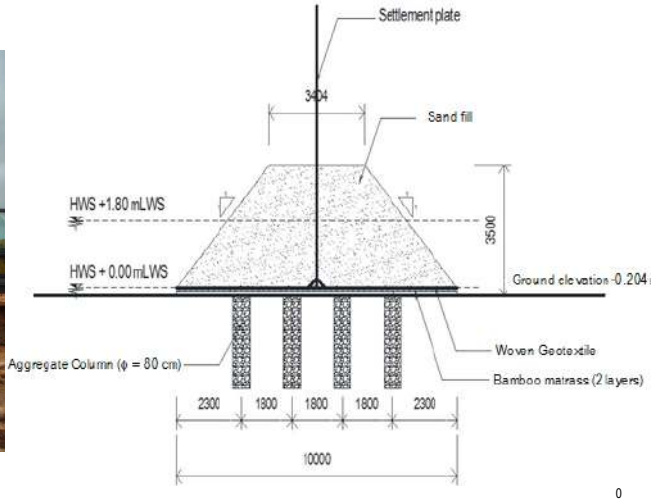
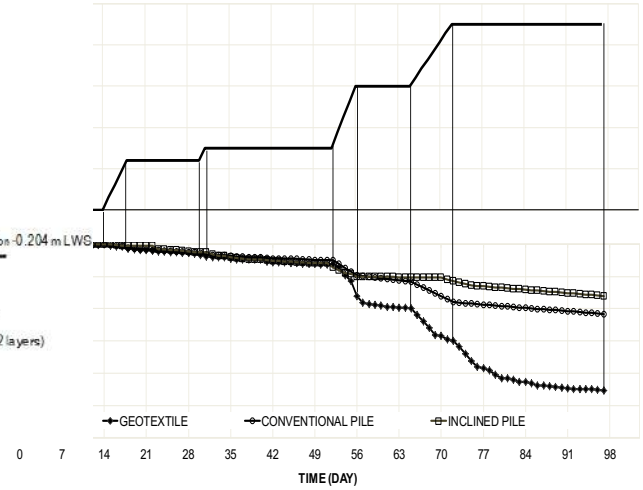
# State of the Art of Soft Soil Reinforcement in Indonesia Practice

**Tri Harianto**

* Associate Professor of Civil Engineering Department, Hasanuddin University, Indonesia



# *Outline of Presentation*

- General understanding of soft soils
- Origin of Soft Soils
- Case Histories
  - *Field Investigation of the Performance of Soft Soil Reinforcement with Inclined Pile*

  - *Full-Scale Test of a Causeway Embankment Supported by Raft-Aggregate Column Foundation on Soft Clay Deposits*

# General Understanding of Soft Soil

- Soils become soft when interacts with water.
  - Clayshales and expansive soils upon wetting
  - Uncompacted fill soften due to water infiltration
  - Soil originated from volcanis ashes

- Soft soil typically characterized as :
  - Low shear strength
  - Low permeability
  - Highly compressible

Source : https://blog.realestate.cornell.edu/2015/12/03/what-lies-below-understanding-unknown-subsurface-conditions/

https://www.thestar.com.my/news/nation/2020/01/17/

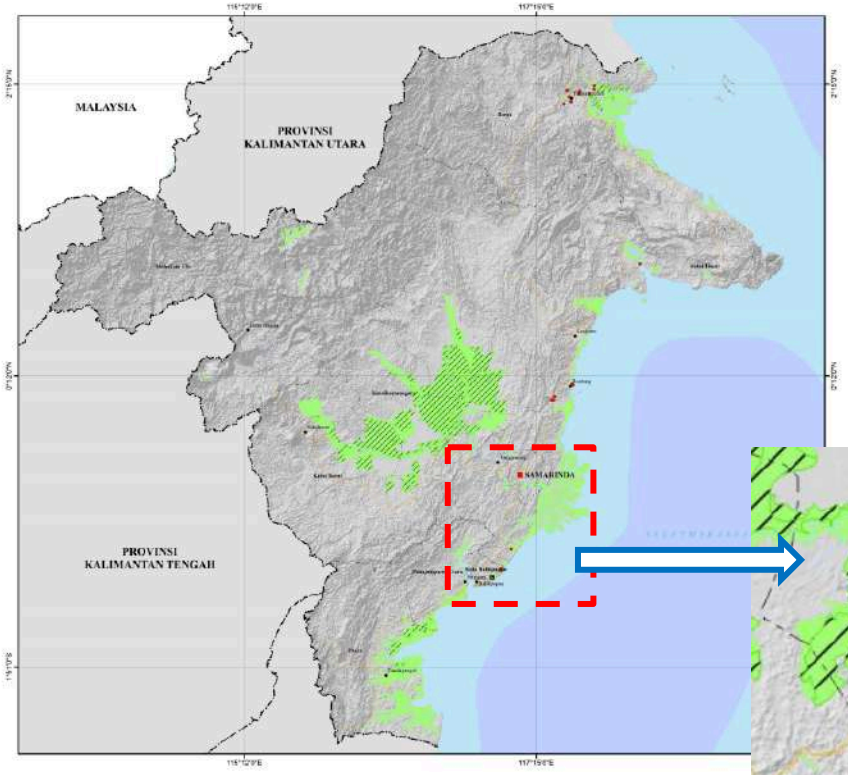
# Origin of Soft Soil


Source: Atlas Sebaran Tanah Lunak Indonesia. ESDM (2019)

Generally, soft soil in Indonesia is considered as quaternary sediment consist of alluvial deposits and organic or peat soils.

Soft soil (soft ground) usually found in the coastal plains and cover large area.

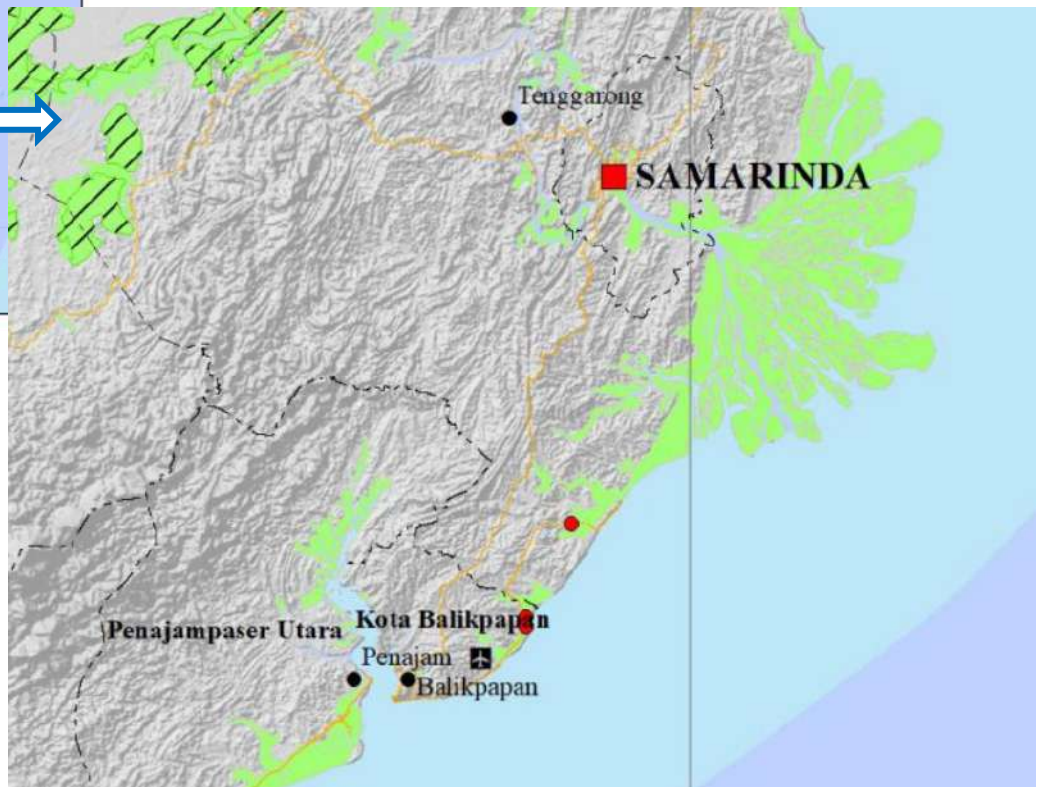
East Kalimantan Province




Soft soils are generally distributed mainly in coastal areas where cities are being constructed.

Soft clay

Peat or Organic soil




Source: Atlas Sebaran Tanah Lunak Indonesia. ESDM (2019)

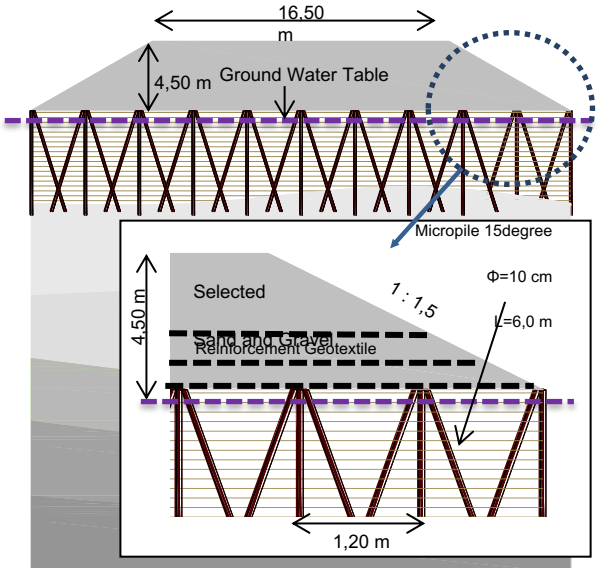
Construction on soft soils has risks of damages/failures

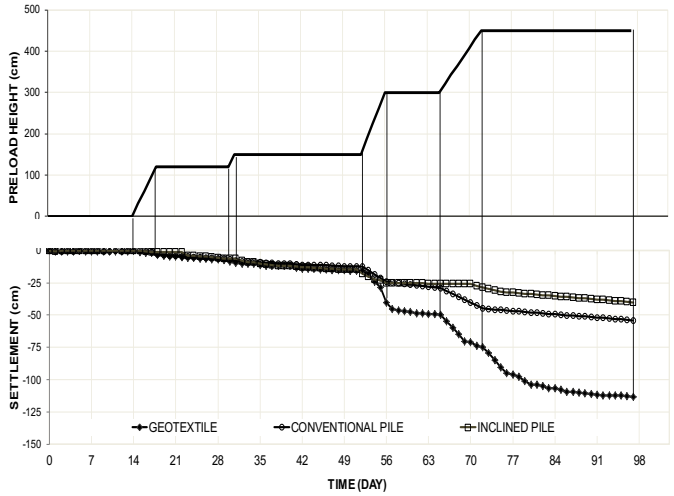
Most of failures are contributed by lack of knowledge on soft soils

International Conference On Geotechnical And Geophysical Site Characterisation
5 - 9 Sep 2016, Gold Coast, Australia

# Field Investigation of the Performance of Soft Soil Reinforcement with Inclined Pile

T. Harianto, L. Samang, Suheriyatna and Y. Sandyutama

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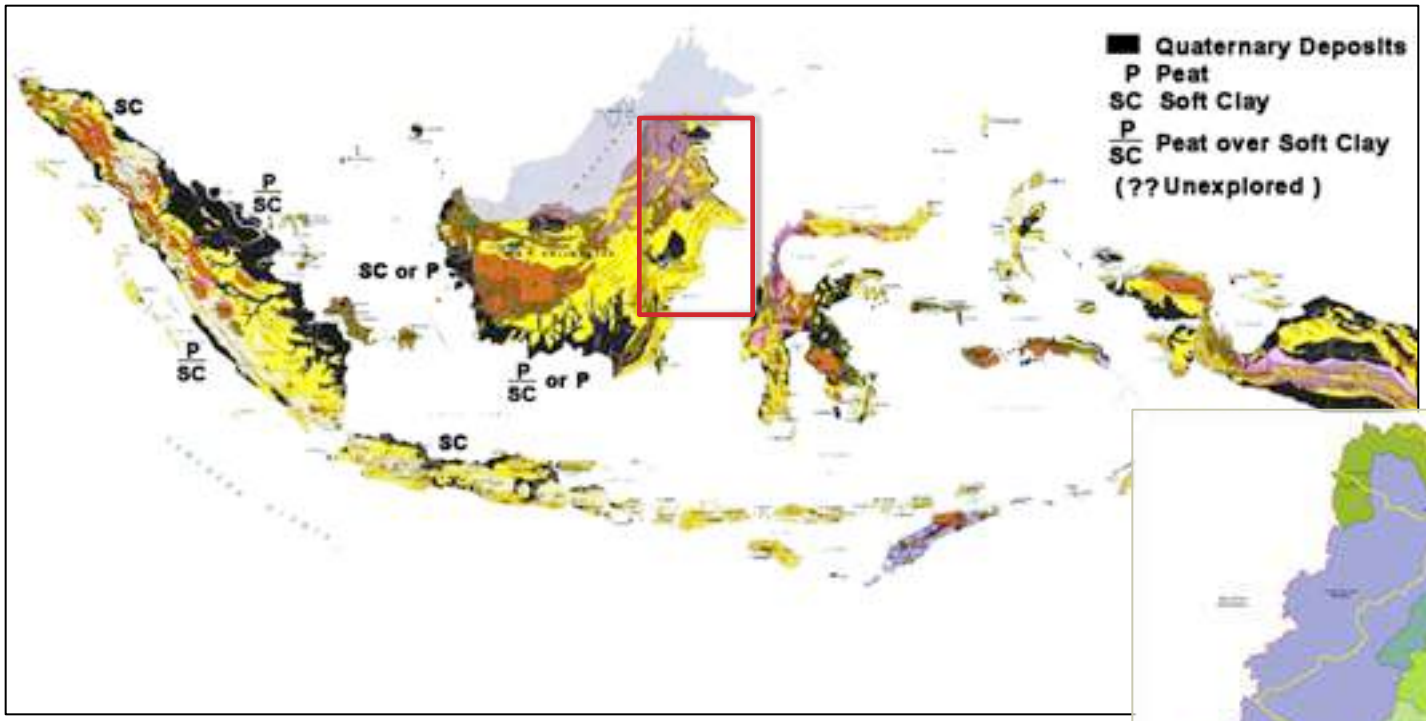
# *Soft Soil Distribution in Indonesia*




