Case studies in Japan

Applications of piled raft foundations to buildings

2 cases from TAISEI Corporation

10 cases from TAKENAKA Corporation

1 case from OBAYASHI Corp. and YASUI KENCHIKU Corp.

Importance of case study

- Load transfer of piled rafts assumed in design is compatible with field performance?
- Influence of construction method on bahaviour of piled rafts?
- Influence of change in ground water table (water pressure at the raft base) on behaviour of piled rafts?

- Confirmation of possibility of piled rafts through field observations.
- Development of new pile construction methods adequate for piled rafts.

Piled raft for low-rise building

TAISEI Corporation

Location: Tsukuba City
Number of stories: Two above grade
Building area: 530 m^2
Total floor area: 1040 m^2

Superstructure type: Reinforced concrete
Foundation type: Piled raft
Construction : July 1999 to March 2000

Piled raft for low-rise building

TAISEI Corporation

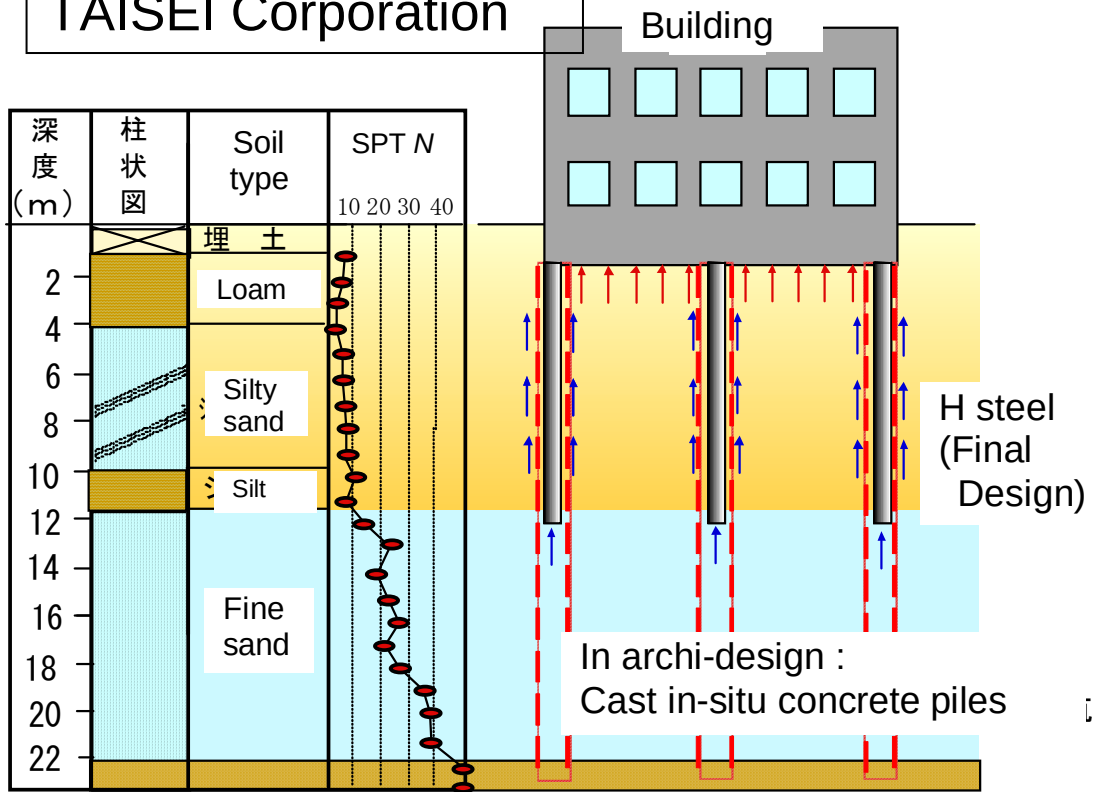
Design process

Pile group in archi-design

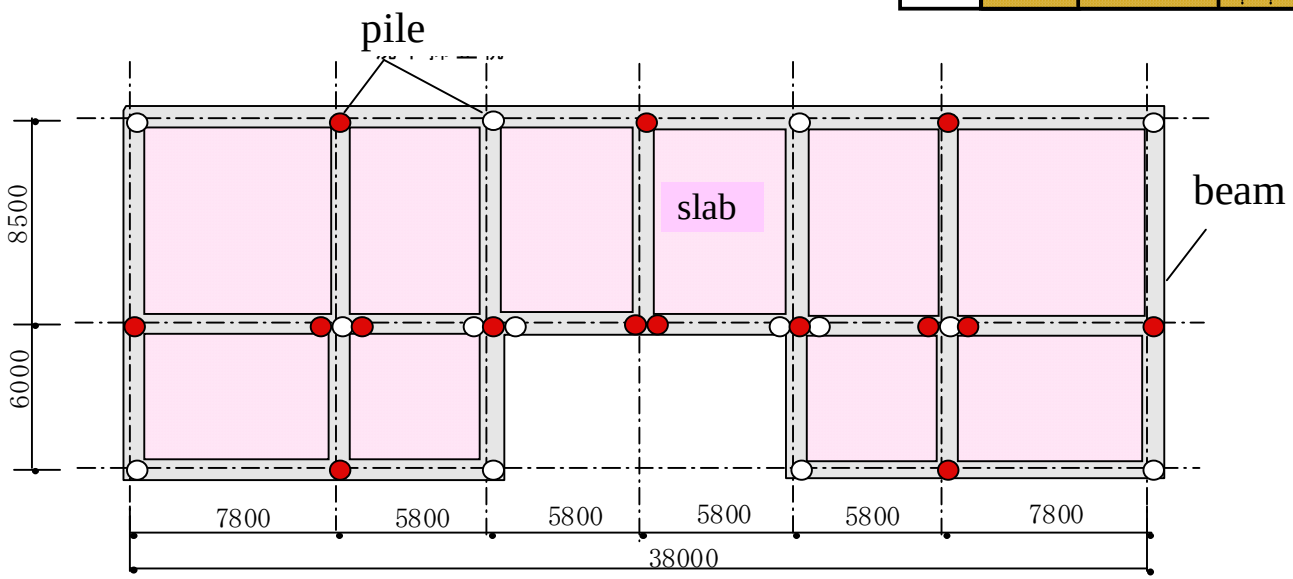
↓

Piled raft in final design

Symbol	Direction	Pile section
○	H	H-250×250×9×14
●	工	H-250×250×9×14



Cross-section



Pile arrangement

Combined use of anti-liquefaction soil improvement and piled raft

Design process

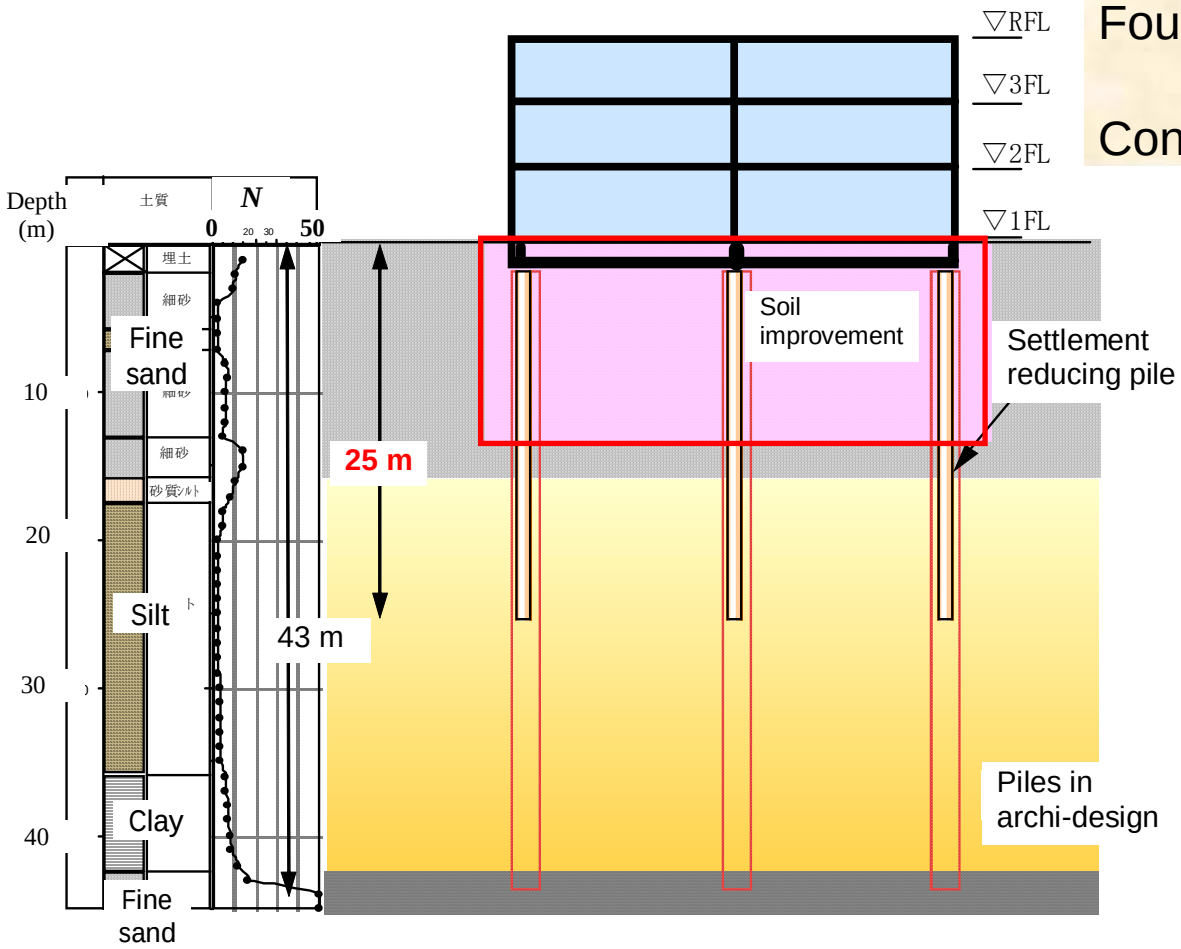
SC piles having a length of 43 m

⇩

SC piles having a length of 25 m

Location: Tokyo
Number of stories: Three above grade
Building area: 810 m^2
Total floor area: 2400 m^2

Foundation type: Soil improvement
+ Piled raft
Construction : Nov. 2000 to May 2001

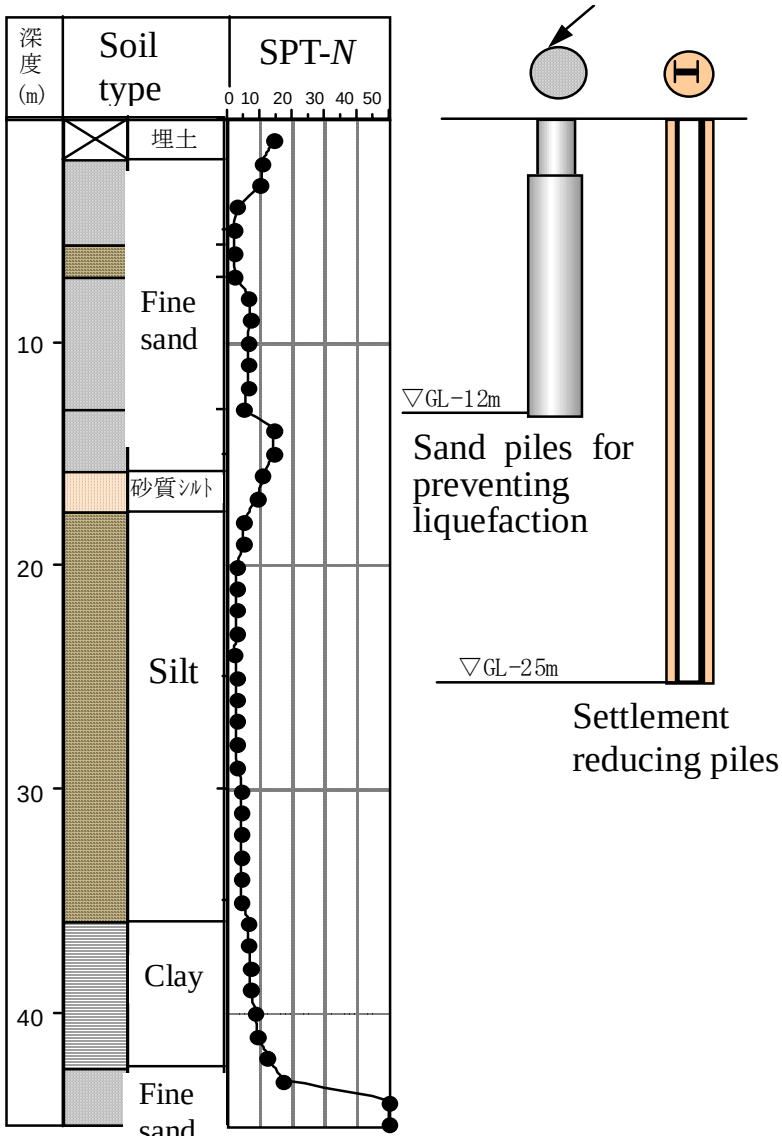


Settlement reducing piles:
SC pile: H-steel + soil cement
45 piles

Soil improvement:
178 sand piles

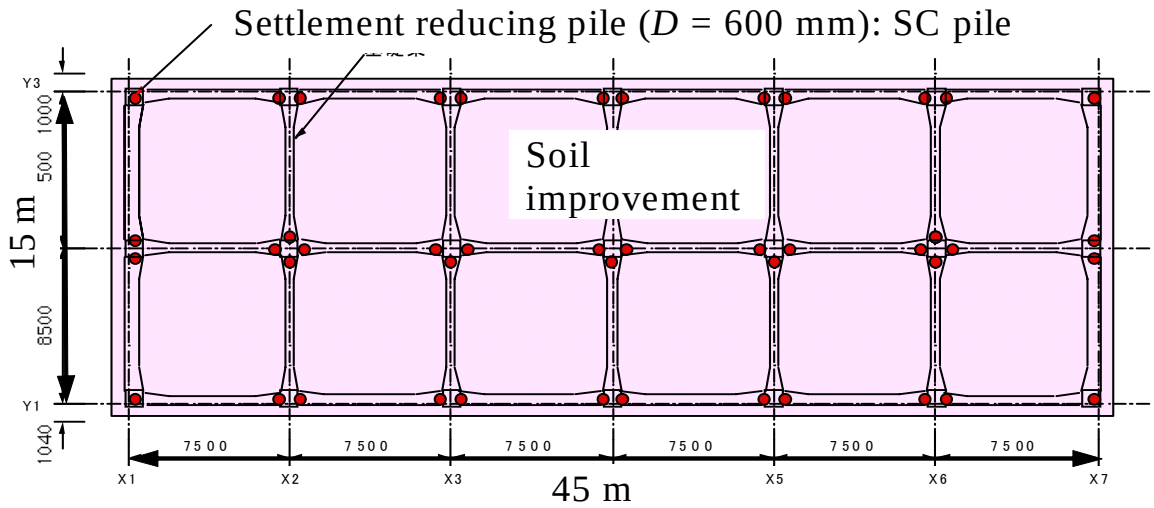
TAISEI Corporation

Combined use of anti-liquefaction soil improvement and piled raft



Sand piles contribute to preventing liquefaction and increasing the bearing resistance of the raft.

