Introduction to Soil Improvement
&
Lesson Learnts

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September 2012

Contents

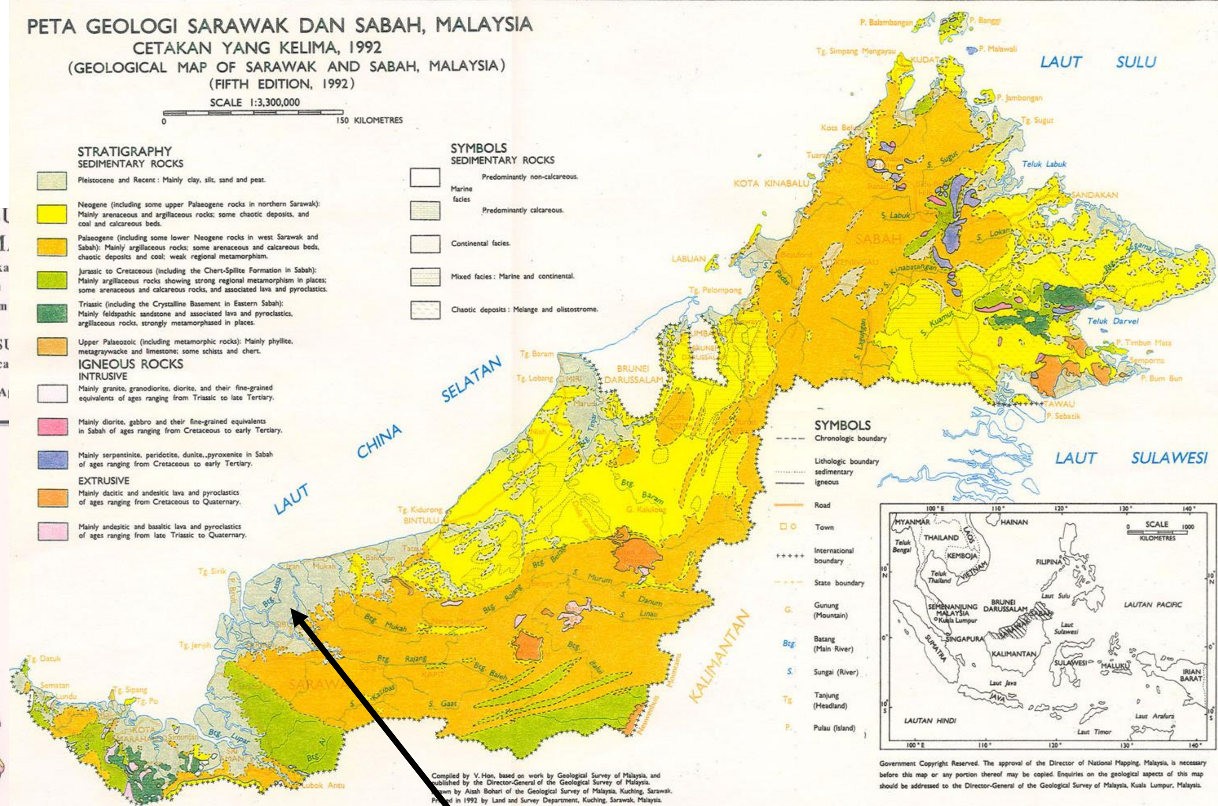
- Why need ground treatment?
- Ground treatment options

Why need ground treatment?

