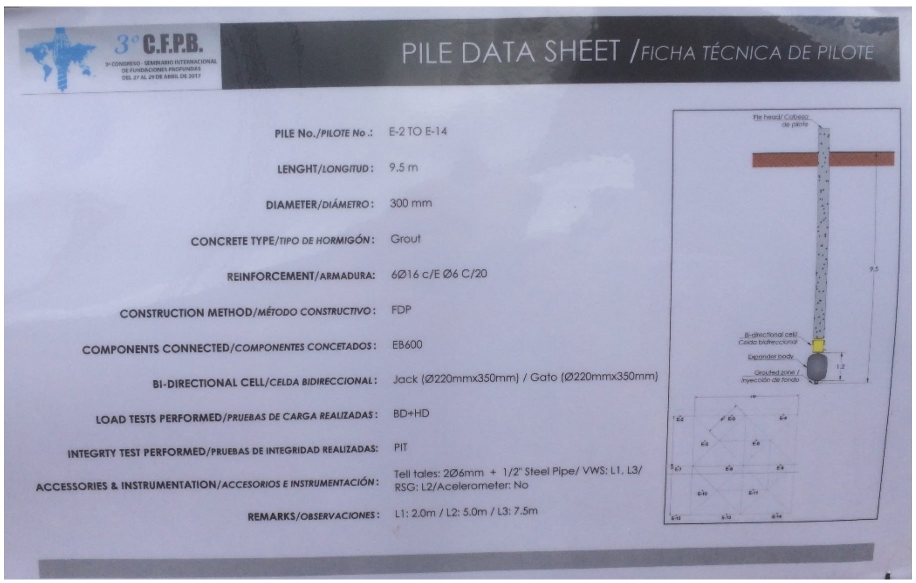
PHASE 1 – BIDIRECTIONAL TEST (all 13 piles)

PHASE 2 – HEAD-DOWN LOAD TEST (all BD cells open)

PHASE 3 – HEAD-DOWN LOAD TEST (all BD cells closed)

WHAT UNTIL NOW ??





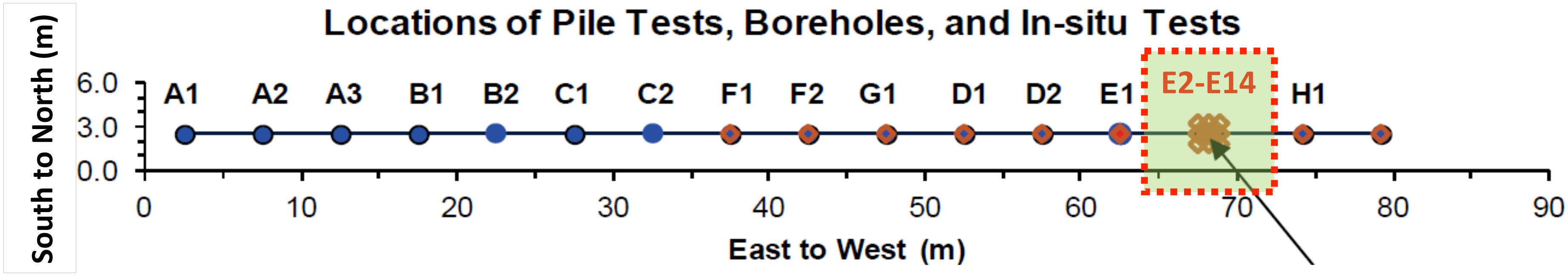
3° C.F.P.B.
3° CONGRESO - SEMINARIO INTERNACIONAL DE FUNDACIONES PROFUNDAS DEL 27 AL 29 DE ABRIL DE 2017

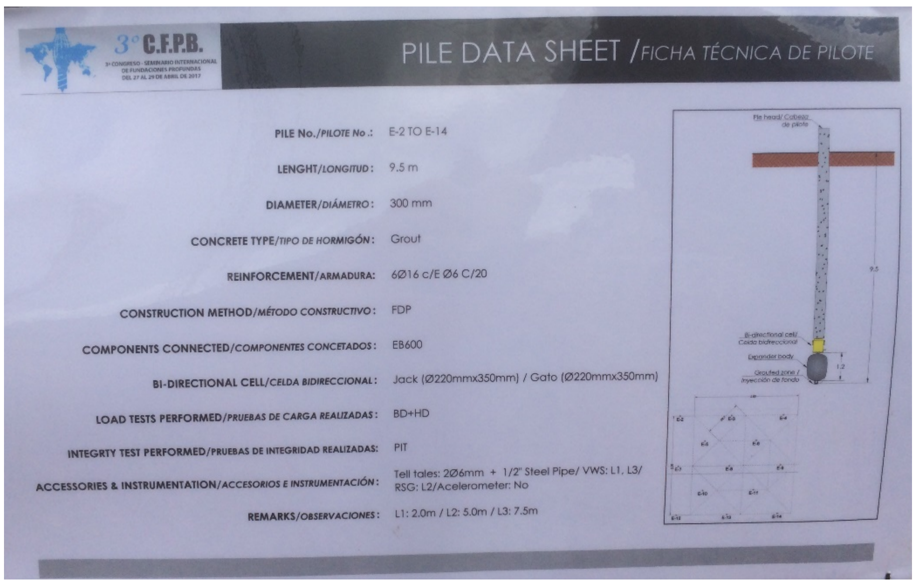
PILE DATA SHEET /*FICHA TÉCNICA DE PILOTE*

PILE No./*PILOTE No*.:	E-2 TO E-14
LENGHT/*LONGITUD*:	9.5 m
DIAMETER/*DIÁMETRO*:	300 mm
CONCRETE TYPE/*TIPO DE HORMIGÓN*:	Grout
REINFORCEMENT/*ARMADURA*:	6Ø16 c/E Ø6 C/20
CONSTRUCTION METHOD/*MÉTODO CONSTRUCTIVO*:	FDP
COMPONENTS CONNECTED/*COMPONENTES CONCETADOS*:	EB600
BI-DIRECTIONAL CELL/*CELDA BIDIRECCIONAL*:	Jack (Ø220mmx350mm) / Gato (Ø220mmx350mm)
LOAD TESTS PERFORMED/*PRUEBAS DE CARGA REALIZADAS*:	BD+HD
INTEGRTY TEST PERFORMED/*PRUEBAS DE INTEGRIDAD REALIZADAS*:	PIT
ACCESSORIES & INSTRUMENTATION/*ACCESORIOS E INSTRUMENTACIÓN*:	Tell tales: 2Ø6mm + 1/2" Steel Pipe/ VWS: L1, L3/ RSG: L2/Acelerometer: No
REMARKS/*OBSERVACIONES*:	L1: 2.0m / L2: 5.0m / L3: 7.5m

Pile head/ Cabeza de pilote
Bi-directional cell/ Celda bidireccional
Expander body
Grouted zone / Inyección de fondo

Final checking before to start test





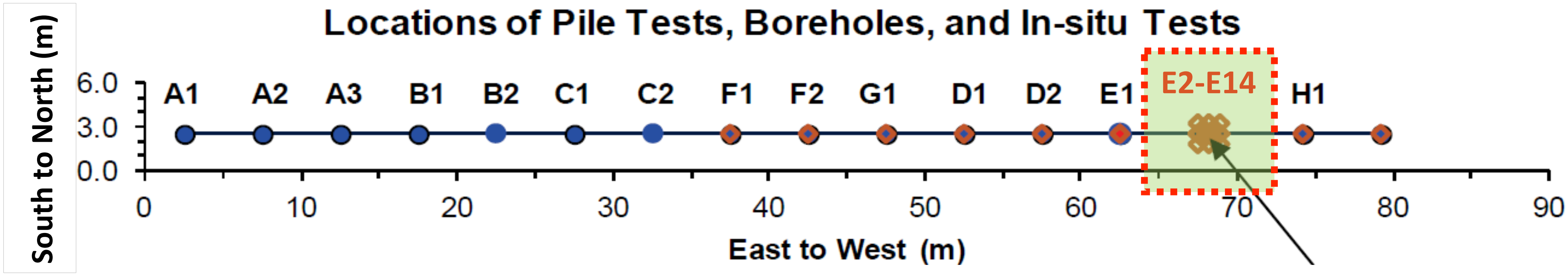
3° C.F.P.B.
3° Congreso - Seminario Internacional de Fundaciones Profundas del 27 al 29 de abril de 2017

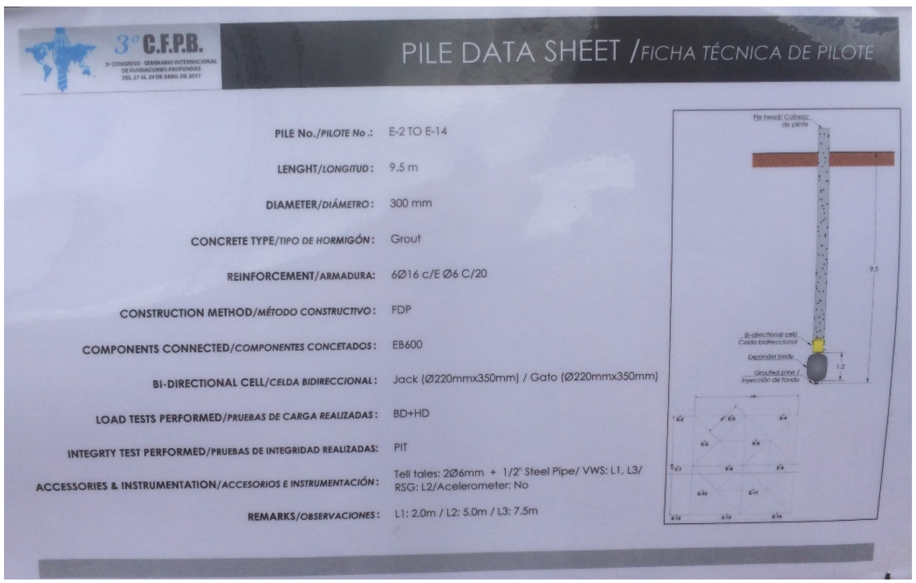
PILE DATA SHEET / *FICHA TÉCNICA DE PILOTE*

PILE No./*PILOTE No*.:	E-2 TO E-14
LENGHT/*LONGITUD*:	9.5 m
DIAMETER/*DIÁMETRO*:	300 mm
CONCRETE TYPE/*TIPO DE HORMIGÓN*:	Grout
REINFORCEMENT/*ARMADURA*:	6Ø16 c/E Ø6 C/20
CONSTRUCTION METHOD/*MÉTODO CONSTRUCTIVO*:	FDP
COMPONENTS CONNECTED/*COMPONENTES CONCETADOS*:	EB600
BI-DIRECTIONAL CELL/*CELDA BIDIRECCIONAL*:	Jack (Ø220mmx350mm) / Gato (Ø220mmx350mm)
LOAD TESTS PERFORMED/*PRUEBAS DE CARGA REALIZADAS*:	BD+HD
INTEGRTY TEST PERFORMED/*PRUEBAS DE INTEGRIDAD REALIZADAS*:	PIT
ACCESSORIES & INSTRUMENTATION/*ACCESORIOS E INSTRUMENTACIÓN*:	Tell tales: 2Ø6mm + 1/2" Steel Pipe/ VWS: L1, L3/ RSG: L2/Acelerometer: No
REMARKS/*OBSERVACIONES*:	L1: 2.0m / L2: 5.0m / L3: 7.5m

Pile head/ Cabeza de pilote
Bi-directional cell/ Celda bidireccional
Expander body
Grouted zone / Inyección de fondo

During the test





3° C.F.P.B.