Length of the settlement reducing piles was reduced to 25 m from 43 m.



TAISEI Corporation

Study on behavior of ve.rtical load transfer of pile foundations

Dr. Thesis of Tokyo Institute of Technology

Masaaki Kakurai

Tokyo Soil Research Corp.

(*formerly Research Institute of Takenaka Corp.*)

10 case studies

Case studies of pile raft foundations

Foundations design as pile groups

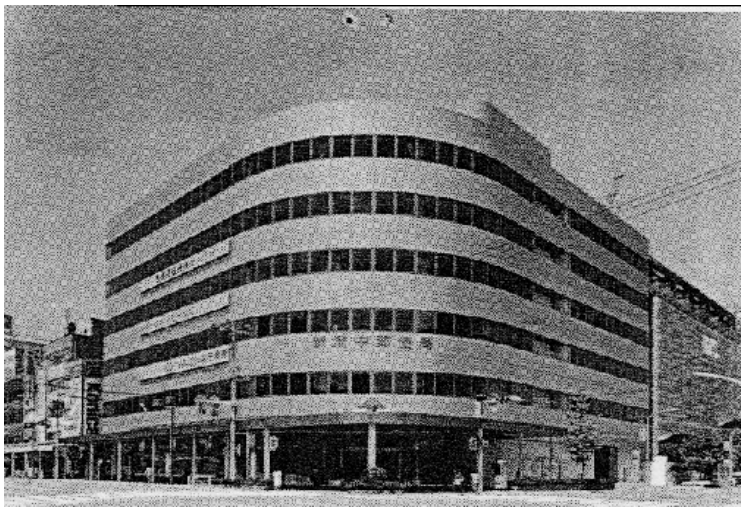
- 3 cases of ordinary construction method
- 2 cases of reverse construction method

Foundations designed as piled rafts

- 3 cases in Alluvial ground
- 2 cases in Diluvial ground

10 cases in total

Foundations constructed by ordinary construction methods

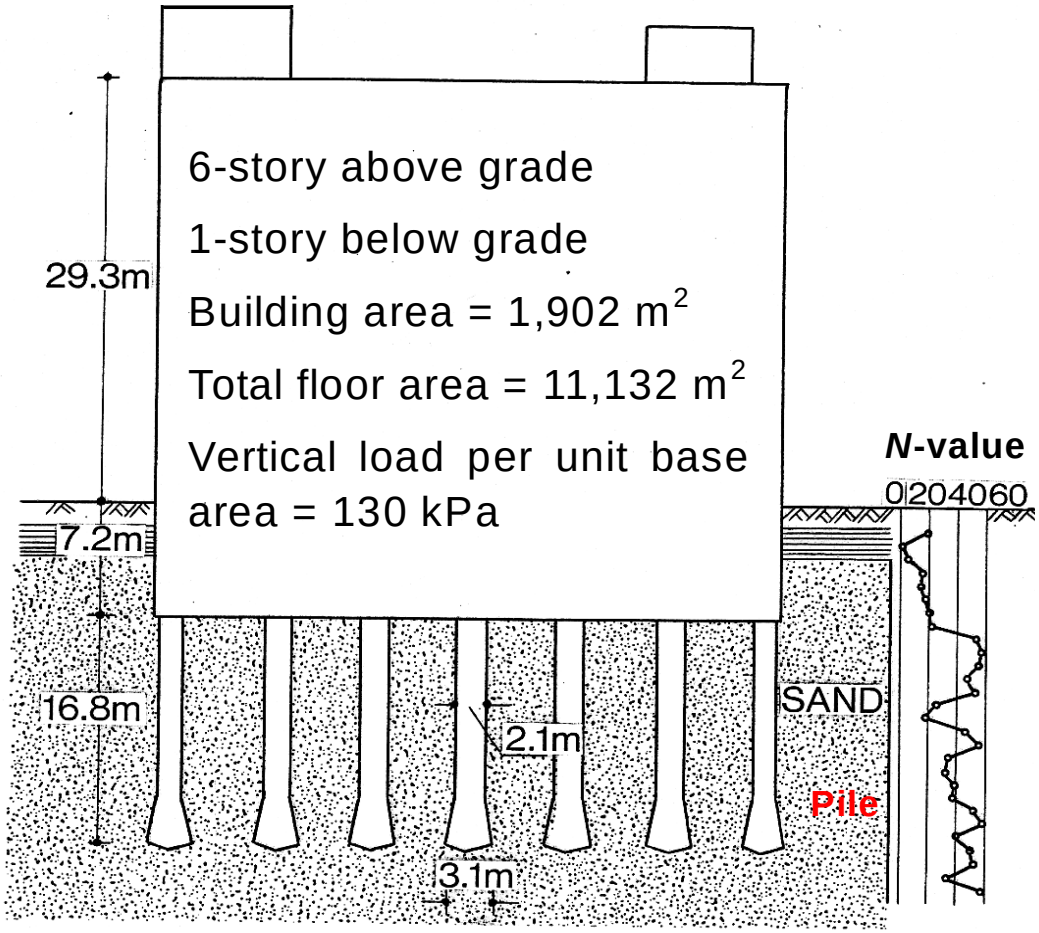


RC building

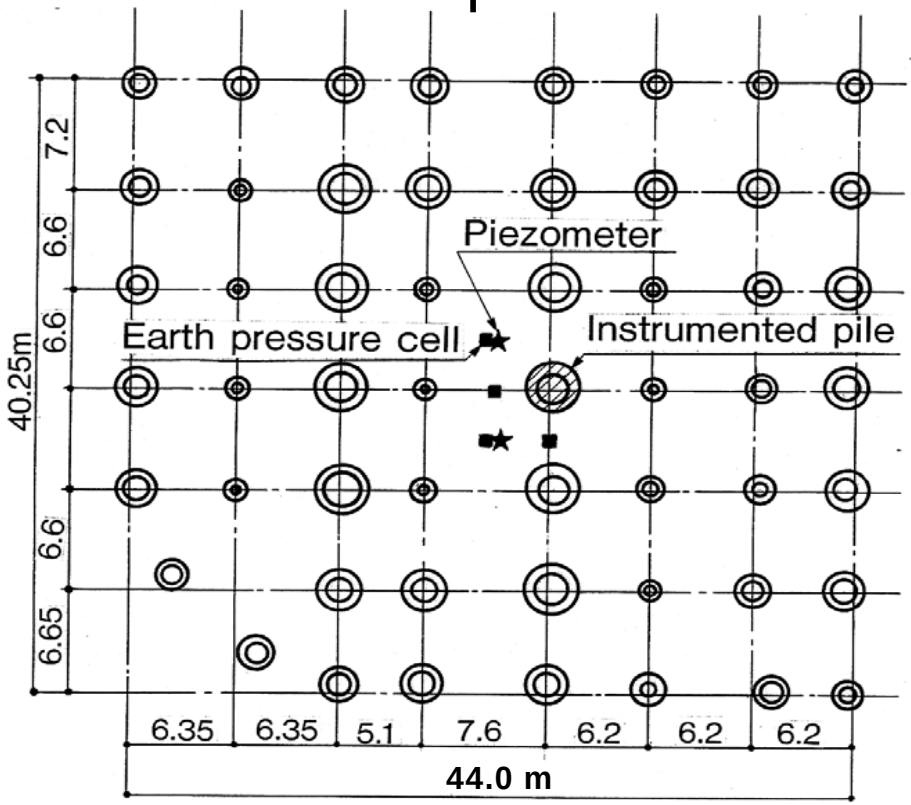
High-rise steel building

Twin building of RC structure

Reinforced concrete building



54 piles



Piles: primarily end-bearing pile (designed as pile group)

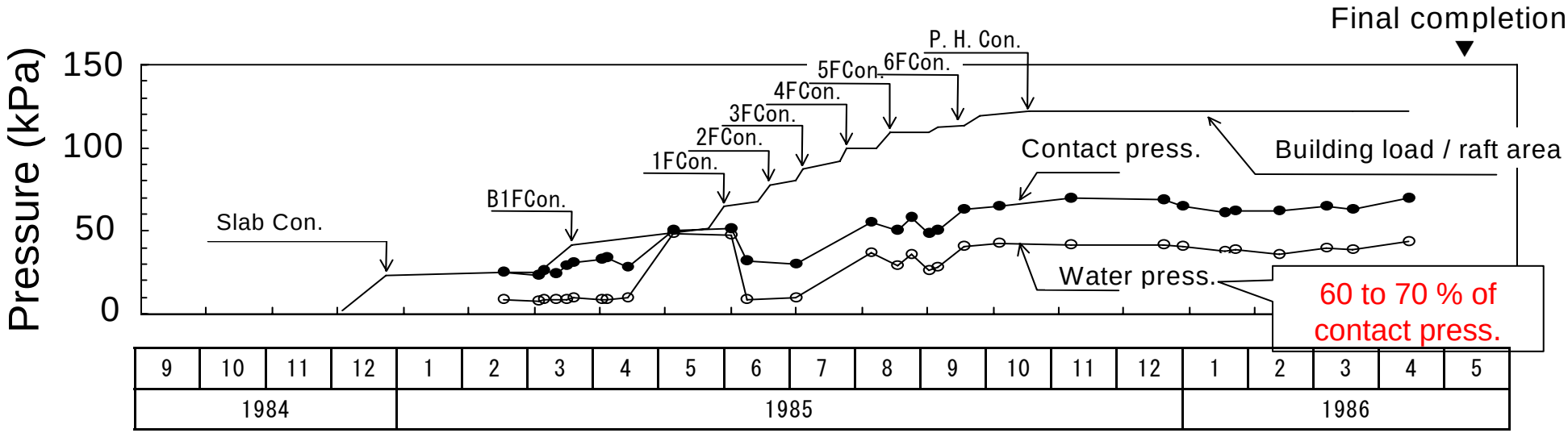
Cast-in-situ concrete pile with bell bottom.
D_s = 2.1 m (shaft), D_b = 3.1 m (base)

Monitoring:

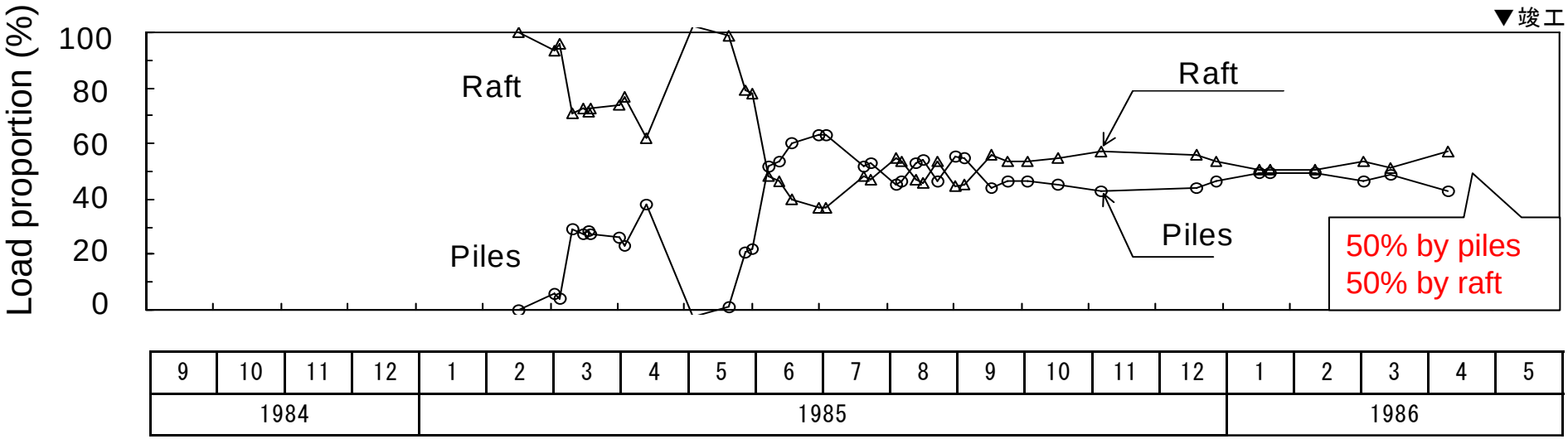
Axial forces in a pile (4 levels).

Contact pressure and water pressure at the center point of the raft.

