Lecture 2 : PROBLEMATIC SOILS

PROBLEMATIC SOILS IN INDONESIA AND LESSONS LEARNED FROM GEOTECHNICAL FAILURES

PRE CONFERENCE WORKSHOP

SOIL IMPROVEMENT FOR MEGA INFRASTRUCTURE

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Bandung – INDONESIA

OUTLINE OF PRESENTATION

- **GENERAL UNDERSTANDING ON SOFT SOILS AND PROBLEMS IN CONSTRUCTION**
- **ORIGINS OF SOFT SOILS**
- **CASE HISTORIES**
- **LESSONS LEARNED AND SUMMARY**

GENERAL UNDERSTANDING ON SOFT SOILS

- Recent Sediments and Organics or Peats
- Soils that become soft when exposed to water
  - Soils originated from Volcanic Ashes
  - Dispersive soils
  - Clayshales and Expansive Soils upon wetting
  - Uncompacted fill soften due to water infiltration

ENGINEERING PROBLEMS OF CONSTRUCTION ON SOFT SOILS

- Problems with low bearing capacity
- Problems with stability in excavation
- Problems with stability of embankment
- Problems with long term settlement
- Problems with constructability
- Problems with Negative Skin Friction
- Problems with Adjacent Structures
- etc

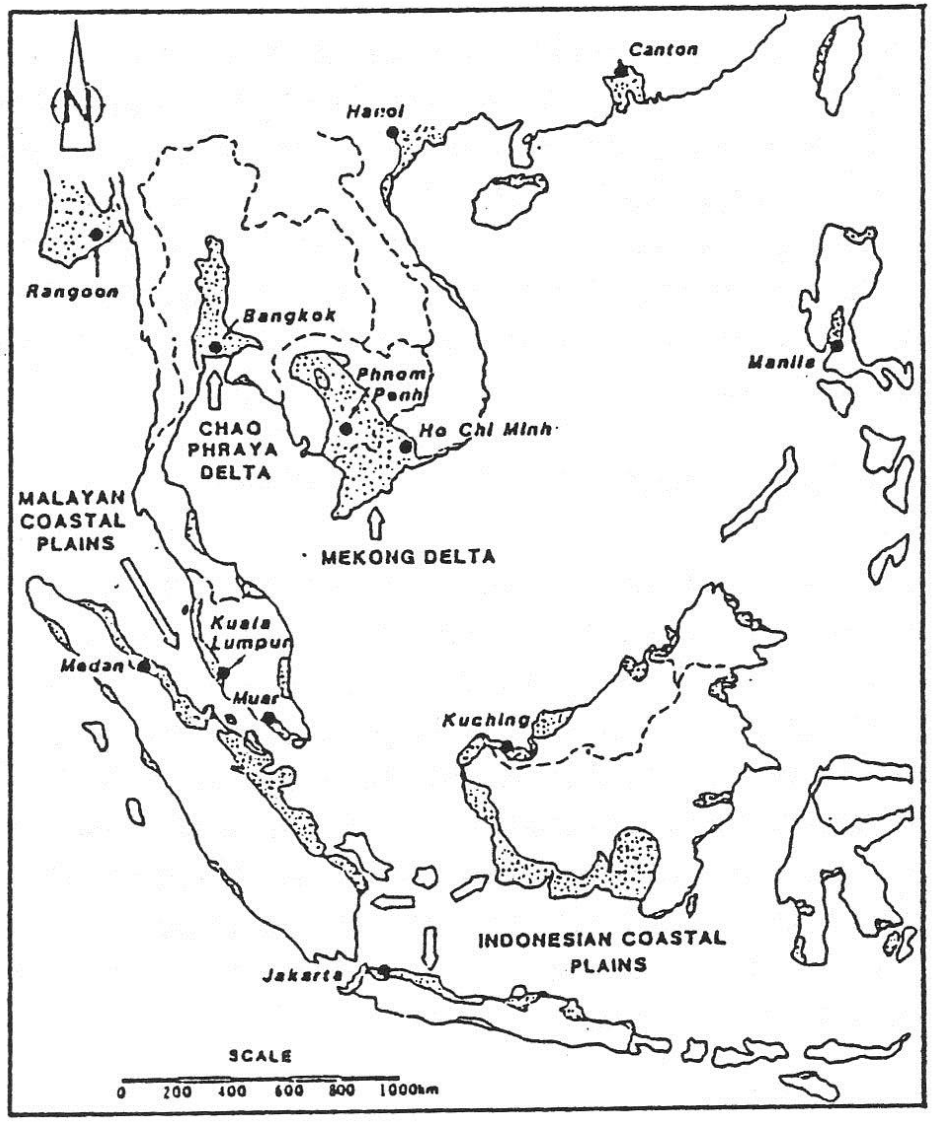
RELATED-ENGINEERING PROBLEMS OF CONSTRUCTION ON SOFT SOILS

- Problems with lack of understanding
- Problems with lack of experience
- Problems with lack of (geotechnical) data (reluctant to conduct soil investigation)
- Problems with ignorance
- Problems with cost limitation
- Problems with in-sufficient time of investigation
- Etc etc …….

ORIGINS OF SOFT SOILS

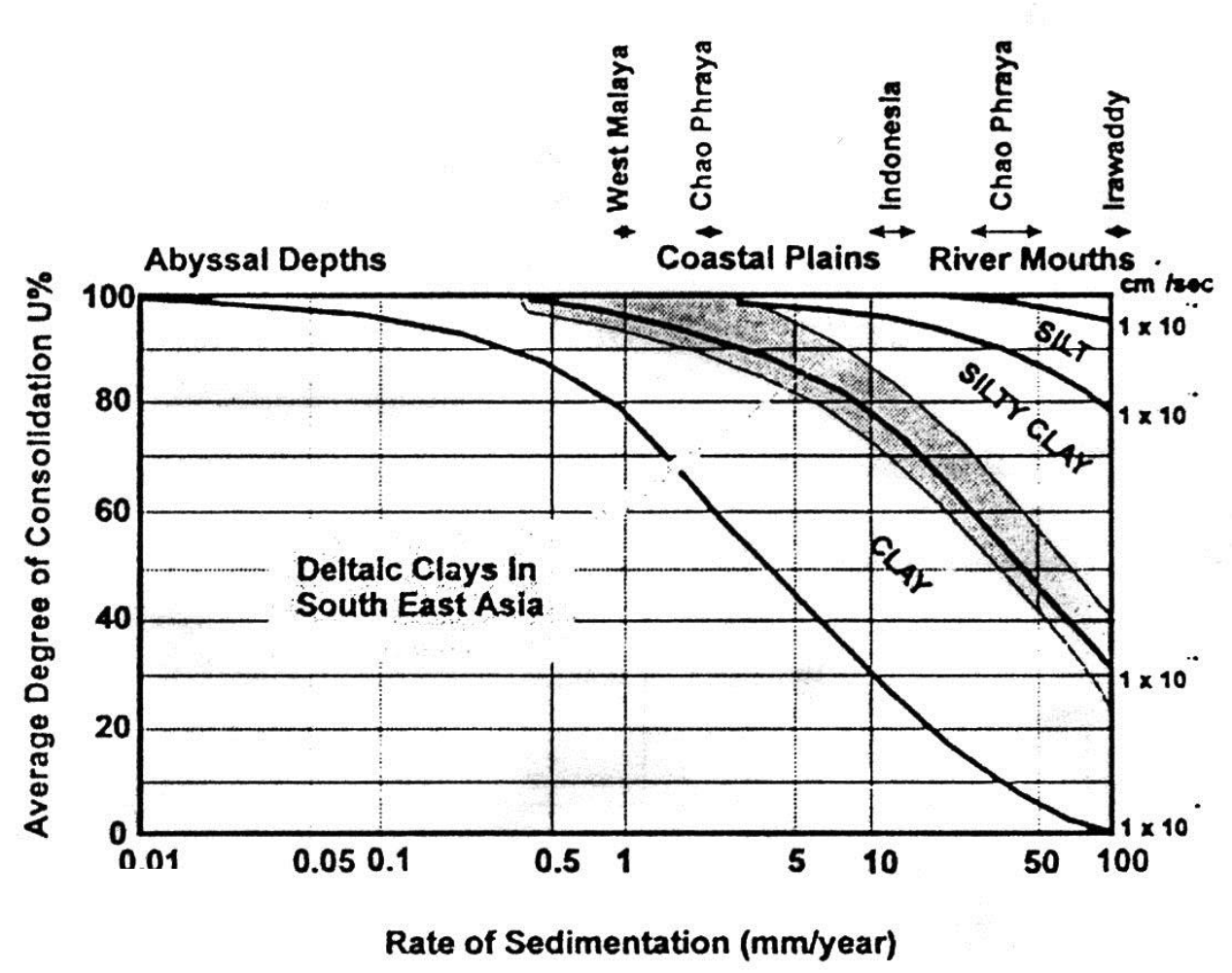
- RECENT SEDIMENTS
- LAKE DEPOSITS
- MUD ERUPTIONS

RECENT SEDIMENTS

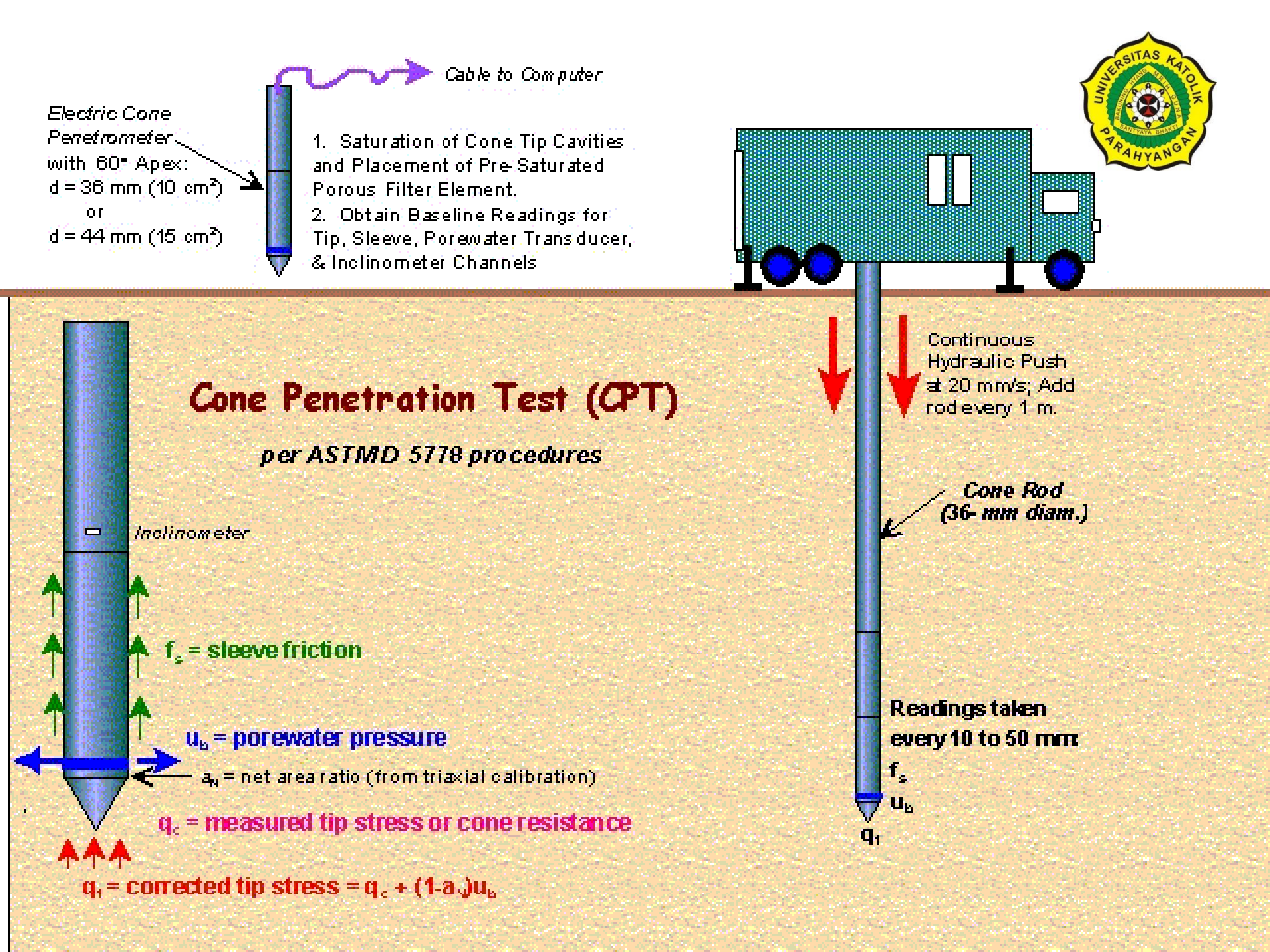


- Soft soils are distributed mainly in coastal areas where big cities are being developed
- Construction on soft soils has risks of failures
- Most of failures are contributed by those who are not aware of the risk or lack of knowledge on soft soils
- Technology has been well developed to work out soft soils