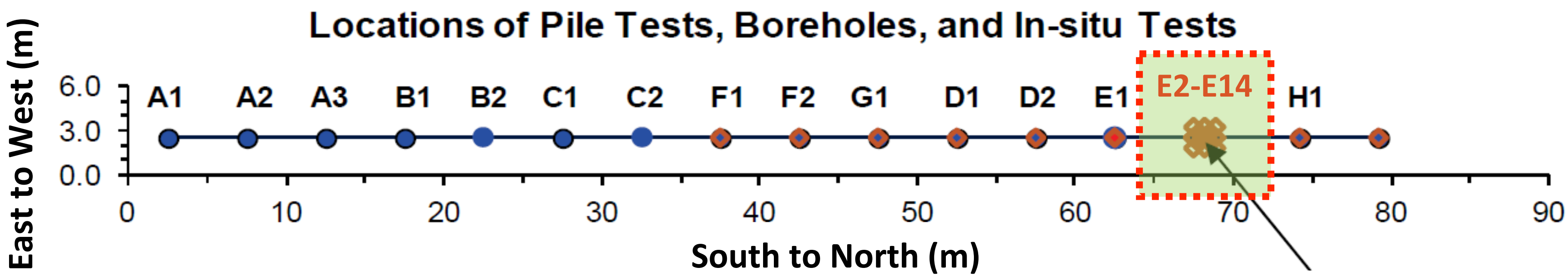
3° CONGRESO - SEMINARIO INTERNACIONAL DE FUNDACIONES PROFUNDAS DEL 27 AL 29 DE ABRIL DE 2017

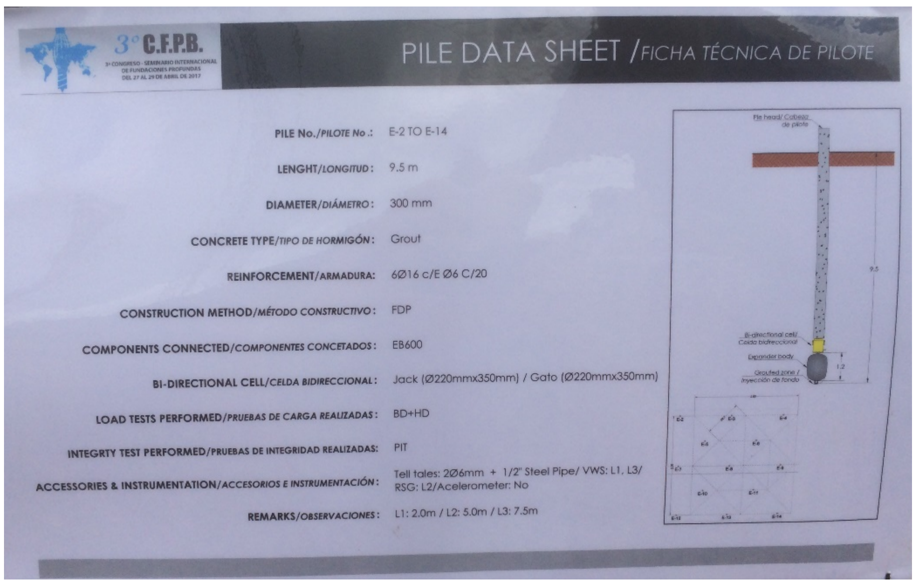
PILE DATA SHEET /FICHA TÉCNICA DE PILOTE

PILE No./PILOTE No.:	E-2 TO E-14
LENGHT/LONGITUD:	9.5 m
DIAMETER/DIÁMETRO:	300 mm
CONCRETE TYPE/TIPO DE HORMIGÓN:	Grout
REINFORCEMENT/ARMADURA:	6Ø16 c/E Ø6 C/20
CONSTRUCTION METHOD/MÉTODO CONSTRUCTIVO:	FDP
COMPONENTS CONNECTED/COMPONENTES CONCETADOS:	EB600
BI-DIRECTIONAL CELL/CELDA BIDIRECCIONAL:	Jack (Ø220mmx350mm) / Gato (Ø220mmx350mm)
LOAD TESTS PERFORMED/PRUEBAS DE CARGA REALIZADAS:	BD+HD
INTEGRTY TEST PERFORMED/PRUEBAS DE INTEGRIDAD REALIZADAS:	PIT
ACCESSORIES & INSTRUMENTATION/ACCESORIOS E INSTRUMENTACIÓN:	Tell tales: 2Ø6mm + 1/2" Steel Pipe/ VWS: L1, L3/ RSG: L2/Acelerometer: No
REMARKS/OBSERVACIONES:	L1: 2.0m / L2: 5.0m / L3: 7.5m

Pile head/ Cabeza de pilote
Bi-directional cell/ Celda bidireccional
Expander body
Grouted zone / Inyección de fondo

At the end of the test

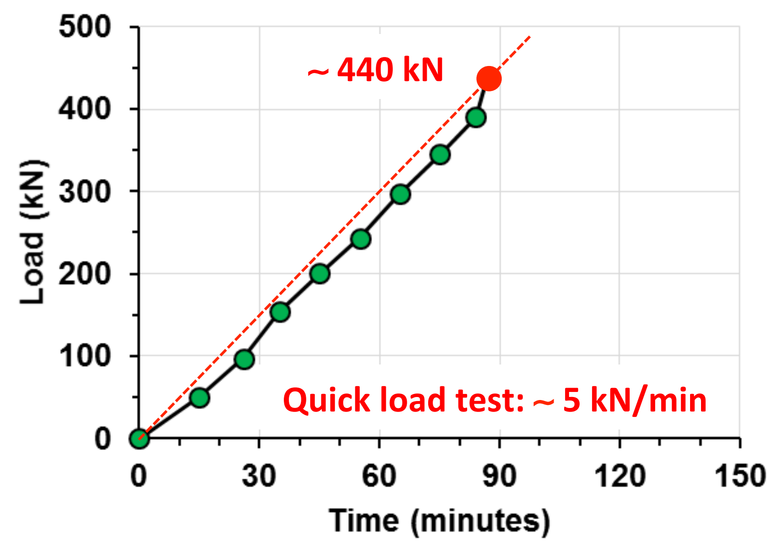


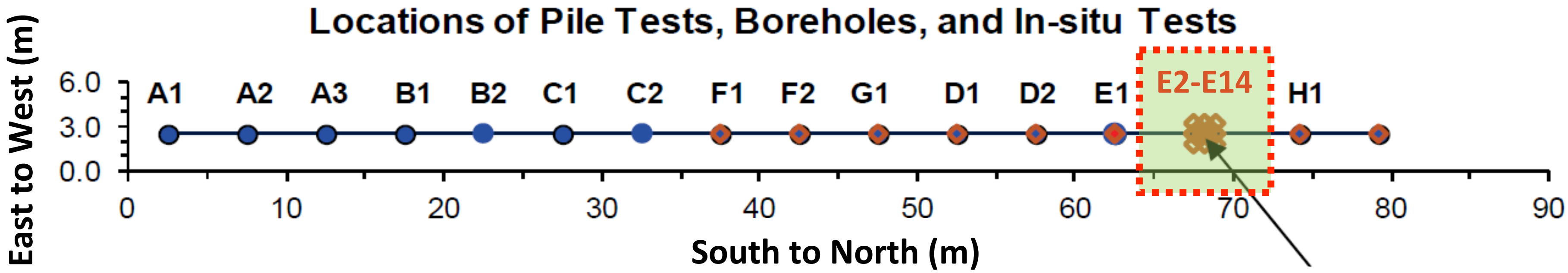


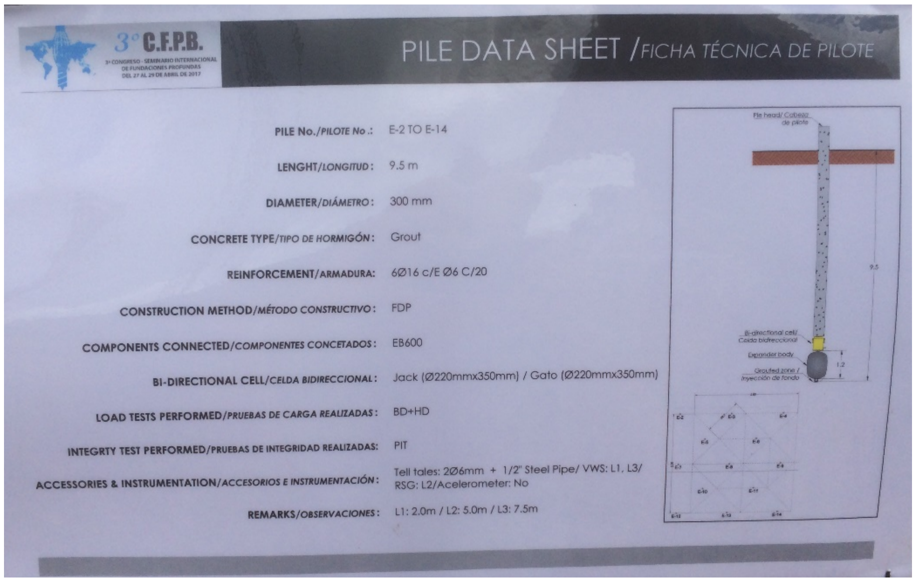
3° C.F.P.B.
3° CONGRESO - SEMINARIO INTERNACIONAL DE FUNDACIONES PROFUNDAS DEL 27 AL 29 DE ABRIL DE 2017

PILE DATA SHEET / FICHA TÉCNICA DE PILOTE

PILE No./PILOTE No.:	E-2 TO E-14
LENGHT/LONGITUD:	9.5 m
DIAMETER/DIÁMETRO:	300 mm
CONCRETE TYPE/TIPO DE HORMIGÓN:	Grout
REINFORCEMENT/ARMADURA:	6Ø16 c/E Ø6 C/20
CONSTRUCTION METHOD/MÉTODO CONSTRUCTIVO:	FDP
COMPONENTS CONNECTED/COMPONENTES CONCETADOS:	EB600
BI-DIRECTIONAL CELL/CELDA BIDIRECCIONAL:	Jack (Ø220mmx350mm) / Gato (Ø220mmx350mm)
LOAD TESTS PERFORMED/PRUEBAS DE CARGA REALIZADAS:	BD+HD
INTEGRTY TEST PERFORMED/PRUEBAS DE INTEGRIDAD REALIZADAS:	PIT
ACCESSORIES & INSTRUMENTATION/ACCESORIOS E INSTRUMENTACIÓN:	Tell tales: 2Ø6mm + 1/2" Steel Pipe/ VWS: L1, L3/ RSG: L2/Accelerometer: No
REMARKS/OBSERVACIONES:	L1: 2.0m / L2: 5.0m / L3: 7.5m