Study location : East Kalimantan Province, Indonesia

Field test location

# Soft Soil Problem for Road Construction in Indonesia

# Reinforcement Material

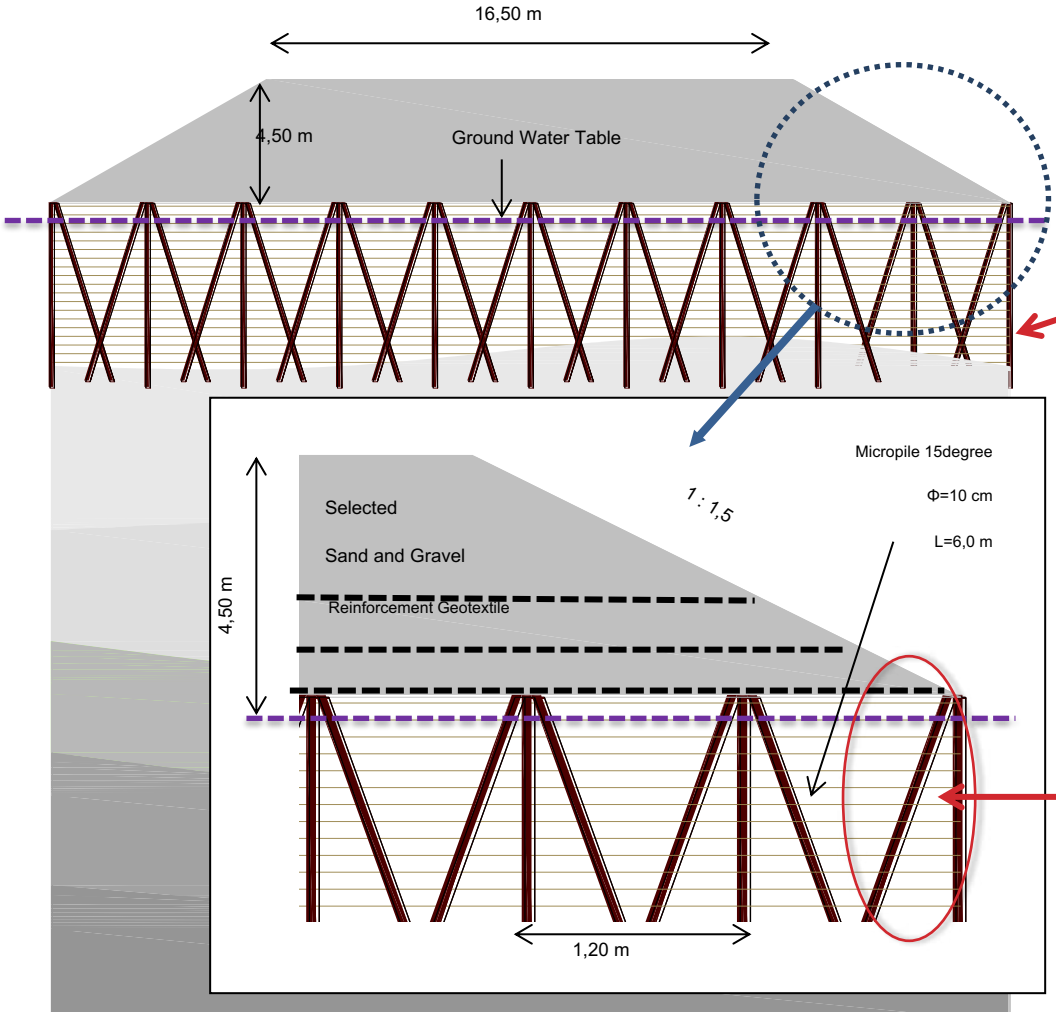
There are many local timber (galam) found in Kalimantan Island that can be utilized as a soil reinforcement material (pile)

| Characteristic of Galam | Value |
|---|---|
| Water Content | 22,95% |
| Compressive Strength // | 23,3 Mpa |
| Compressive Strength ⊥ | 14,4 Mpa |
| Tensile Strength | 17,9 Mpa |
| Bending Strength | 101,4 Mpa |

***Advantages :***

- Easy planted
- Rapid growth

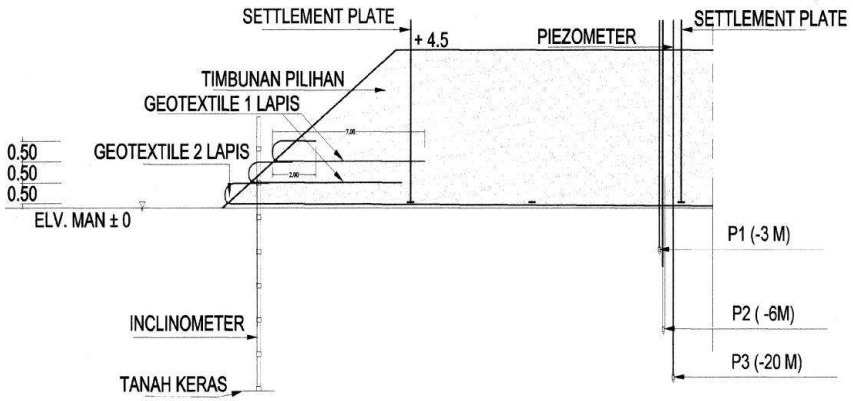
# Proposed Soil Reinforcement Technique



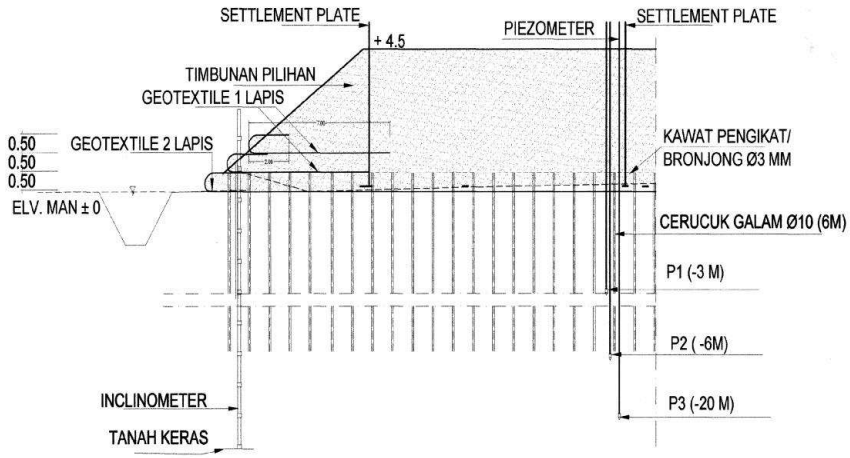

Local timber (galam)

Inclined pile

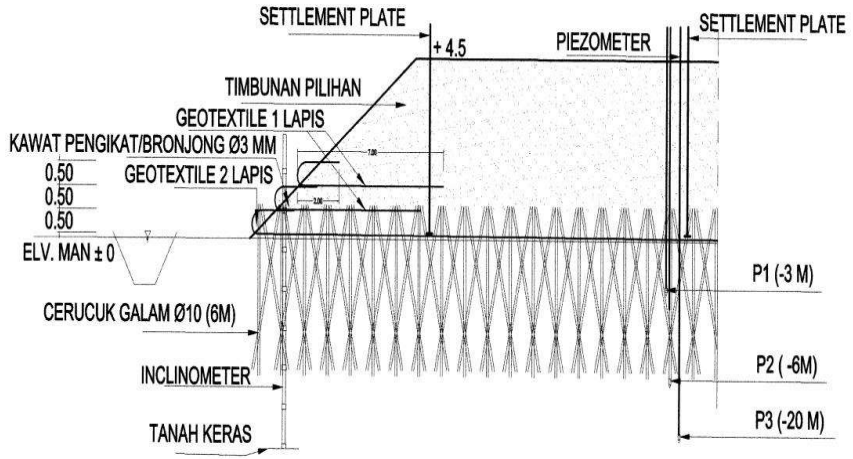
# Types of Soil Reinforcement Technique




(a)




(b)




(c)

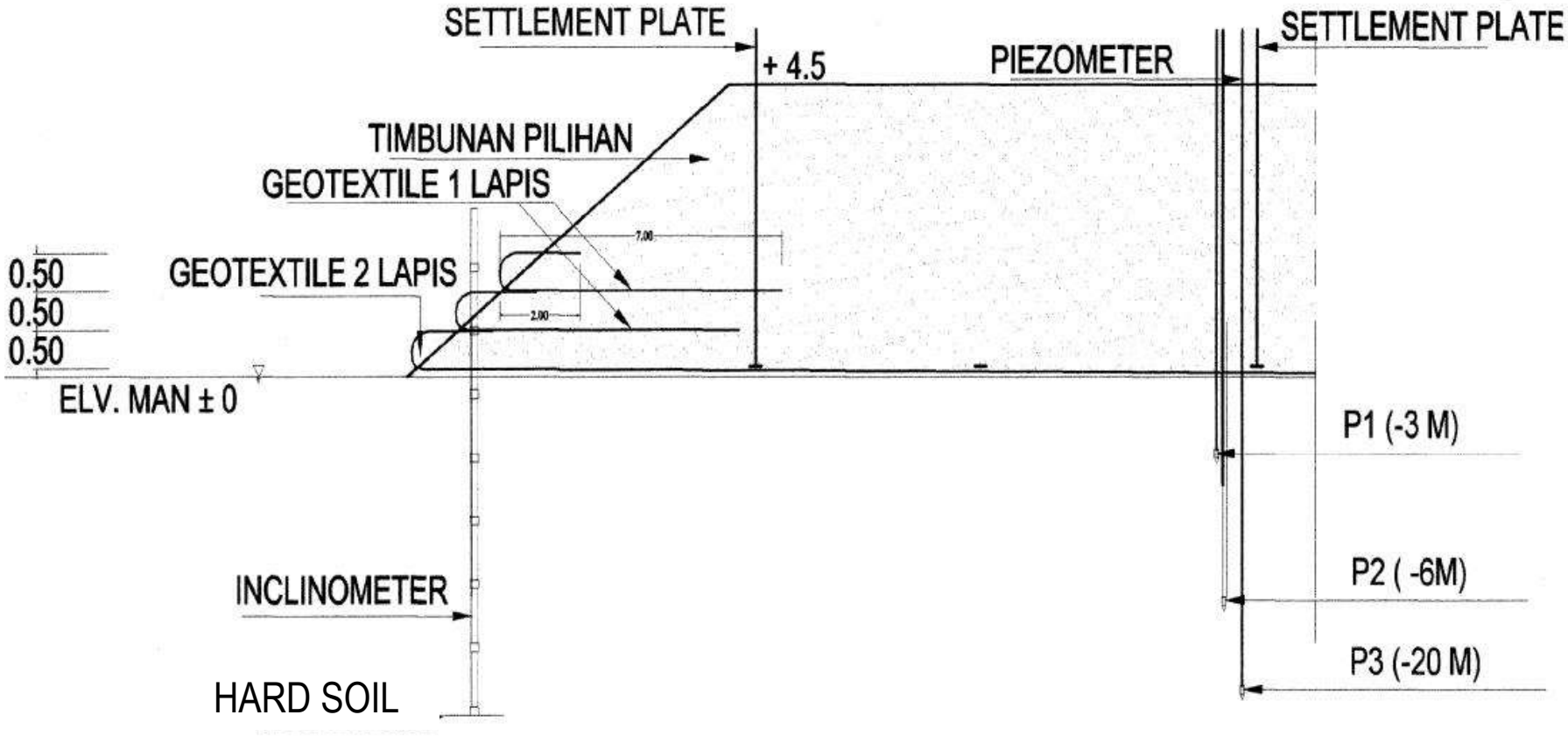
(a) Geotextile (Type 1)

(b) Conventional Pile (Type 2)

(c) Inclined Pile (Type 3)