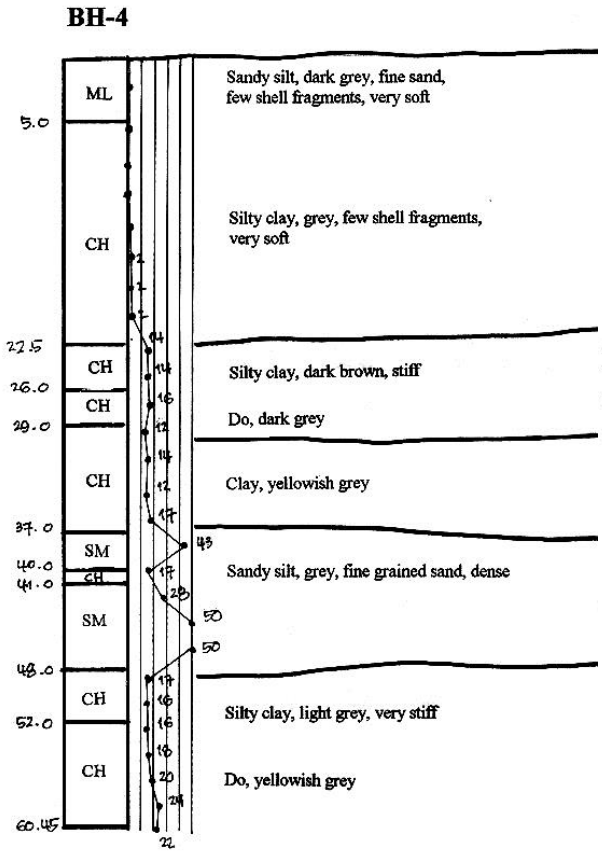
Soft soils in South East Asia: young and consolidating

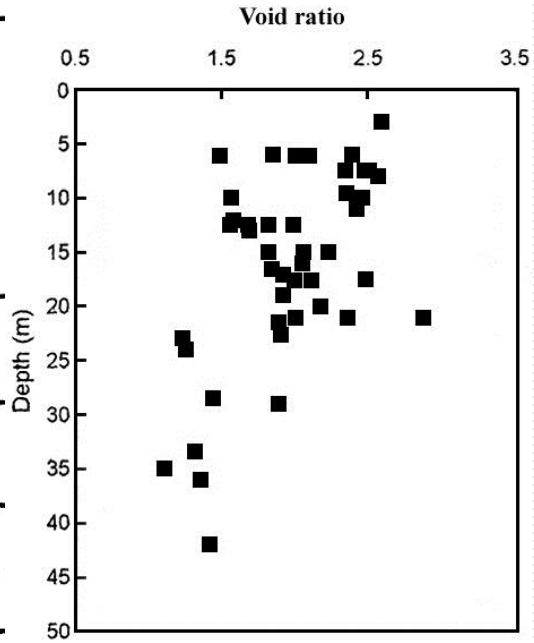


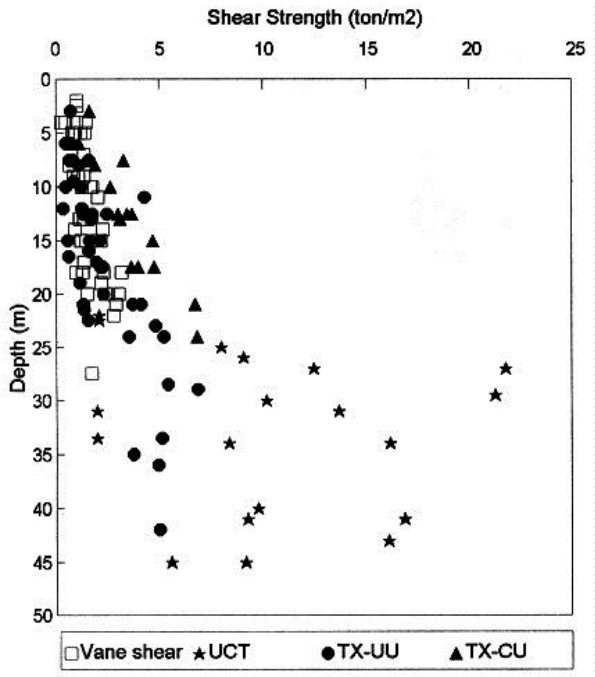
Cox 1970


Cable to Computer
Electric Cone Penetrometer with 60° Apex:
d = 36 mm (10 cm²)
or
d = 44 mm (15 cm²)
1. Saturation of Cone Tip Cavities and Placement of Pre-Saturated Porous Filter Element.
2. Obtain Baseline Readings for Tip, Sleeve, Porewater Transducer, & Inclinometer Channels
Continuous Hydraulic Push at 20 mm/s; Add rod every 1 m.
Cone Penetration Test (CPT)
per ASTMD 5778 procedures
Cone Rod (36- mm diam.)
Inclinometer
f_s = sleeve friction
u_b = porewater pressure
a_N = net area ratio (from triaxial calibration)
q_c = measured tip stress or cone resistance
q_t = corrected tip stress = $q_c + (1-a_N)u_b$
Readings taken every 10 to 50 mm
f_s
u_b
q_t

Example of Soft Soils in Indonesia North Semarang City (Central Java)