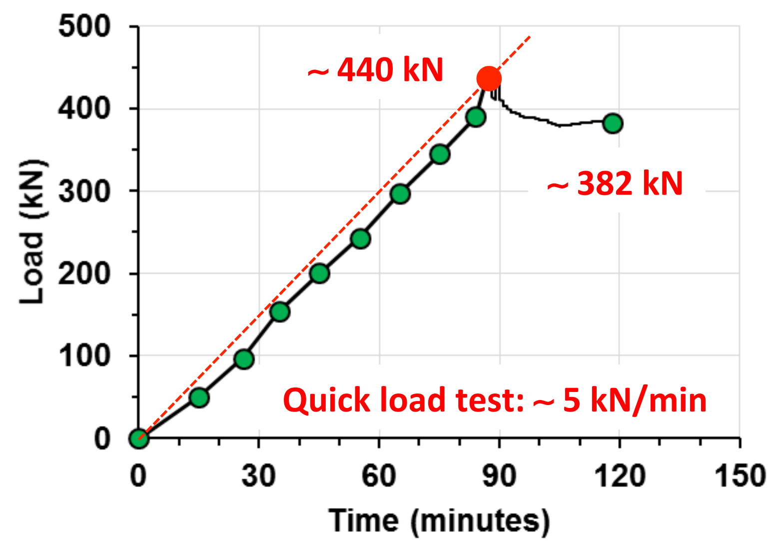


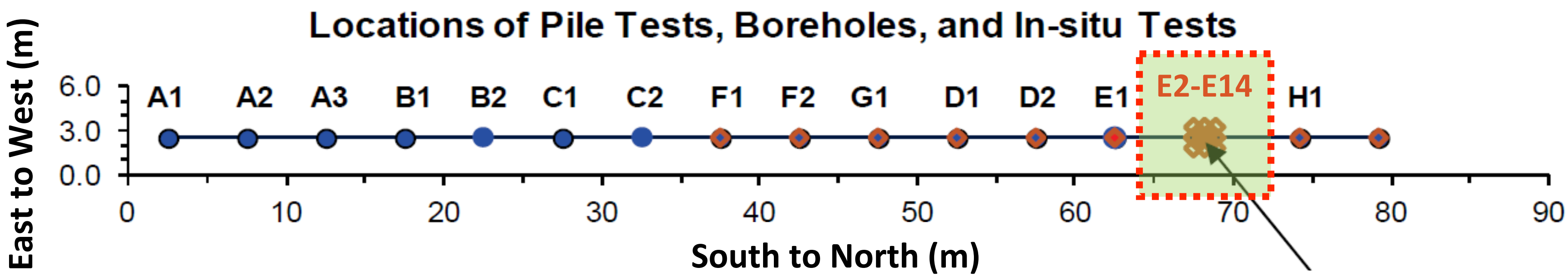
3° C.F.P.B.
3° CONGRESO - SEMINARIO INTERNACIONAL DE FUNDACIONES PROFUNDAS DEL 27 AL 29 DE ABRIL DE 2017

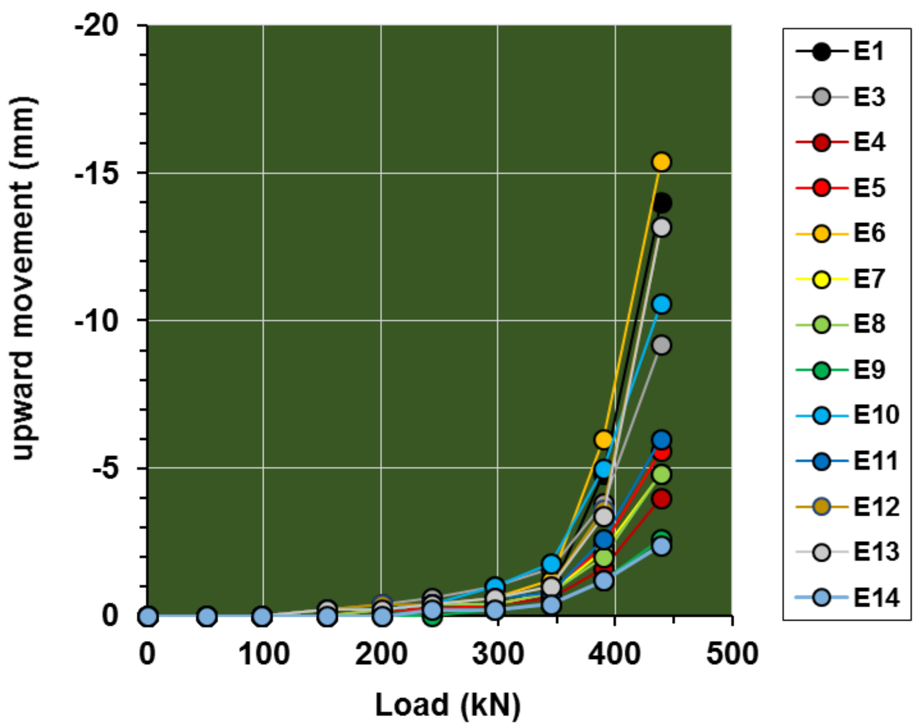
PILE DATA SHEET / *FICHA TÉCNICA DE PILOTE*

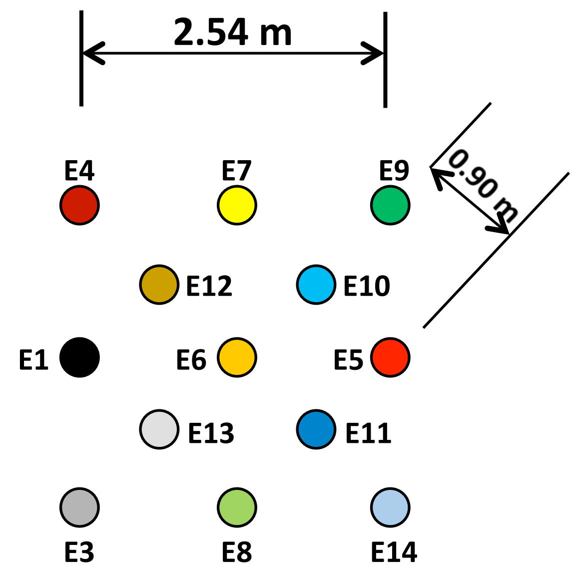
PILE No./*PILOTE No*.:	E-2 TO E-14
LENGHT/*LONGITUD*:	9.5 m
DIAMETER/*DIÁMETRO*:	300 mm
CONCRETE TYPE/*TIPO DE HORMIGÓN*:	Grout
REINFORCEMENT/*ARMADURA*:	6Ø16 c/E Ø6 C/20
CONSTRUCTION METHOD/*MÉTODO CONSTRUCTIVO*:	FDP
COMPONENTS CONNECTED/*COMPONENTES CONCETADOS*:	EB600
BI-DIRECTIONAL CELL/*CELDA BIDIRECCIONAL*:	Jack (Ø220mmx350mm) / Gato (Ø220mmx350mm)
LOAD TESTS PERFORMED/*PRUEBAS DE CARGA REALIZADAS*:	BD+HD
INTEGRTY TEST PERFORMED/*PRUEBAS DE INTEGRIDAD REALIZADAS*:	PIT
ACCESSORIES & INSTRUMENTATION/*ACCESORIOS E INSTRUMENTACIÓN*:	Tell tales: 2Ø6mm + 1/2" Steel Pipe/ VWS: L1, L3/ RSG: L2/Acelerometer: No
REMARKS/*OBSERVACIONES*:	L1: 2.0m / L2: 5.0m / L3: 7.5m

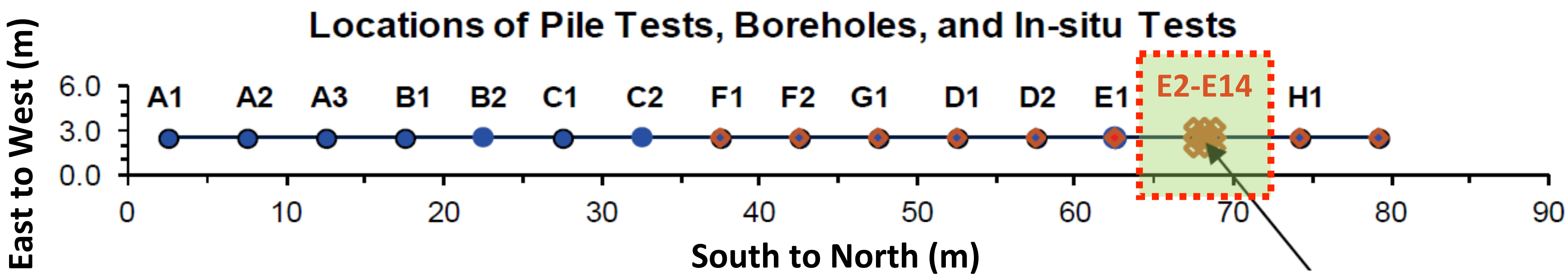
Pile head/ Cabeza de pilote
Bi-directional cell/ Celda bidireccional
Expander body
Grouted zone / Inyección de fondo

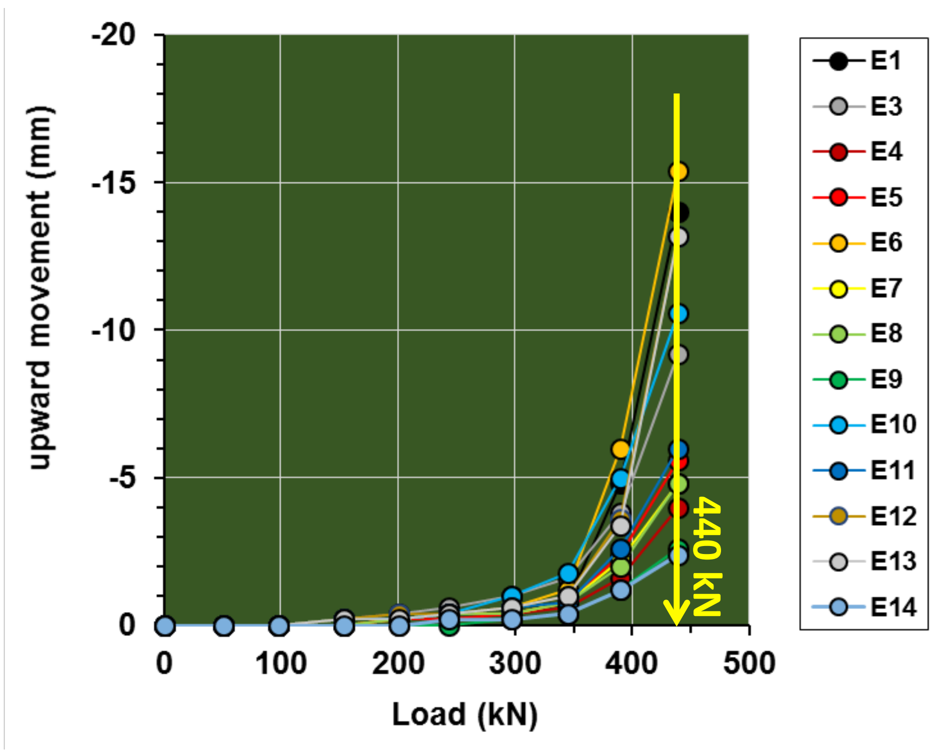


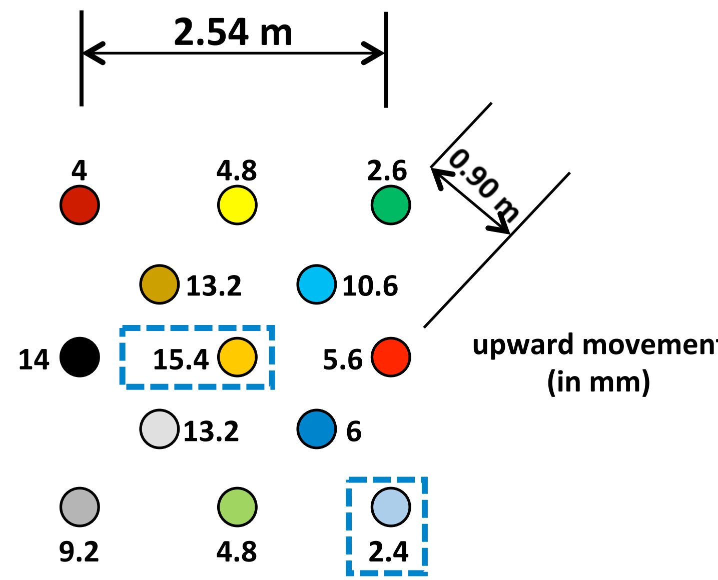

Locations of Pile Tests, Boreholes, and In-situ Tests
East to West (m)
6.0
3.0
0.0
A1
A2
A3
B1
B2
C1
C2
F1
F2
G1
D1
D2
E1
E2-E14
H1
0
10
20
30
40
50
60
70
80
90
South to North (m)


upward movement (mm)
-20
-15
-10
-5
0
0
100
200
300
400
500
Load (kN)
E1
E3
E4
E5
E6
E7
E8
E9
E10
E11
E12
E13
E14