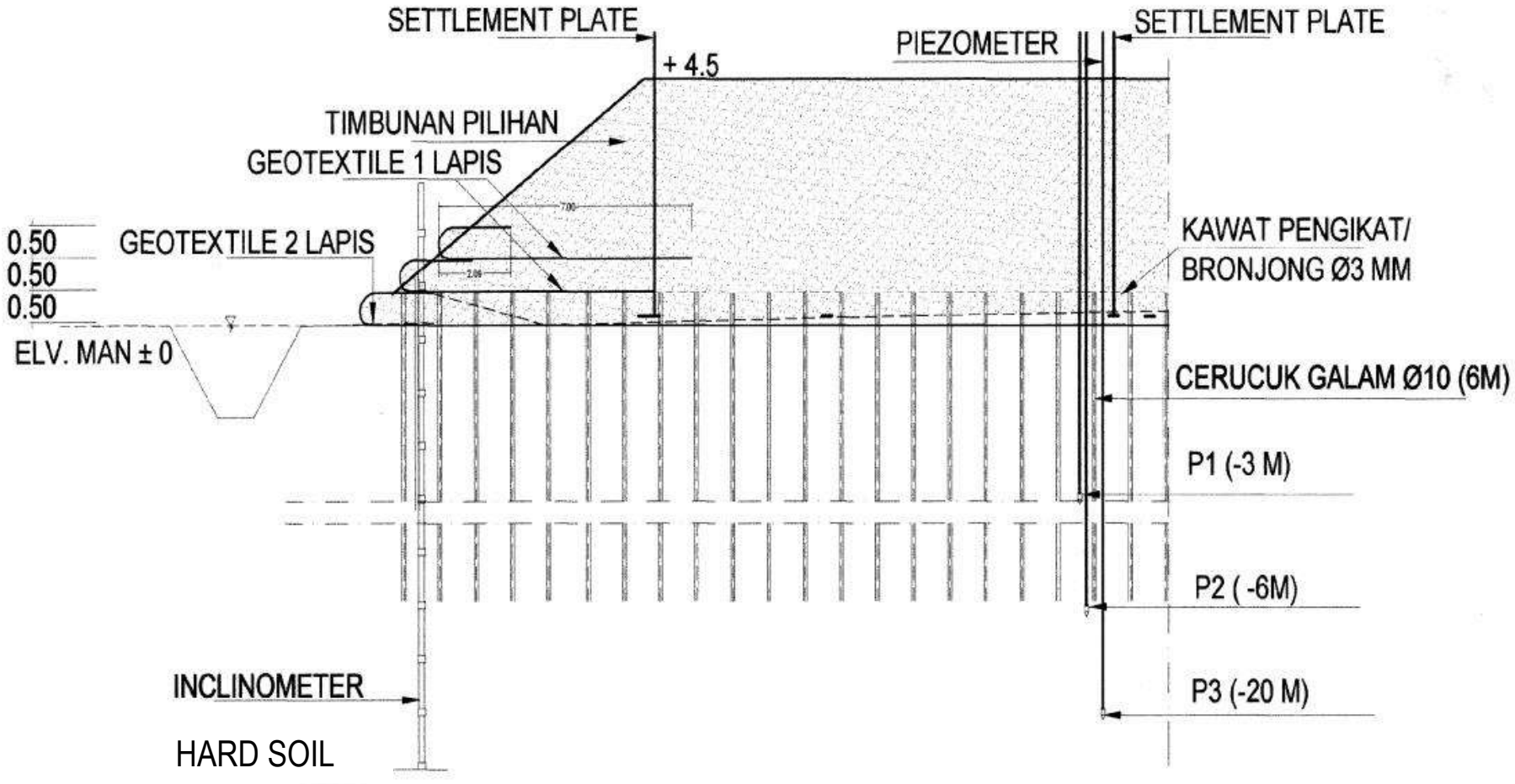
# Soil Reinforcement Technique Type 1

## (Geotextile)



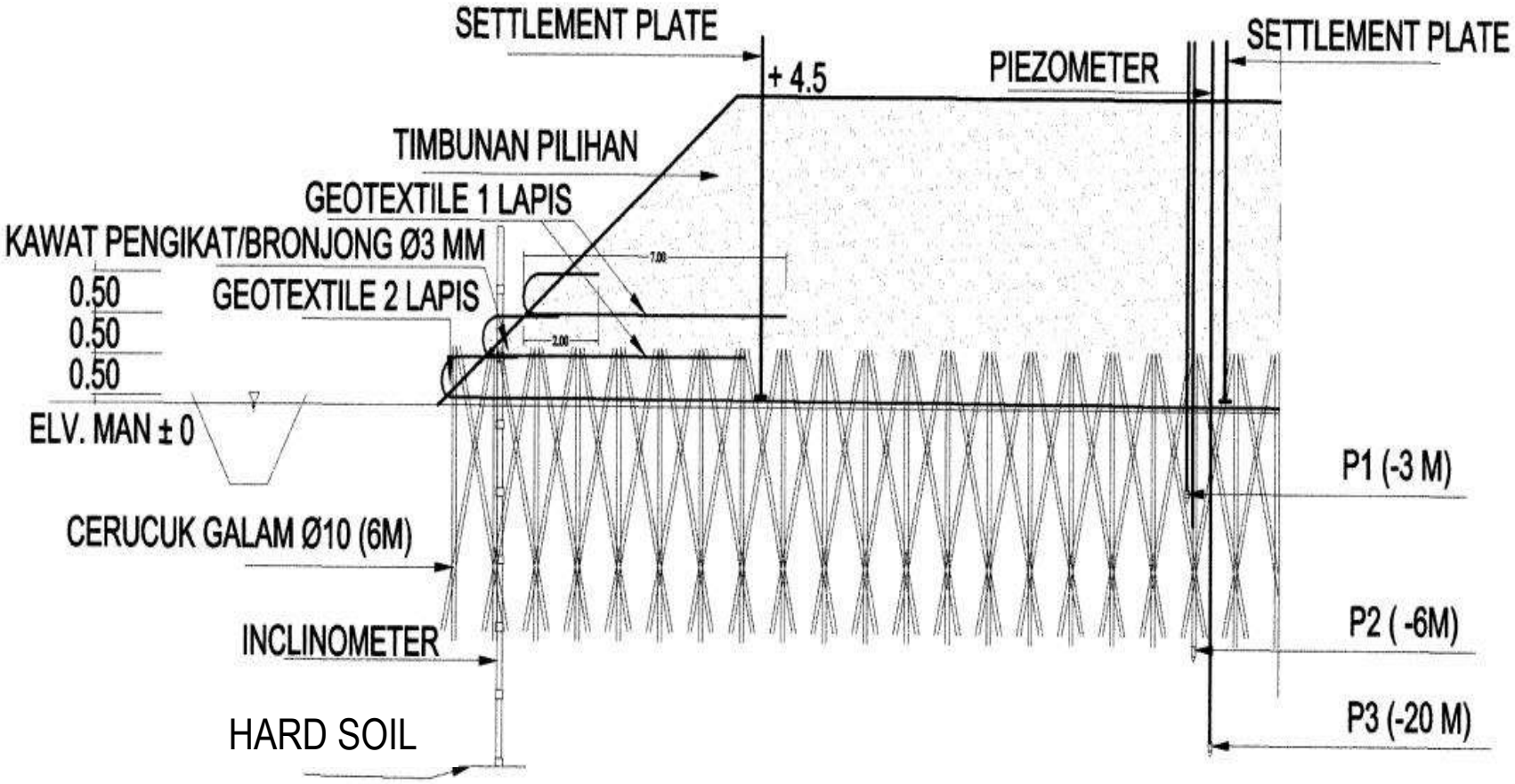
# Soil Reinforcement Technique Type 2

## (Conventional Pile)

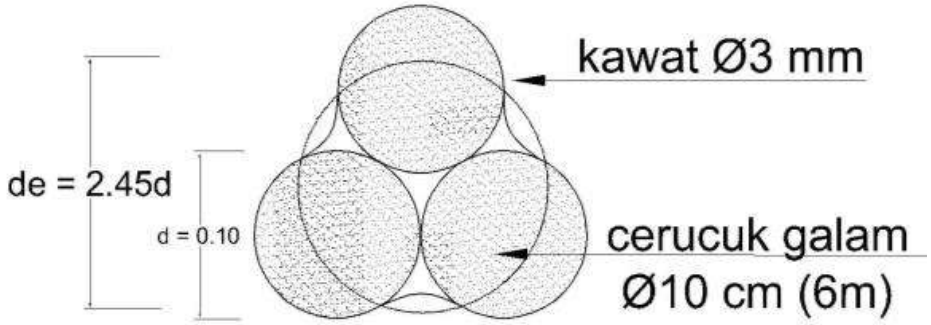


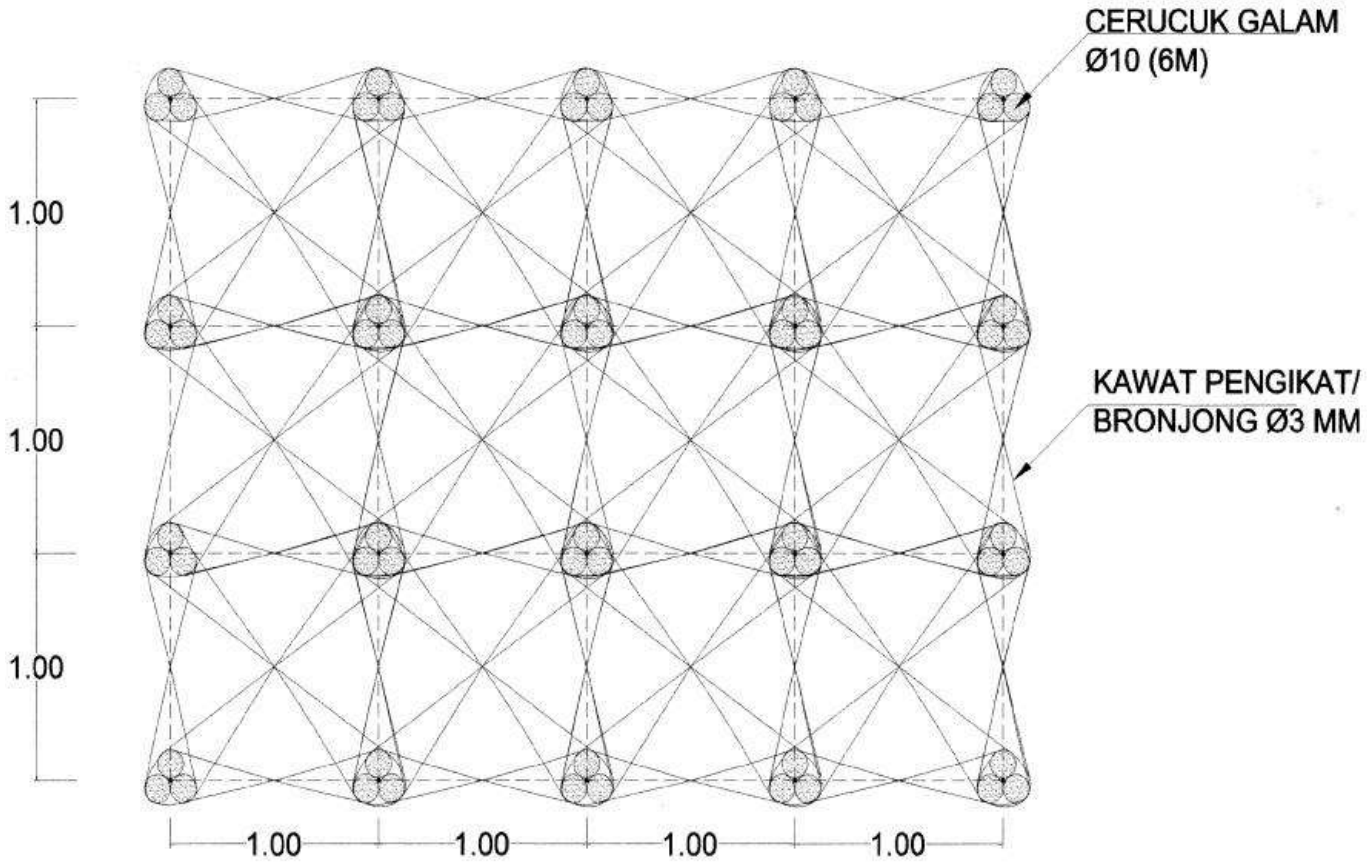
# Soil Reinforcement Technique Type 3

## (Inclined Pile)

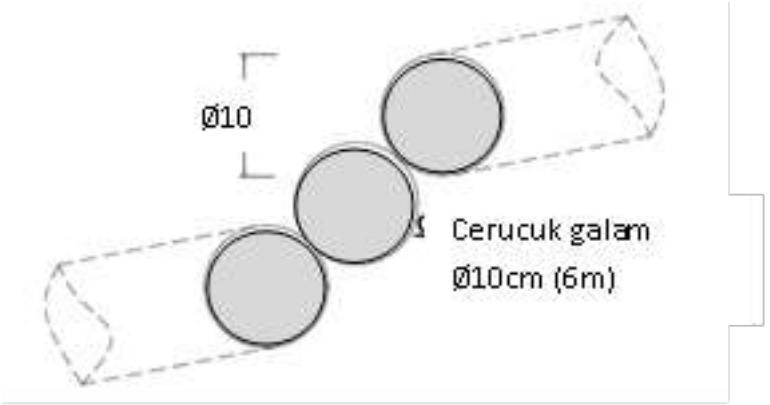


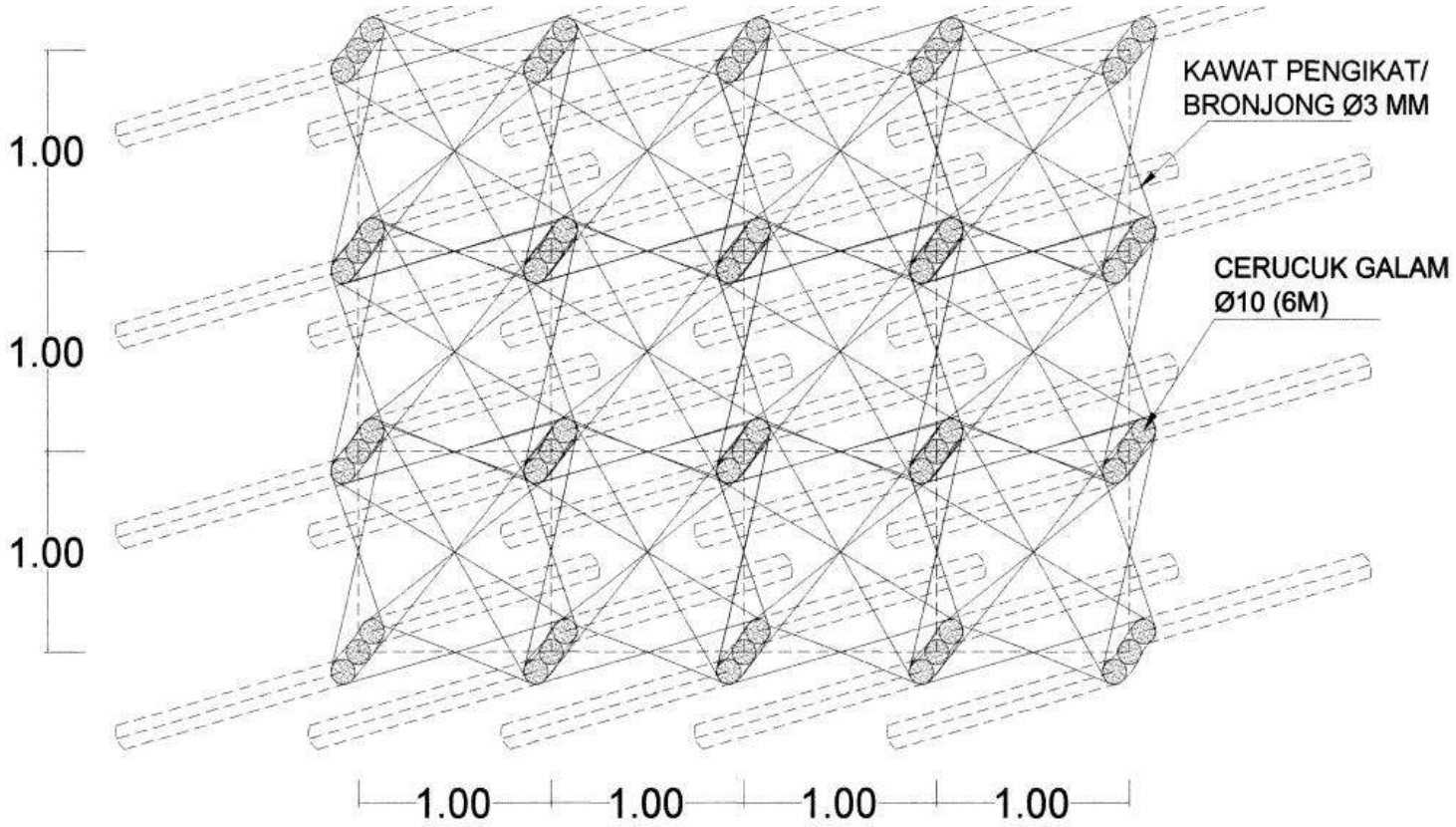
# Pile Arrangement of Conventional Pile (Type 2)