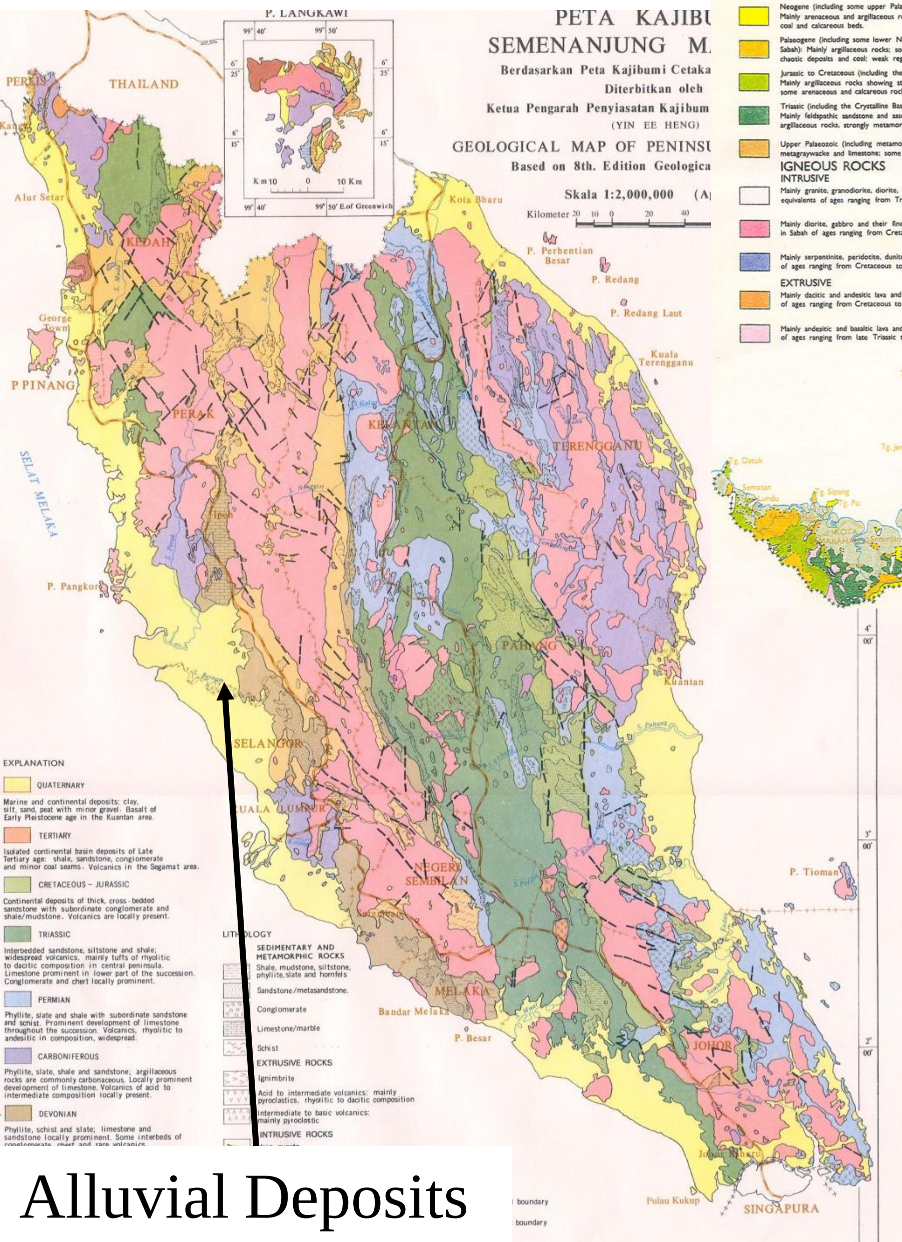
- To fulfill settlement criteria
- To enhance stability of embankment and prevent collapse
- Normally at soft ground area