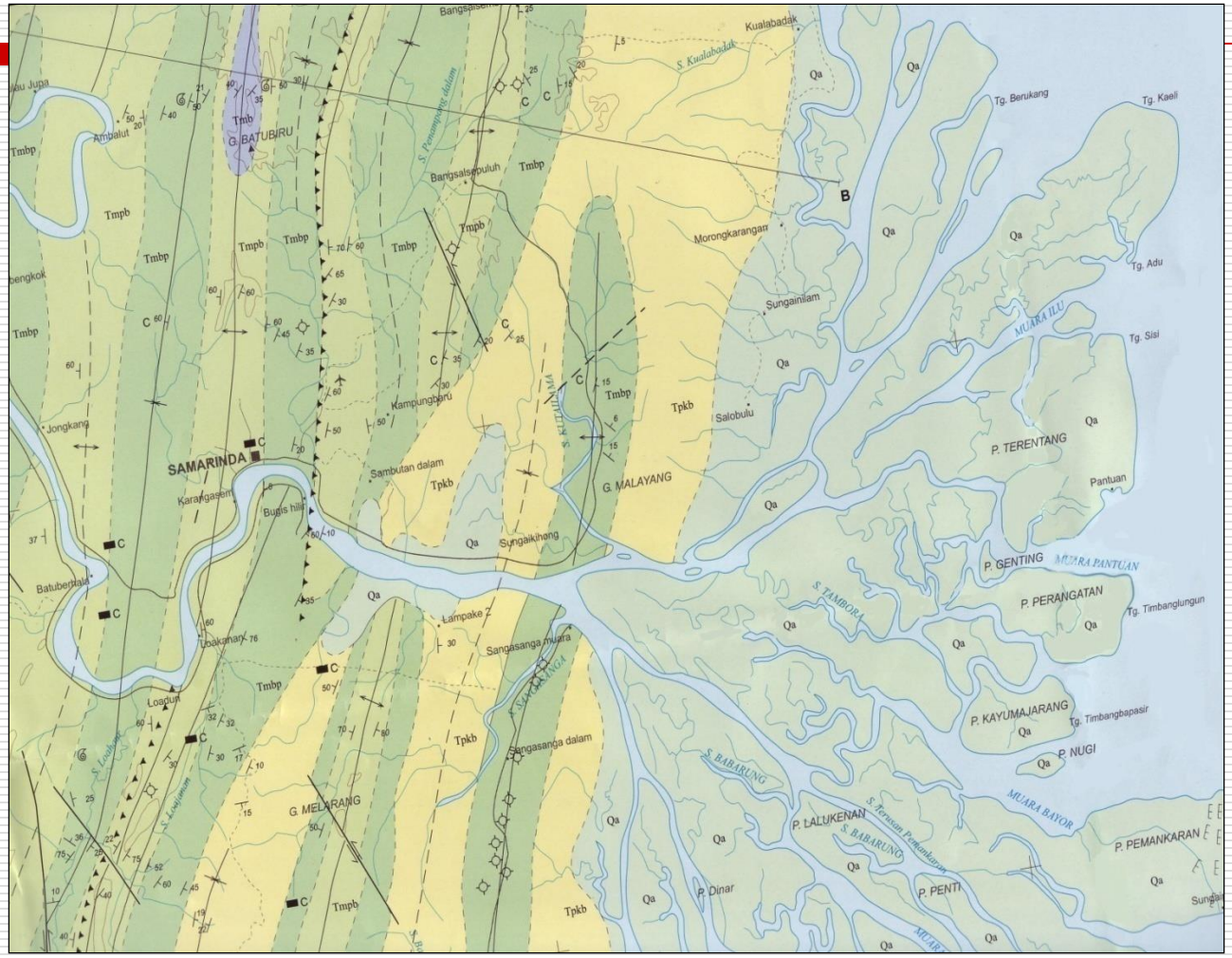


High void ratio
High water content

Low Shear Strength
Highly Compressible

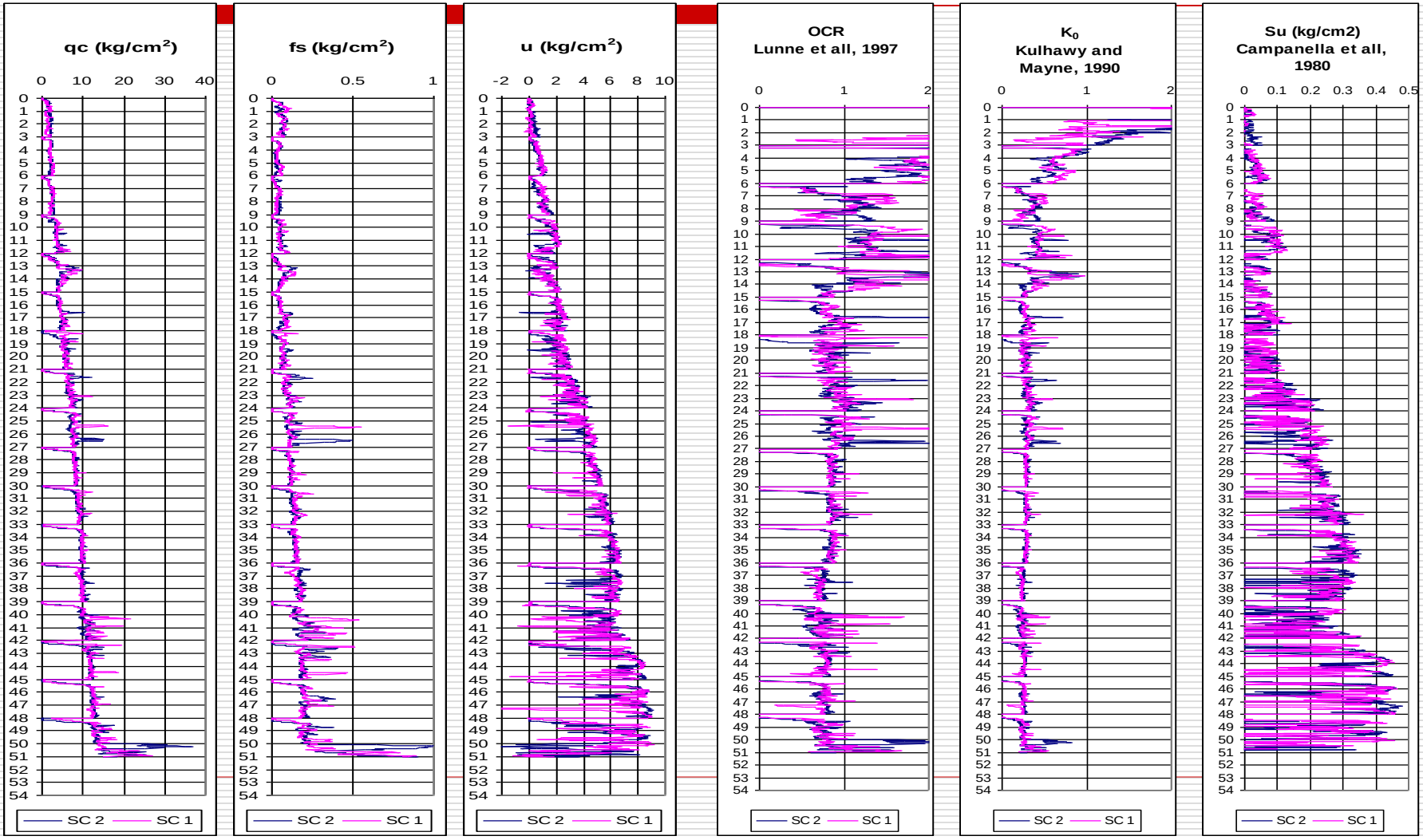
General Soft Soil Condition in Semarang

Examples of soft soils in INDONESIA
Mahakam Delta – East Kalimantan

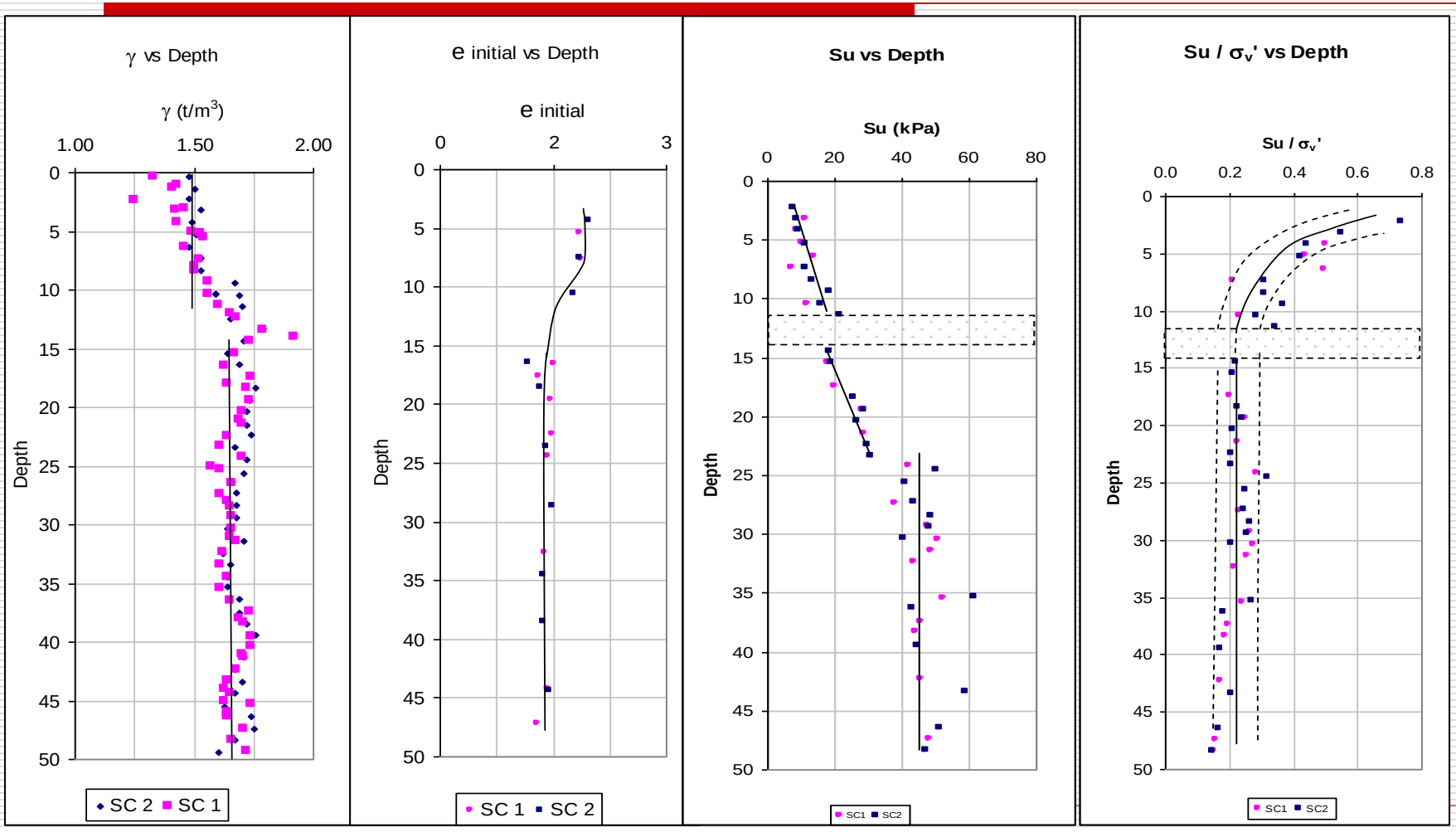


Mahakam River is the longest in Indonesia, Recent sediment of 50 – 80 m depth

Site Characterization of deep soft Mahakam deltaic soils using CPTu

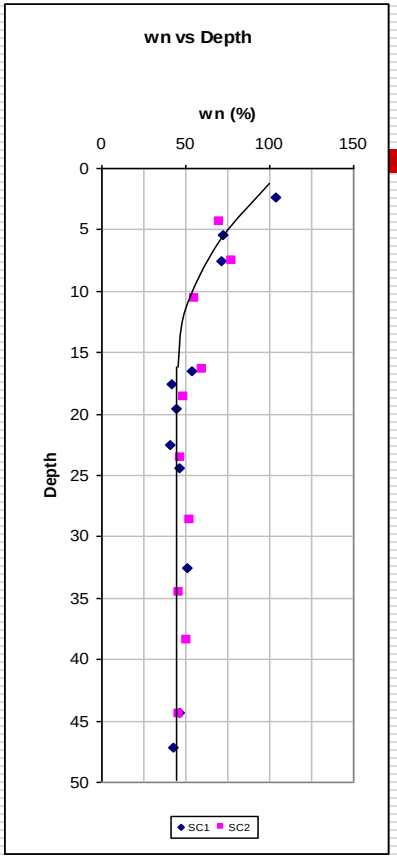


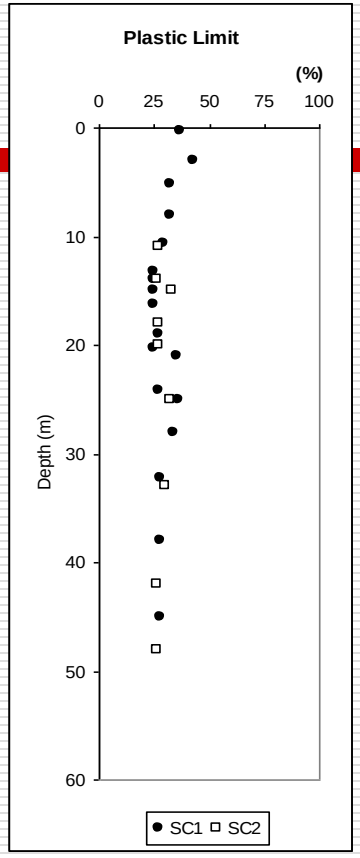
Examples of soft soils in INDONESIA
Mahakam Delta – East Kalimantan

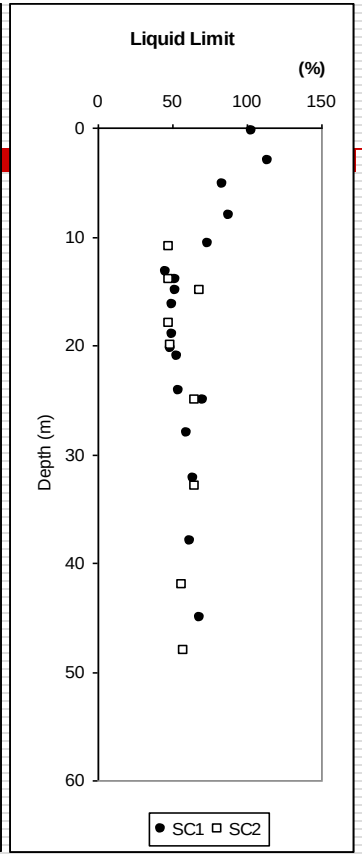


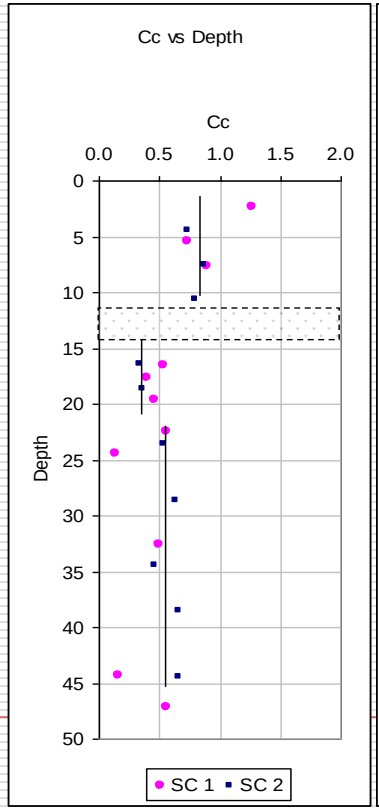
Void Ratios and Shear Strength

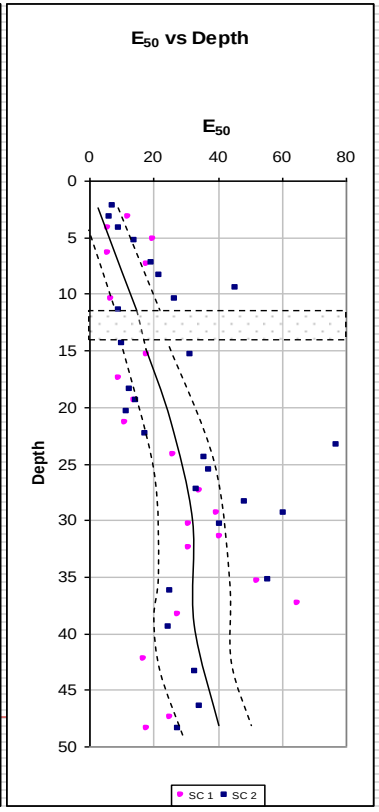
Example of Soft Soils in INDONESIA





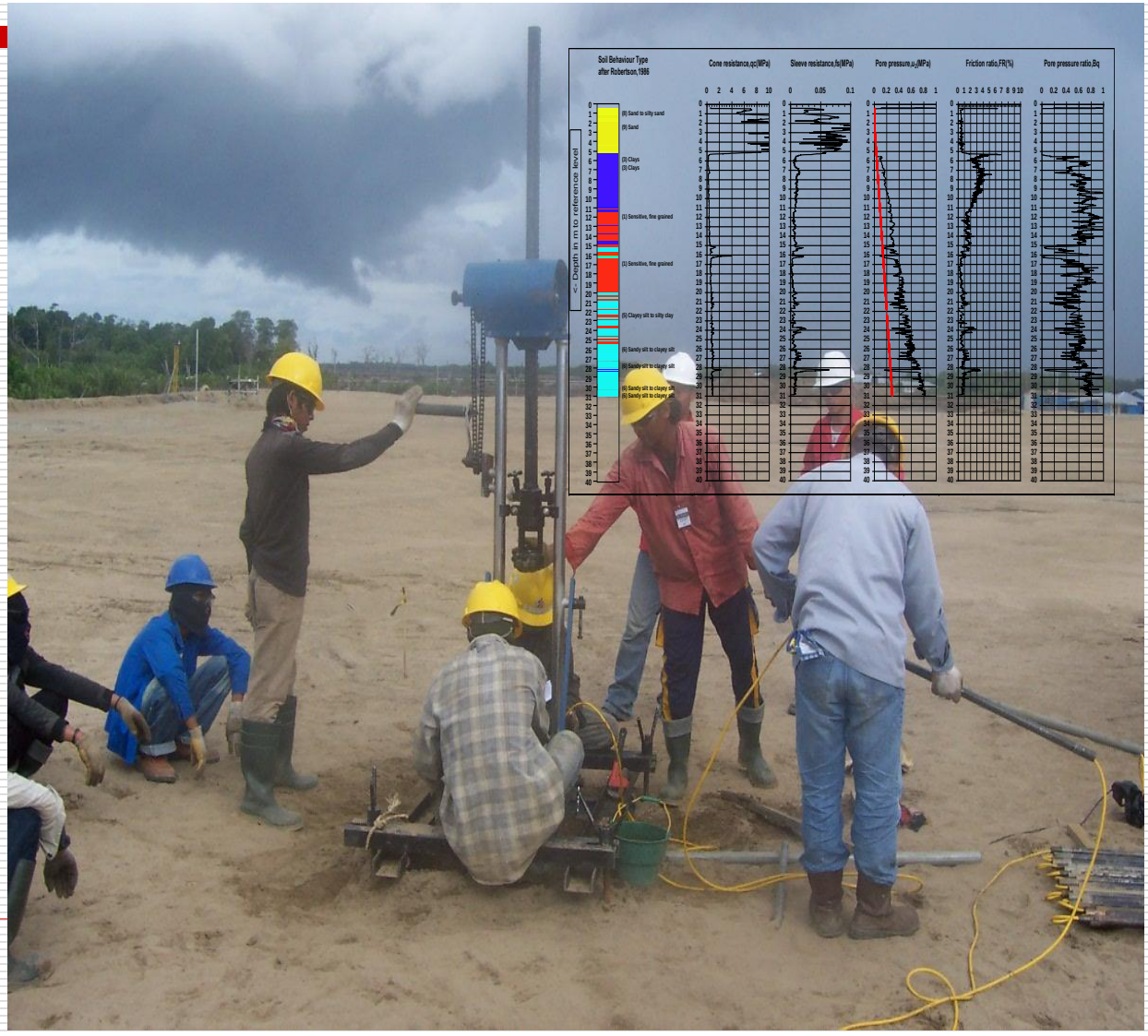




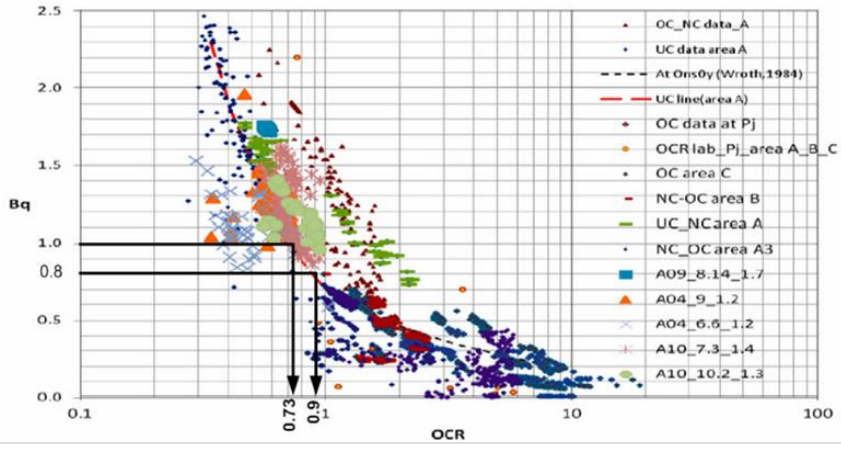


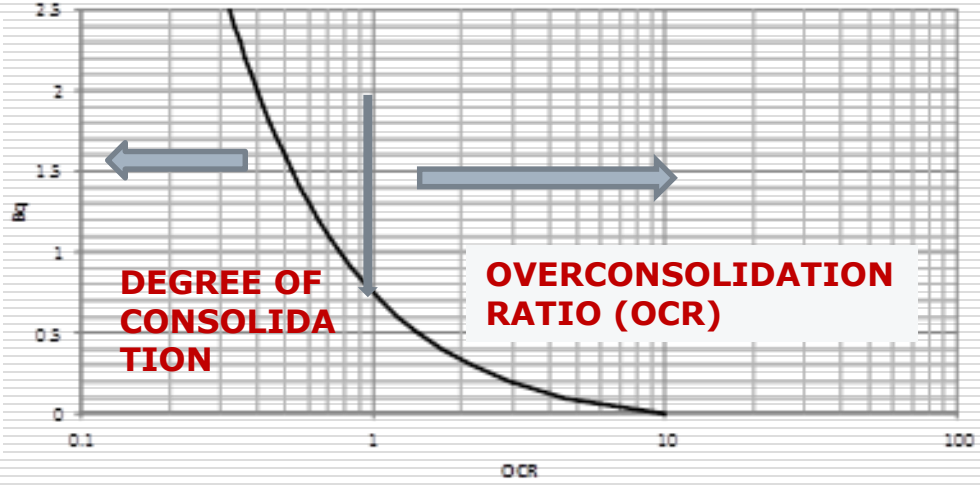
Water Content, Plasticity and Compressibility at Mahakam delta