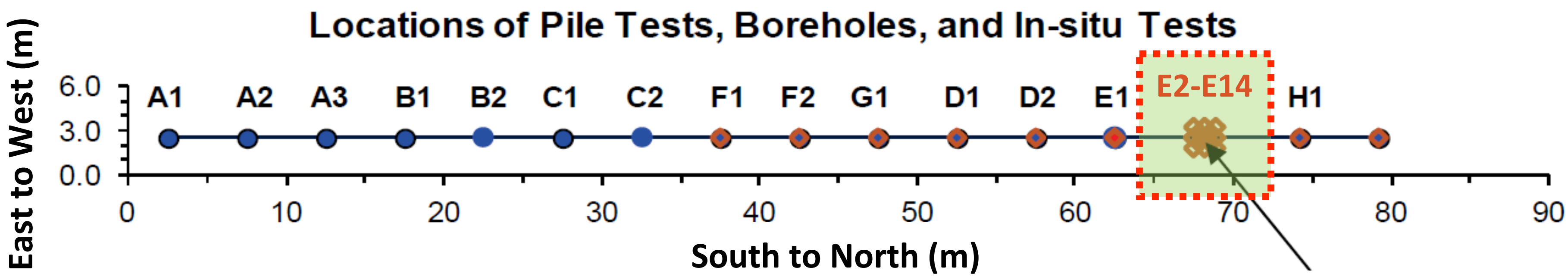

2.54 m
0.90 m
E4
E7
E9
E12
E10
E1
E6
E5
E13
E11
E3
E8
E14

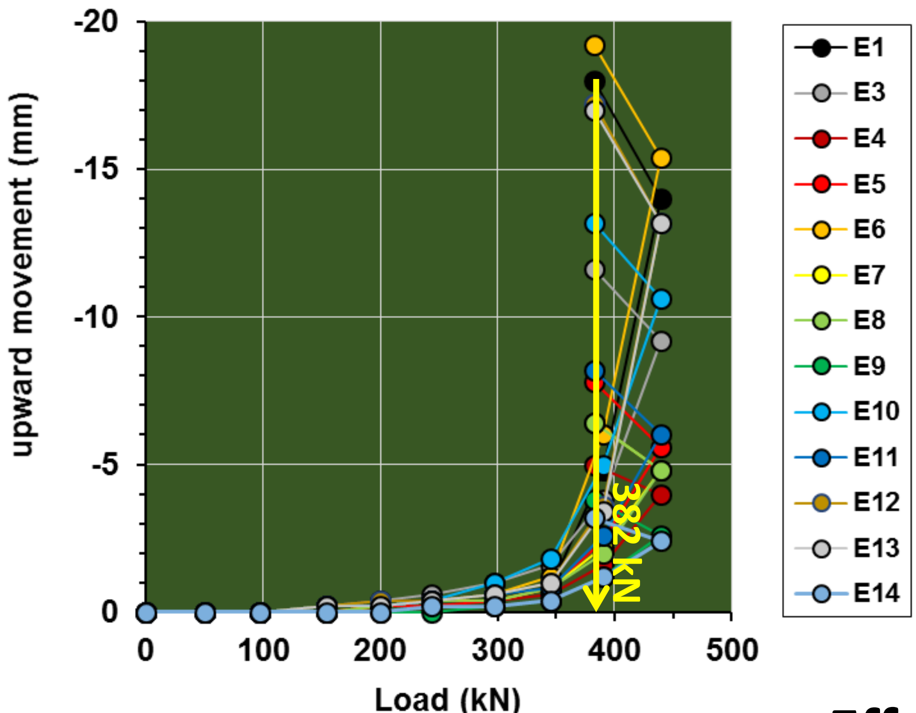


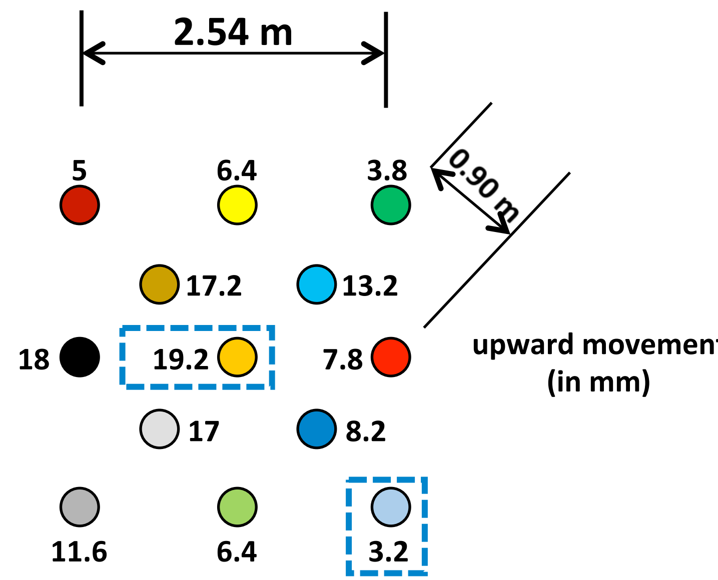




Min. movement: 2.4 mm
Max. movement: 15.4 mm

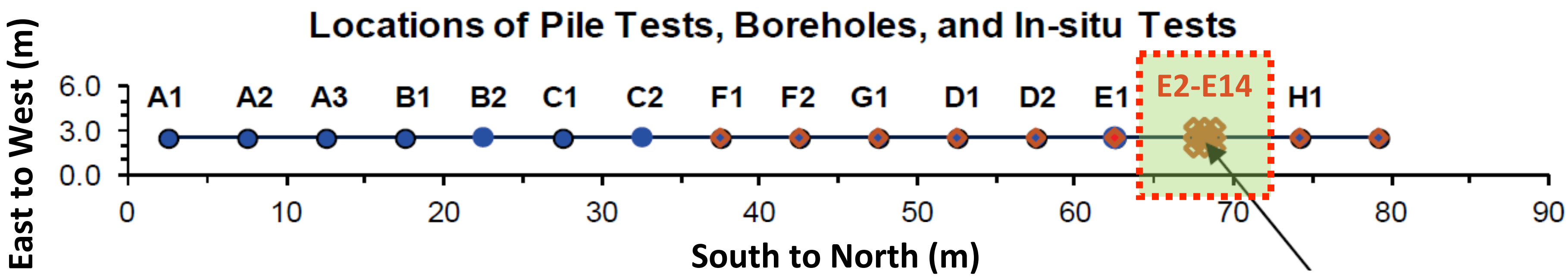




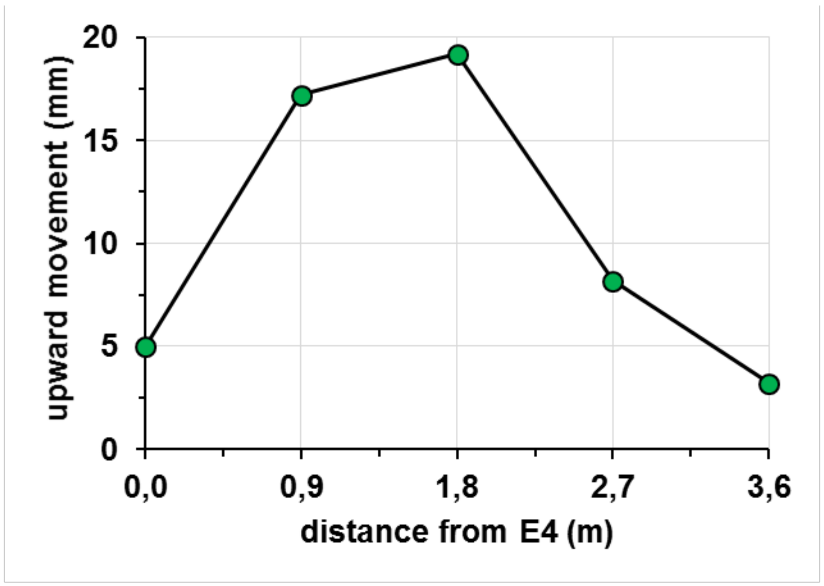


Effect of the load relaxation (~ 30 min)

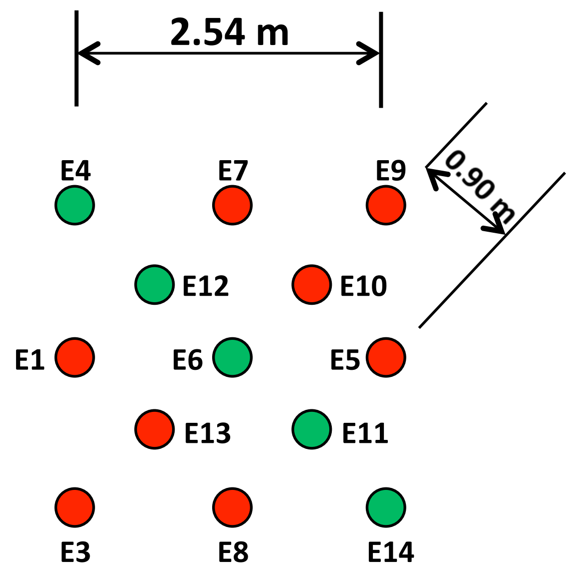
Min. movement: 3.2 mm (+0.8 mm)
Max. movement: 19.2 mm (+3.8 mm)



Locations of Pile Tests, Boreholes, and In-situ Tests
East to West (m)
South to North (m)
A1
A2
A3
B1
B2
C1
C2
F1
F2
G1
D1
D2
E1
E2-E14
H1