# Pile Arrangement of Inclined Pile (Type 3)

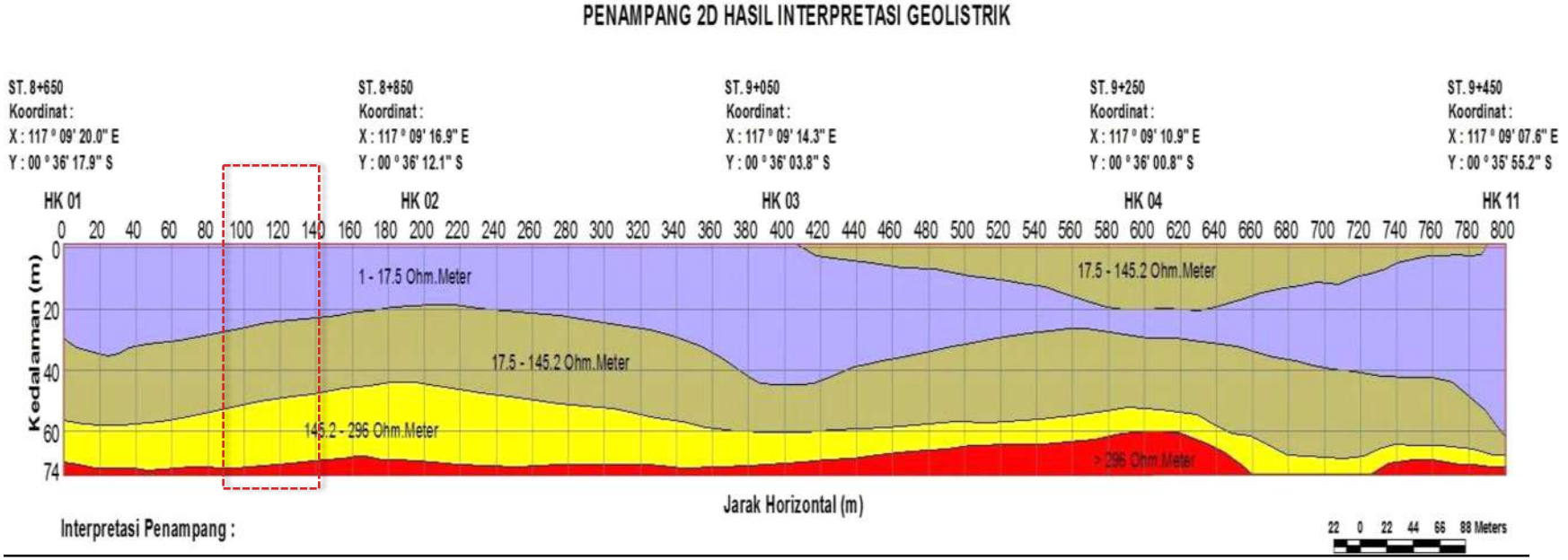



Instalation of pile

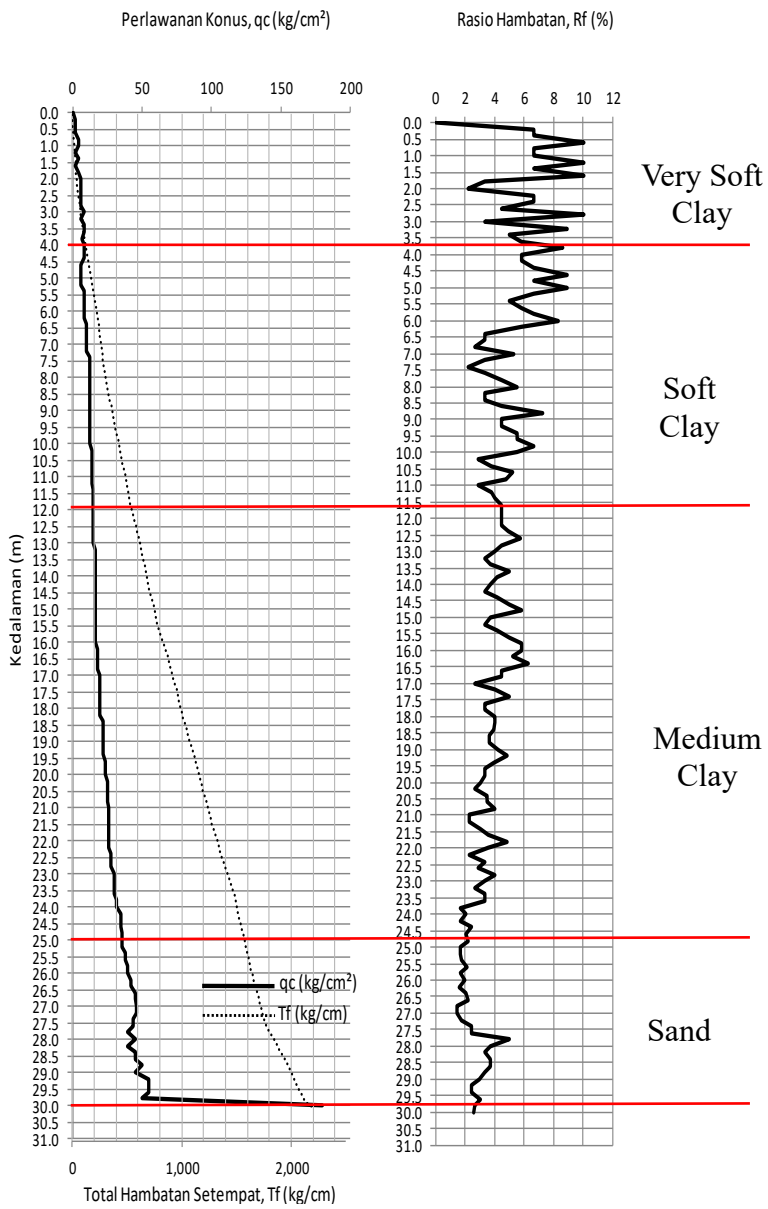
Pile arrangement

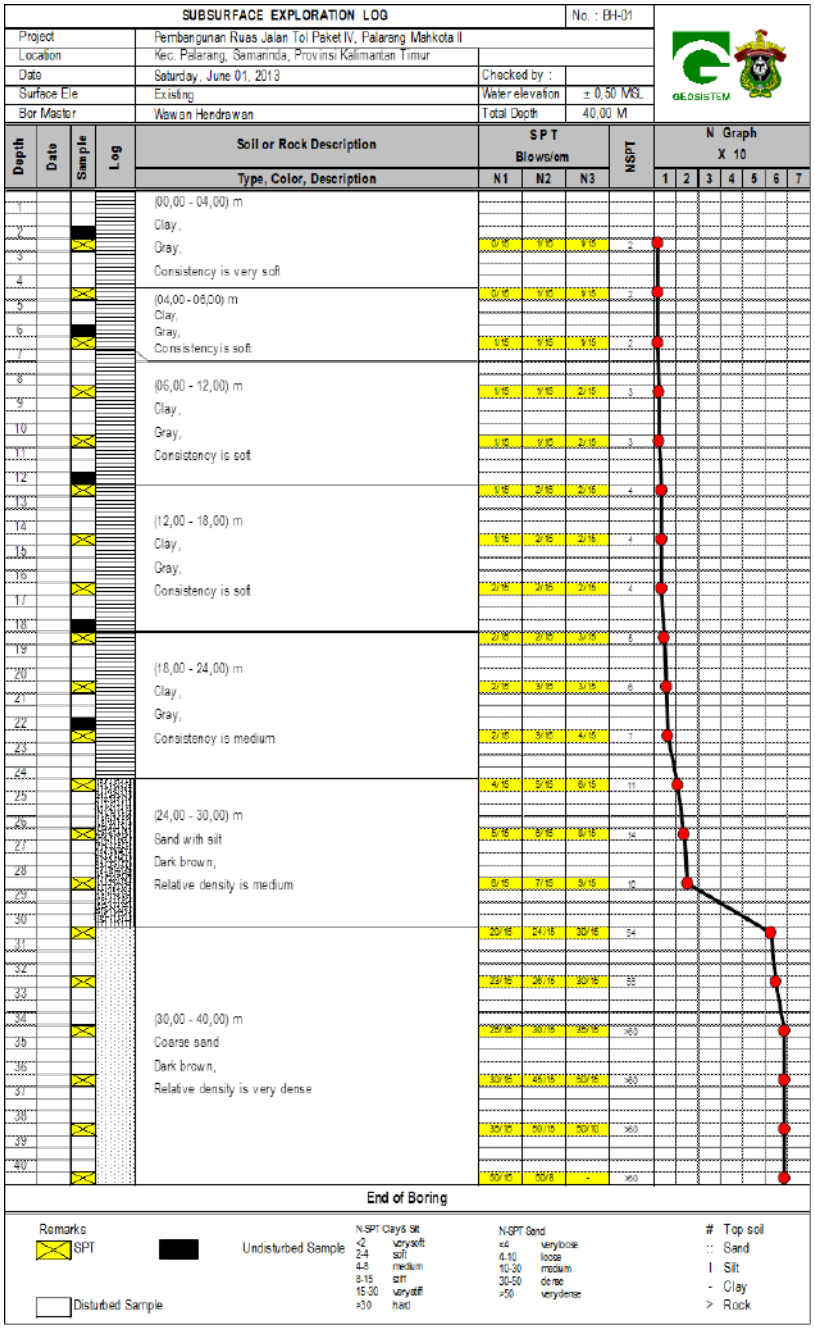
# Geotechnical Properties of Kalimantan Soil