Determination of the degree of consolidation of Reclaimed Site on deep soft Mahakam deltaic soils using CPTu



Method of Determination of the Degree of Consolidation Based on Bq from CPTu
(Setionegoro, 2013 and Rahardjo et al 2014)

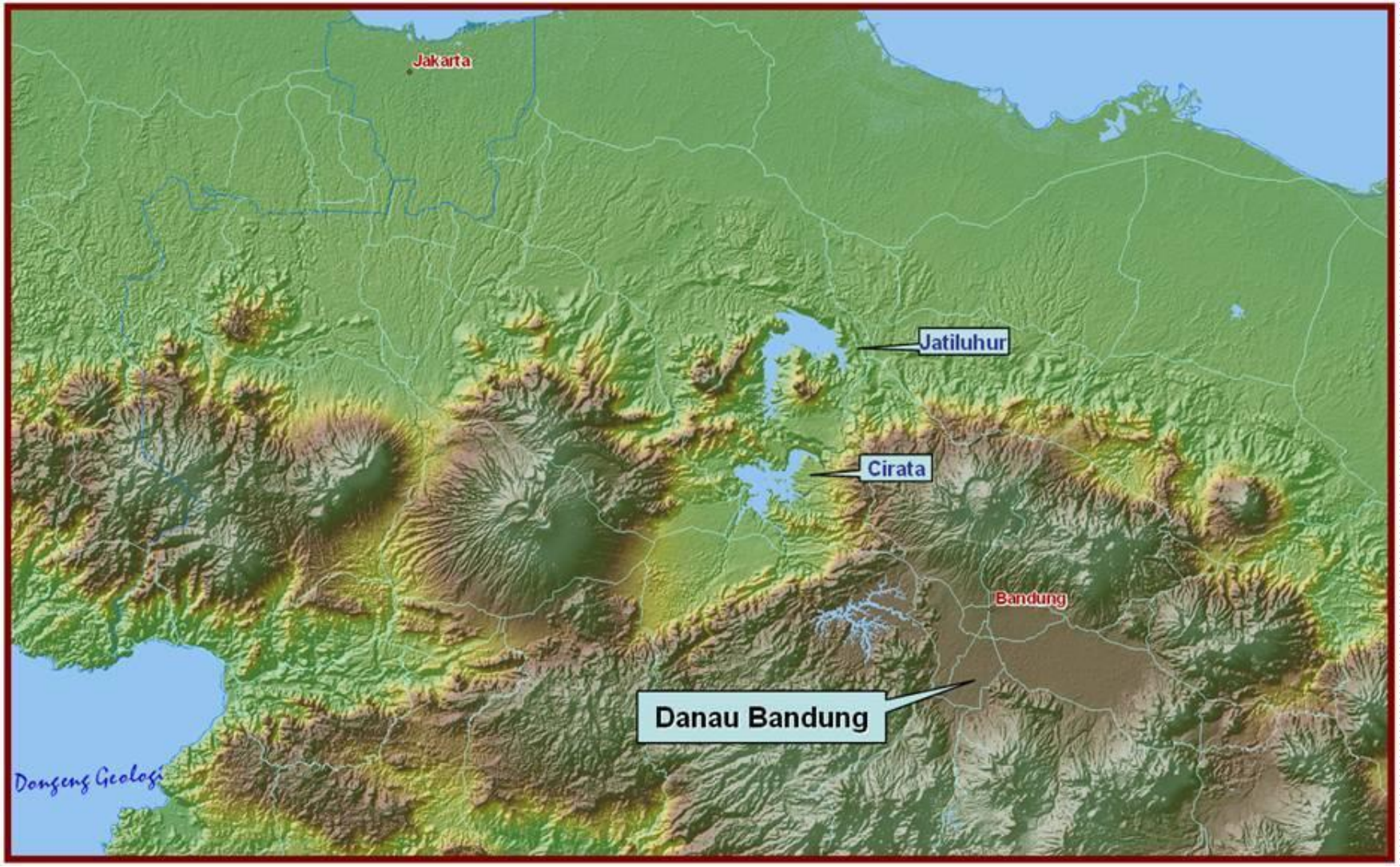




- Setionegoro 2013

Rahardjo et al 2014

Bandung Lake Deposit



South Bandung was originated from ancient lake

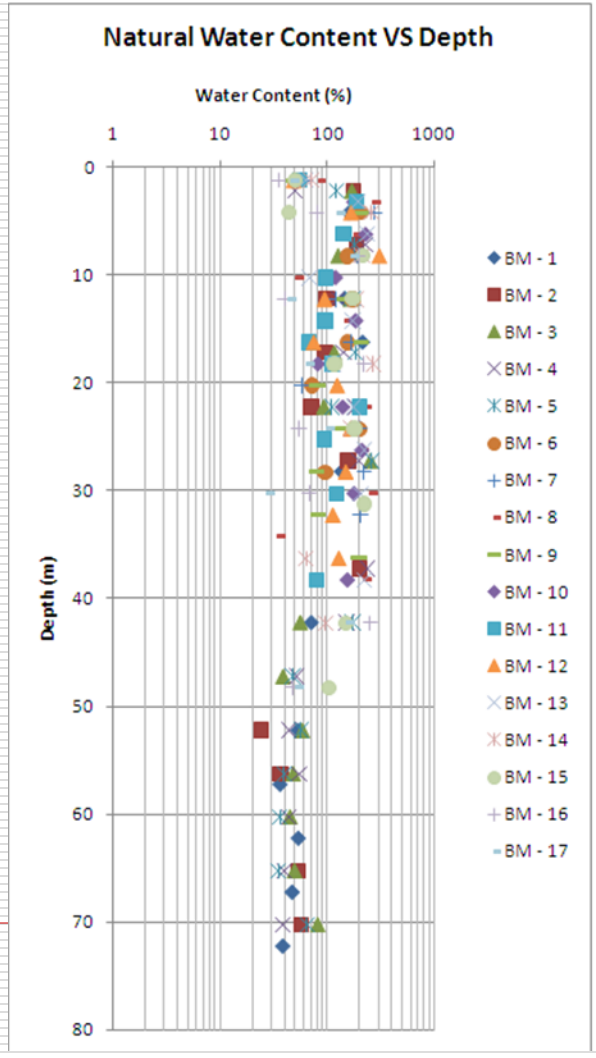
Sanghyang Tikoro

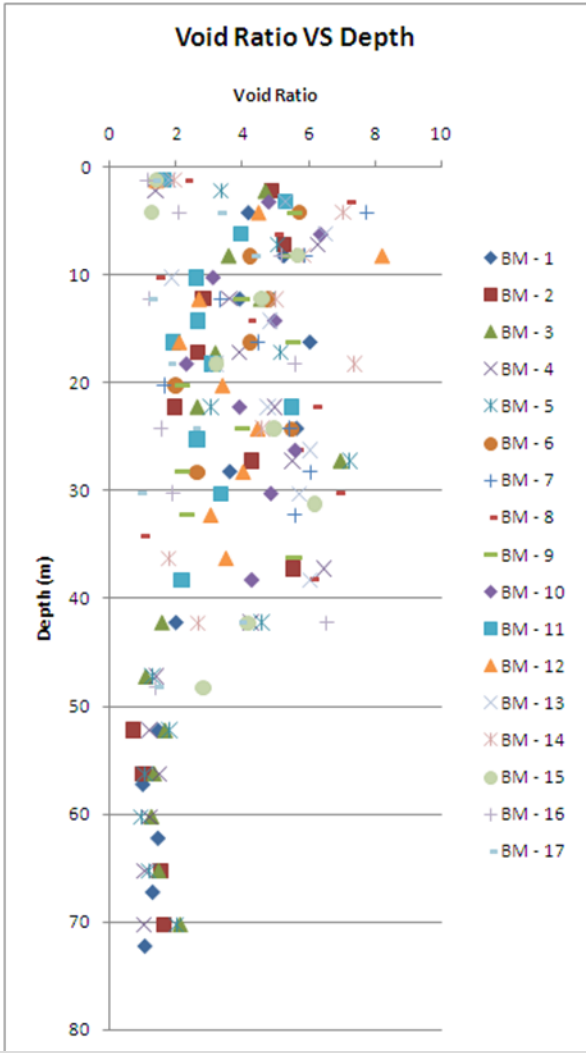
Origin of Bandung Soft Soils were two ancient Lakes