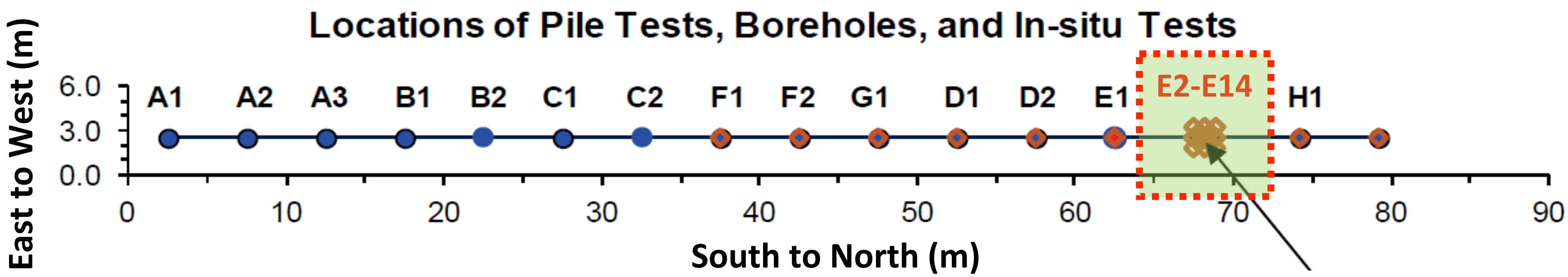


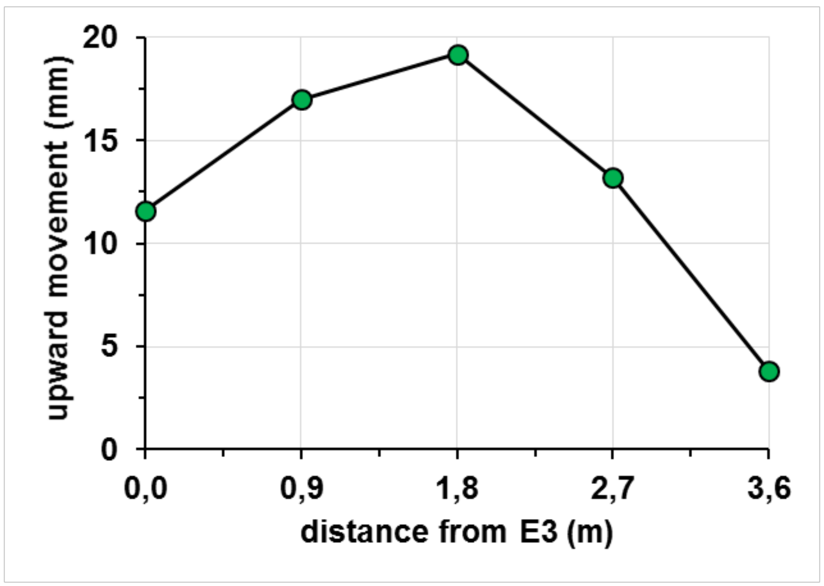
upward movement (mm)
distance from E4 (m)

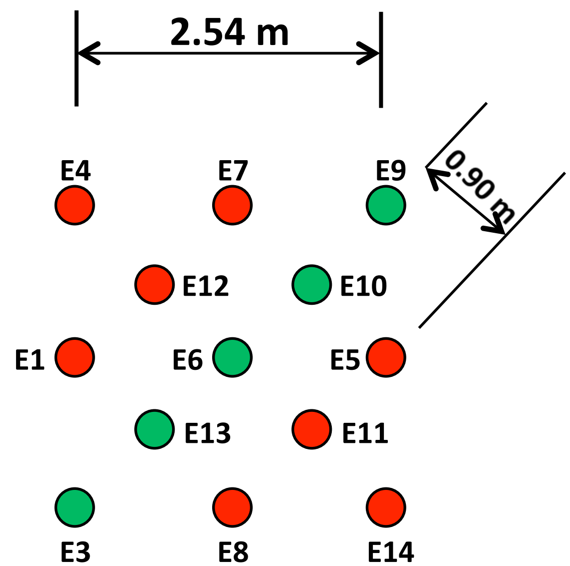


2.54 m
0.90 m
E4
E7
E9
E12
E10
E1
E6
E5
E13
E11
E3
E8
E14

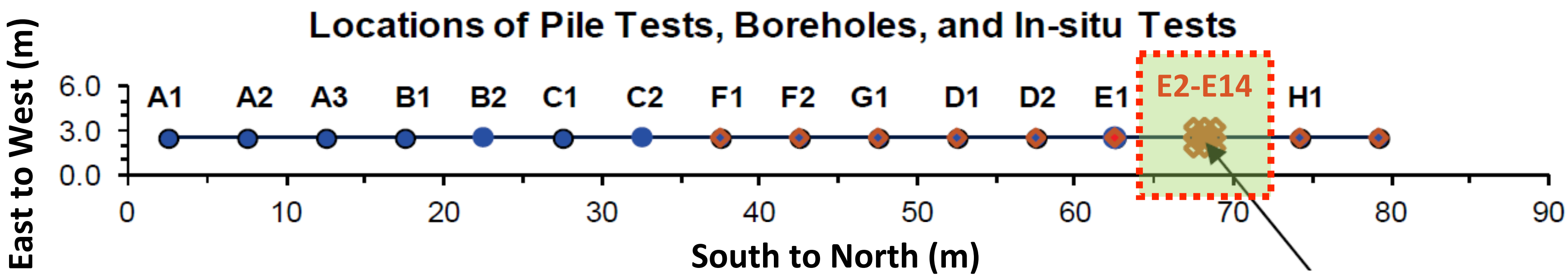
NO SYMMETRY

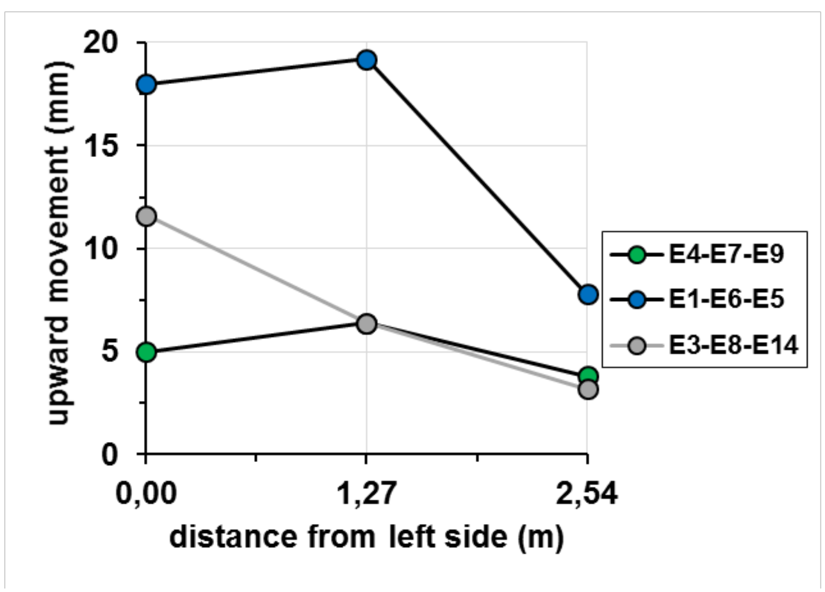

Locations of Pile Tests, Boreholes, and In-situ Tests
East to West (m)
6.0
3.0
0.0
A1
A2
A3
B1
B2
C1
C2
F1
F2
G1
D1
D2
E1
E2-E14
H1
0
10
20
30
40
50
60
70
80
90
South to North (m)

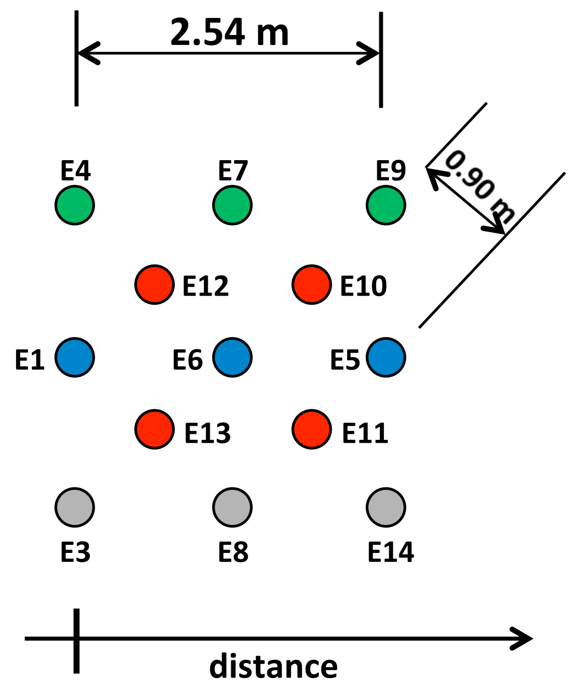

upward movement (mm)
20
15
10
5
0
0,0
0,9
1,8
2,7
3,6
distance from E3 (m)


2.54 m
0.90 m
E4
E7
E9
E12
E10
E1
E6
E5
E13
E11
E3
E8
E14

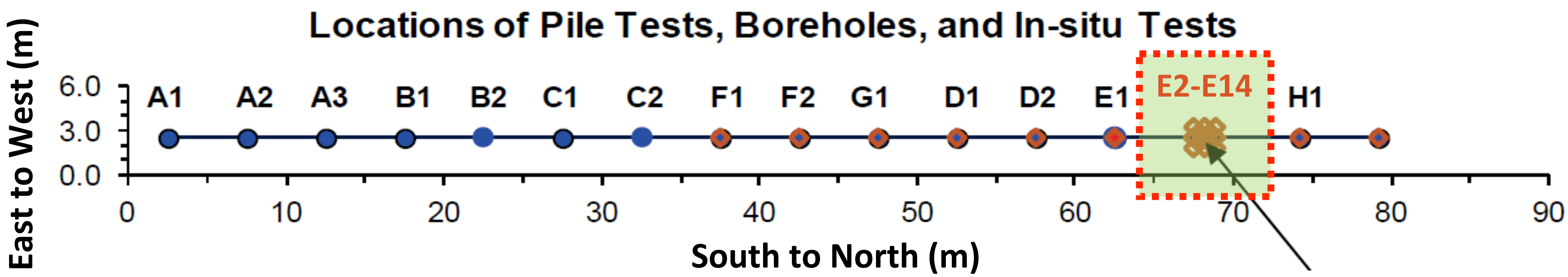
NO SYMMETRY

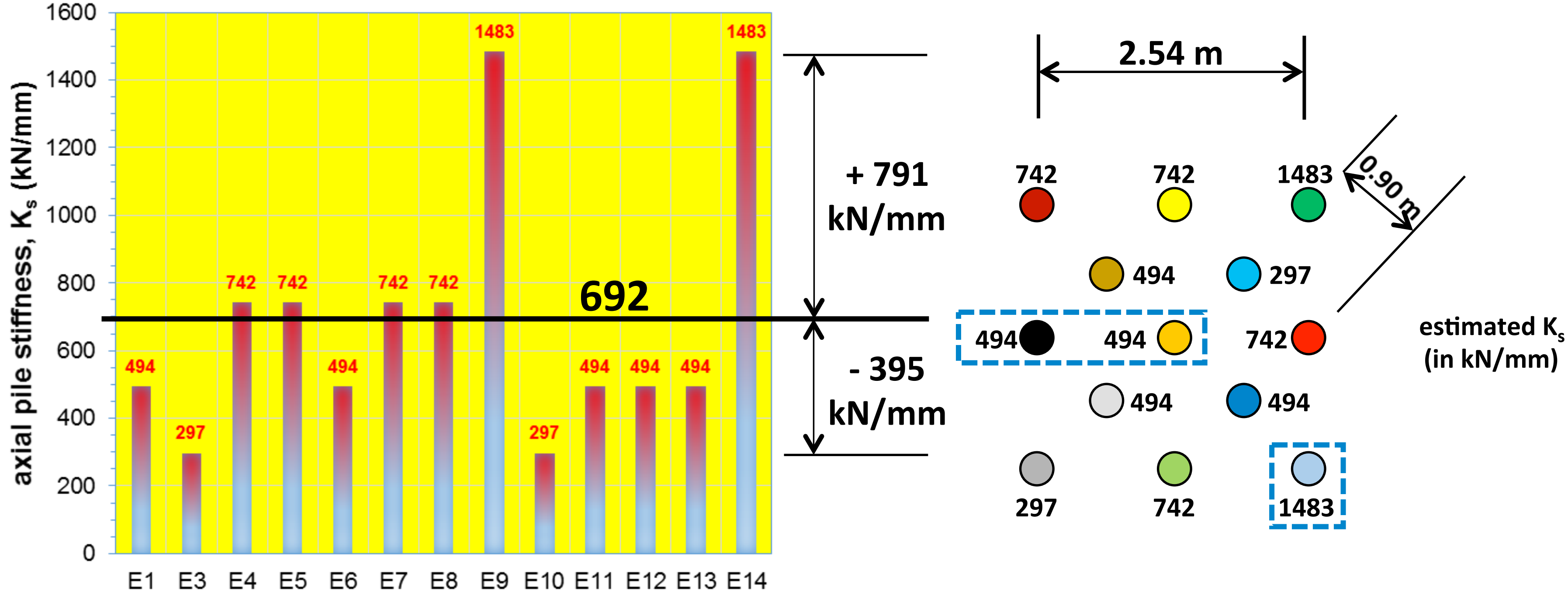

Locations of Pile Tests, Boreholes, and In-situ Tests
East to West (m)
South to North (m)
A1
A2
A3
B1
B2
C1
C2
F1
F2
G1
D1
D2
E1
E2-E14
H1
6.0
3.0
0.0
0
10
20
30
40
50
60
70
80
90


upward movement (mm)
distance from left side (m)
20
15
10
5
0
0,00
1,27
2,54
E4-E7-E9
E1-E6-E5
E3-E8-E14