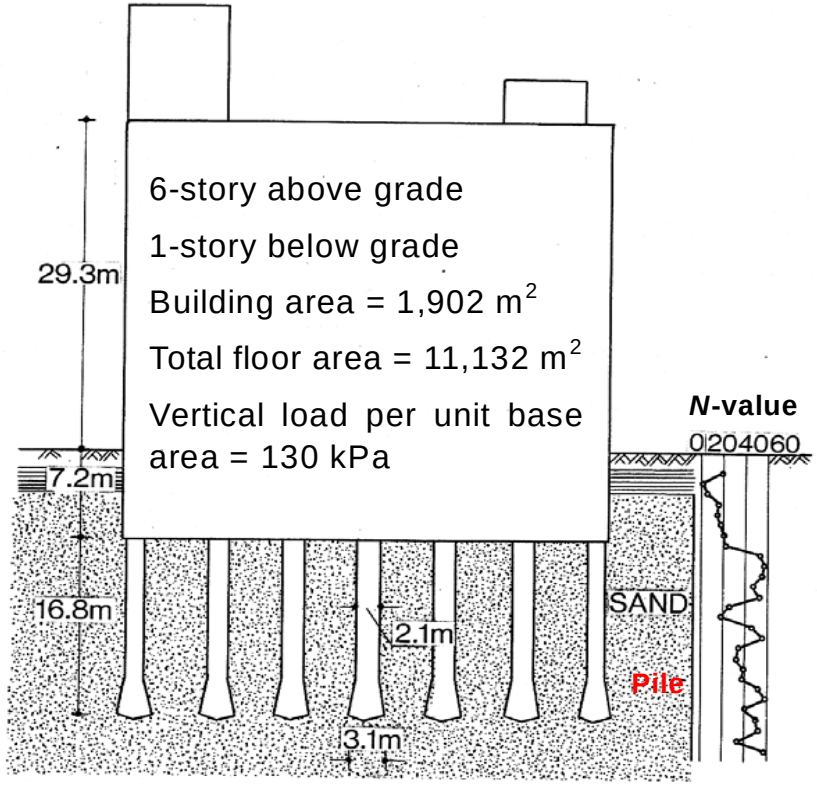
Vertical load, earth pressure and water pressure beneath the raft



Proportions of total vertical load carried by the piles and the raft



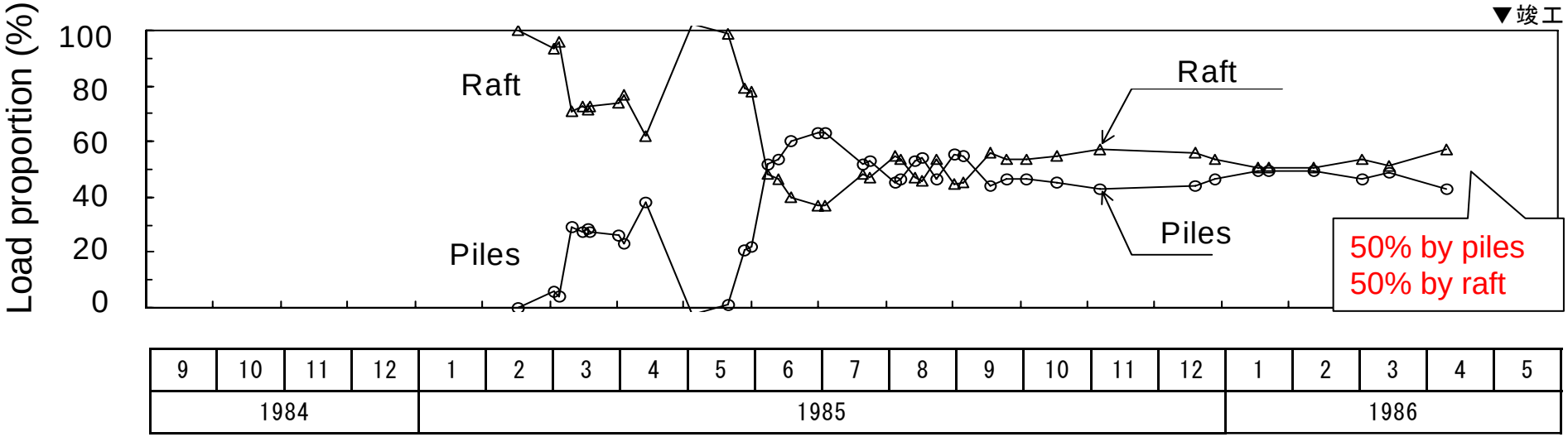
Reinforced concrete building



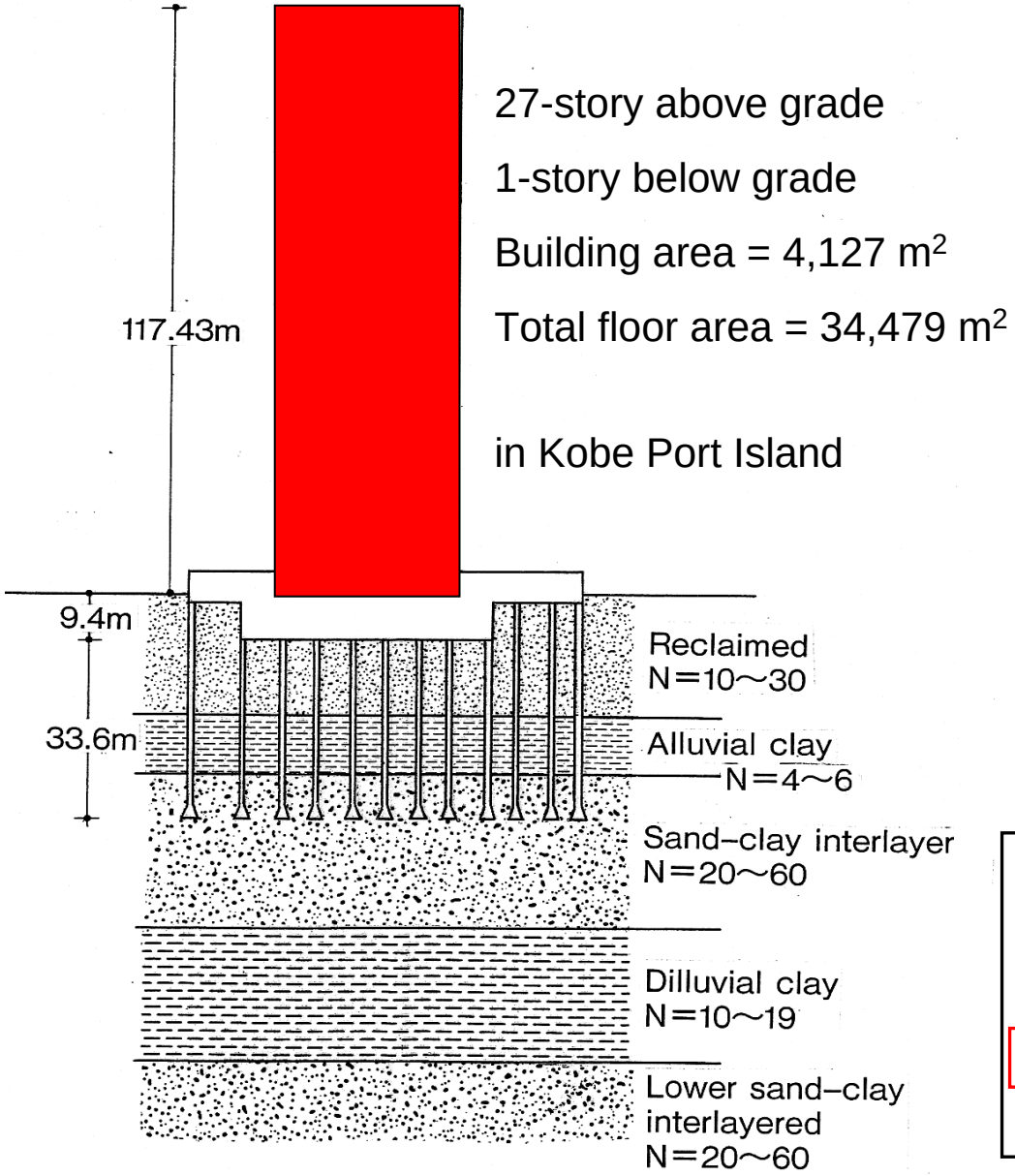
Piles: primarily end-bearing pile

Cast-in-situ concrete pile with bell bottom.
D_s = 2.1 m (shaft), D_b = 3.1 m (base)

Design concept of piled raft can be applied to end-bearing piles, if adequate arrangement and configuration of the piles are selected.



High-rise steel building



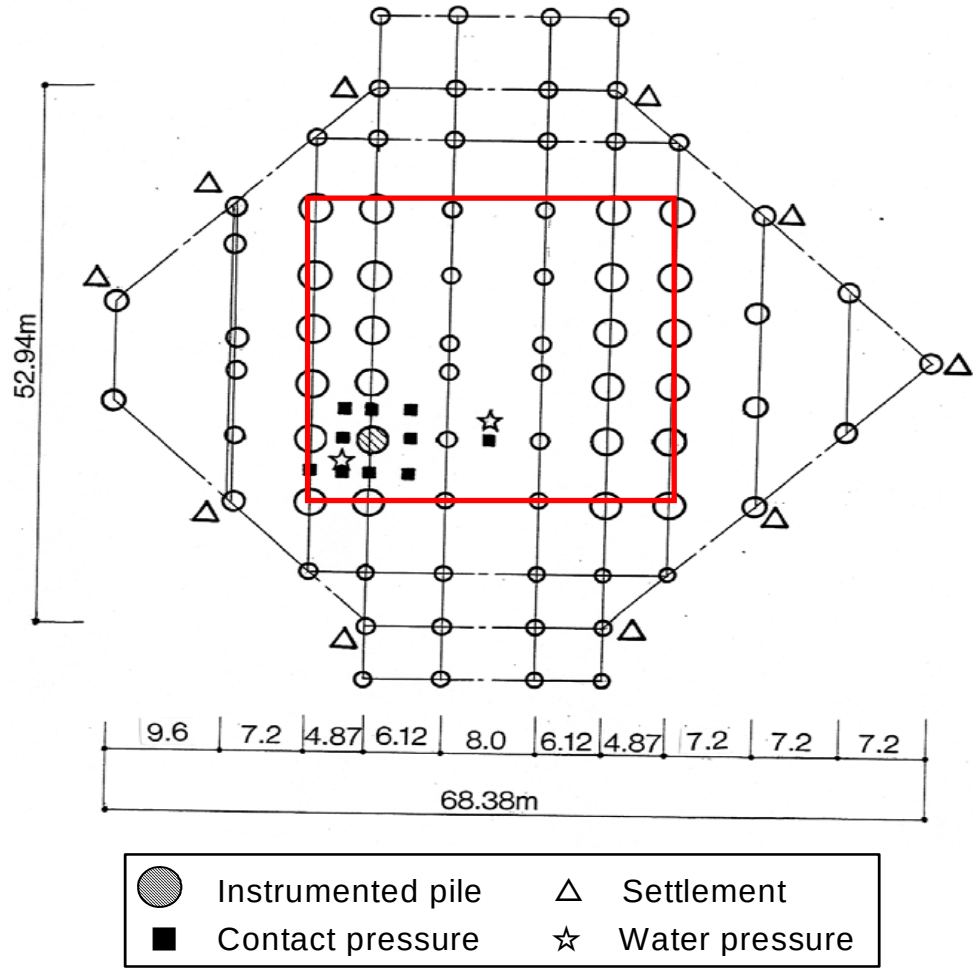
27-story above grade

1-story below grade

Building area = 4,127 m^2

Total floor area = 34,479 m^2

in Kobe Port Island



Piles: 79 piles, primarily end-bearing pile (designed as pile group)

Cast in-situ concrete pile with bell bottom.

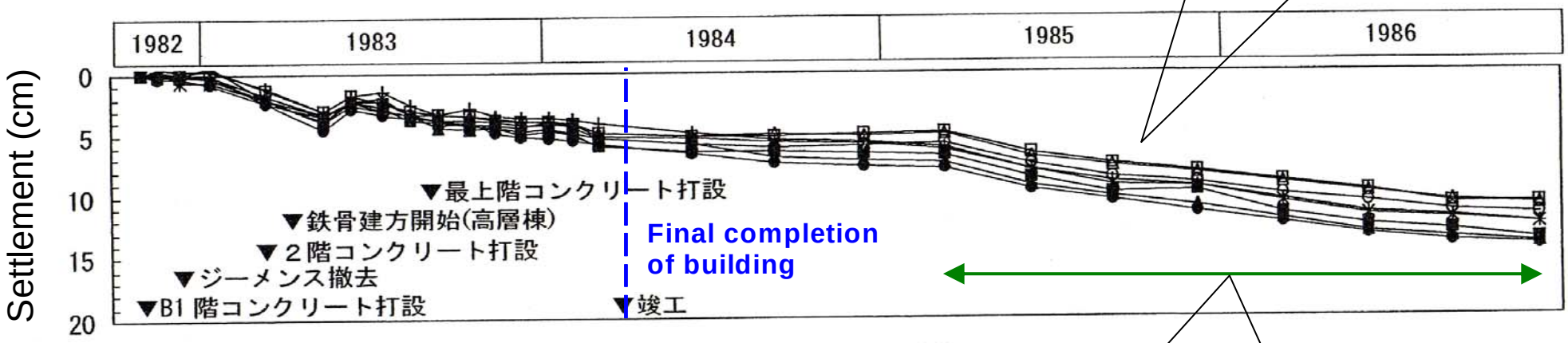
D_s = 1.8 m (shaft), D_b = 3.1 m (base) 24 piles