07-Feb-09 19:25


SOFT
21.04.2008 09:41



Alluvial Deposits



Alluvial Deposits

Options of Ground Treatment

Ground Treatment Options

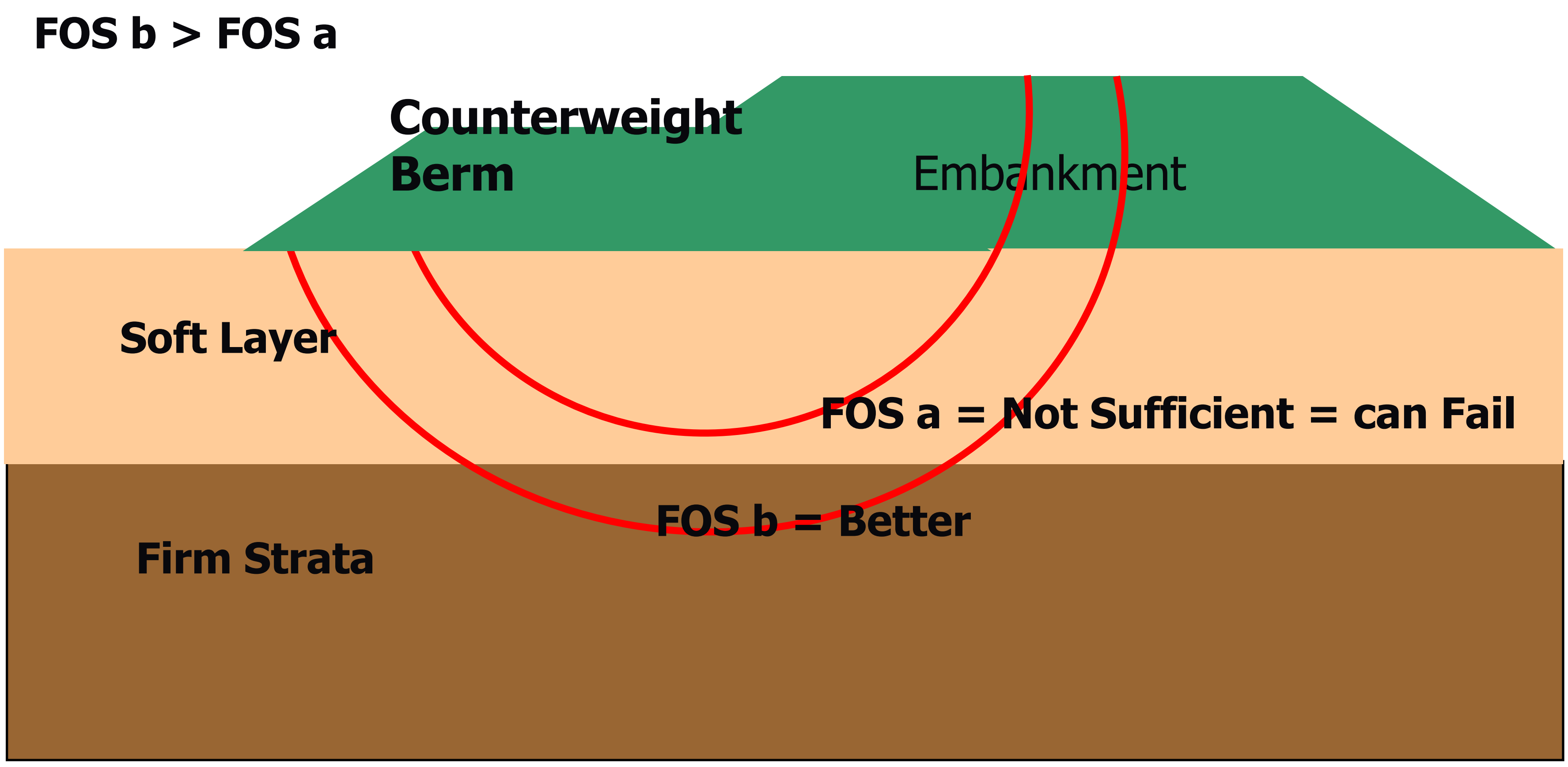
- Modification of Embankment Geometry
- Excavate and replacement
- Temporary surcharge
- Prefabricated vertical drains
- Basal reinforcement
- Piled embankments
- Stone column