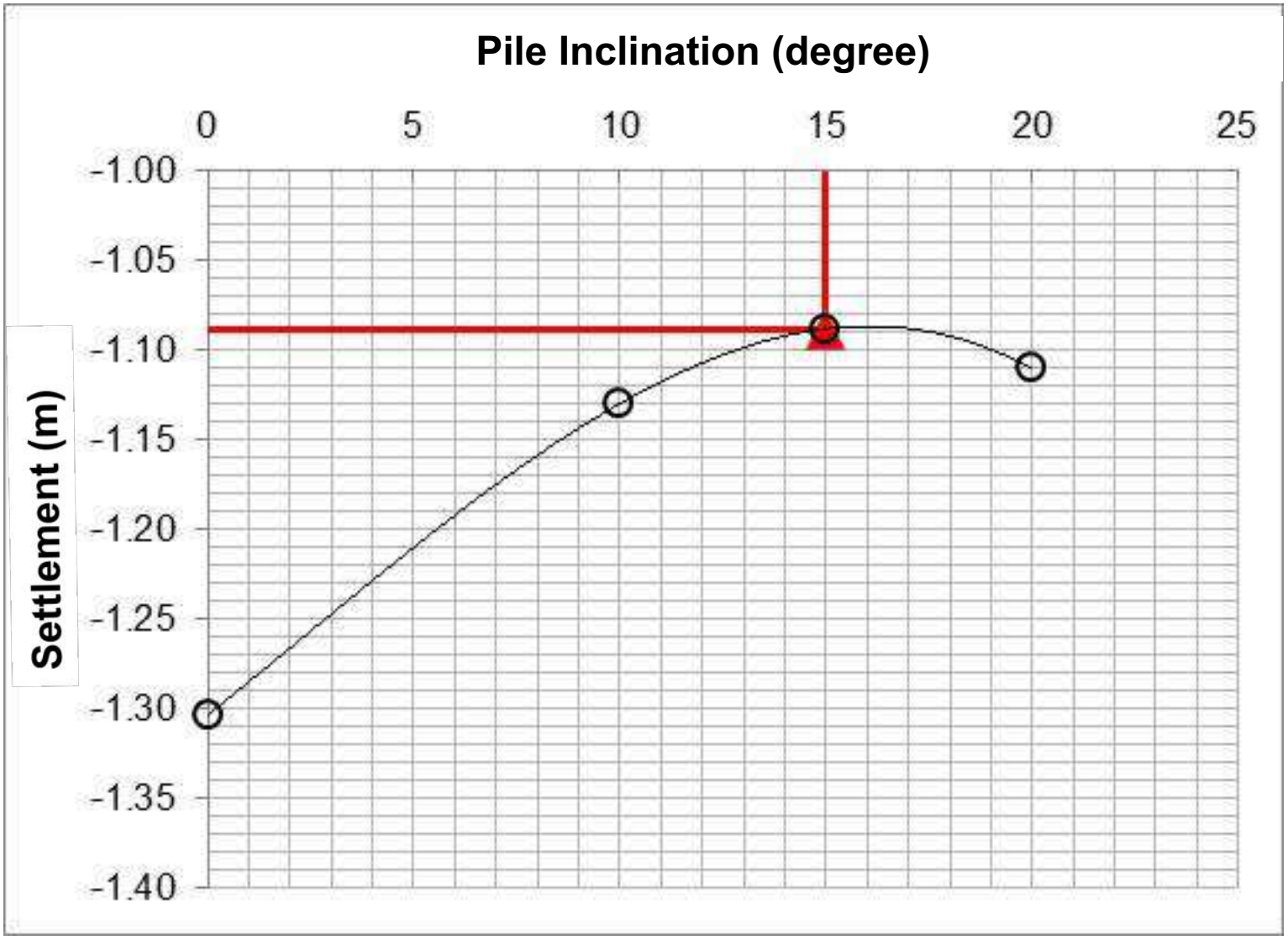

| Soil Type | | Layer 1 (0,00 - 4,00) m | Layer 2 (4,00 - 6,00) m | Layer 3 (6,00 - 12,00) m | Layer 4 (12,00 - 18,00) m | Layer 5 (18,00 - 25,00) m | Layer 6 (25,00 - 30,00) m | Fill |
|---|---|---|---|---|---|---|---|---|
| | | Soft Clay | | | | | Sand | Slected Sand and Gravel |
| $\gamma_{unsat}$ | [kN/m³] | 12 | 12 | 13 | 15 | 16 | 16.5 | 19 |
| $\gamma_{sat}$ | [kN/m³] | 14.5 | 14.5 | 15 | 16 | 18 | 20 | 20 |
| $k_x$ | [m/day] | 6.89E-04 | 6.89E-04 | 6.89E-04 | 6.89E-04 | 6.89E-04 | 2 | 2 |
| $k_y$ | [m/day] | 1.38E-03 | 1.38E-03 | 1.38E-03 | 1.38E-03 | 1.38E-03 | 1 | 1 |
| E | [kN/m²] | - | - | - | - | - | 8000 | 10000 |
| v | [-] | - | - | - | - | - | 0.35 | 0.35 |
| Cc | [kN/m²] | 0.9 | 0.9 | 0.85 | 0.6 | 0.4 | - | - |
| Cs | [kN/m²] | 0.13 | 0.11 | 0.13 | 0.09 | 0.09 | - | - |
| $e_0$ | [-] | 2.2 | 2.2 | 2 | 1.8 | 1.5 | - | - |
| φ | [°] | 5 | 8 | 12 | 14 | 16.5 | 30 | 33 |
| c | [kN/m²] | 10 | 12 | 20 | 25 | 30 | 1 | 1 |

# CPT and Boring Log Result

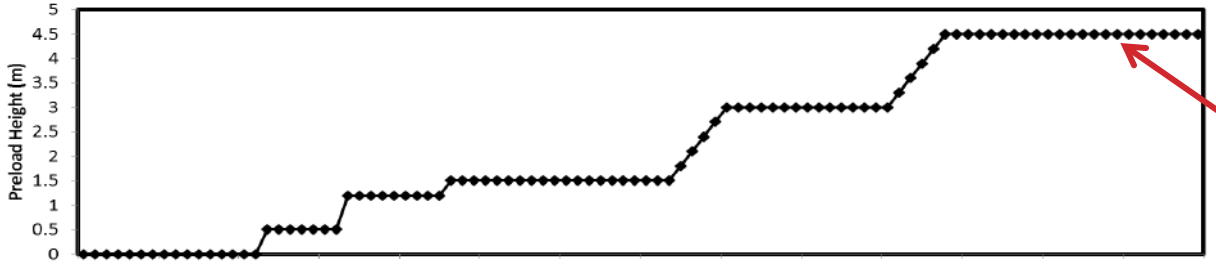


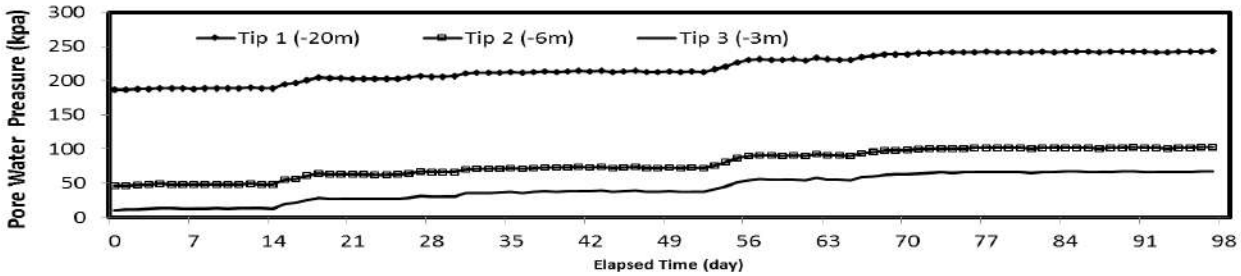
# Determination of Pile Inclination



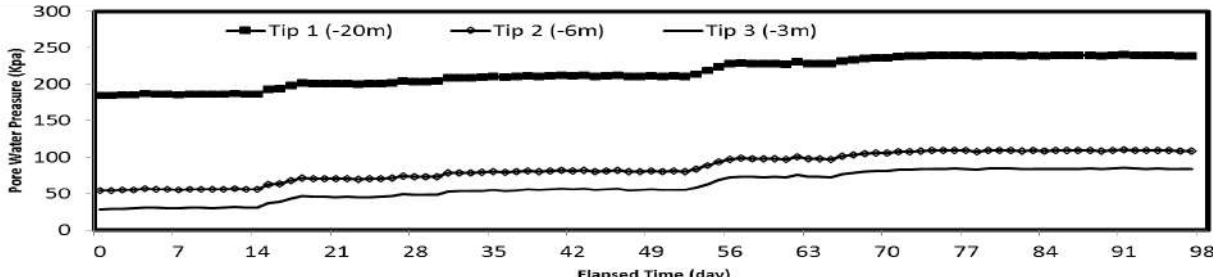
# *Pore Water Pressure Profile*



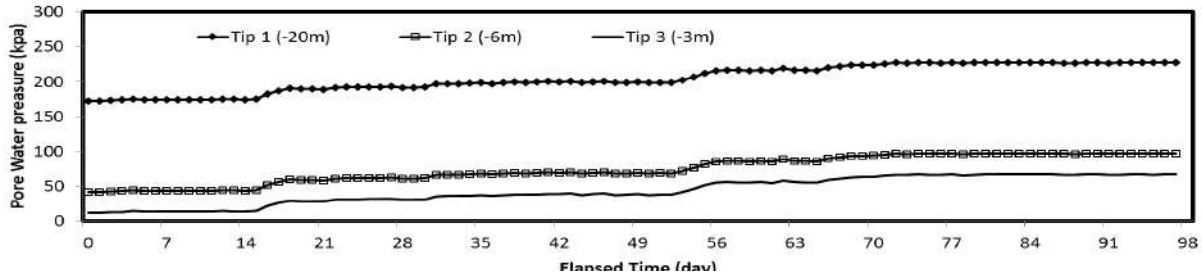

Final stage (4,5 m)



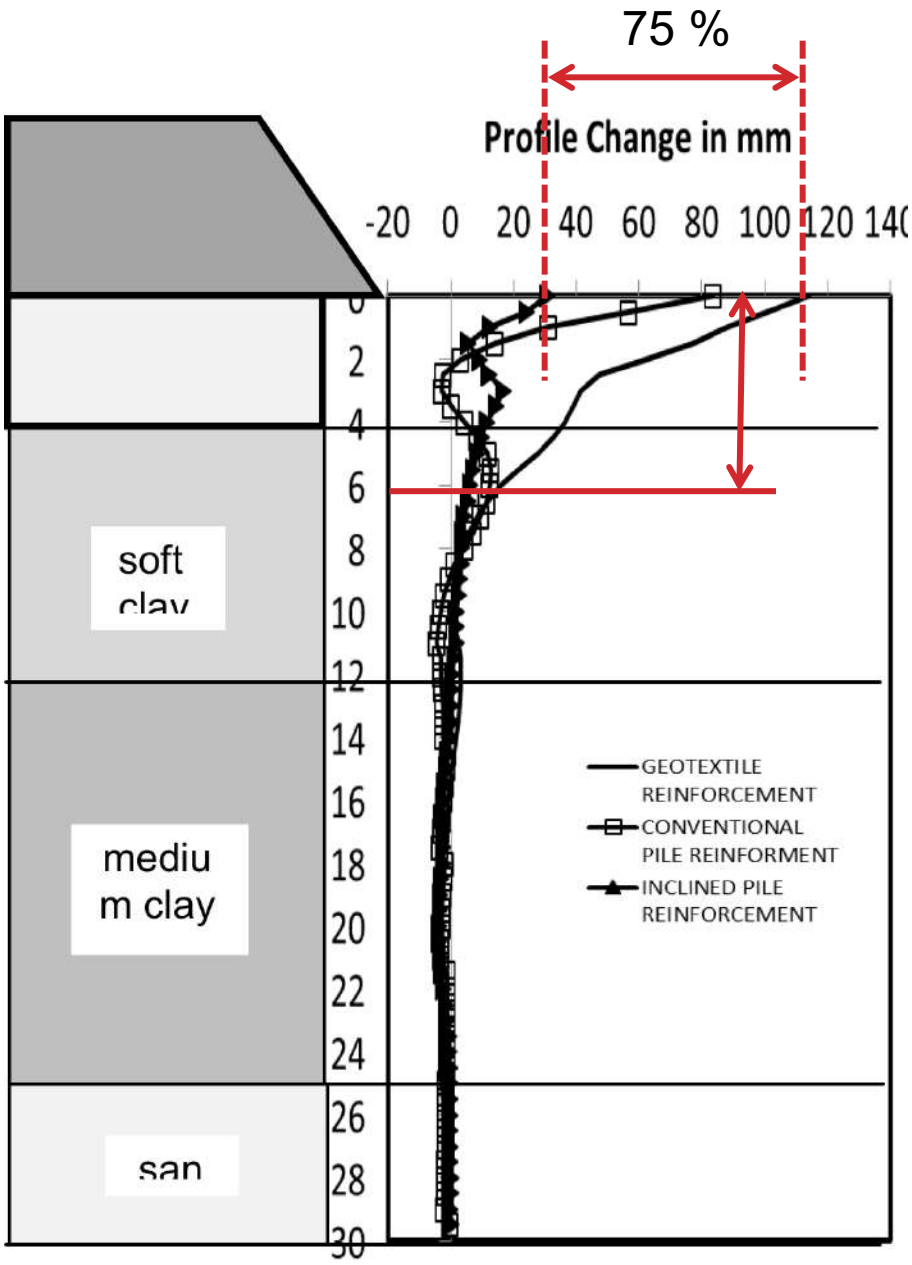

***(a) geotextile***




***(b) conventional pile***




***(a) inclined pile***

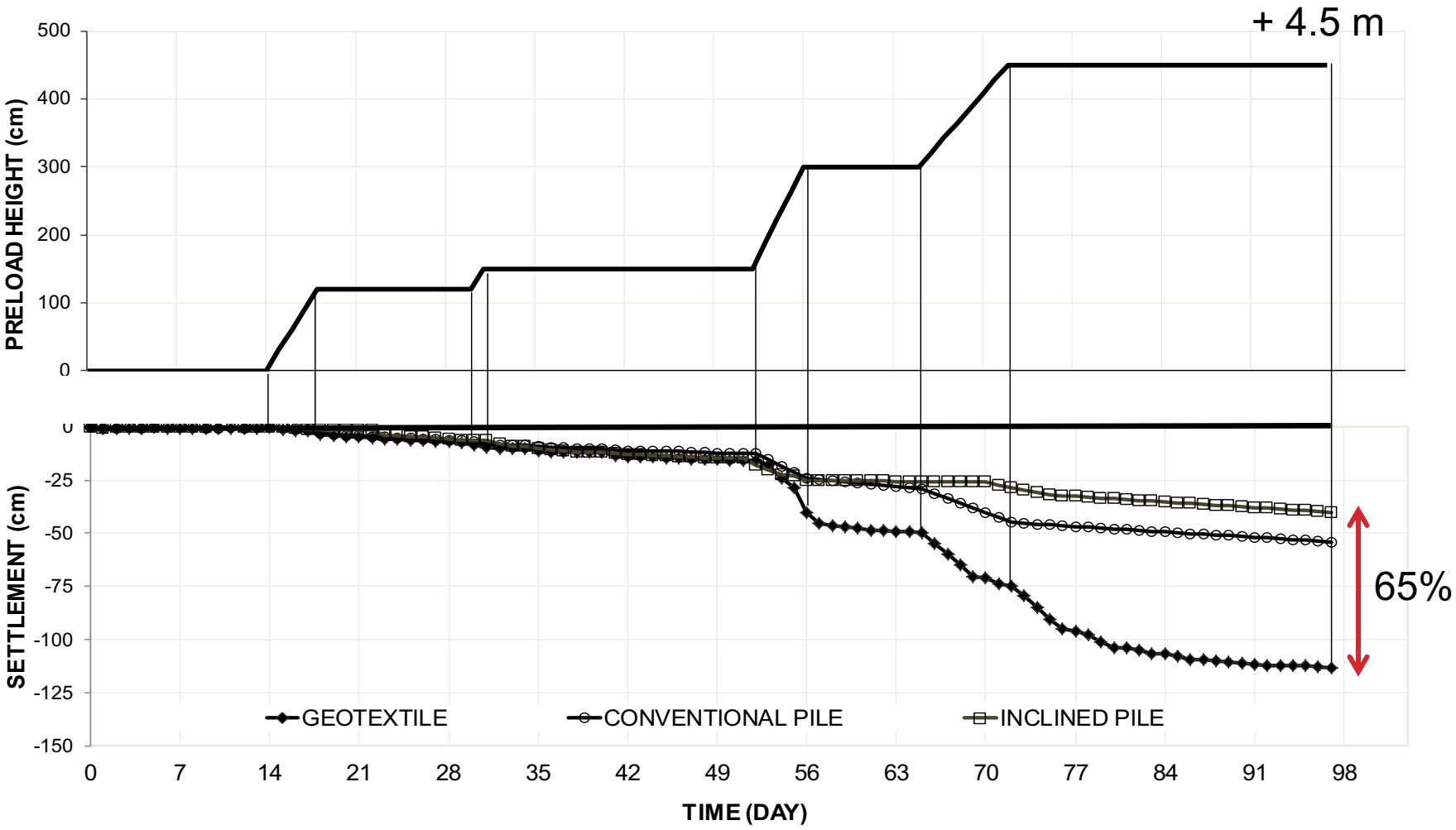



## *Observation of Lateral Movement*

Installation of inclined pile significantly reduces the amount of lateral movement about 75% compared to geotextile reinforcement.