D_s = 1.3 m (shaft), D_b = 2.5 m (base) 55 piles

High-rise steel building

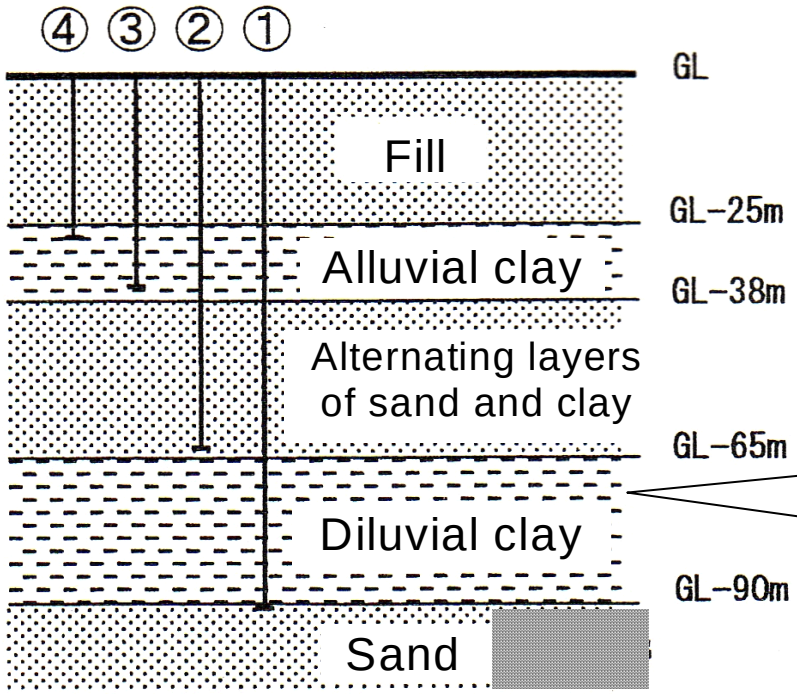
Settlements

Long term settlements were observed



Differential settlement is kept constant

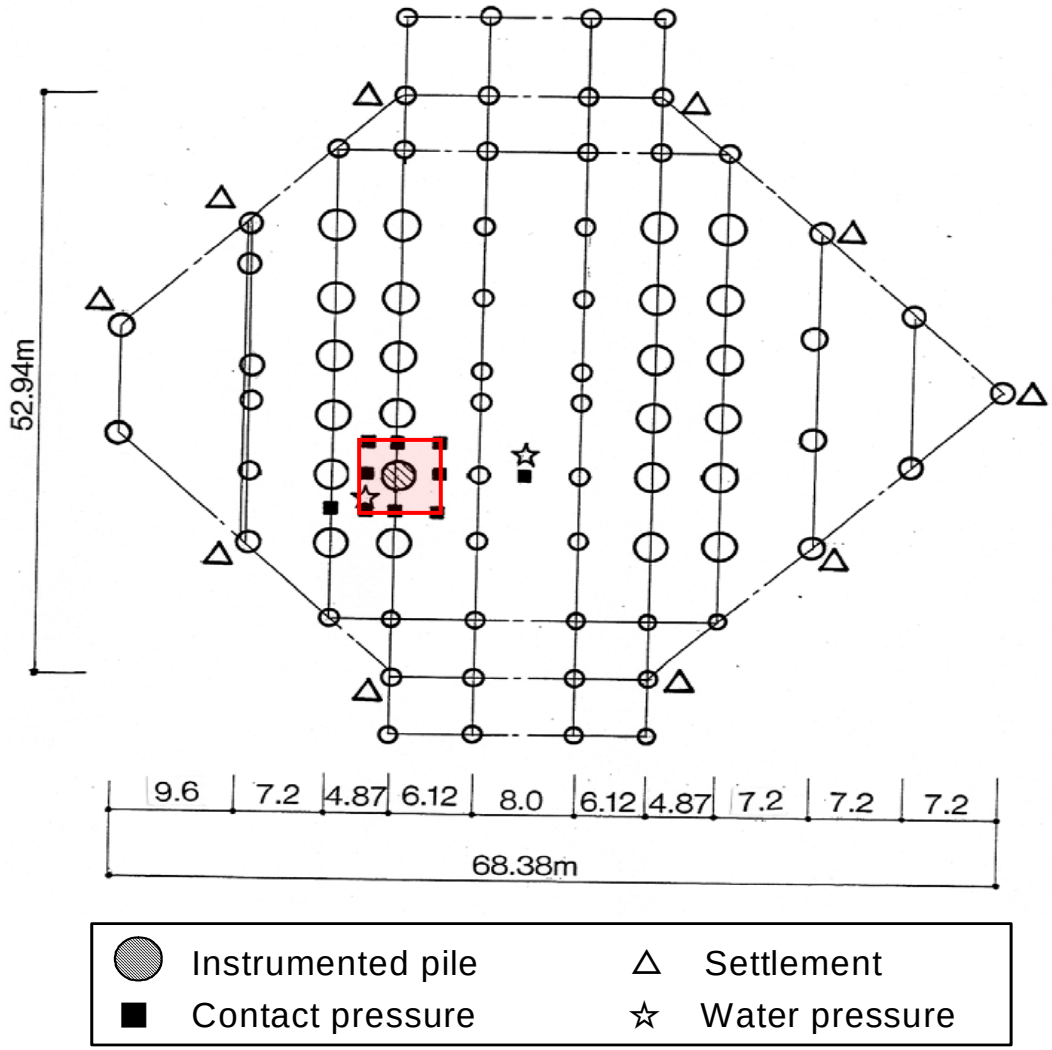
Settlements were measured at various levels in the ground



Long term settlements of the foundation is caused mainly by settlement of the diluvial clay layer.

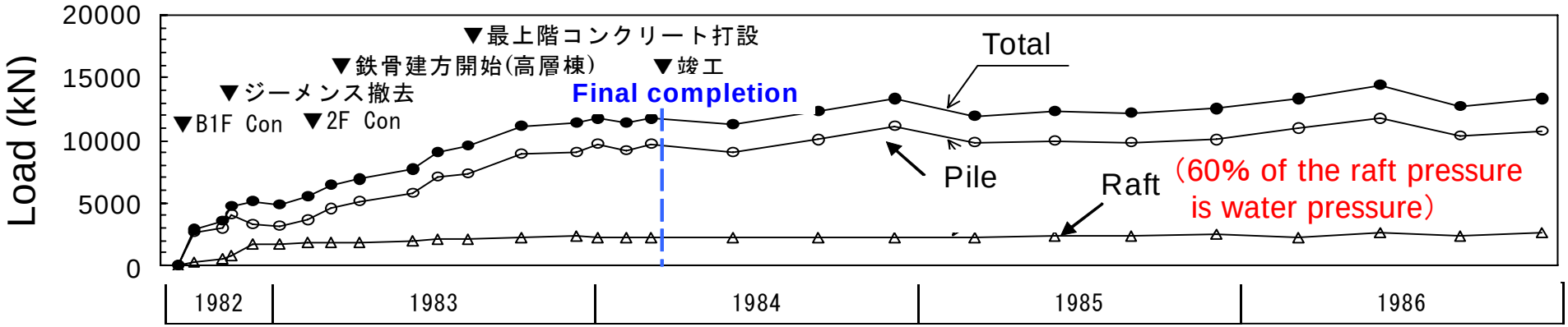
High-rise steel building

Loads carried by pile and raft
(as for the area around the instrumented pile)

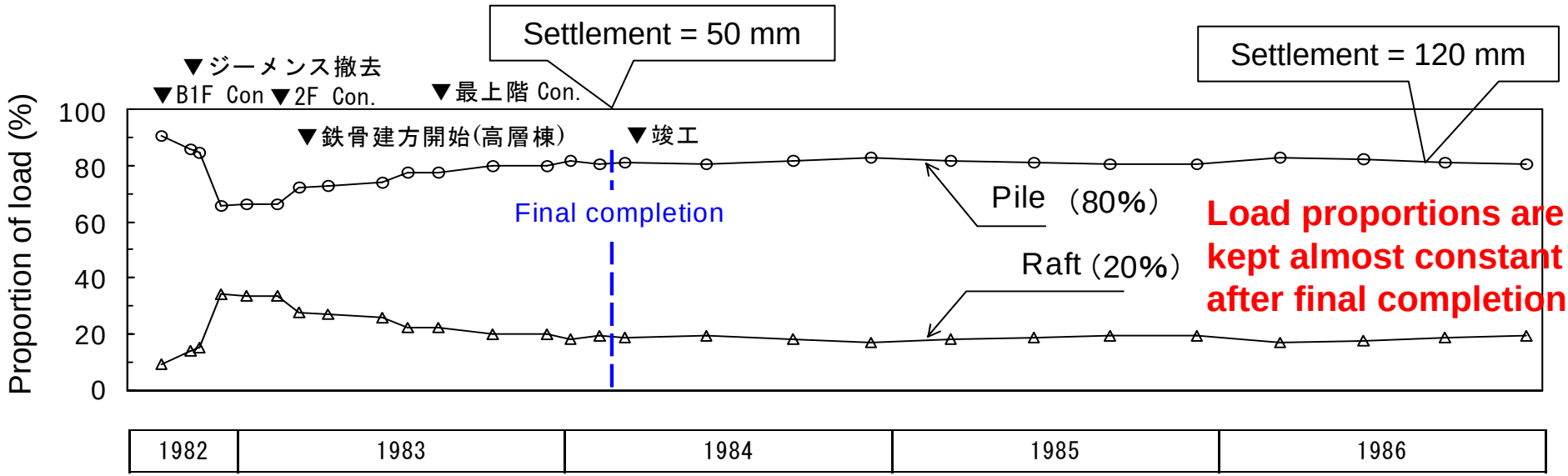


High-rise steel building

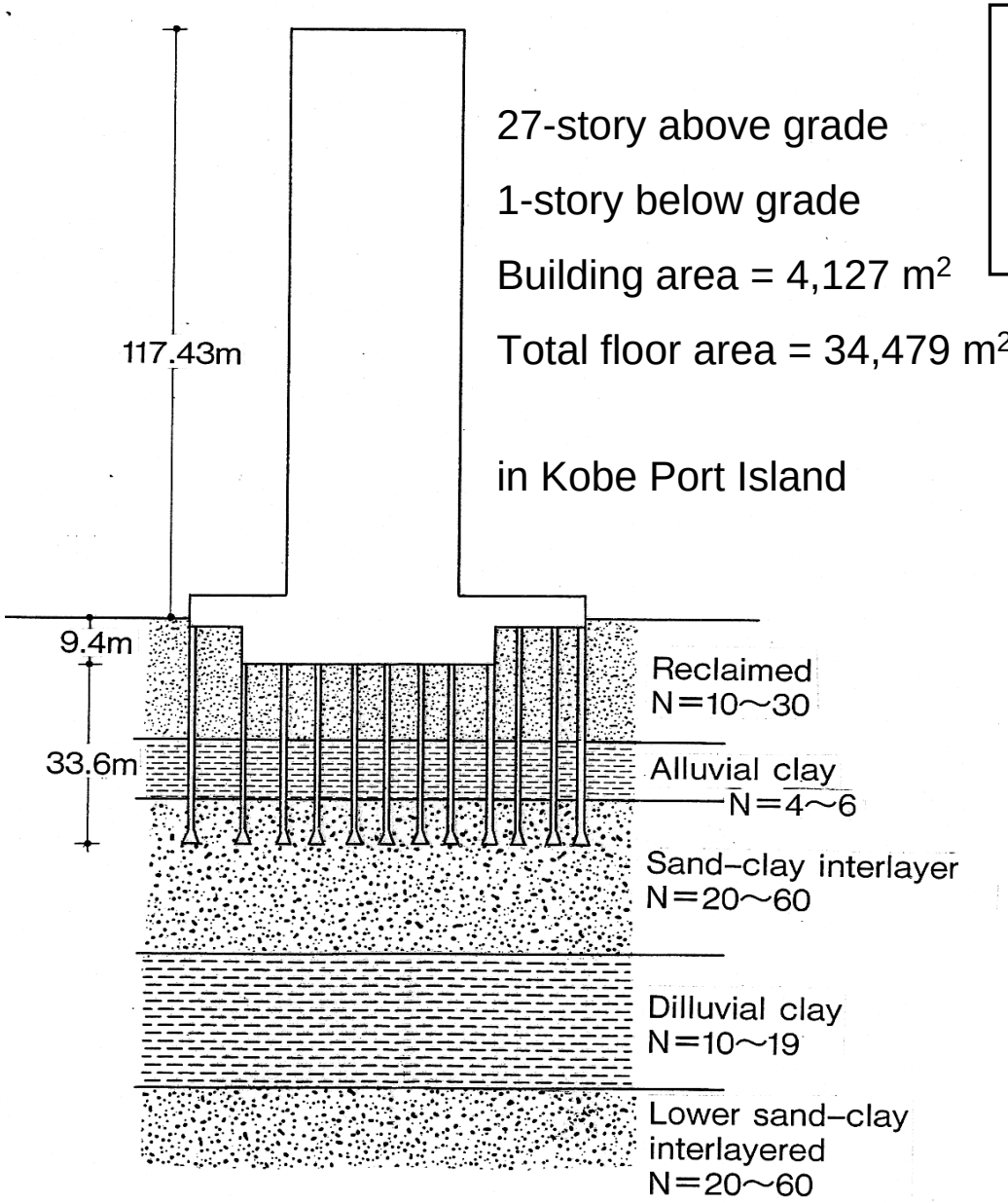
Loads carried by pile and raft (as for the area around the instrumented pile)



Proportions of load carried by pile and raft



High-rise steel building



27-story above grade

1-story below grade

Building area = 4,127 m^2

Total floor area = 34,479 m^2

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Piles: 79 piles, primarily end-bearing pile

Cast in-situ concrete pile with bell bottom.