Modification of Embankment Geometry

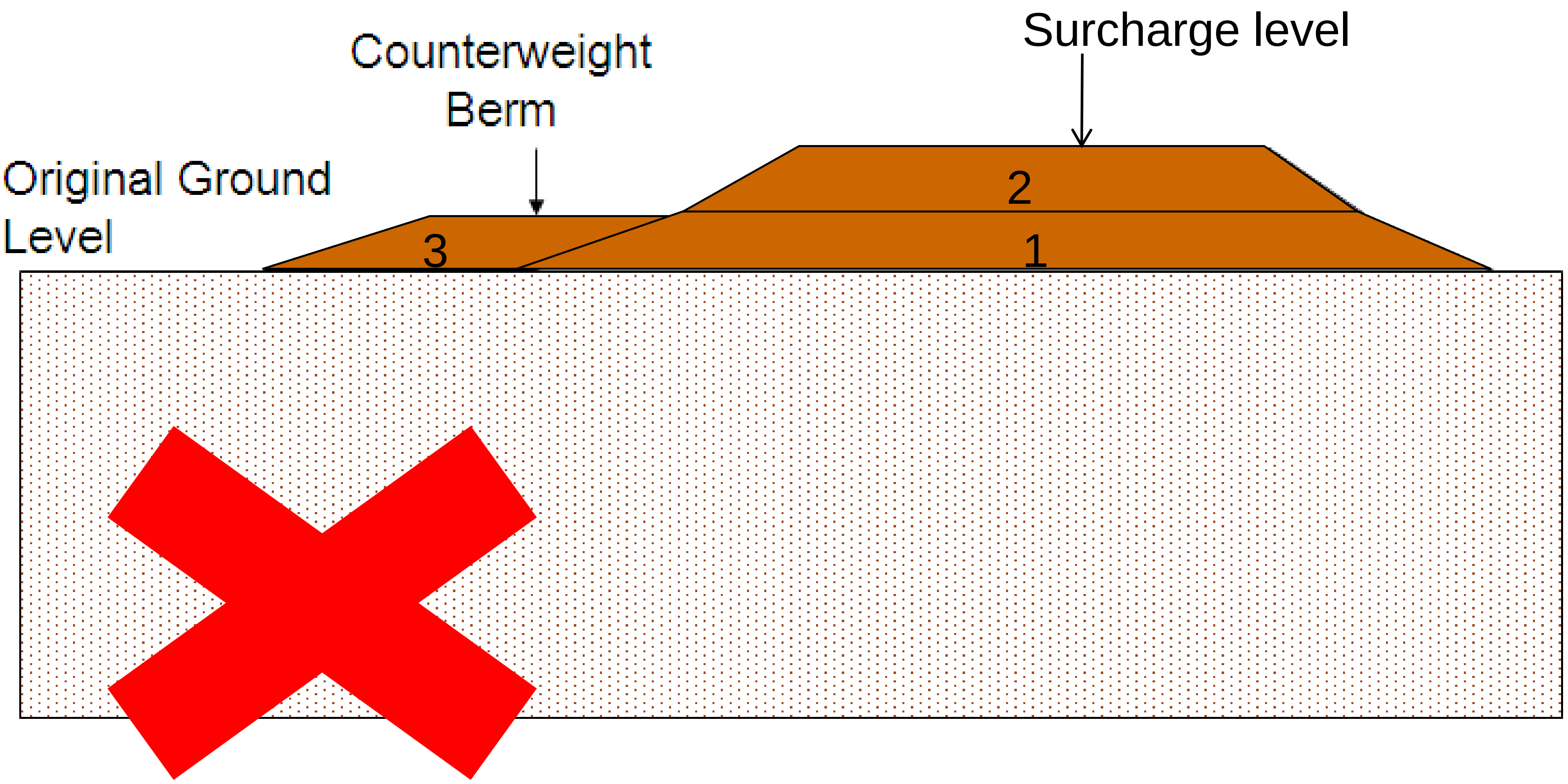
Modification of Embankment Geometry

- ❖ Reduction of Slope Angle
- ❖ Counterweight Berm
  - → to counter disturbing moment
  - → to increases length of failure surface
- ❖ Disadvantage
  - (a) Greater land-take
  - (b) Larger volume of fill