This phenomenon mainly due to the presence of pile up to 6 m depth that provide the lateral resistance in the zone with pile reinforcement.

# Trial Embankment Observation




Reduction of settlement of inclined pile type was found around 65% compare to geotextile reinforcement.

## *Conclusions*

The bearing capacity of reinforced soil with conventional and inclined pile is sufficient to support the trial embankment (4,5 m).

The small amount of lateral movement was observed for both pile reinforcement, which is indicated that the sufficient slope stability of trial embankment, occur with the installation of pile reinforcement.

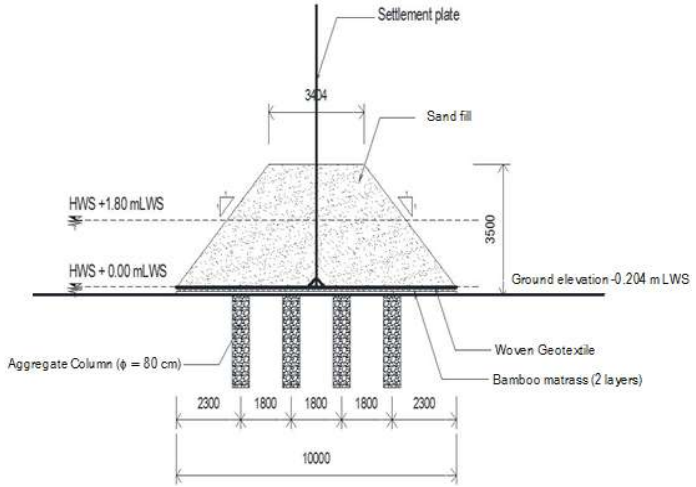
The total settlement reduction for both conventional and inclined pile compared to geotextile reinforcement was found 52% and 65% respectively.

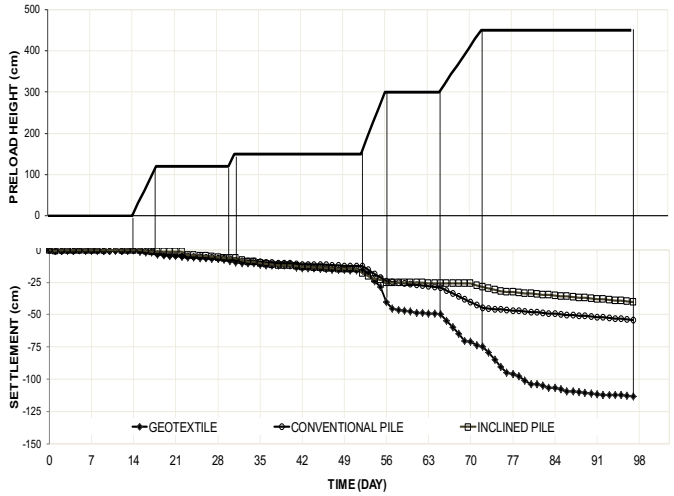
Therefore, the inclined pile reinforcement has a potential application for road construction on soft soil as an alternative construction method.

International Conference On Soil Mechanics and Geotechnical Engineering
23 - 24 Feb 2017, Paris, France

# Full-Scale Test of a Causeway Embankment Supported by Raft-Aggregate Column Foundation on Soft Clay Deposits

T. Harianto, L. Samang, S. H. Nur, Arwin

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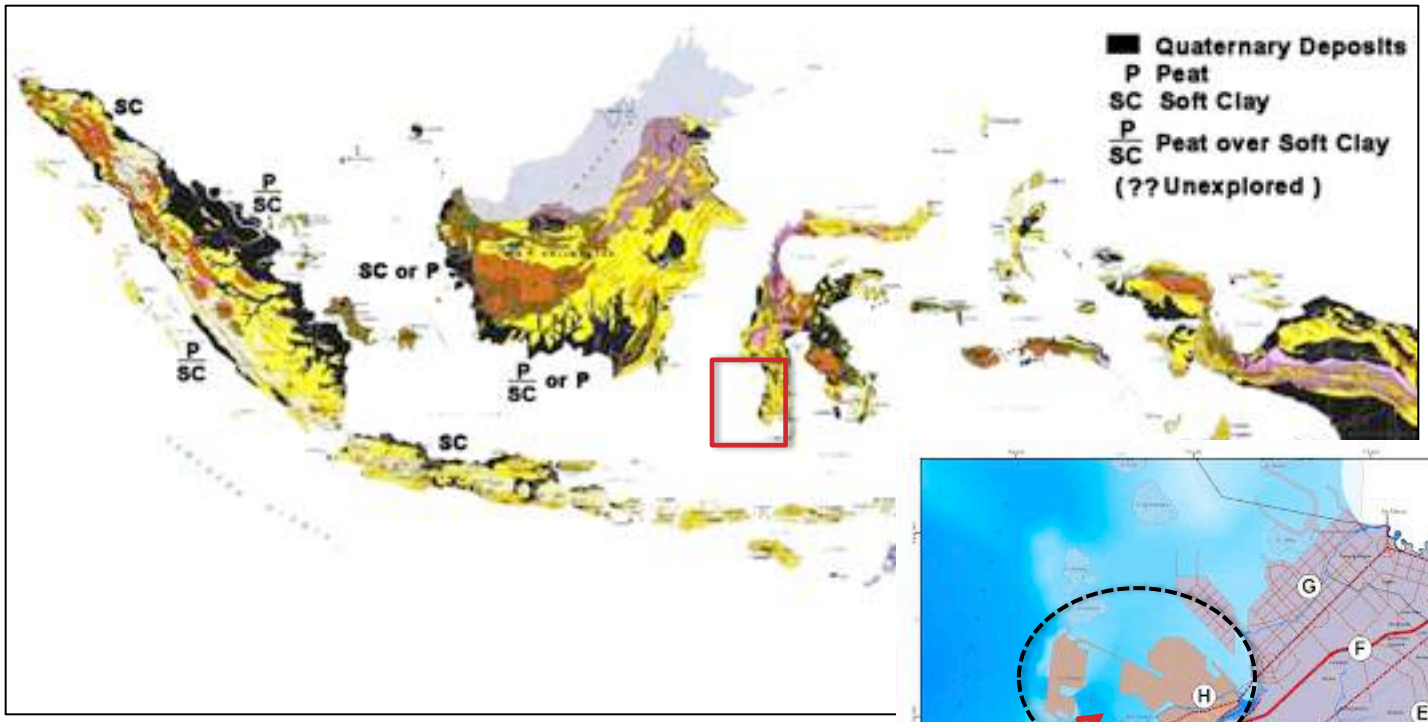
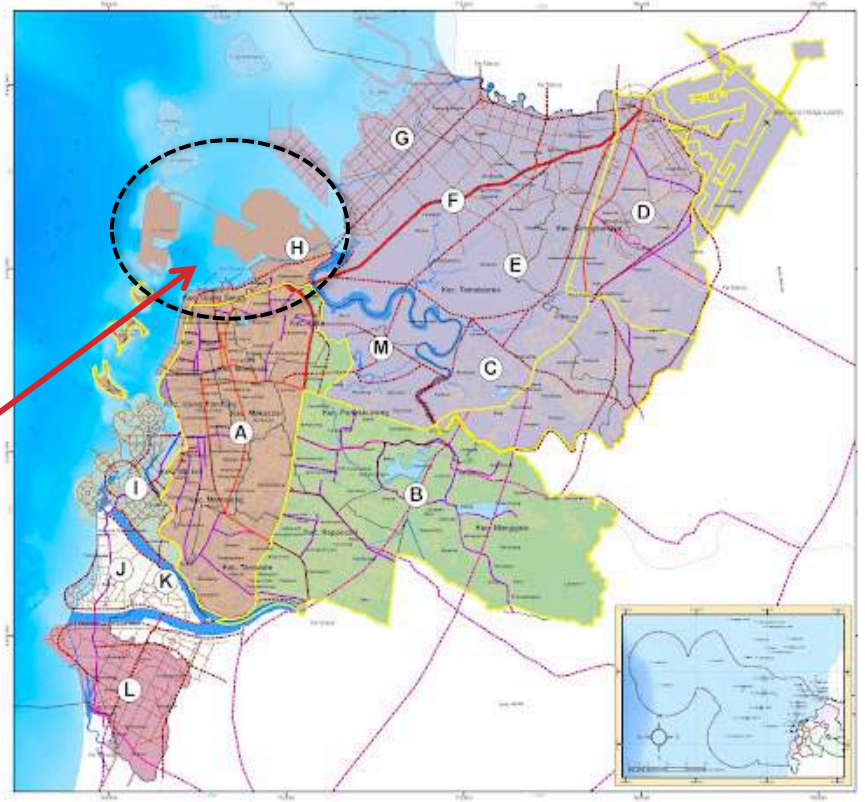
# *Soft Soil Distribution in Indonesia*