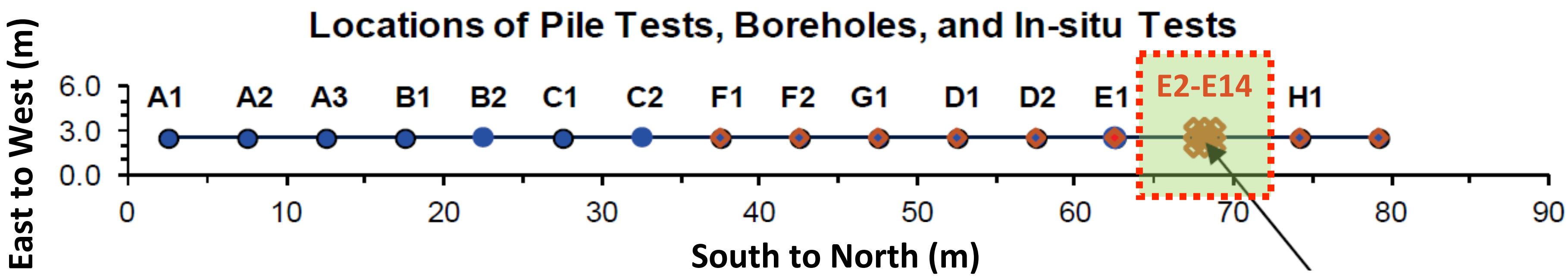

2.54 m
0.90 m
E4
E7
E9
E12
E10
E1
E6
E5
E13
E11
E3
E8
E14
distance

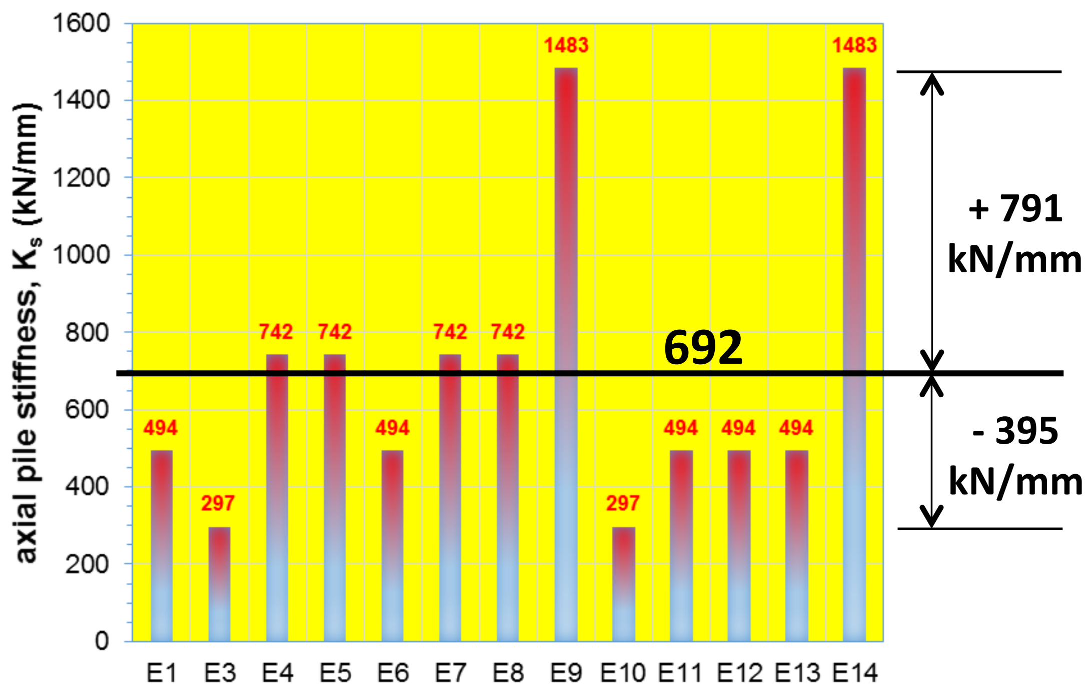
NO SYMMETRY

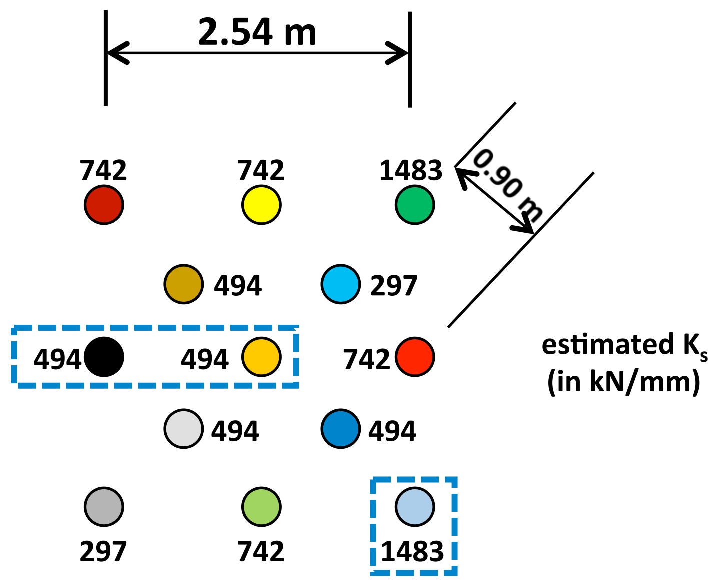




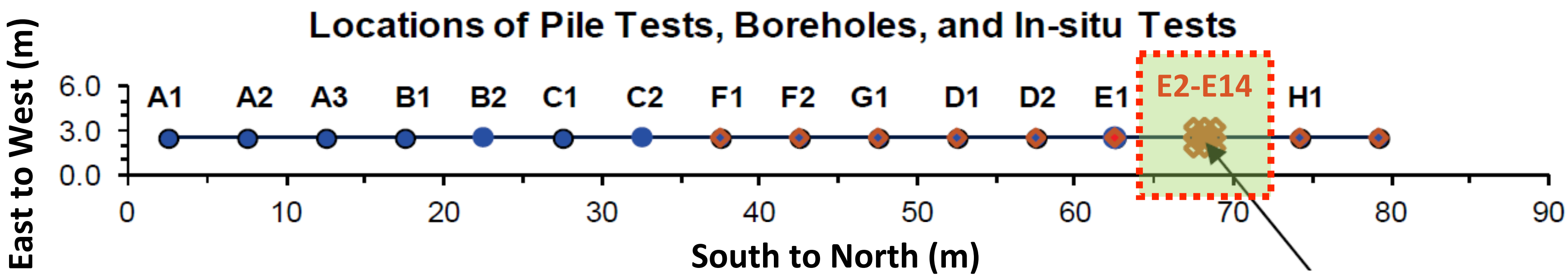
Large scatter (1:3)