Counterweight Berm…

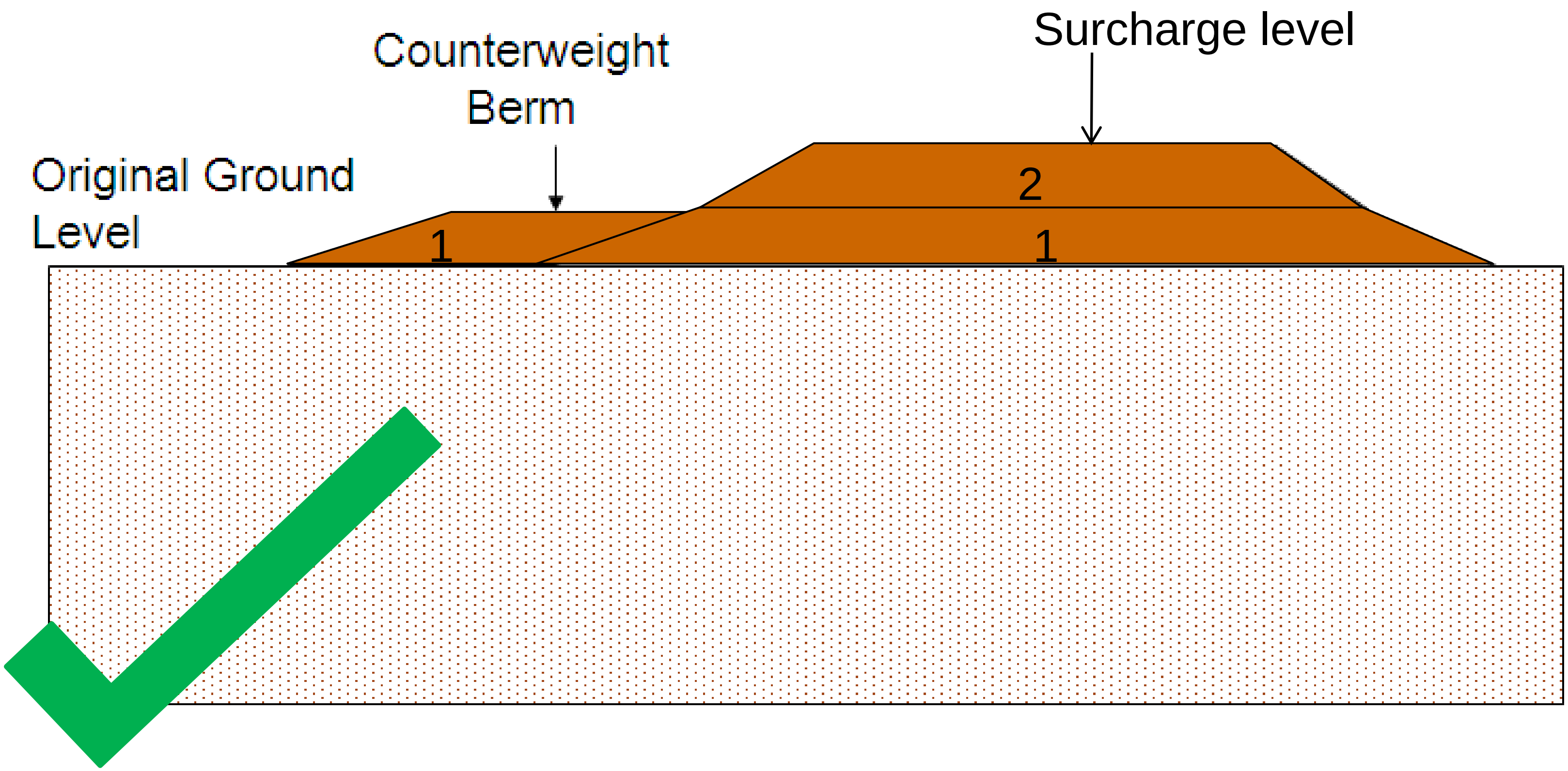


WRONG SEQUENCE OF CONSTRUCTION



WRONG = DANGEROUS = WILL FAIL

Construction of Counterweight Berm



CORRECT !!!! = SAFE

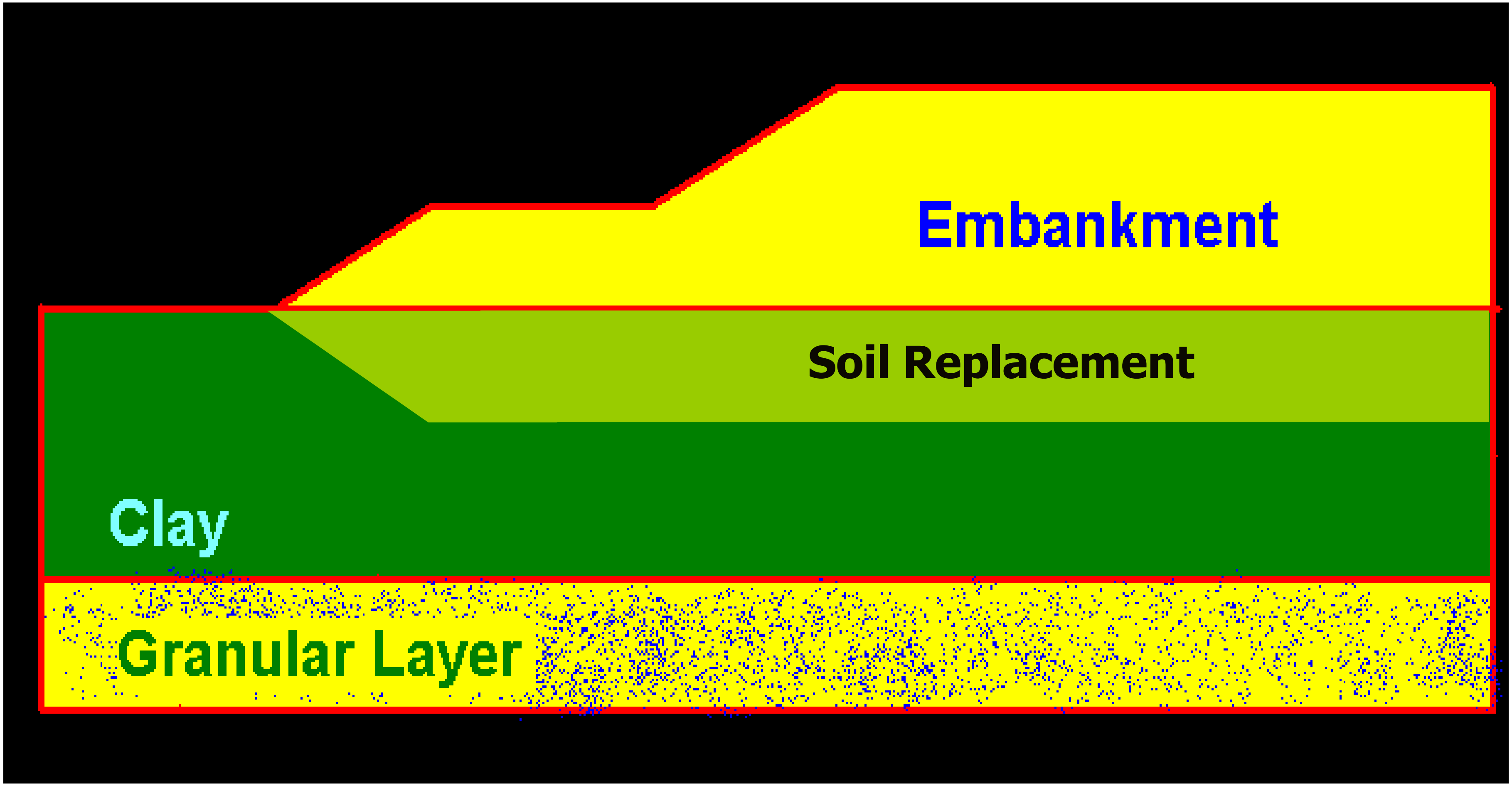
Together with Embankment to height of BERM