D_s = 1.8 m (shaft), D_b = 3.1 m (base) 24 piles

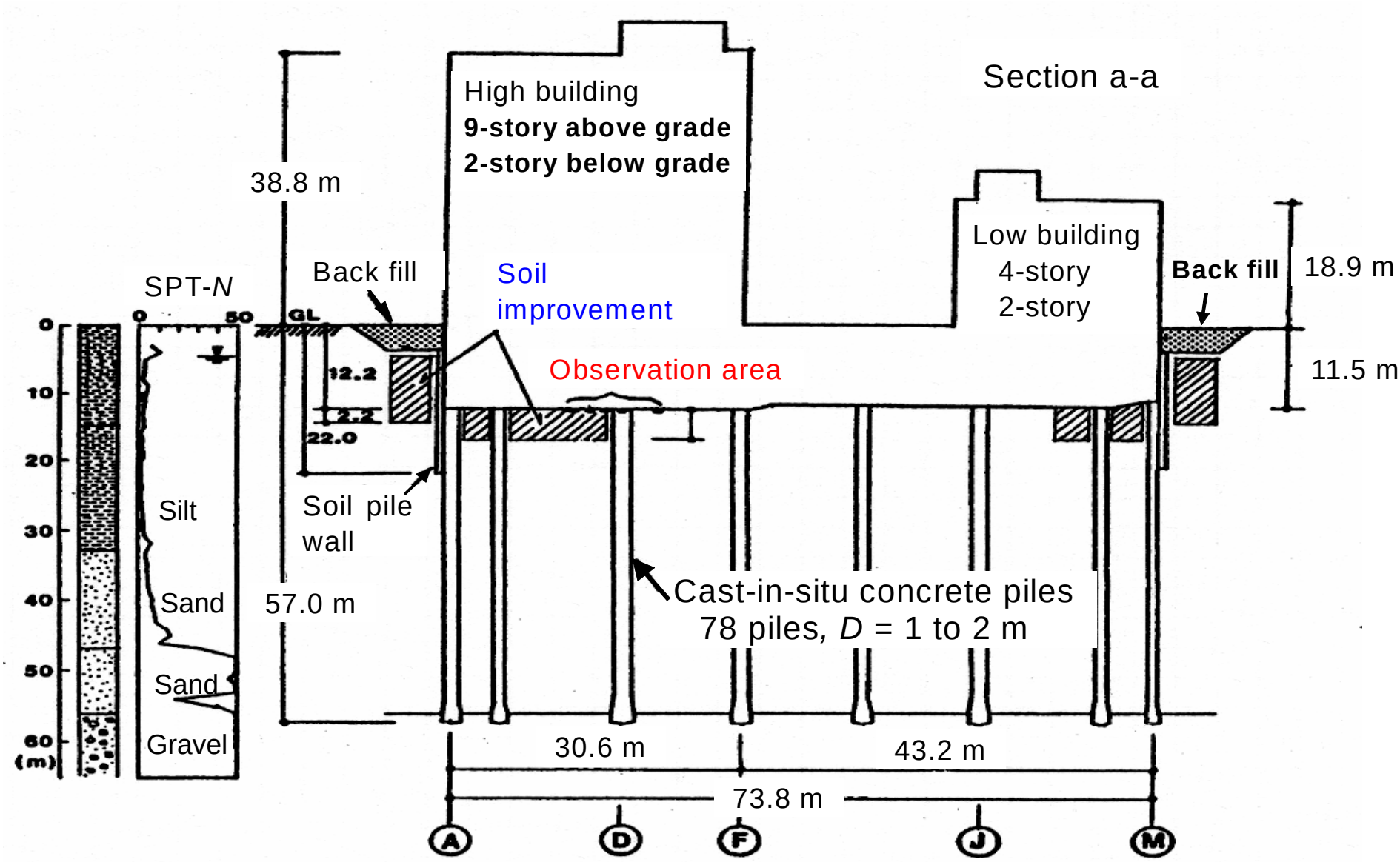
D_s = 1.3 m (shaft), D_b = 2.5 m (base) 55 piles

Design concept of piled raft can be applied to end-bearing piles, if adequate arrangement and configuration of the piles are selected.

Twin building of reinforced concrete structure

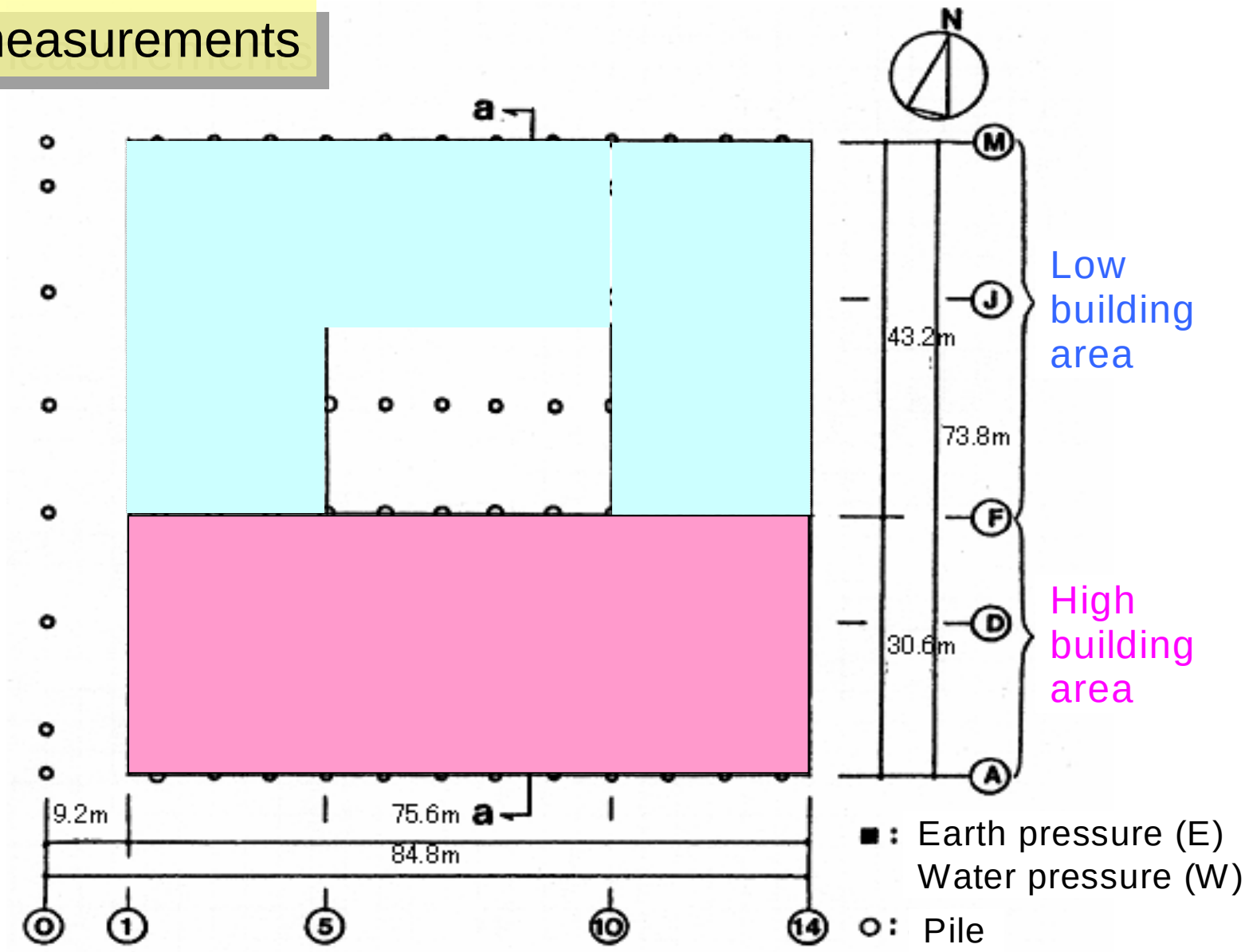
Intensive field measurements were carried out over a large part of the foundation area.

Twin building of reinforced concrete structure



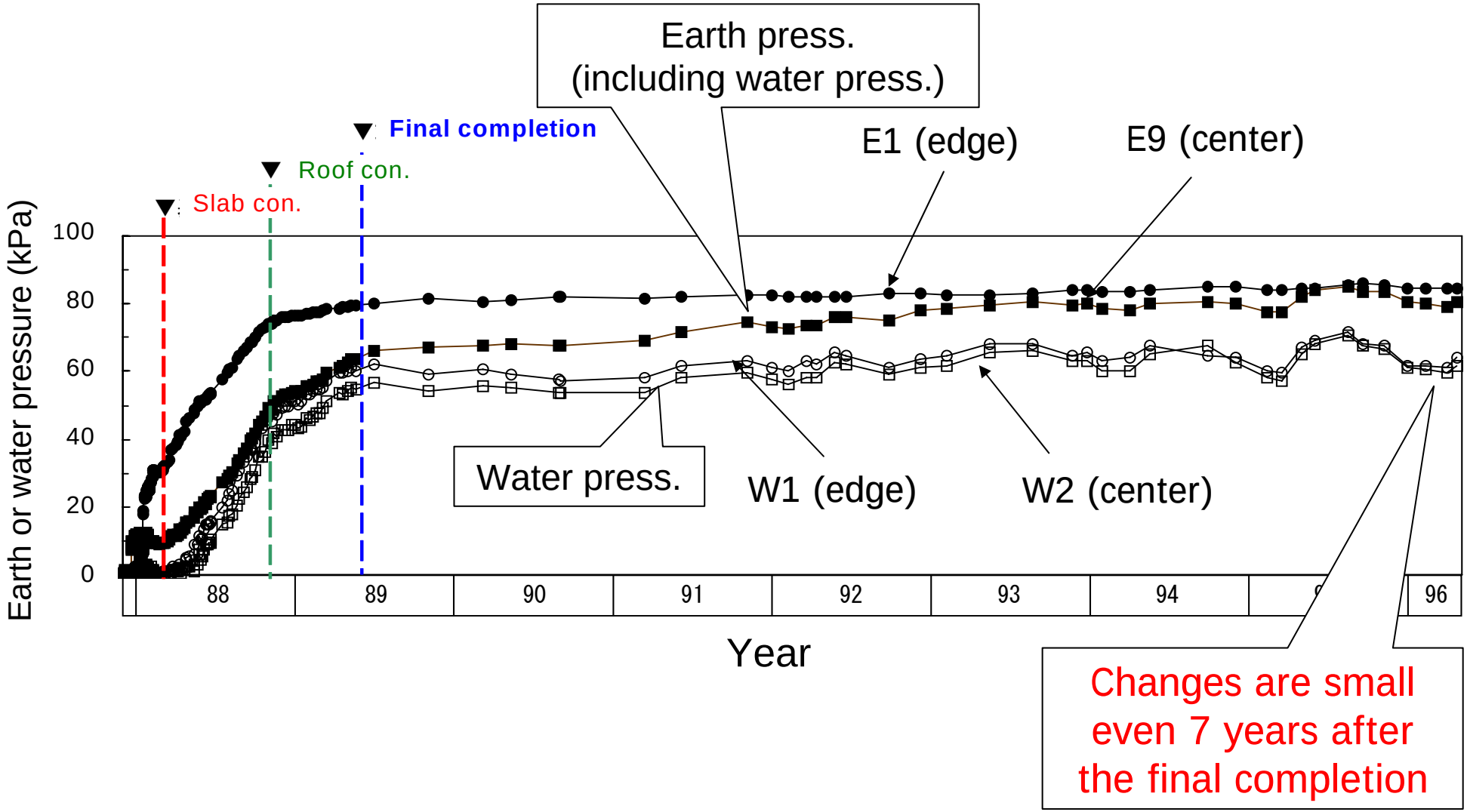
Twin building of reinforced concrete structure

Field measurements



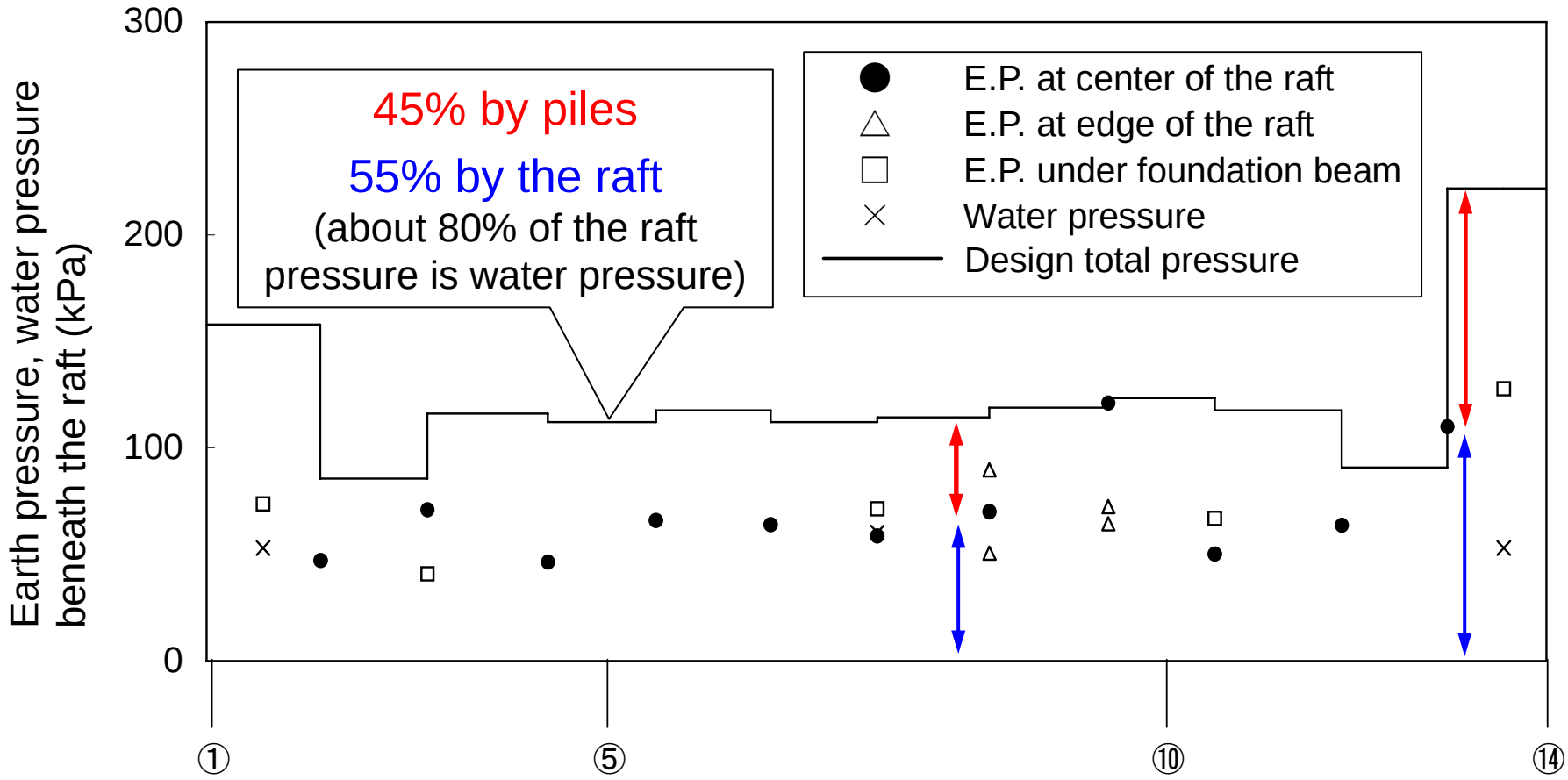
Twin building of reinforced concrete structure

Time histories of earth pressures and water pressures



Twin building of reinforced concrete structure

Distributions of earth pressures and water pressures beneath the raft (slab) at 1 year after the final completion