Sanghyang Tikoro

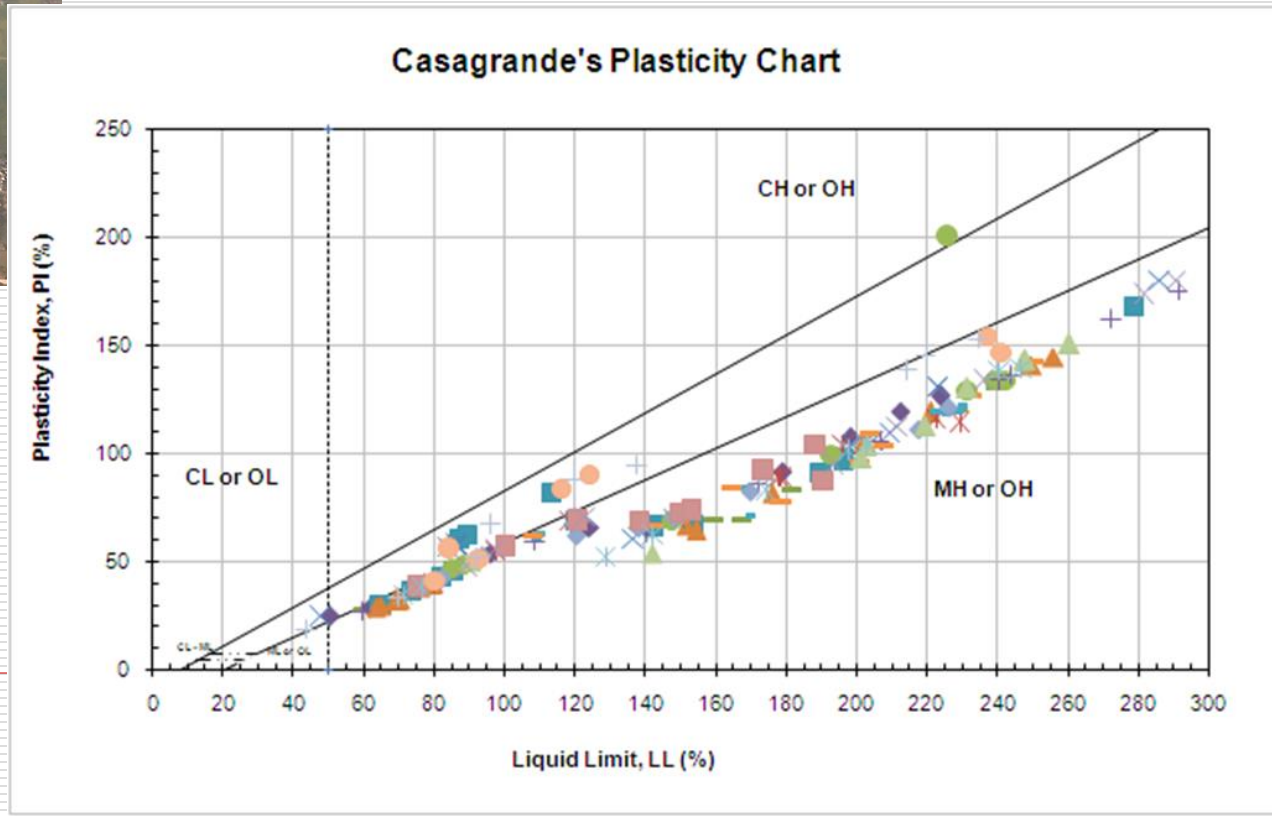
Bandung Soft Clays

Upper Layer (0-42m)
Void Ratio 1.0-8.3
Water content 50-300%



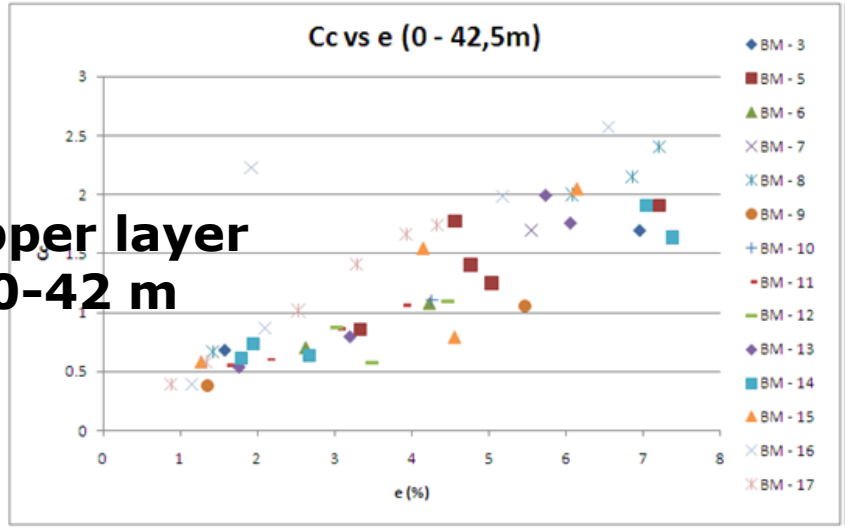


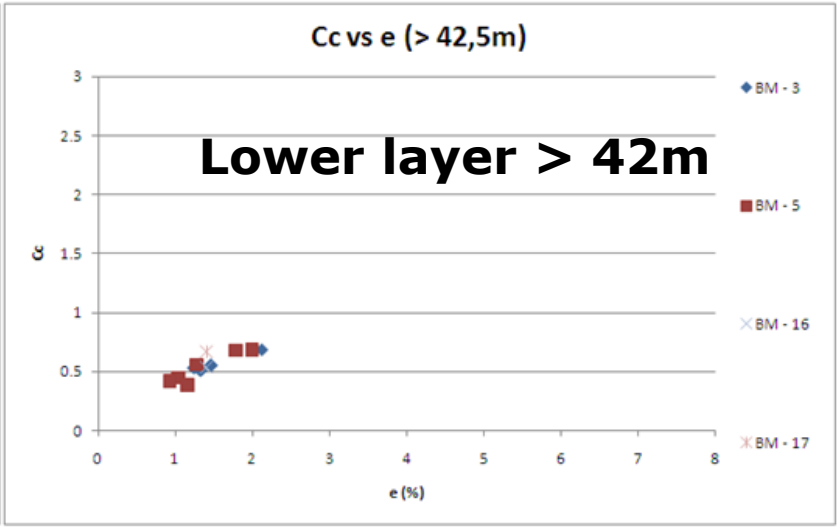
Bandung Soft Clays

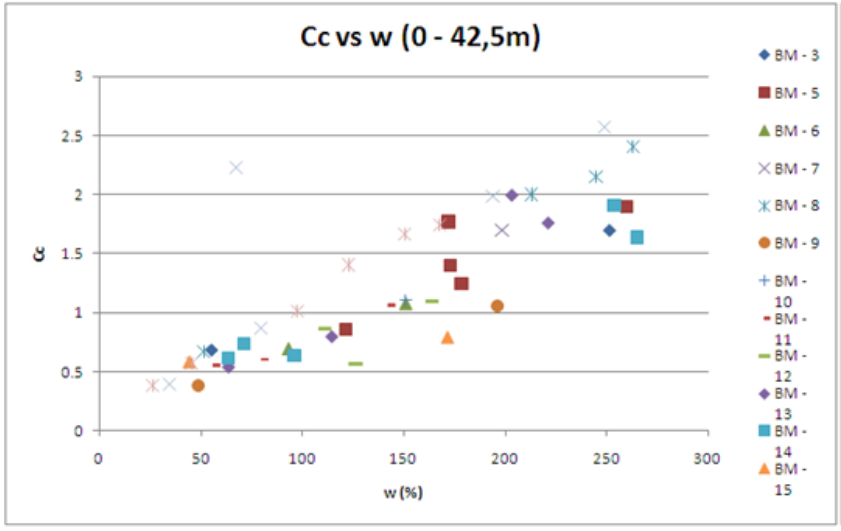


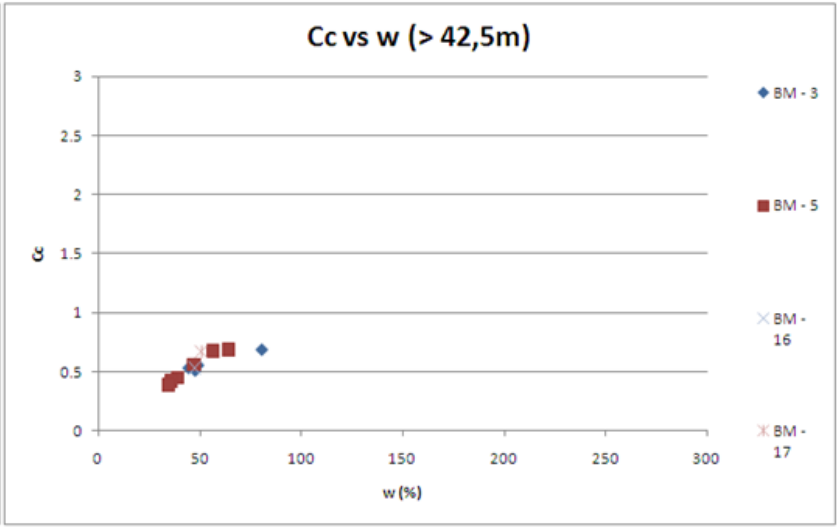
Bandung Soft Clays

Upper layer
0.0-42 m









Other origin of soft soils
Mud Eruption in East Java
(Sidoardjo Mud – since May 29, 2006)

Site Condition of the Mud

Mud Eruption in East Java (Sidoardjo Mud)

Sidoardjo Mud created geotechnical problems

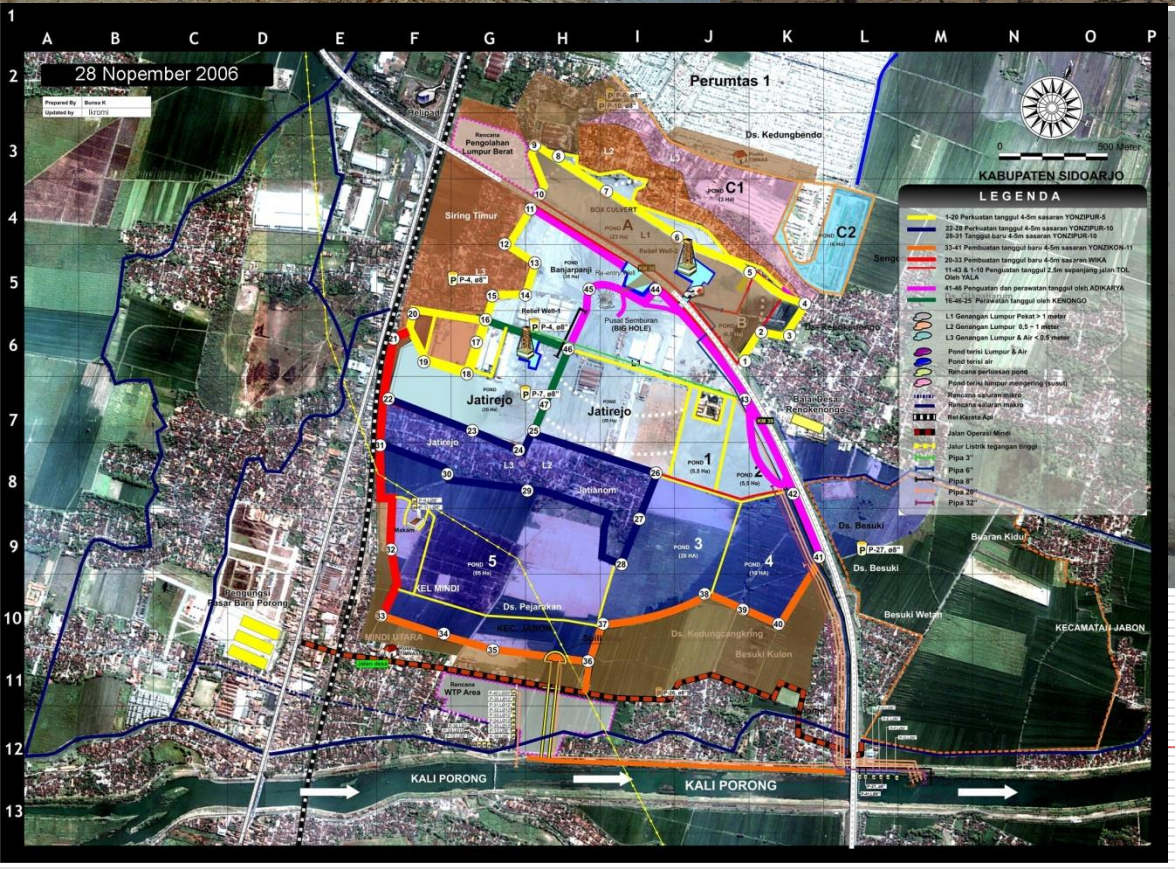
GEOTECHNICAL PROBLEMS

-Mud Removal

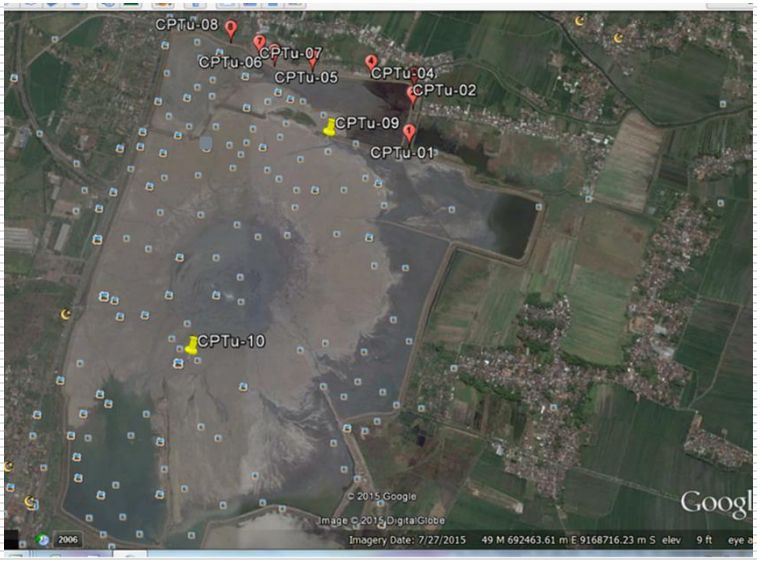
-Dyke Failures

-Settlement in Large areas

-Mud properties Difficult to handle


28 Nopember 2006
Perumtas 1
KABUPATEN SIDOARJO
LEGENDA
Ds. Kedungbendo
Siring Timur
Jatirejo
Ds. Besuki
Besuki Wetan
KEL MINDI
Ds. Pejarakan
Ds. Kedungcangkring
Besuki Kulon
KECAMATAN JABON
KALI PORONG
KALI PORONG

Investigation of Mud Eruption Disaster Area

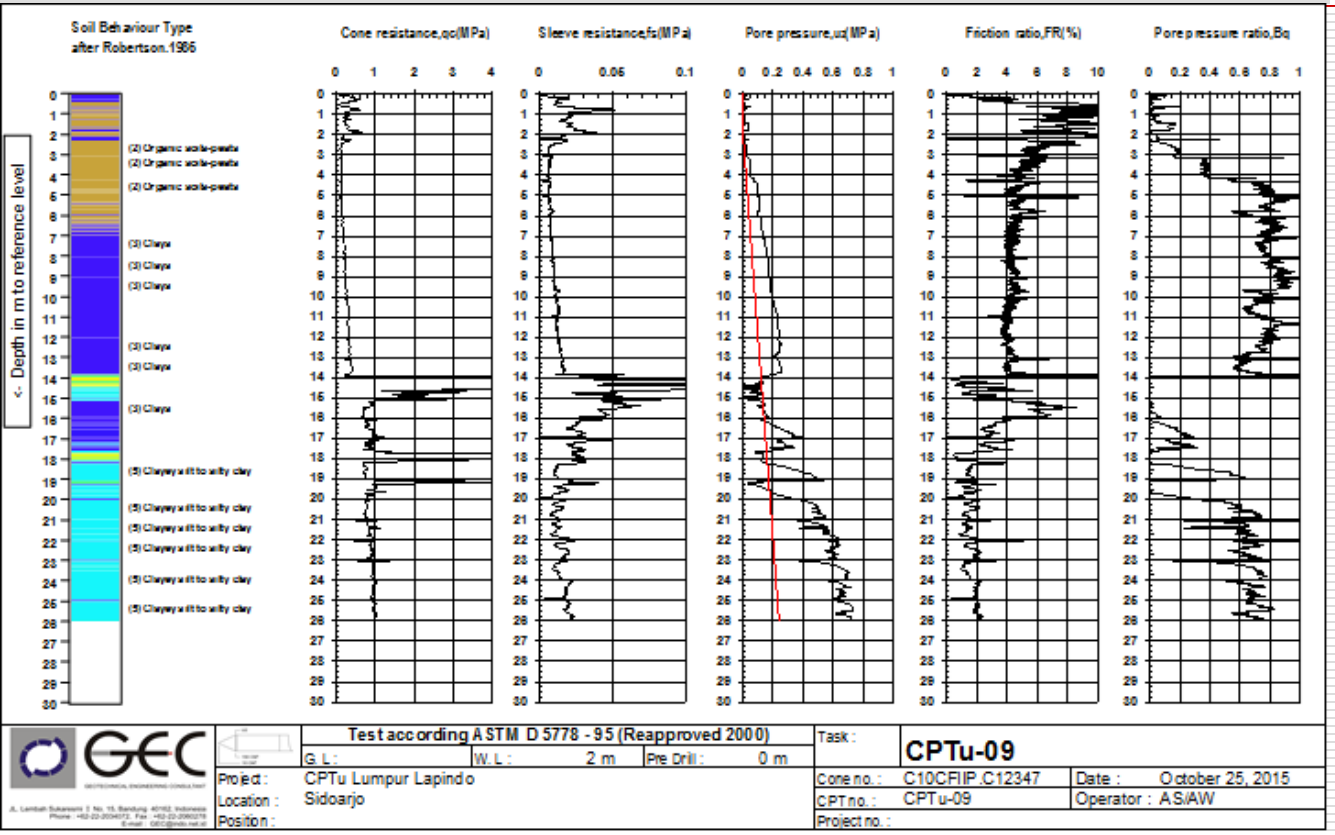


Results of CPTu at MUD ERUPTION AREA

CPTu-9 : through the mud

Ground water -2.0 m
0-2 m : mud crust
6-14 m : mud
14-15m: silty sand (lenses)
> 15m : soft clays