Excavate and Replace
(Soft Soil Replacement)

Excavate and Replace (Soft Soil Replacement)

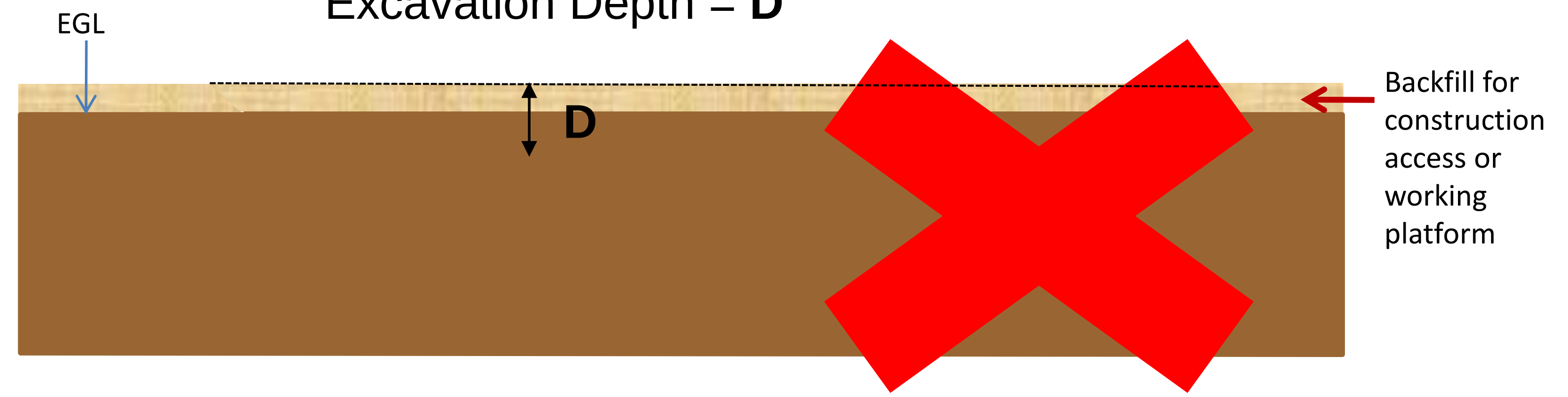
- Old but still viable
- Replace with better materials
- Stronger & less compressible foundation
- Generally limit to 3.0m
- Extended to at least the TOE of Embankment
- Partial Replacement (if very deep layer)