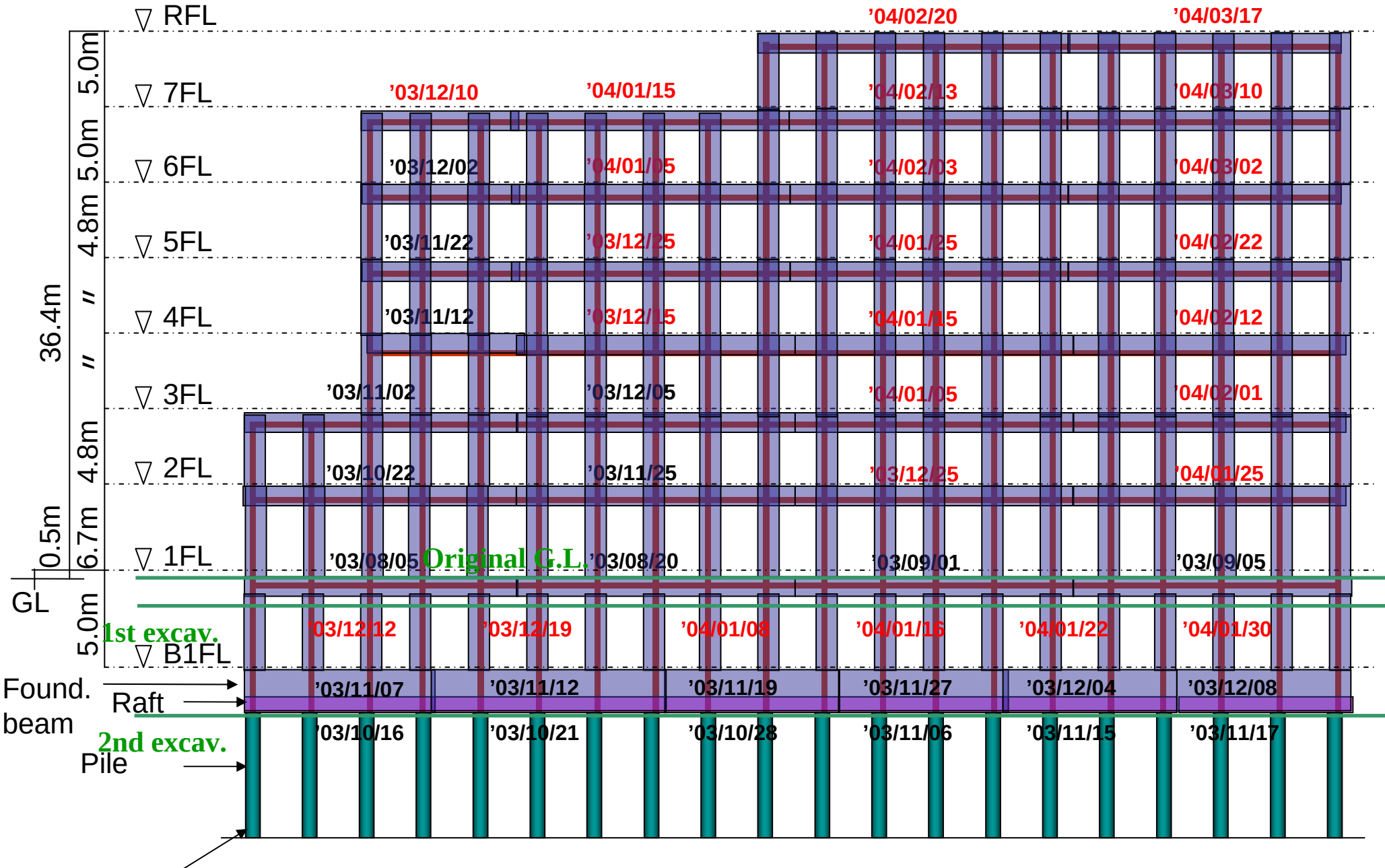


Foundations in reverse construction methods

RC building #1

RC building #2

Reverse construction method



Reverse construction method: RC superstructure (1)

Building:

7-story above grade

2-story below grade

Building area = 5,067 m^2

Total floor area = 28,685 m^2

Foundation:

Raft foundation in design

Ave. press. = 102 kPa

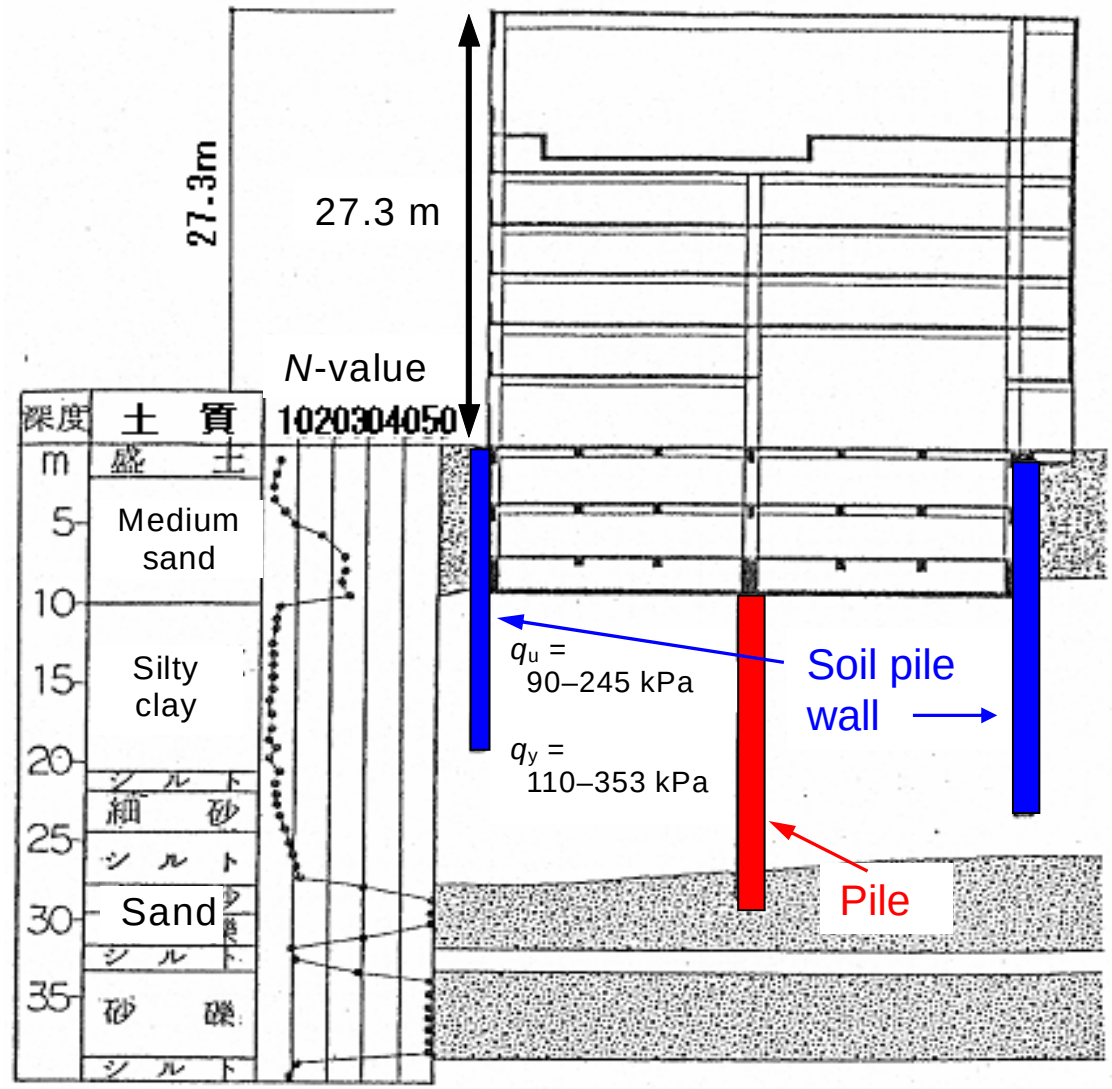
Max. press. = 139 kPa

Pile:

Cast-in-situ concrete piles with D = 1.6 m

Soil pile wall:

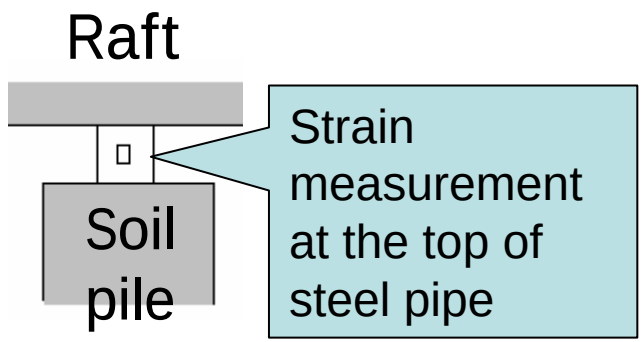
Cement mortar with steel pipe pile

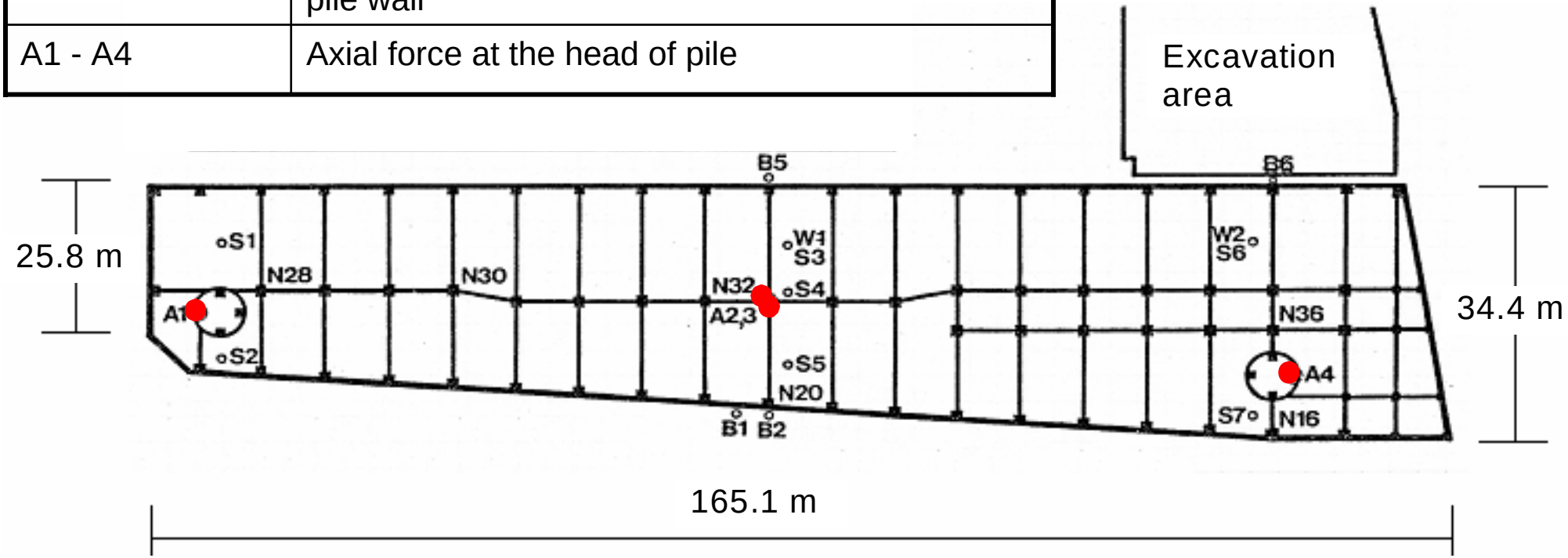


Reverse construction method: RC superstructure (1)

Field measurements

Location	Measured item
N1 - N37	Settlement
S1 - S7	Earth pressure
W1 & W2	Water pressure
B1 to B6	Axial force at the head of steel pipe pile for soil pile wall
A1 - A4	Axial force at the head of pile





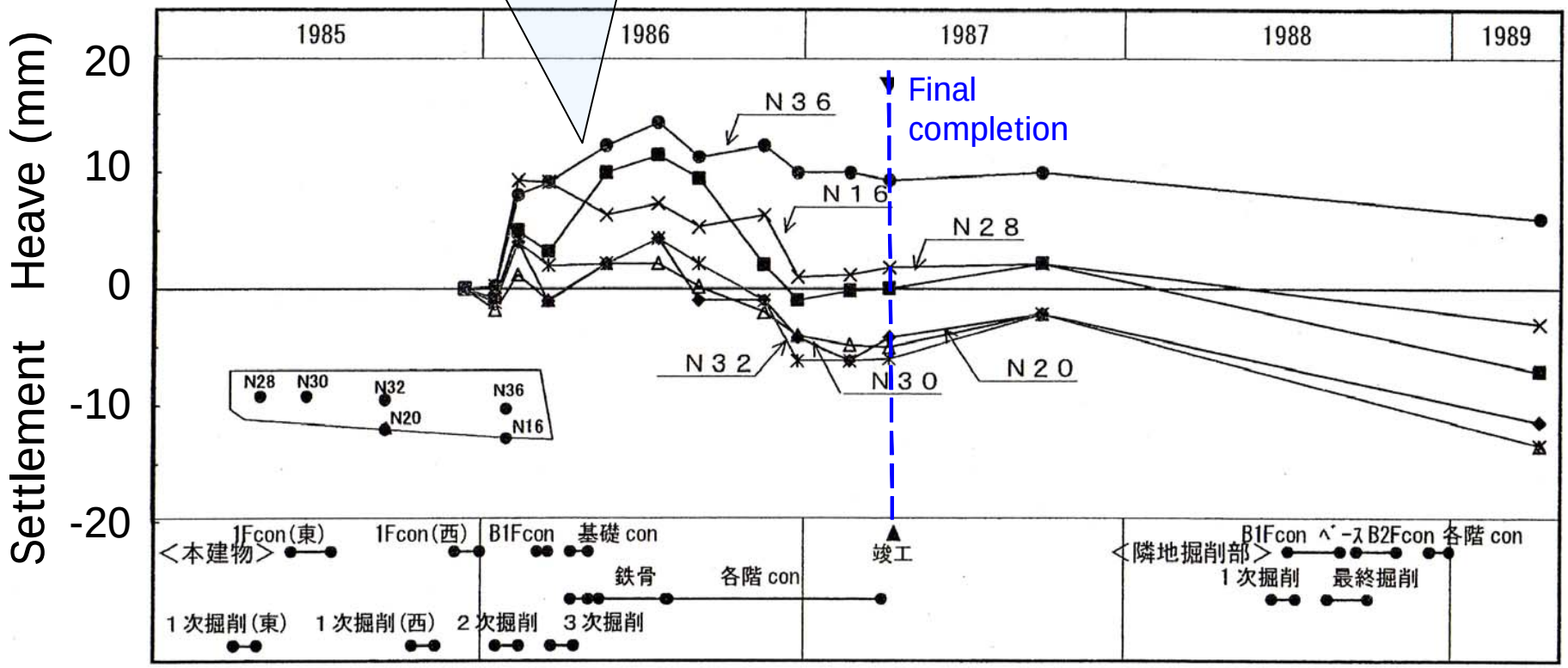
Reverse construction method: RC superstructure (1)