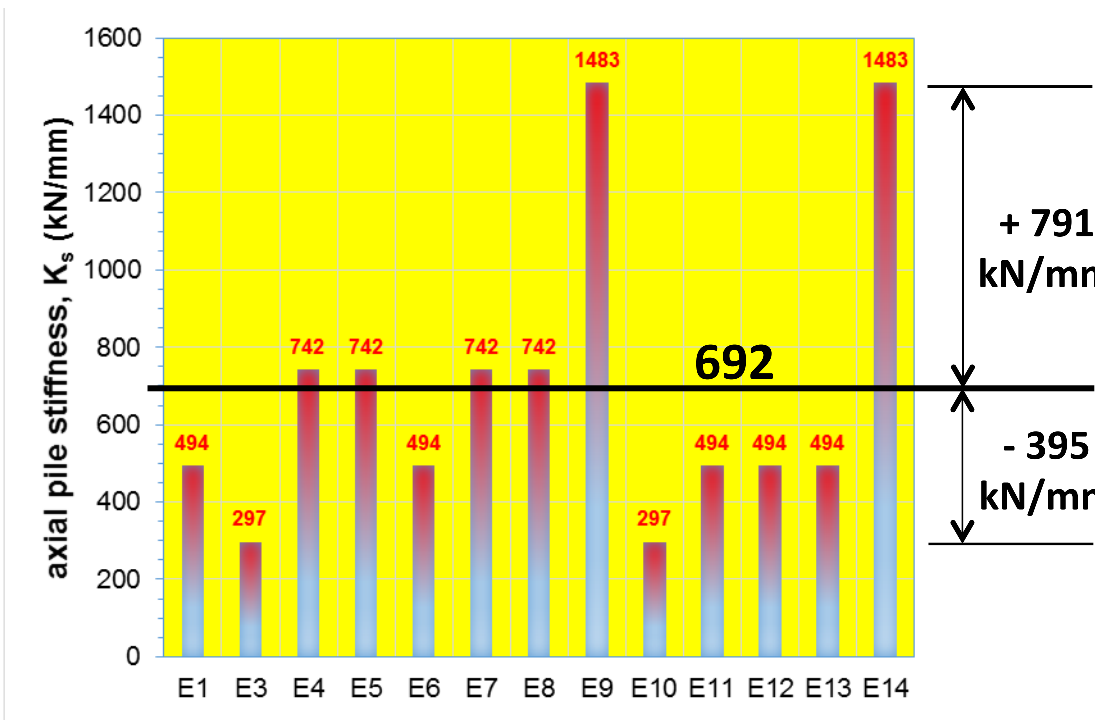


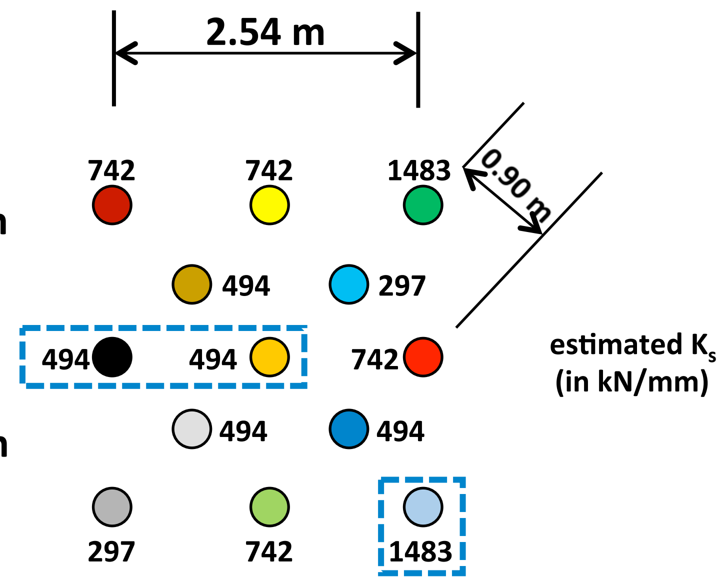




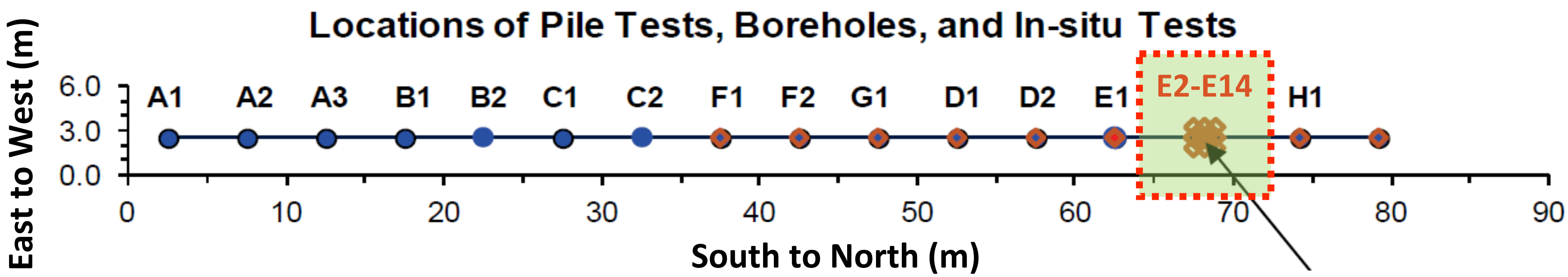
$$K_{s,Ei} / K_{s,E2} = 32 \div 162\%$$

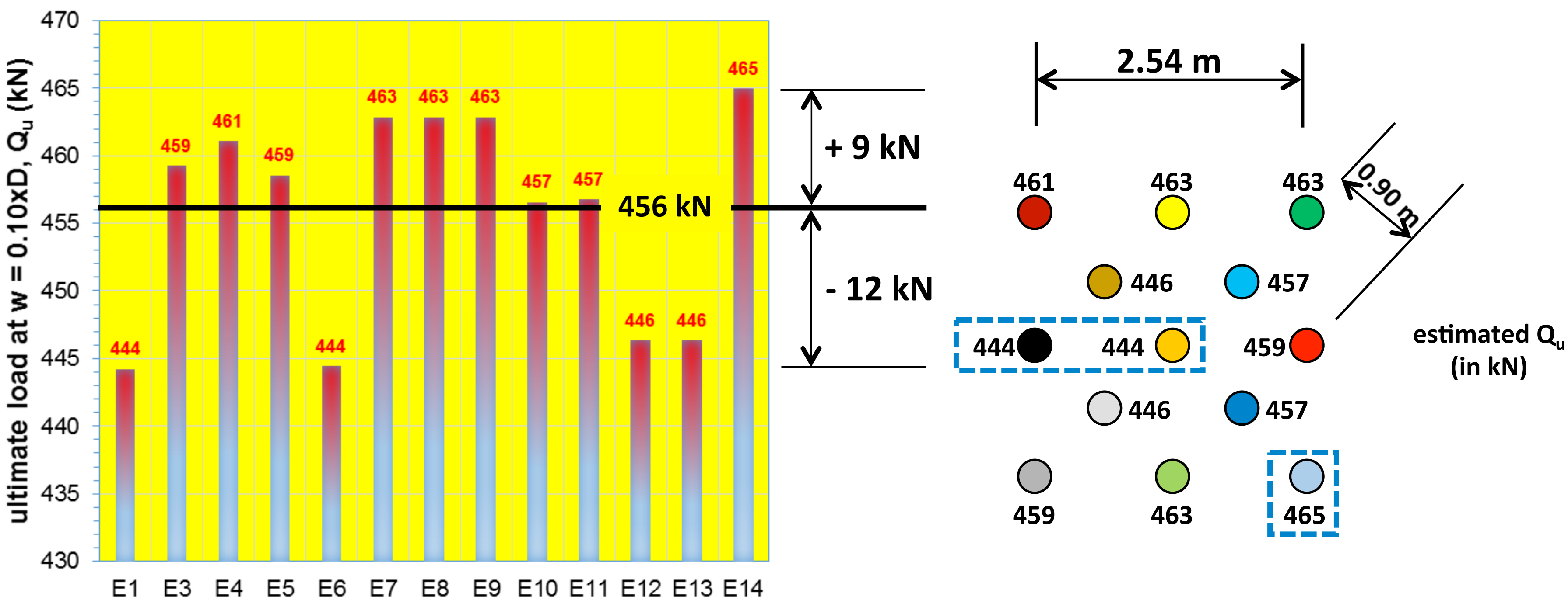

Locations of Pile Tests, Boreholes, and In-situ Tests
East to West (m)
6.0
3.0
0.0
A1
A2
A3
B1
B2
C1
C2
F1
F2
G1
D1
D2
E1
E2-E14
H1
0
10
20
30
40
50
60
70
80
90
South to North (m)


axial pile stiffness, K_s (kN/mm)
1600
1400
1200
1000
800
600
400
200
0
494
297
742
742
494
742
742
1483
297
494
494
494
1483
692
E1 E3 E4 E5 E6 E7 E8 E9 E10 E11 E12 E13 E14
+ 791
kN/mm
- 395
kN/mm

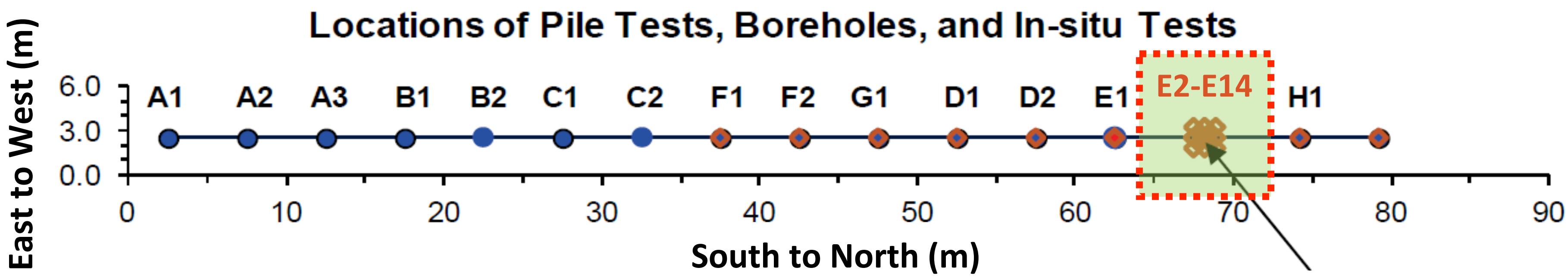

2.54 m
0.90 m
742
742
1483
494
297
494
494
742
494
494
297
742
1483
estimated K_s
(in kN/mm)

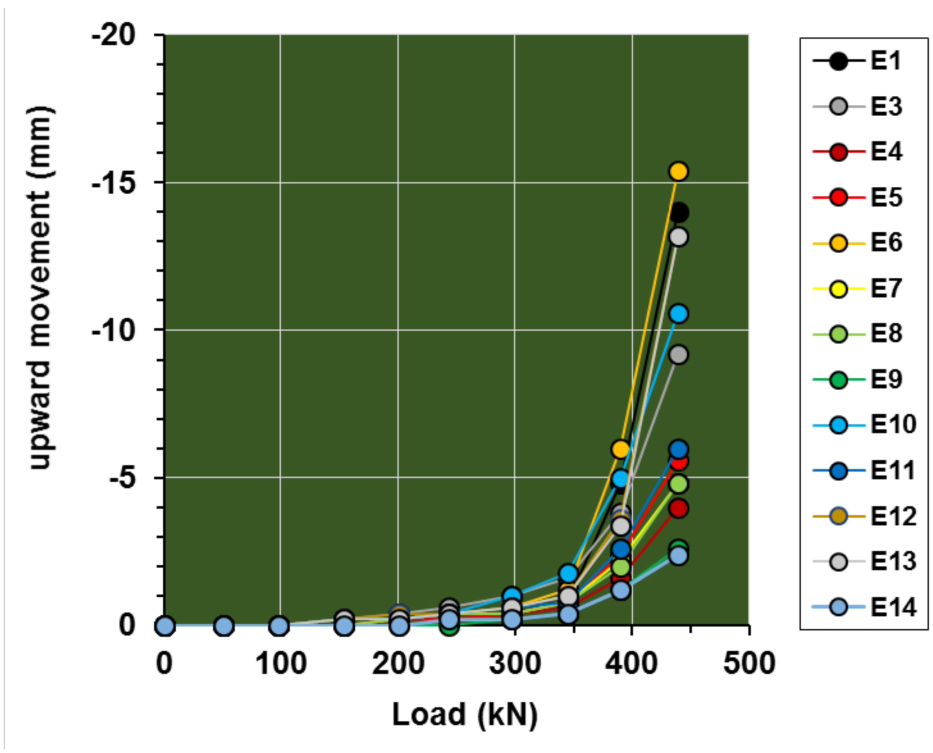
$$K_{s,av} / K_{s,E2} = 76\%$$

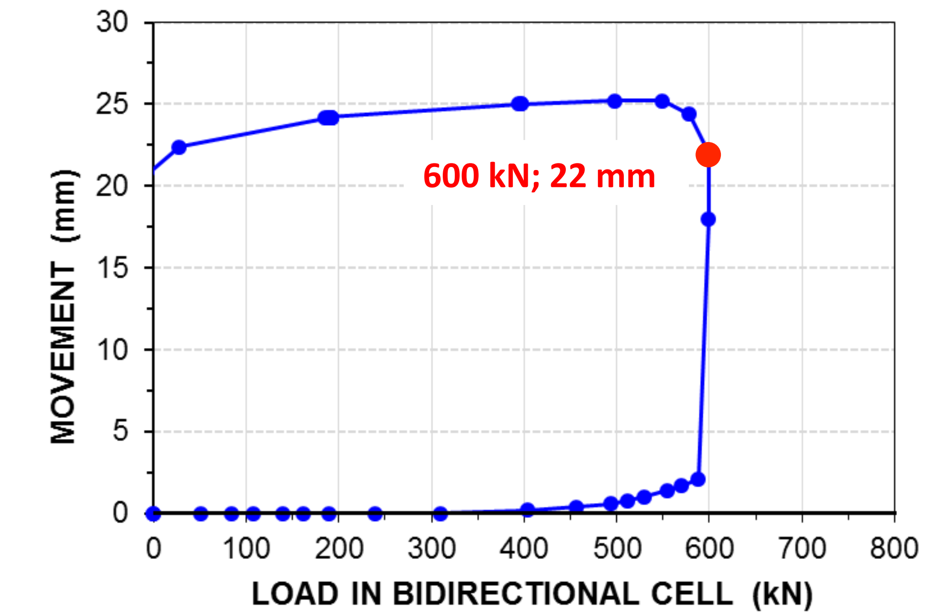




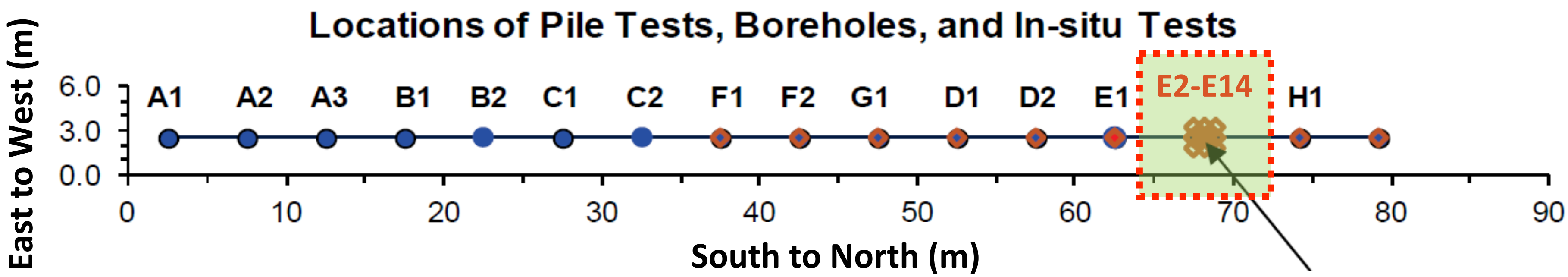
Small scatter (1:1.05)