Excavate and Replace

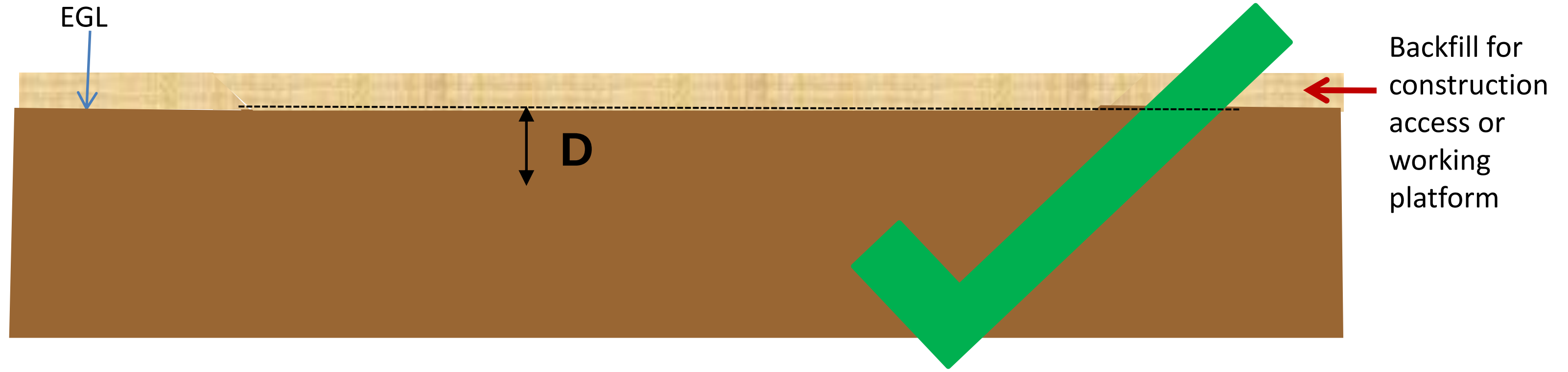


Proper Way for Excavation

Excavation Depth = **D**



**The required excavation depth shall not be measured from backfill for construction access or working platform

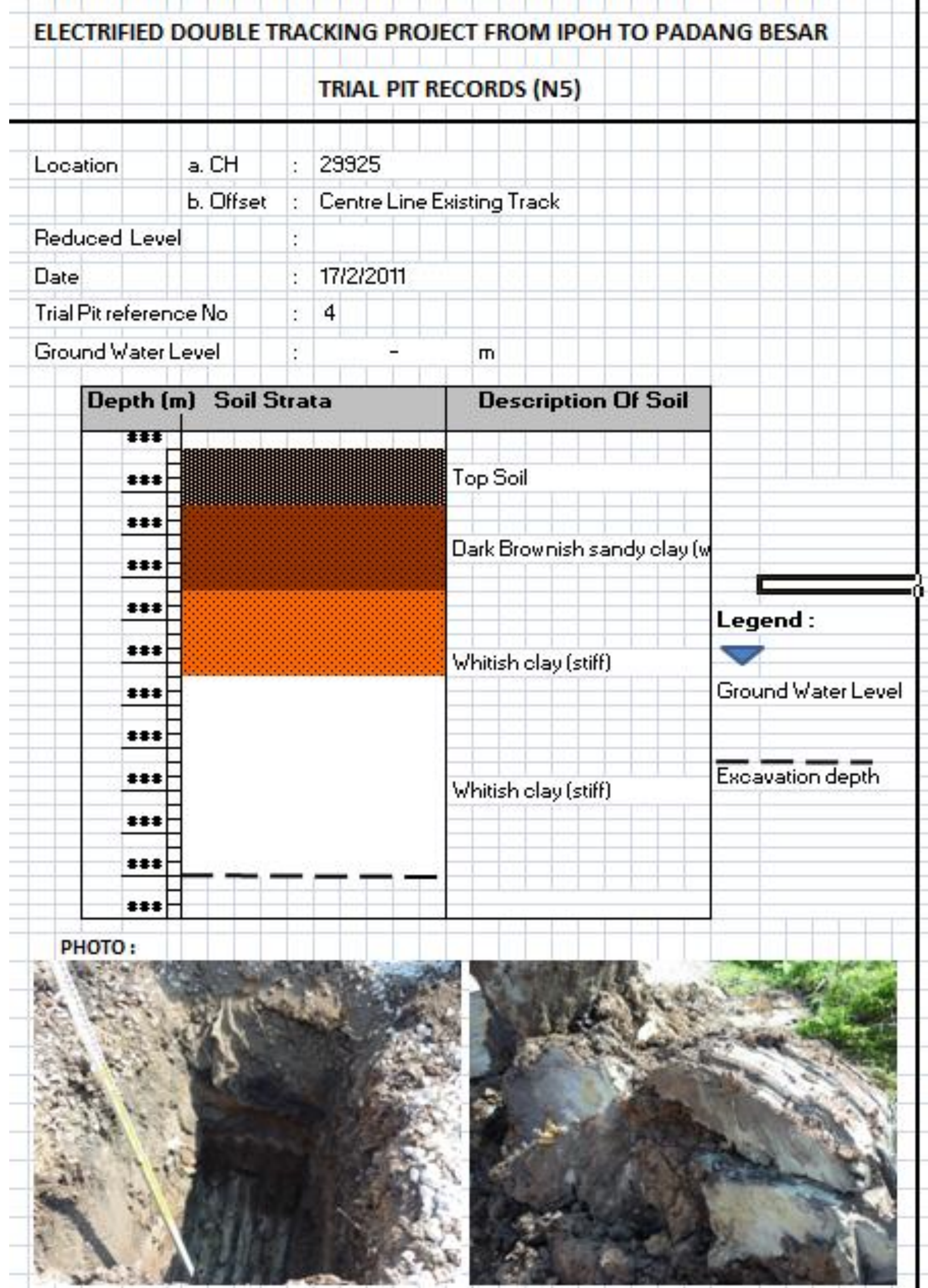


**The required excavation depth shall be measured from EGL.

To “understand” about the subsoil condition:

a) To carry out Mackintosh Probe tests

b) To carry out trial pits


ELECTRIFIED DOUBLE TRACKING PROJECT FROM IPOH TO PADANG BESAR