Time history of settlements

Ground heaving due to excavation work for reverse method

Long-term settlements

Small differential settlements

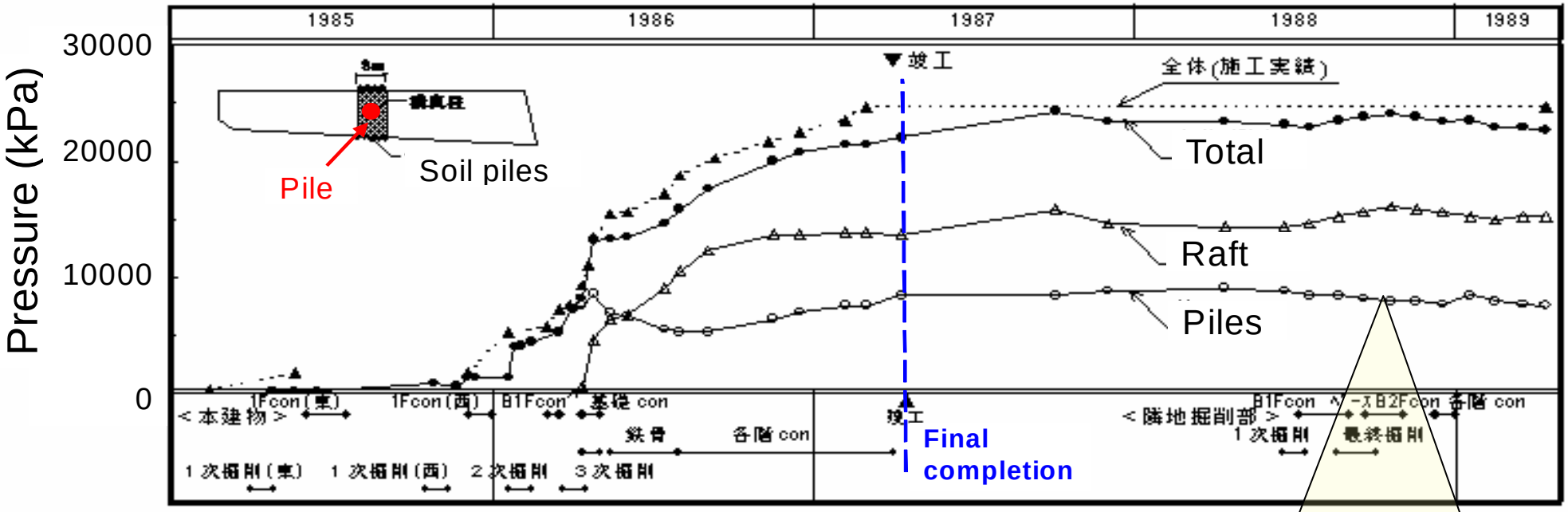


Reverse construction method: RC superstructure (1)

Time history of pressures for a central area

Heaving = 5 - 15 mm

Settlements = 10 - 20 mm

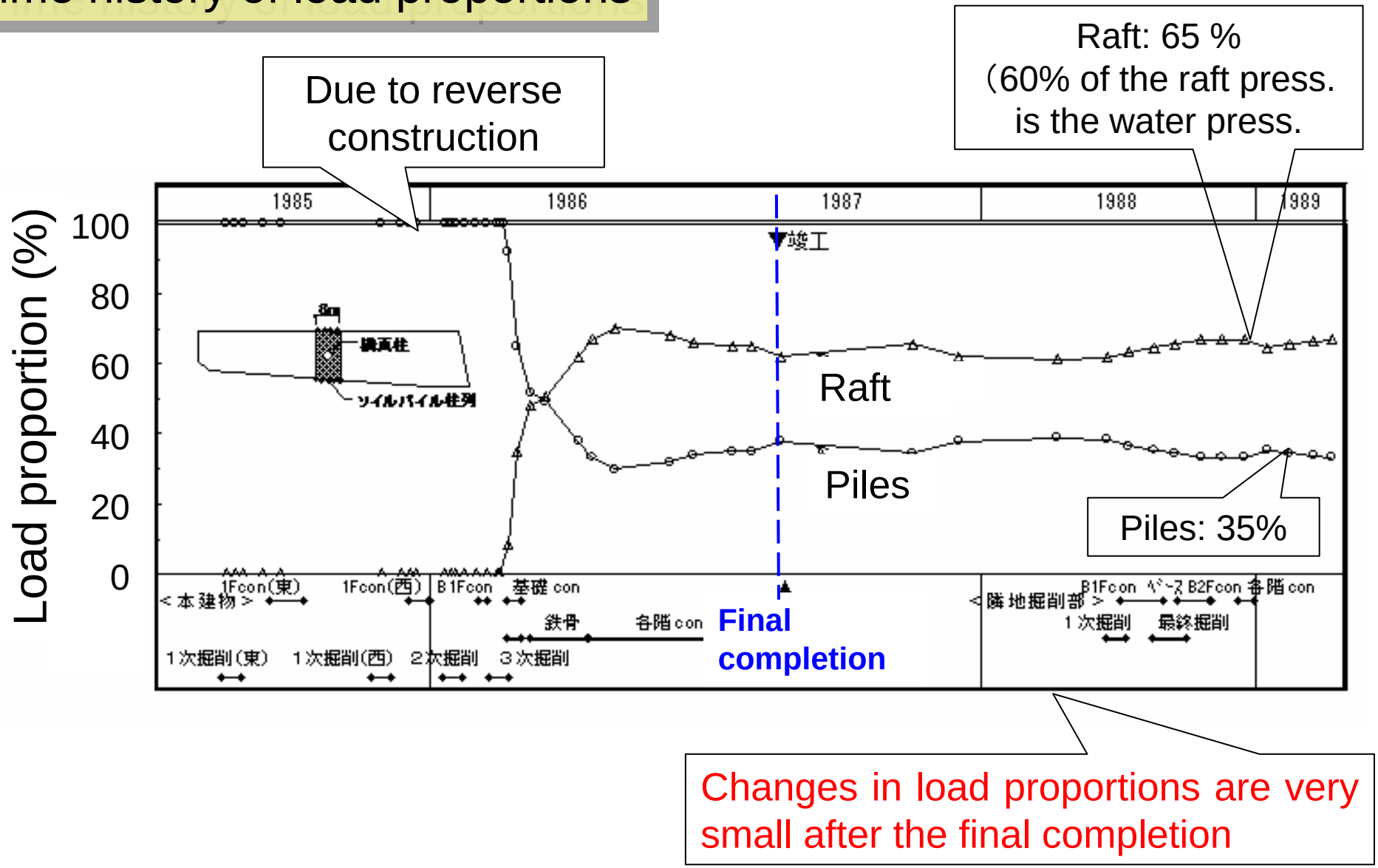


Piles: 35 % Raft : 65 %

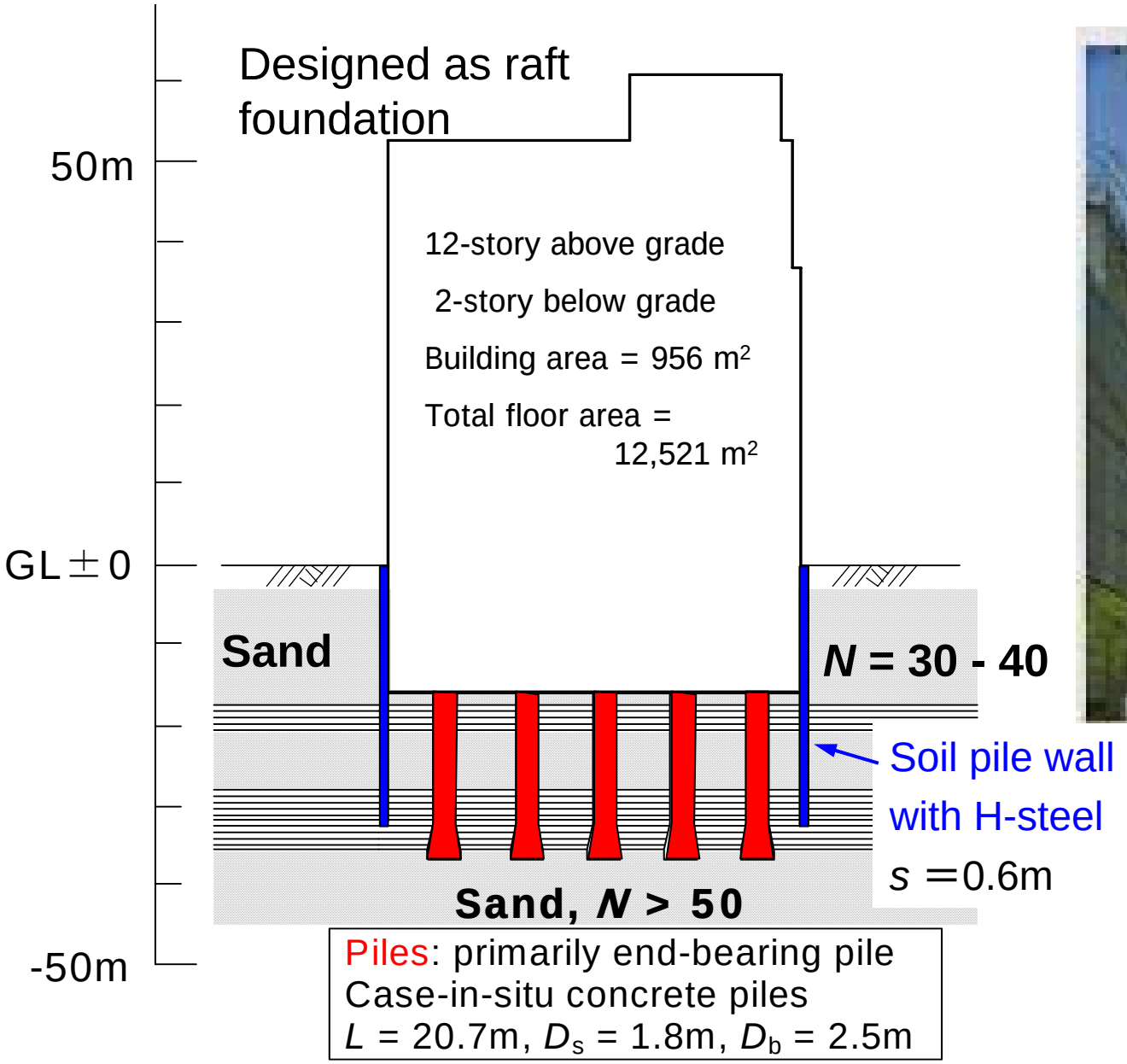
Even though the foundation was designed as the raft foundation, the piles carry a relative large portion of the total pressure.

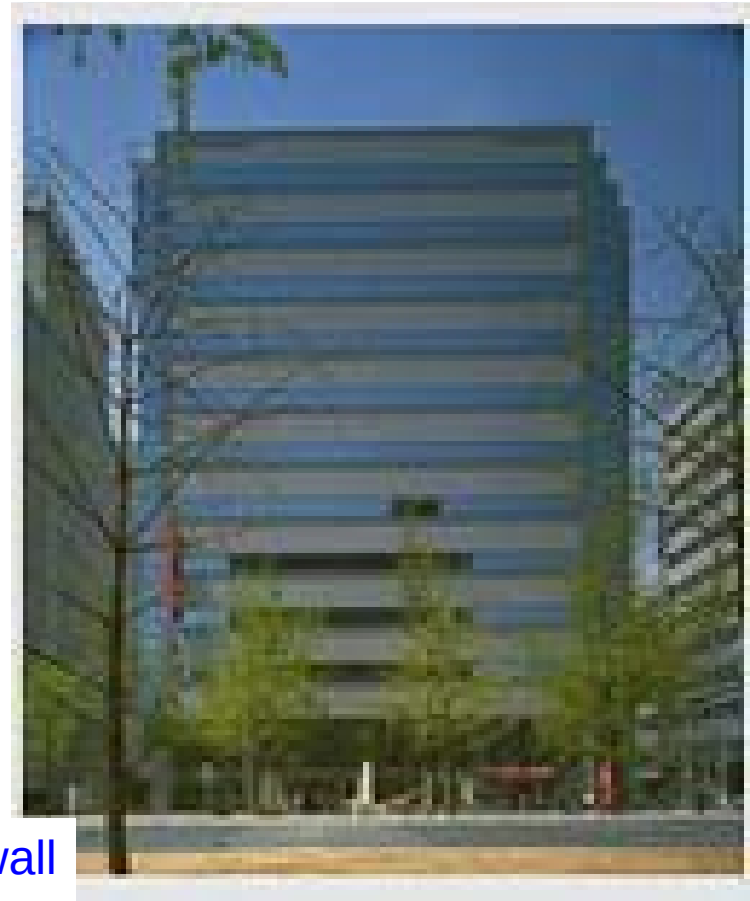
Reverse construction method: RC superstructure (1)

Time history of load proportions



Reverse construction method: RC superstructure (2)