$$Q_{u,Ei} / Q_{u,E2} = 74 \div 78\%$$



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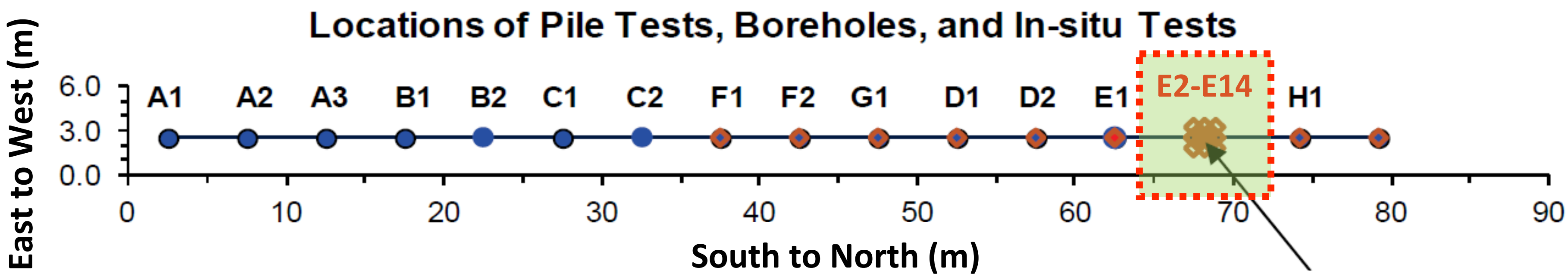
2) **Single pile BD test completed on 22/03/2017**
3) **Phase 1: Pile Group BD test completed on 25/04/2017**
4) **Phase 2 & 3: planned closely (not yet available)**



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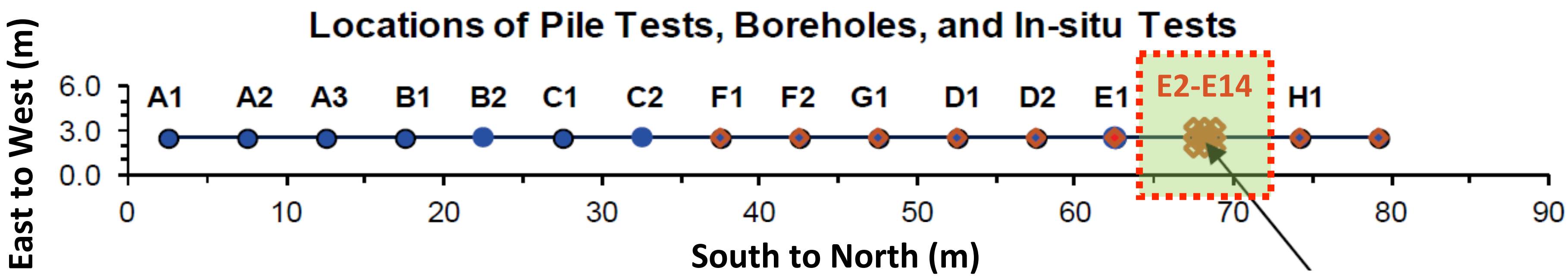
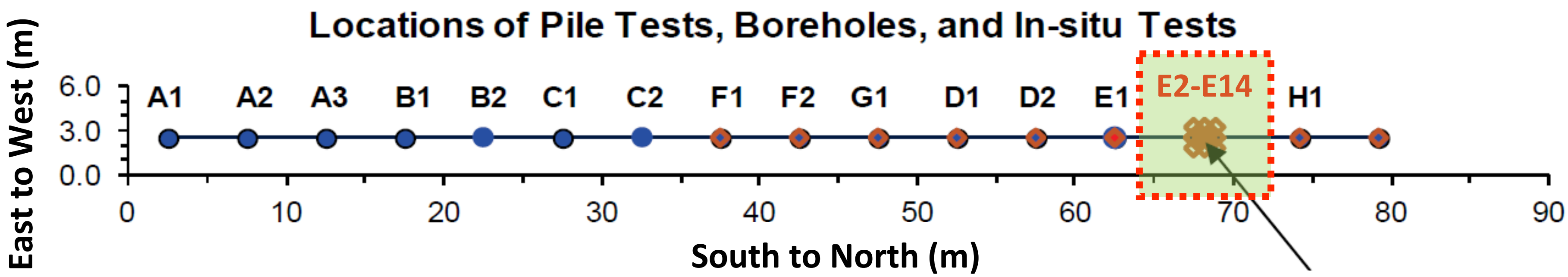
PHASE 1: NO ENOUGH TIME FOR A COMPLETE DATA PROCESS



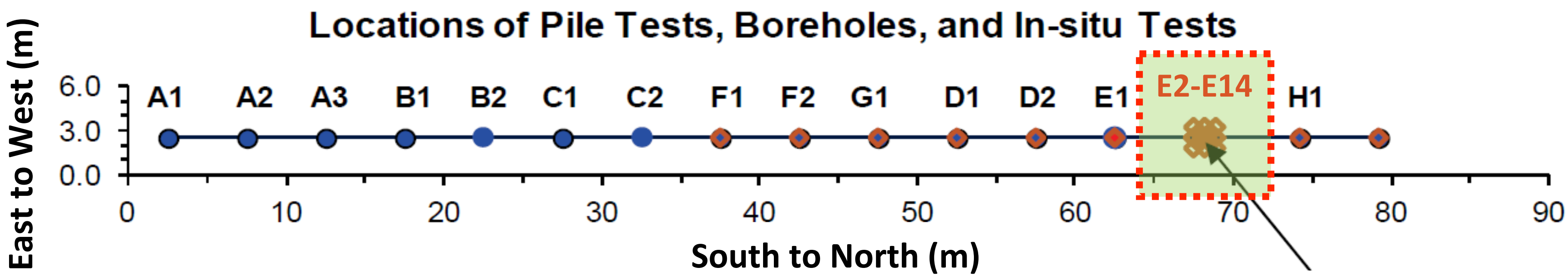
PRELIMINARY REMARKS (limited to Phase 1)

UNIVERSITÀ DEGLI STUDI DELLA CAMPANIA
LUIGI VANVITELLI
SCUOLA POLITECNICA E DELLE SCIENZE DI BASE
DIPARTIMENTO DI INGEGNERIA CIVILE
DESIGN EDILIZIA E AMBIENTE



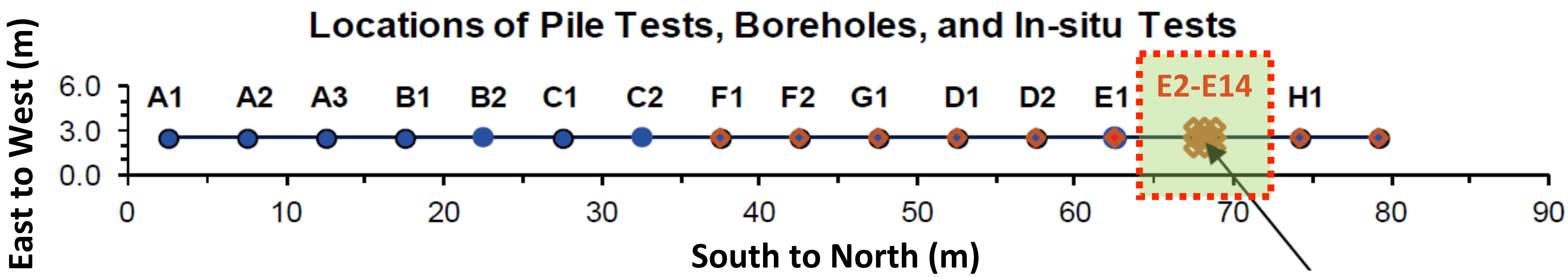
PRELIMINARY REMARKS (limited to Phase 1)

- **Asymmetric pile response will make very hard the interpretation by any model;**



PRELIMINARY REMARKS (limited to Phase 1)

- ❑ Asymmetric pile response will make very hard the interpretation by any model;
- ❑ Piles exhibited similar response at large movement (as extrapolated at w = 0.10xD; small scatter, 1:1.05), contrarily to what observed at small movement (large scatter, 1:3);



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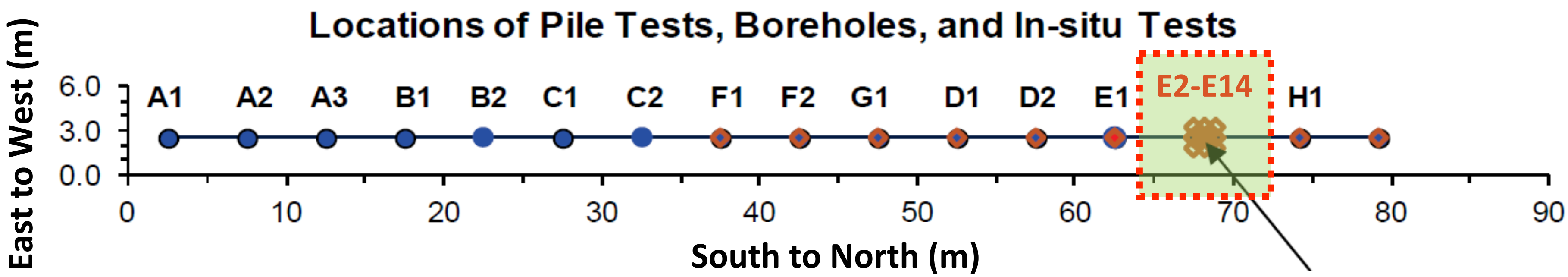

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- The same applies to stiffness, although some piles exhibited stiffer response of that observed on single pile E1.

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BOLIVIAN EXPERIMENTAL SITE FOR TESTING (B.E.S.T.)

SESSION 3: Experimental Results and Predictions

Pile Group and Piled Raft

Main conclusion from the site (Bengt, Mario jr. & Alessandro):

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“We don’t know what we learned but something we will learn”