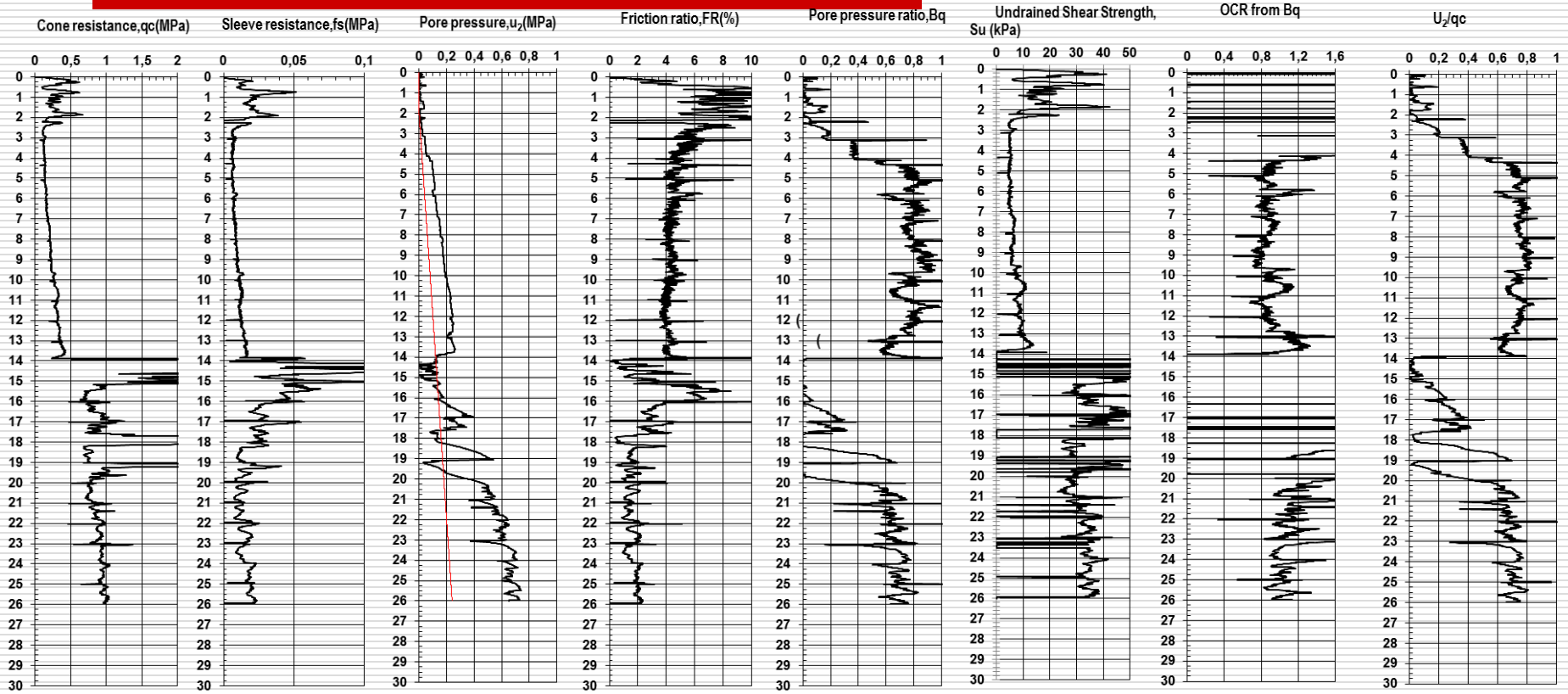
Results of CPTu at MUD ERUPTION AREA



CPTu-9 : through the mud

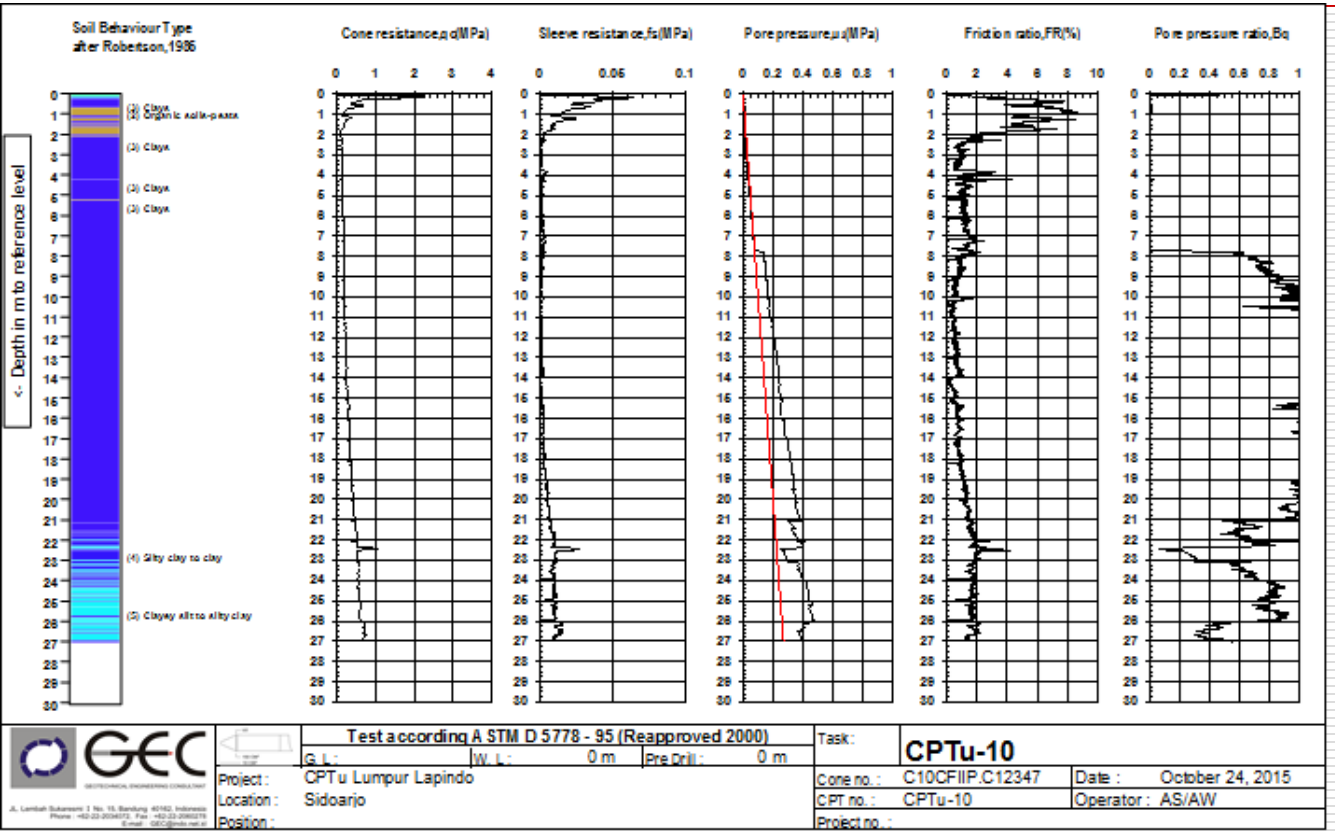
Ground water -2.0 m
0-2 m : mud crust
6-14 m : mud
14-15m: silty sand (lenses)
> 15m : soft clays

Interpretation of CPTu-09 (inside the dyke)



Mud Characterization by CPTu-10

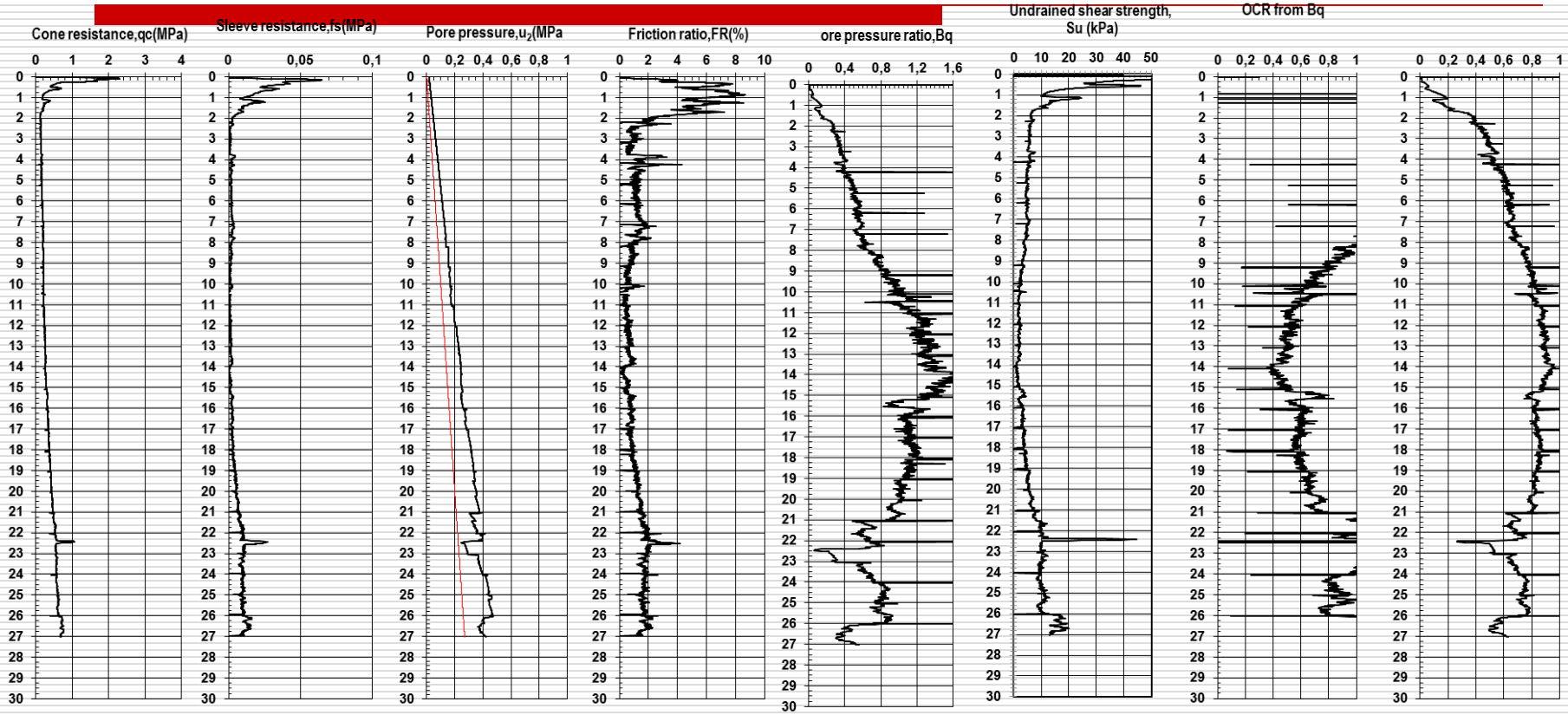
Results of CPTu at MUD ERUPTION AREA



CPTu-10 : through the mud

Ground water -0.0 m
0-2 m : mud crust
2-21 m : mud (consolidating mud) Bq = 0.8-1.2)
> 21m : soft clays

Interpretation of CPTu-10 (center of eruption)



CASE HISTORIES

- **RECENT SEDIMENTS AND ORGANICS OR PEATS**
- SOILS THAT BECOMES SOFT UPON EXPOSURE TO WATER
- SOILS THAT LIQUEFIES DURING EARTHQUAKES

1. Failures of embankment and fill placement on soft soils

- Large long term consolidation settlement
- Placement of embankment fill
- Failures of sheetpiles retaining structures