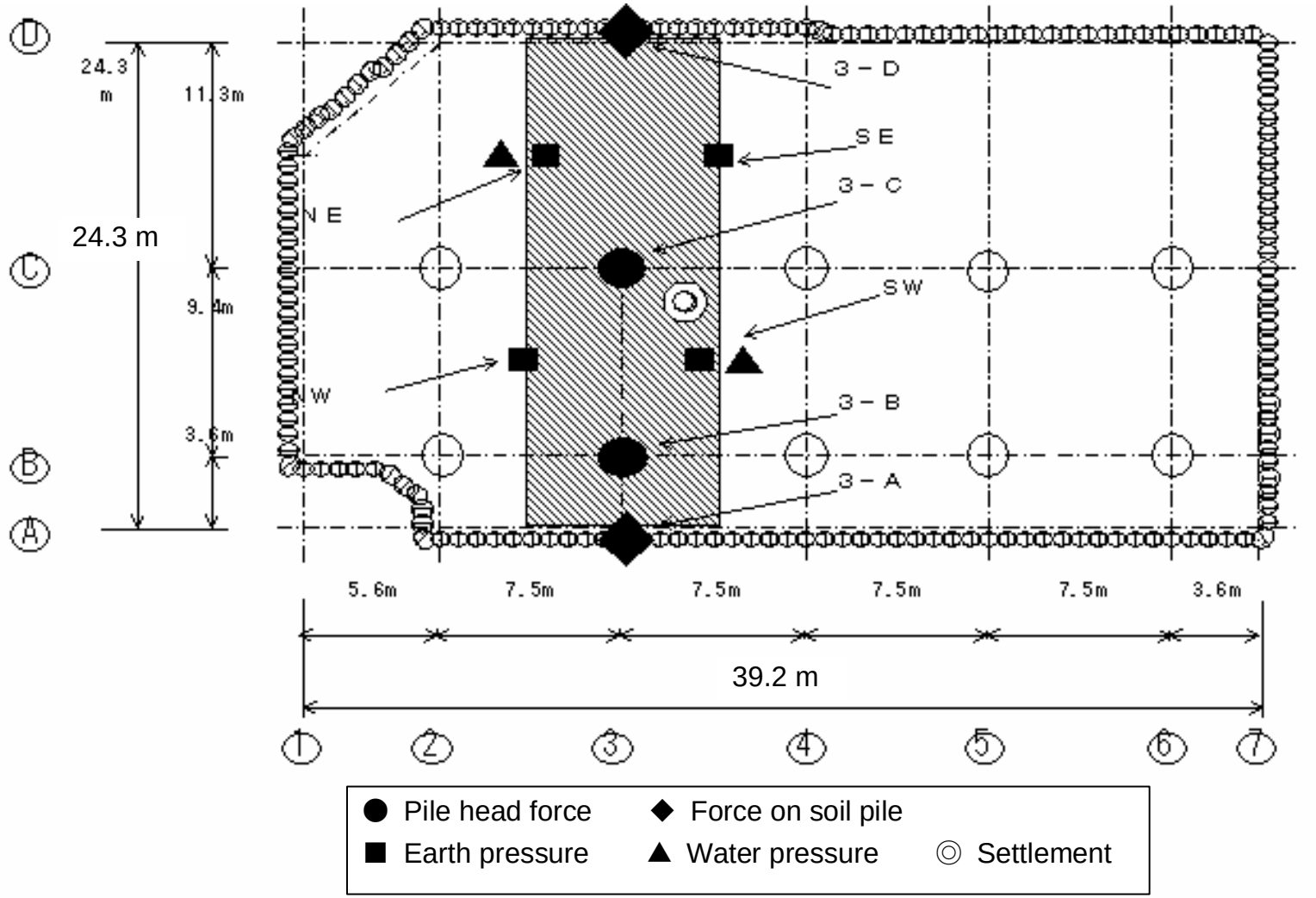




Location: Kobe

Reverse construction method: RC superstructure (2)

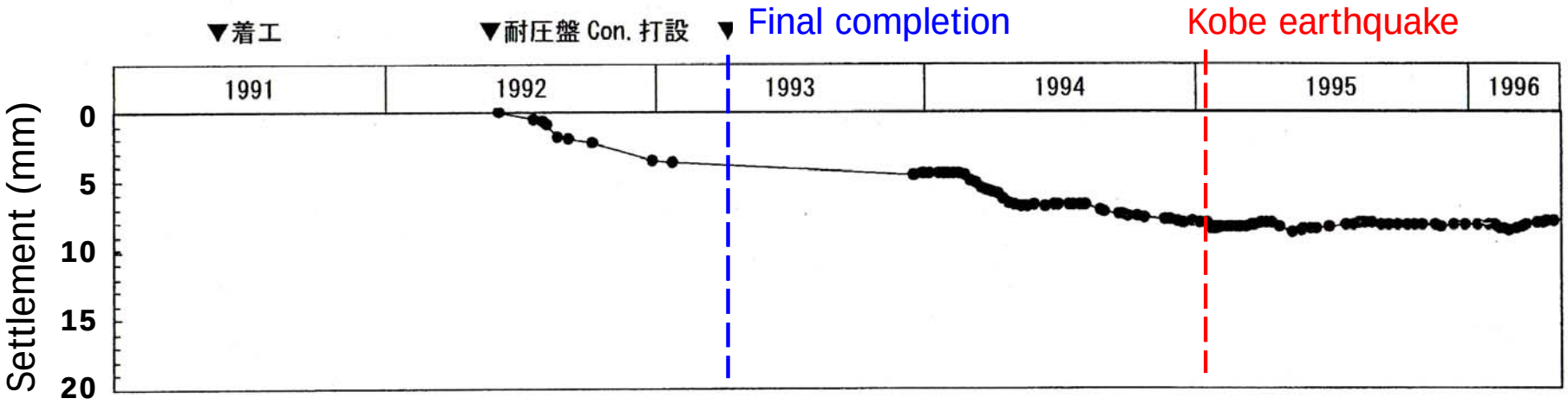
Field measurements

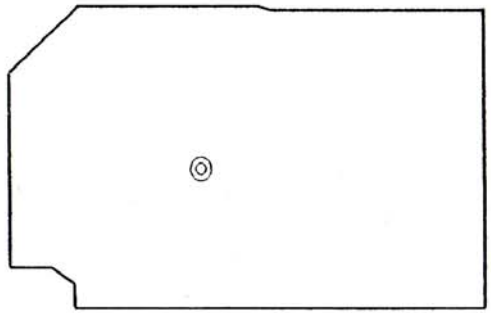


Reverse construction method: RC superstructure (2)

Time history of settlements

Acceleration at the ground surface = 0.2 m/s^2





Kobe earthquake (Hyogoken-Nambu Earthquake)

January 17, 1995

Magnitude:
7.2

Maximum acceleration:
833 gal

Number of sacrifices:
more than 6000

Number of damaged superstructures:
more than 200,000

January 17, 1995

Hyogoken-Nambu Earthquake(1)

January 17, 1995

〈神戸大橋ポートターミナル取付部・神戸市〉

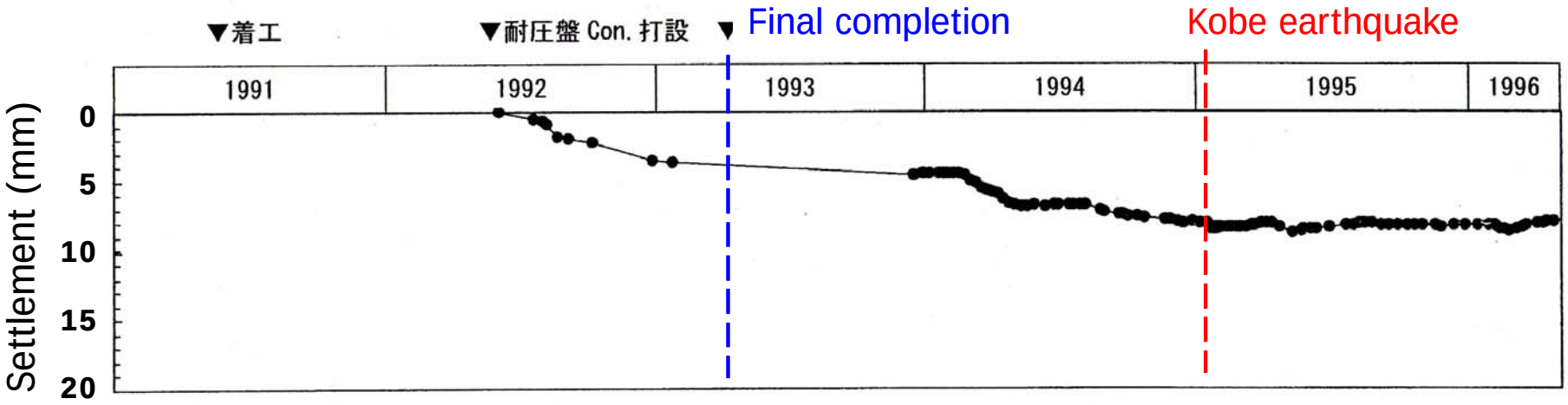
〈摩耶大橋・神戸市〉

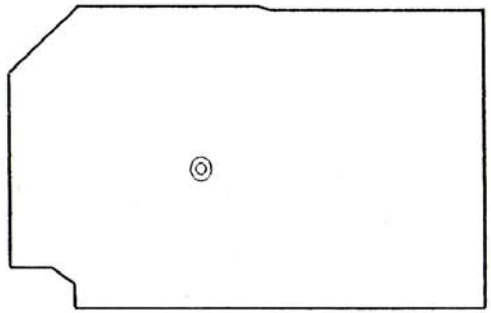
Hyogoken-Nambu Earthquake(2)

Reverse construction method: RC superstructure (2)

Time history of settlements

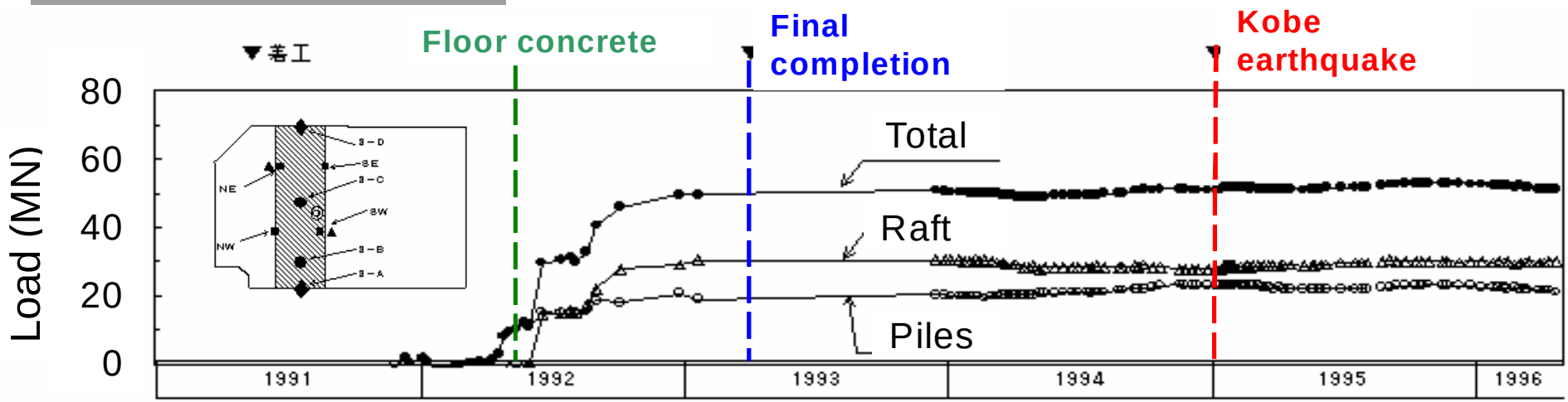
Acceleration at the ground surface = 0.2 m/s^2





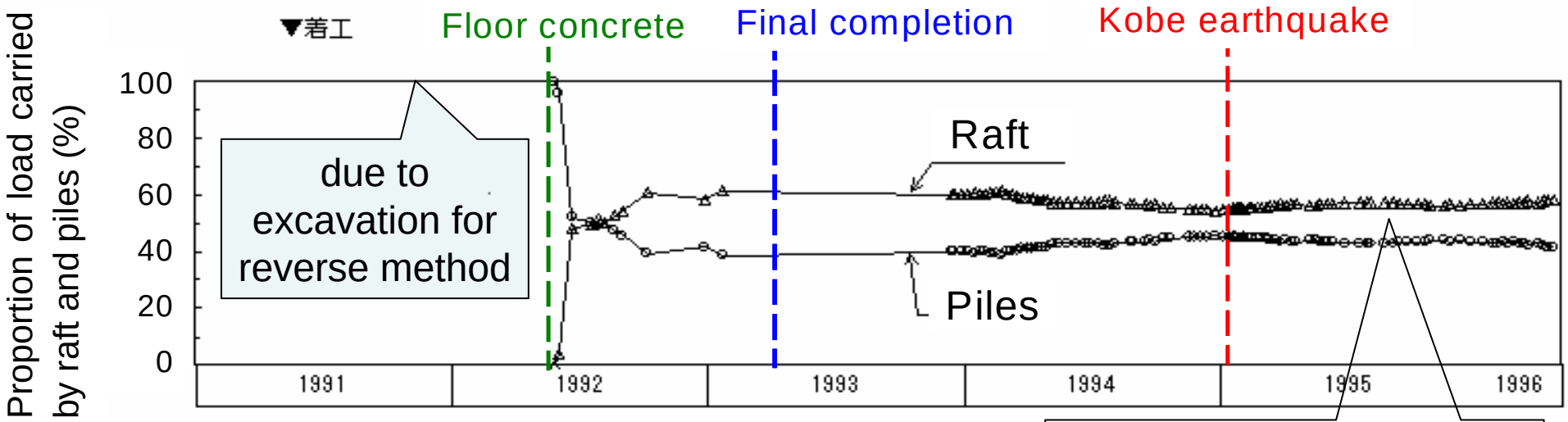
Time histories of loads

Settlement = 8 mm



Acceleration at the ground surface = 0.2 m/s²

Time histories of load proportions



due to excavation for reverse method

Raft: 60 % Piles: 40 %
(20-30% of the raft pressure is the water pressure)

Intercurrent Summary

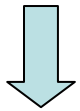
Design concepts

Pile group: Piles carry all the vertical load

Raft alone: Raft carries all the vertical load

Reality

- Even if buildings are supported by end-bearing piles, 20 to 50% of vertical loads (weights of buildings) are carried by rafts.
- In reverse construction methods where foundations are designed as rafts alone, 30 to 35% of vertical loads (weights of buildings) are carried by piles.



Design of a foundation as piled raft are is needed to predict behaviour of the foundation correctly.