Study location : South Sulawesi Province, Indonesia

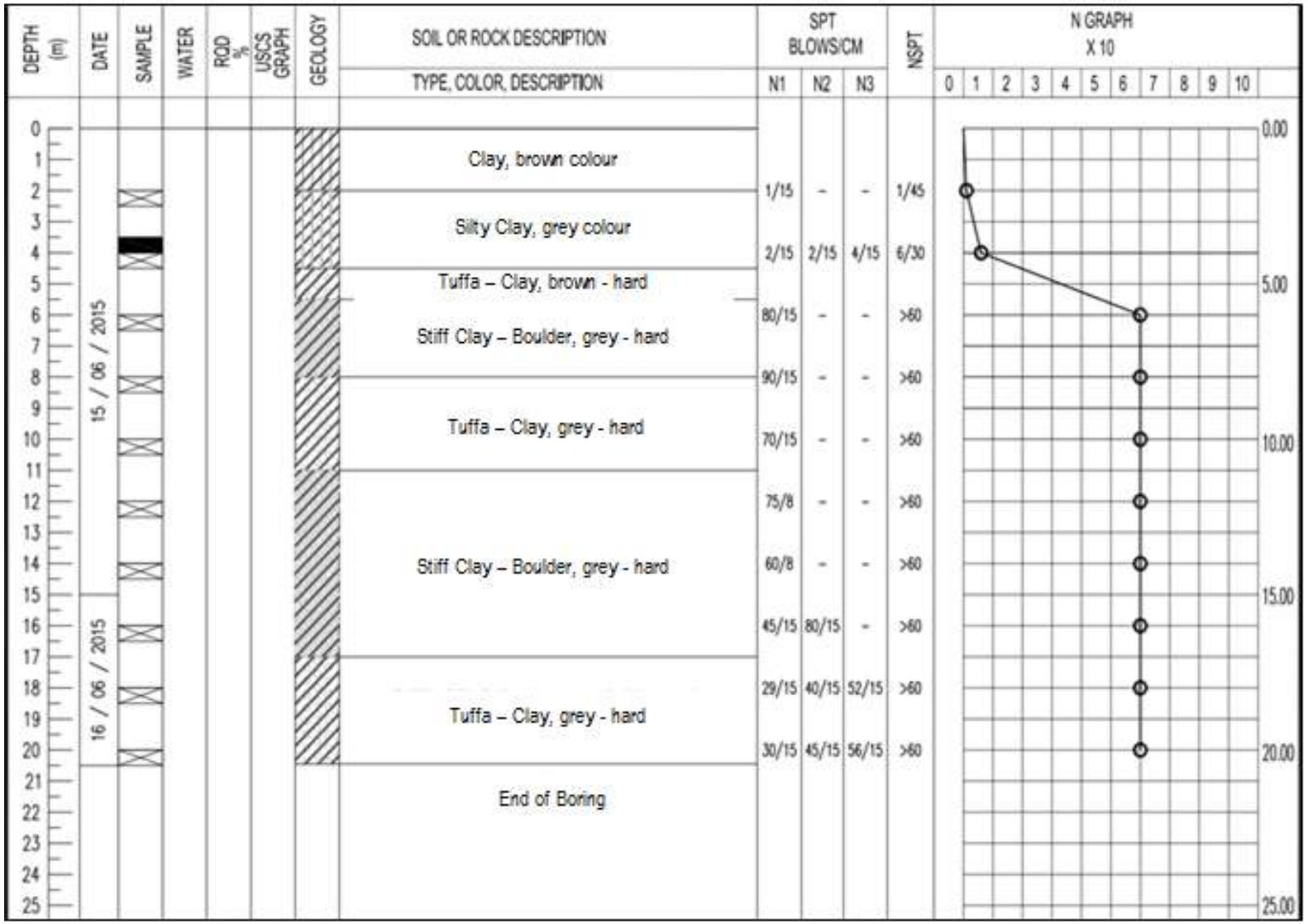
Field test location



# Soft Soil Problem for Construction in Indonesia

ICSMG2017, 23-24 February 2017, Paris, France

# Soft Soil Characteristics (Boring Log)



# Reinforcement Material

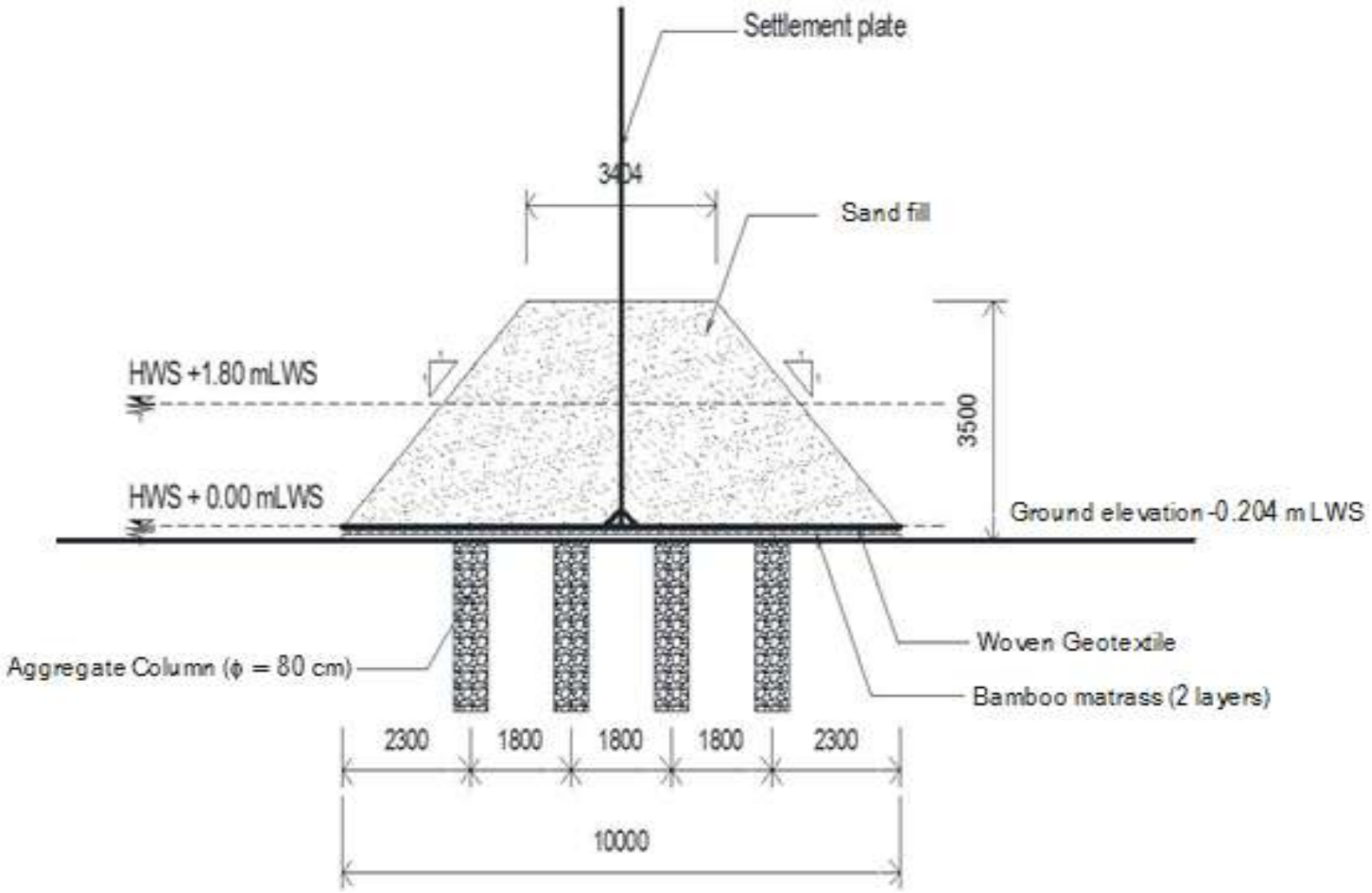
There are many local timber (bamboo) found in Sulawesi Island that can be utilized as a soil reinforcement material

***Advantages :***

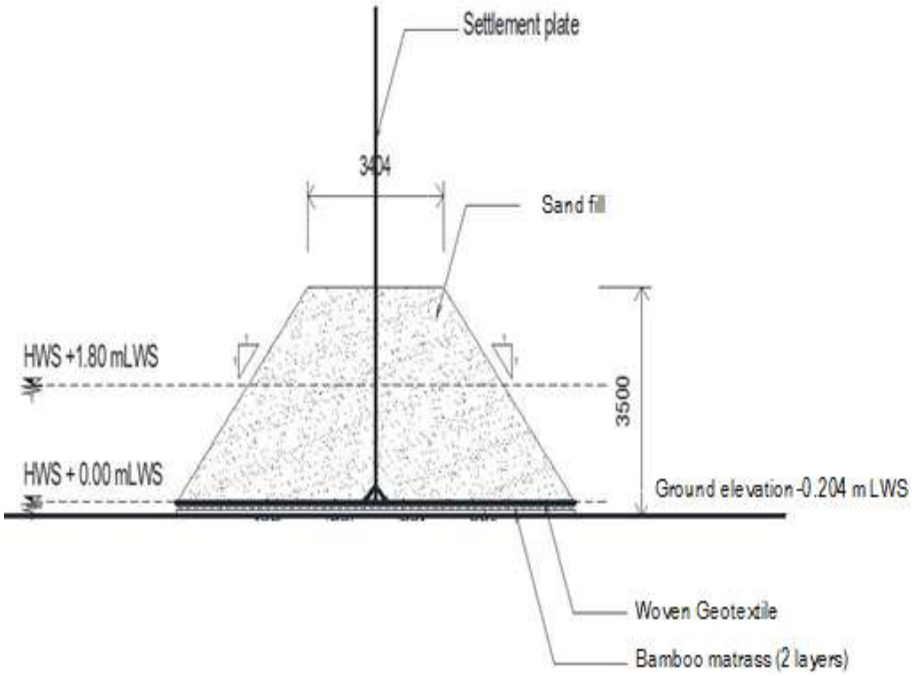
- Easy planted
- Rapid growth

# Aggregate Material

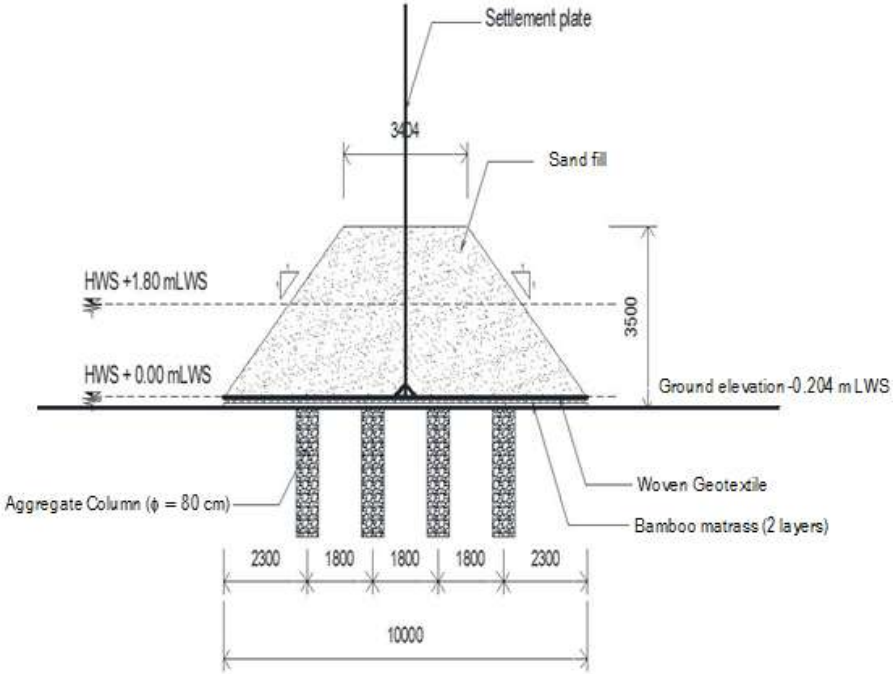
# Proposed Soil Reinforcement Technique



# Types of Soil Reinforcement Technique




(a)

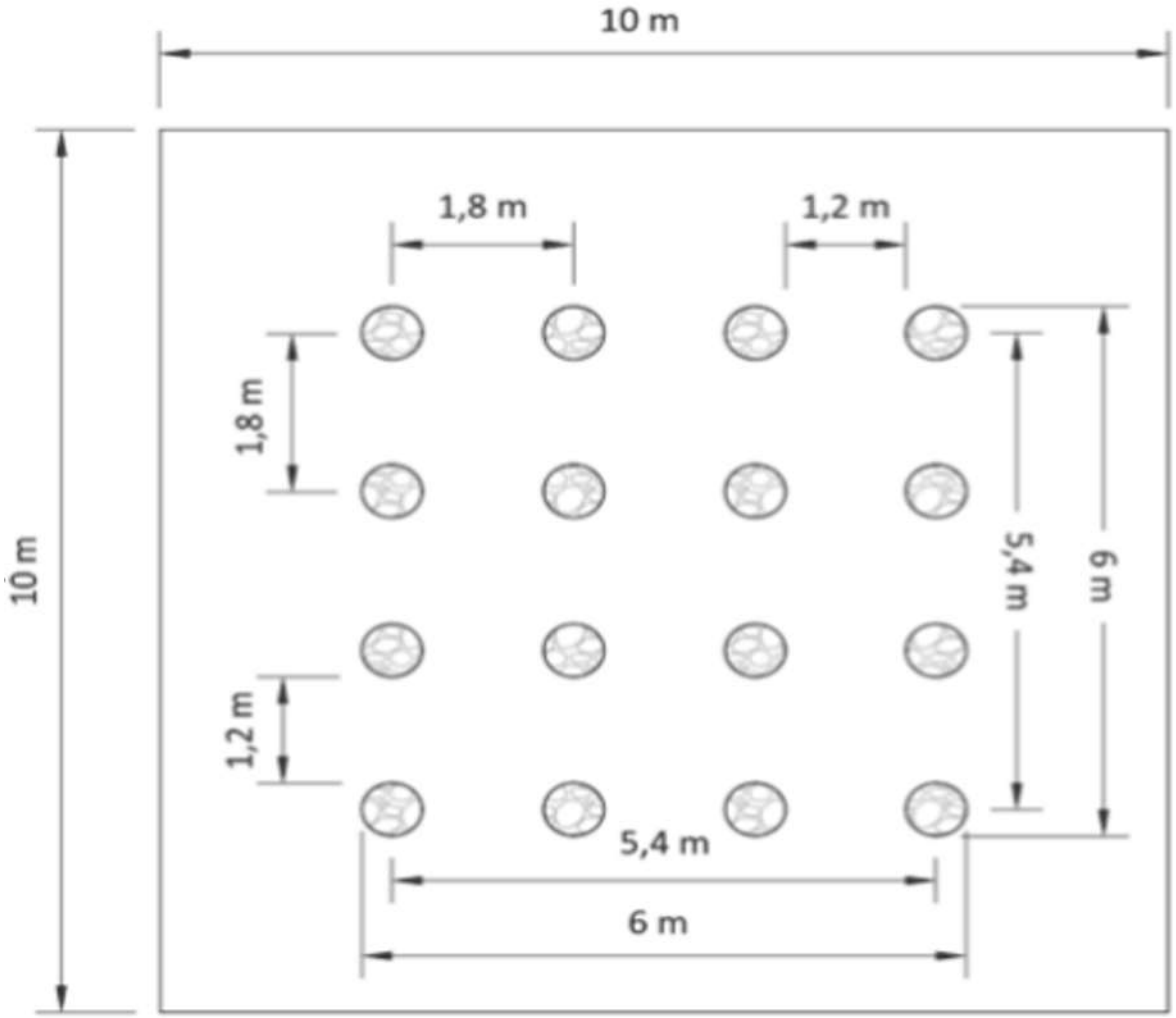



(b)

(a) Bamboo raft (Type 1)

(b) Raft-Aggregate column (Type 2)