1.1. Problems of Soft Soil : Large and long term settlement

Marunda, north Jakarta

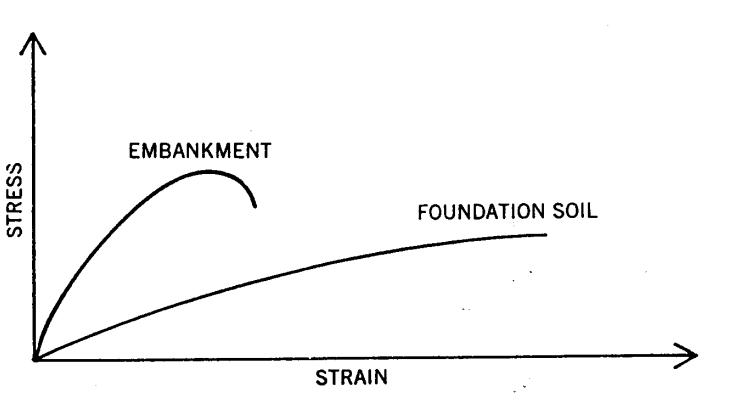
Settlement of buildings on shallow Foundation Constructed on fill on top of Soft soils

East Java

-Very common situation
- fill thickness in the range of 1-5 meters
- no engineering or design
- mostly without soil investigation or lack of geotechnical data

1.2.PROBLEM OF SOFT SOIL IN INDONESIA
Failures of Embankment Constructed on Soft Soils

Location : Senoni, Samarinda

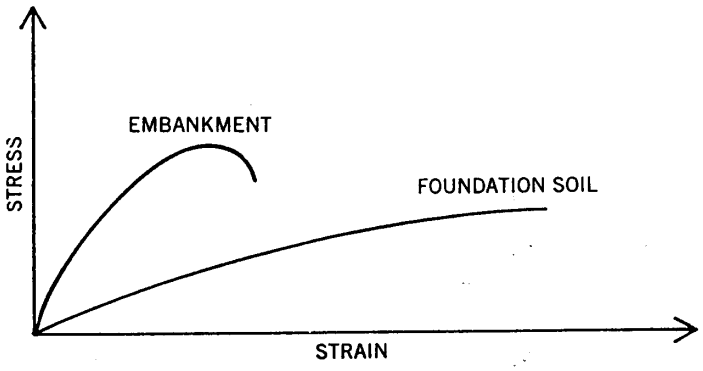


Fill Material : Well Compacted Sandy Material

Failures was deep slide type , very high pore pressures and incompatibility in stiffness of foundation soils and fill

1.2.PROBLEM OF SOFT SOIL IN INDONESIA
Failures of Embankment Constructed on Soft Soils

Location : East Java



Fill Material : Well Compacted Sandy Material

Failures was deep slide type , very high pore pressures and incompatibility in stiffness of foundation soils and fill

PROBLEM SOFT SOIL IN INDONESIA :

1.3. Failures of sheet piles due to excess pore water pressures resulted from fill

PROBLEM SOFT SOIL IN INDONESIA :

1.4. Failures of bridge abutment due to excess pore water pressures resulted from fill

PROBLEM SOFT SOIL IN INDONESIA :

1.5. Failures of soft soils due to sudden drawdon causing collapse of sheetpile

PROBLEM SOFT SOIL IN INDONESIA :

1.5. Failures of soft soils due to sudden drawdon causing collapse of sheetpile

Condition During Flood

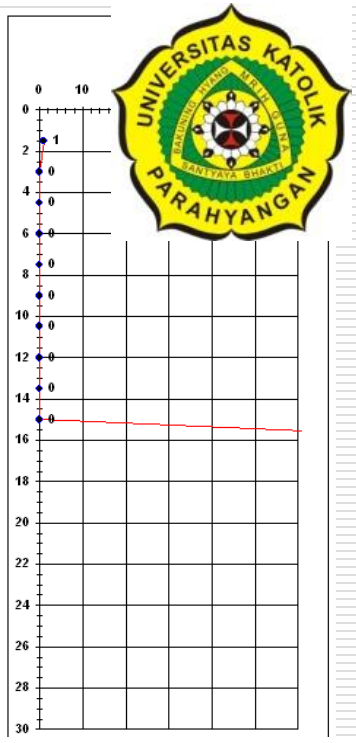
Sudden Drawdown Condition

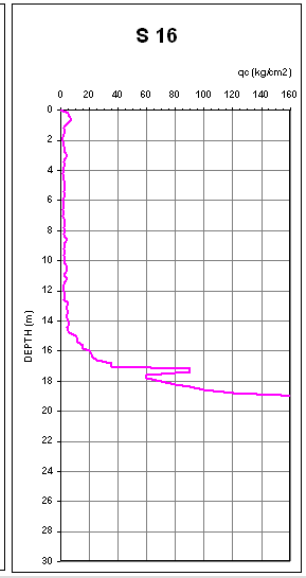
PROBLEM SOFT SOIL IN INDONESIA :

1.5. Failures of soft soils due to sudden drawdon causing collapse of sheetpile

Measurement of flood level

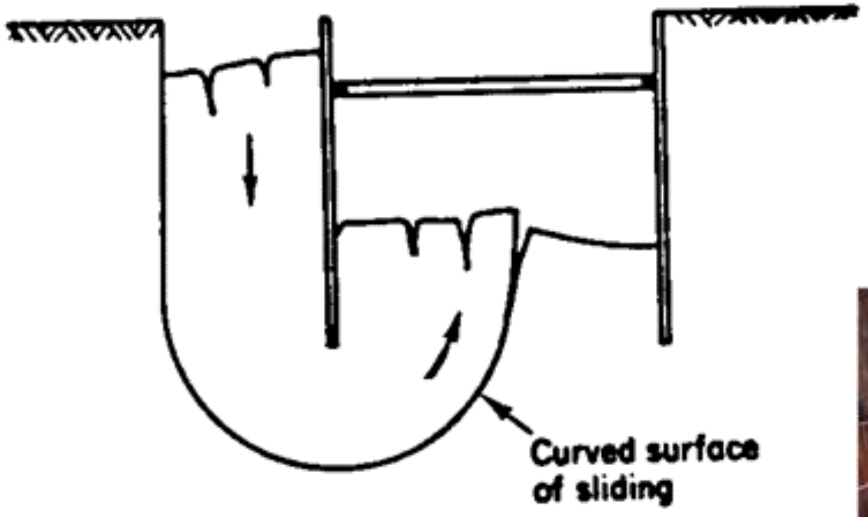
1.5.Problems of Soft Soil in Indonesia: FAILURES OF SHEET PILES WITHOUT EMBEDMENT INTO FIRM LAYER FAIL BY SUDDEN DRAWDOWN





PROBLEM SOFT SOIL IN INDONESIA :

1.6. Failures of excavation in consolidating soils → initial pore pressure not considered

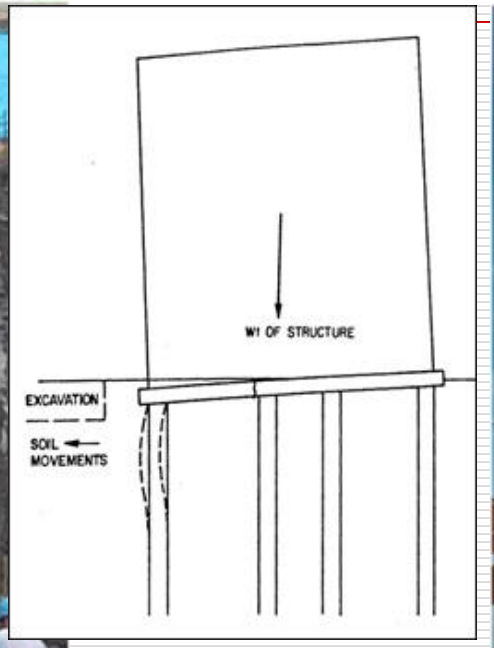


Condition During Flood

Failures of excavation in Underconsolidating soils

PROBLEM SOFT SOIL IN INDONESIA :

1.6. Failures of excavation in consolidating soils → initial pore pressure not considered



Excavation cause sliding and Tilting (and breaking) of Piles

Failures of building foundation Due to excavation in Underconsolidating soils

PROBLEM SOFT SOIL IN INDONESIA :

1.6. Proper Method for Excavation in Soft Soils

Excavation in Jakarta Marine Clay

Protection Using Diaphram Wall And struts in underconsilidating soil

PROBLEM SOFT SOIL IN INDONESIA :

1.6. Proper Method for Excavation in Soft Soils

Excavation in Jakarta Soft Marine Clay

Protection Using Top Down Method

SOFT SOILS

- RECENT SEDIMENTS AND ORGANICS OR PEATS
- **SOILS THAT BECOMES SOFT UPON EXPOSURE TO WATER**
- SOILS THAT LIQUEFIES DURING EARTHQUAKES

2. Soils sensitive to water or soils that become soft due to exposure to water

2.1. Soils originated from volcanic ashes
2.2. Expansive soils
2.3. Clayshales
2.4. Uncompacted materials

2.1 ENGINEERING PROBLEMS OF CONSTRUCTION ON SOILS ORIGINATED FROM VOLCANICS ASH

- Problems with water sensitivity
- Problems with high plasticity and difficulty in compaction work

Volcanic Ashes

- strong mineralogical influence (allophane)
- some micro but no macro-structural influence

L.D. Wesley (2001)

Tuff at Sepinggan (Balikpapan)

Clay with Allophane content Geothermal Project, West Java

Problems with cut slopes

Problems of Embankment using Volcanic Ash material

Road after construction

Road Condition after rains

Timika - Papua

Problems in Embankment using Volcanic Ash material

Timika - Papua

Road Condition after rains

Problems of Embankment using Volcanic Ash material

Timika - Papua

Road Condition after rains

Problems of retaining structures using tuff material for backfill

Samarinda – East Kalimantan

Road Condition after failures by rains

Problems of retaining structures using tuff material forbackfill

Samarinda – East Kalimantan

Road Condition after failures by rains

Summary on tuff and volcanic soils

- Material originated from volcanic ash are generally sensitive to the presence of water
- Problems arised in stability of cuts and fill, also on the performance of embankment
- Some methods of stabilization needed when those material should be used

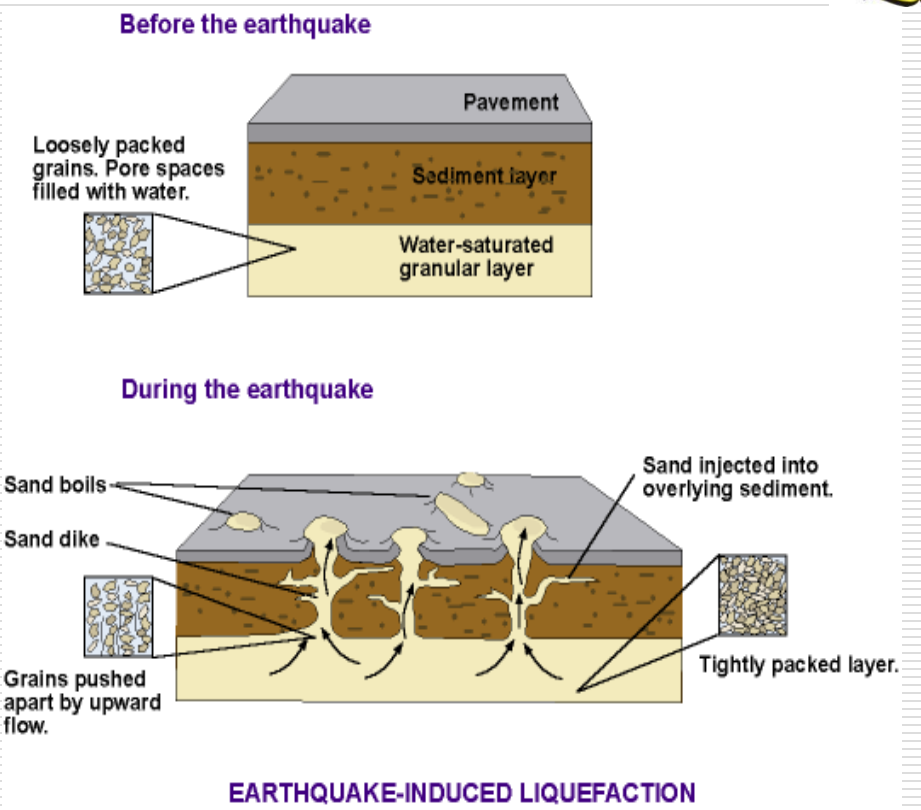
Soil that becomes Soft LIQUIFACTION

- **LIQUIFACTION** : is phenomena where soils lost their strength and flow at constant volume, constant shear stress and constant effective stress due to increase in excess pore water pressure during earthquake.
- **Liquefaction Phenomena** may be sand blows, flow liquifaction/Liquifaksi or lateral spreading dan landslides) or cyclic mobility

Damages

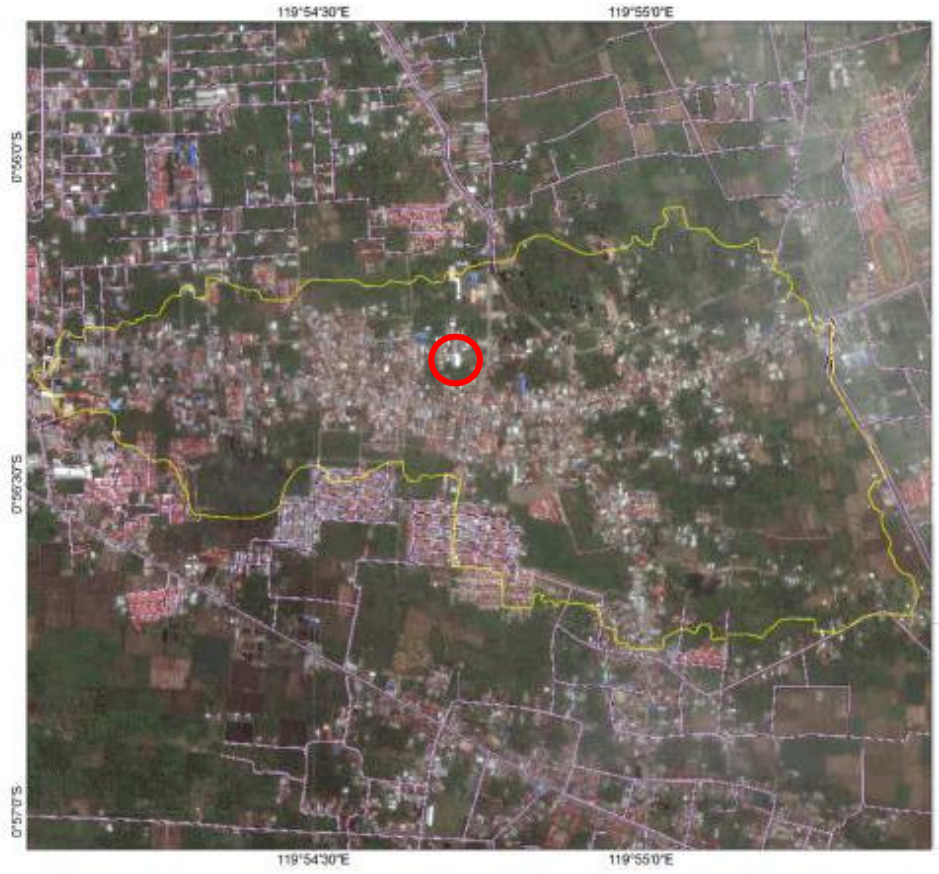
- Failures of Shallow Foundation
- Failures of deep foundation due to degradation of strength and lateral spreading
- Foundation displacement
- Failures of retaining structures
- Large scale Settlement and heave
- Lateral spreading
- Landslides and **flow liquifaction**

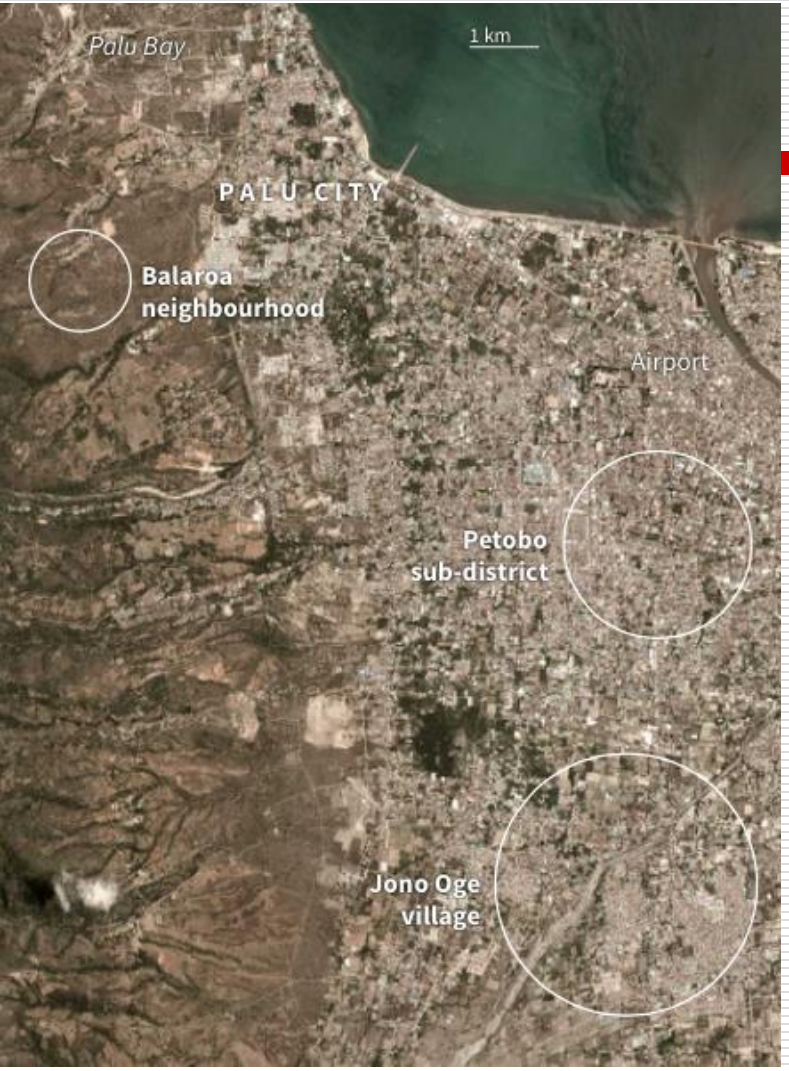
Phenomena of sand blows



Phenomena of Flow Liquefaction

(Satelite image of Petobo – Palu Donggala Eartquake)





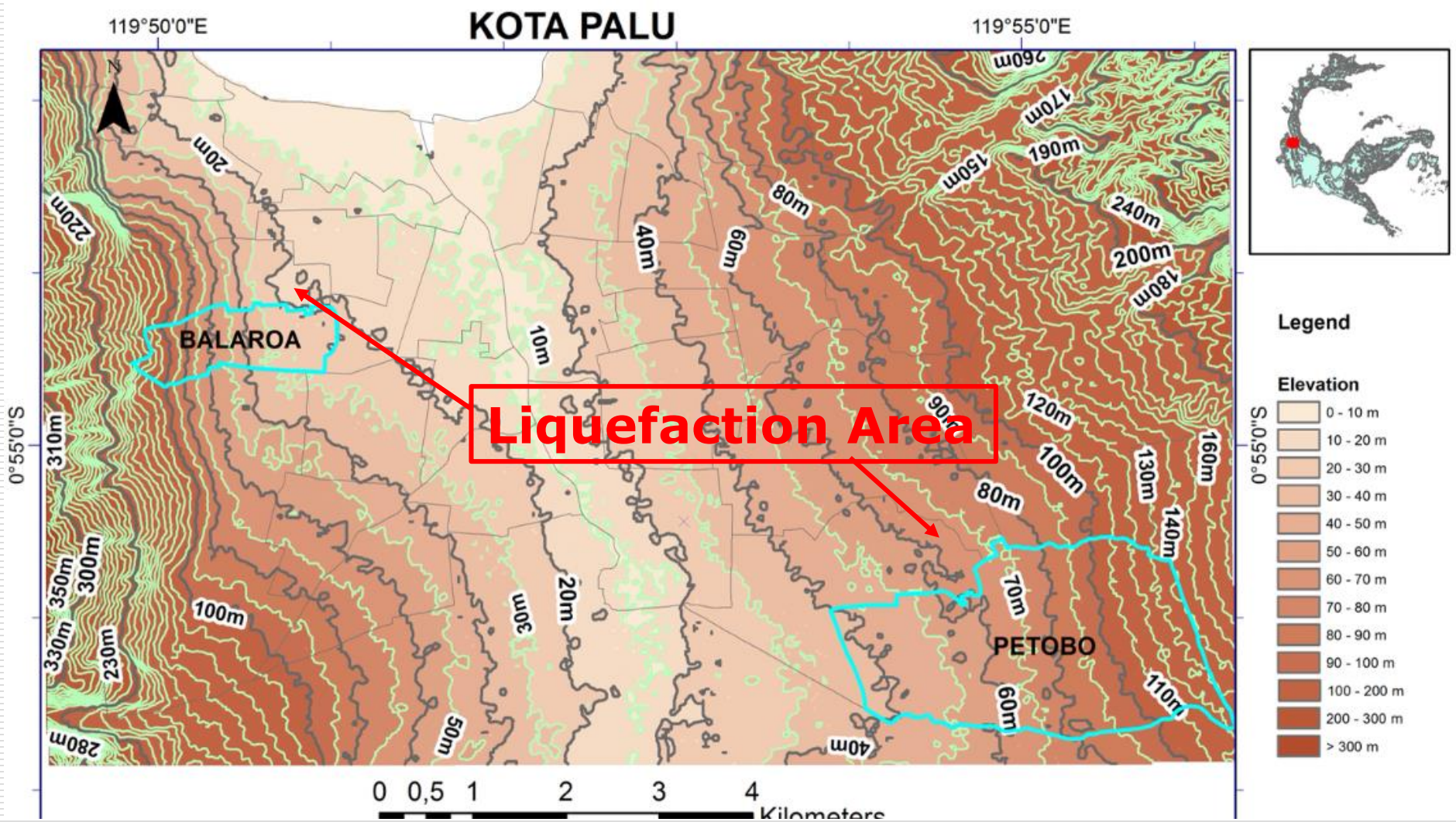
Damage due to Liquifaction

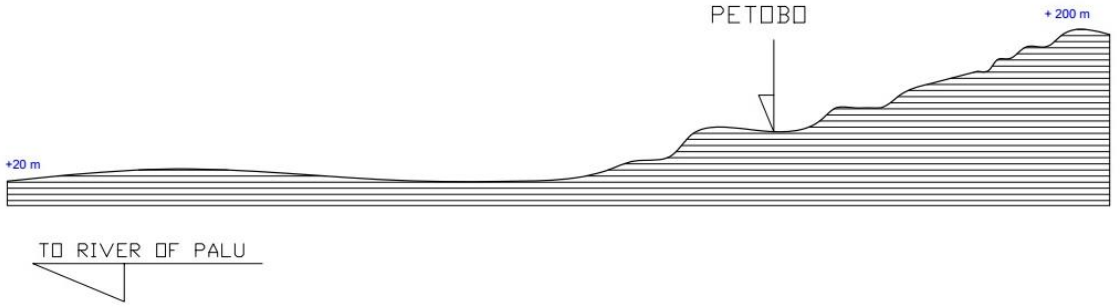
- Petobo : 744 houses
- Balaroa : 1700 houses
- Jono Oge :

Massive Liquefaction
Petobo village and Perumnas Balaroa

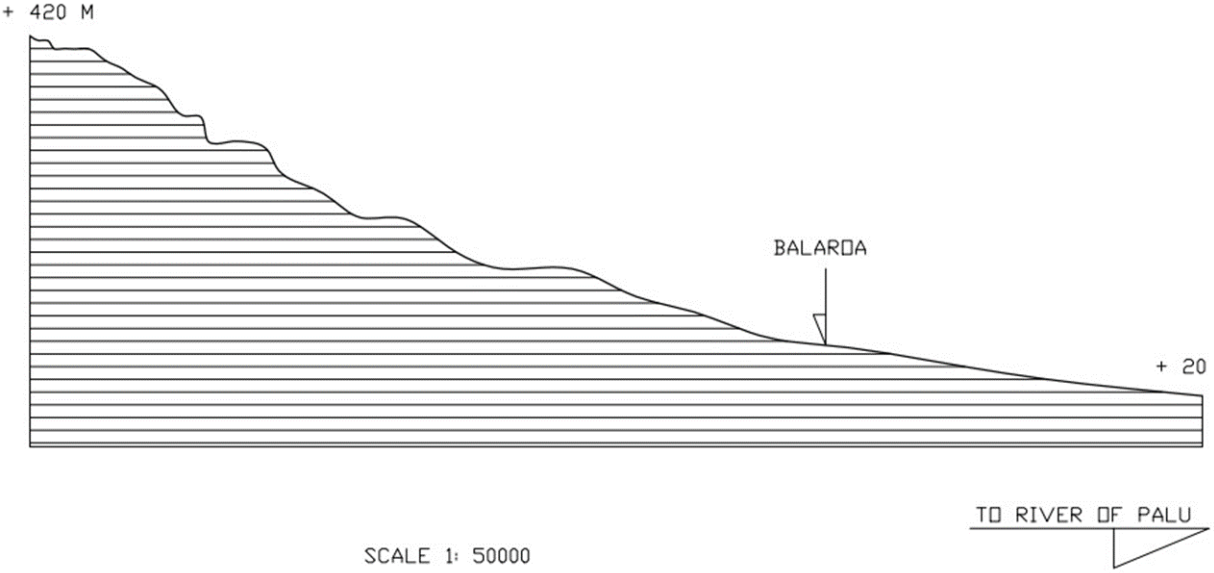
Balaroa located at Palu-Koro Fault. After liquefaction, some area settled 5 m, and other area heave 2m
1.747 units of houses damage or gone

Petobo, hundreds of houses sink into mud 3-5 m deep
744 units of houses damage or gone


KOTA PALU
119°50'0"E
119°55'0"E
0°55'0"S
N
BALAROA
PETOBO
Liquefaction Area
0 0,5 1 2 3 4
Kilometers
Legend
Elevation
0 - 10 m
10 - 20 m
20 - 30 m
30 - 40 m
40 - 50 m
50 - 60 m
60 - 70 m
70 - 80 m
80 - 90 m
90 - 100 m
100 - 200 m
200 - 300 m
> 300 m



SCALE 1: 80000


+ 420 M
BALARDA
+ 20
TO RIVER OF PALU
SCALE 1: 50000

Scenes at Petobo

Scenes in Petobo (photo on Oct 1, 2018)

Scenes at Petobo

Liquifaction at Balaroa - Palu, Central Sulawesi Thirsday, (foto on 11 Oktober 2018)

Liquefaction at Desa Lolu Kecamatan Sigi

(foto on oct 5, 2018)

Evacuation of the liquefaction area

Evacuation of Liquefaction debris

Conclusions

- Soft soils origin and phenomena have been presented, there are originally deposited soft soils and soil that becomes soft due to water or excess pore water pressures
- There have been many cases which are very valuable as lessons learned and should be very good reference