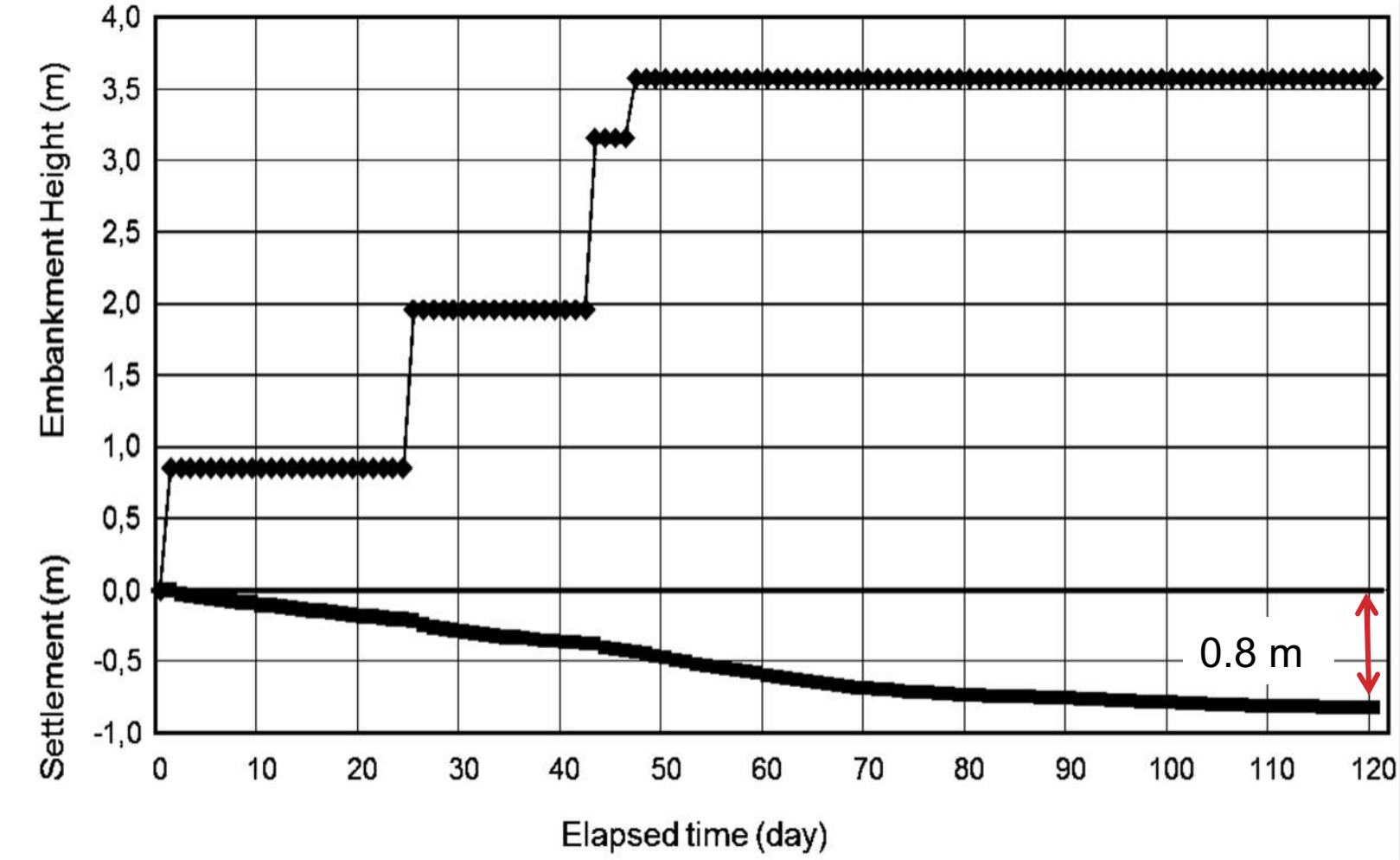
# Arrangement of Aggregate Column



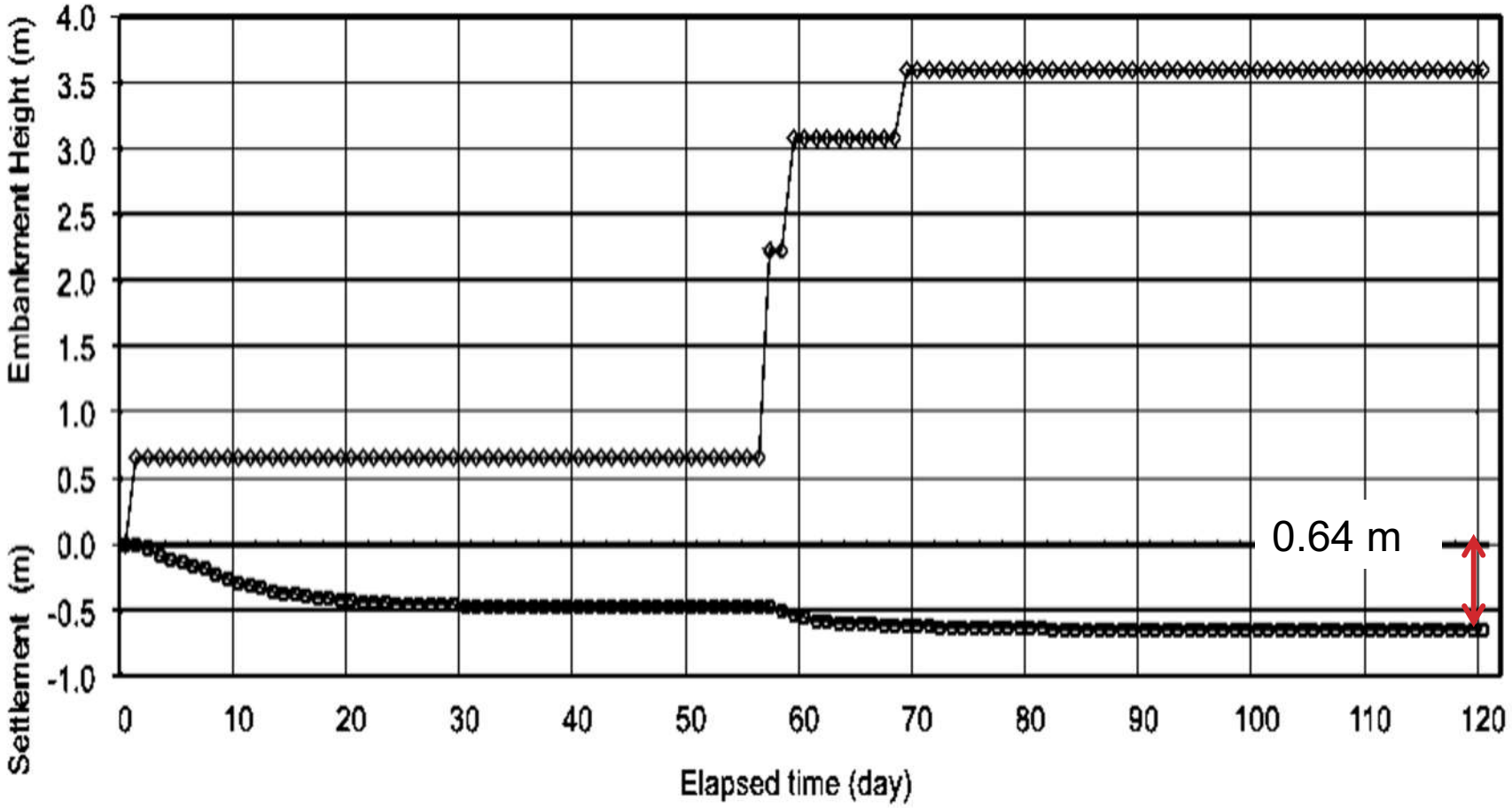
# Installation of Aggregate Column

# Installation of Raft

# Trial Embankment Observation (Bamboo Raft)

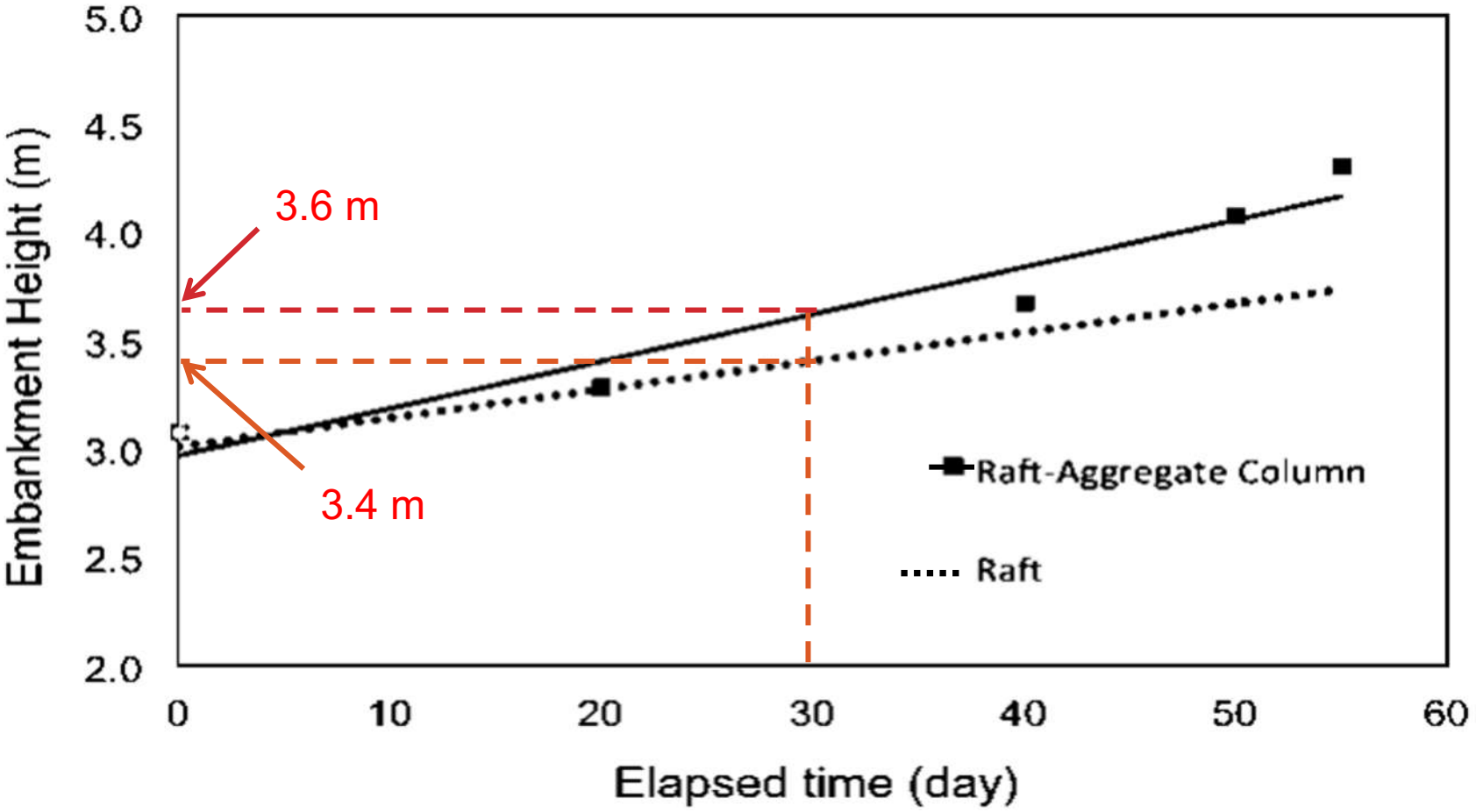


# Trial Embankment Observation (Raft-Aggregate Column)



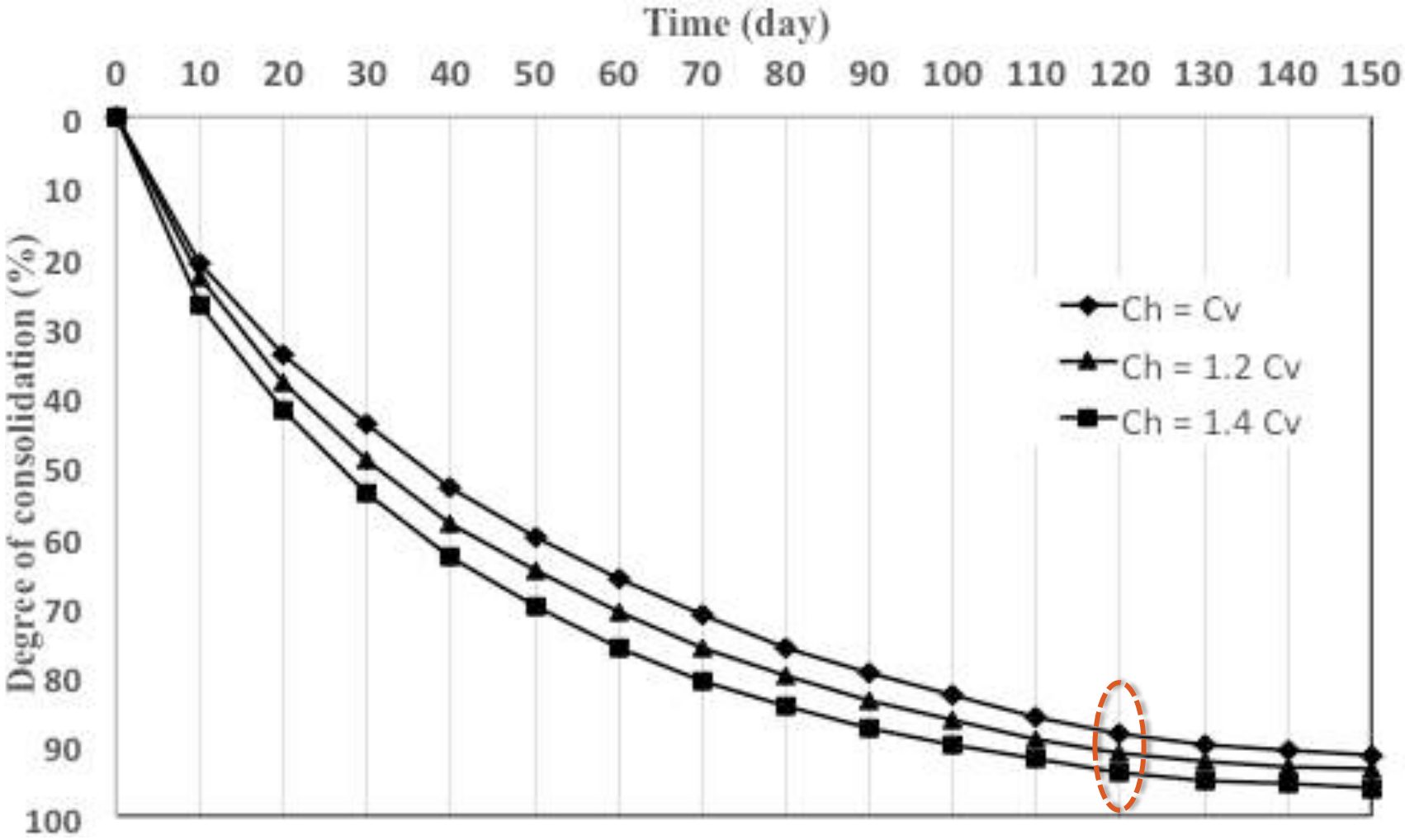

Reduction of settlement of inclined pile type was found around 25% (120 days) compare to bamboo raft reinforcement.

# Comparison of Embankment Height




In the same period of time (day), the Raft-Aggregate Column could received higher load than Raft reinforcement itself.

# Predicted degree of consolidation of raft-aggregate column



# COMPARISON OF CONSOLIDATION SETTLEMENT

| Reinforcement Method | Settlement | | |
|---|---|---|---|
| | Field Observation (m) | Asaoka (m) | Calculated 1-D/3-D (m) |
| Raft | 0.80 | 0.73 | 0.85 |
| Raft-Aggregate Column | 0.64 | 0.68 | 0.61 |

According to the analytical method, the amount of settlement found lower than the result from field observation. Empirical method showed a higher amount of settlement than field observation.

# *Conclusions*

The performance of raft-aggregate column compared to raft itself showed a reduction of settlement by about 25% in 120 days observation.

Verification of the amount of settlement by conducting empirical method and analytical calculation for each type of reinforcement indicated insignificant difference to the full-scale test results.

The rate of settlement of raft-aggregate column foundation is much higher than the raft foundation due to the aggregate column behaved as a vertical path to allow the excess pore water pressure dissipating.

# Thank you very much for your kind attention

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