TRIAL PIT RECORDS (N5)

Location	a. CH	:	29925
	b. Offset	:	Centre Line Existing Track
Reduced Level		:	
Date		:	17/2/2011
Trial Pit reference No		:	4
Ground Water Level		:	- m

Depth (m)	Soil Strata	Description Of Soil
###		
###		Top Soil
###		
###		Dark Brownish sandy clay (w
###		
###		Whitish clay (stiff)
###		
###		
###		Whitish clay (stiff)
###		
###		
###		

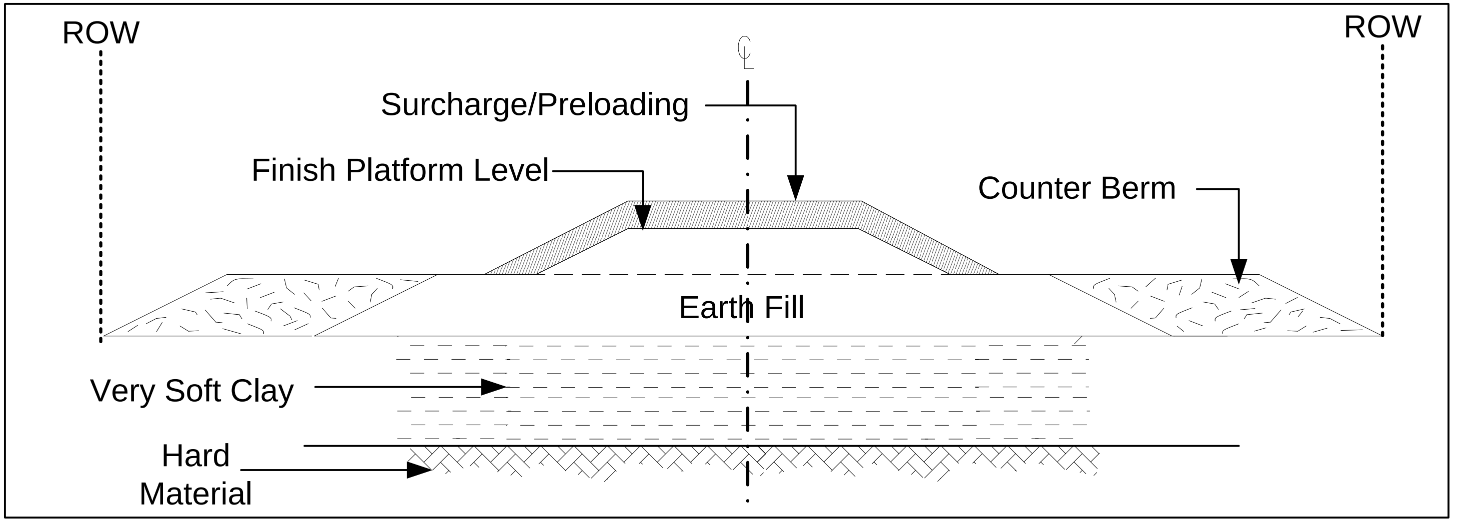
Legend :

Ground Water Level

Excavation depth

PHOTO :

Temporary surcharge

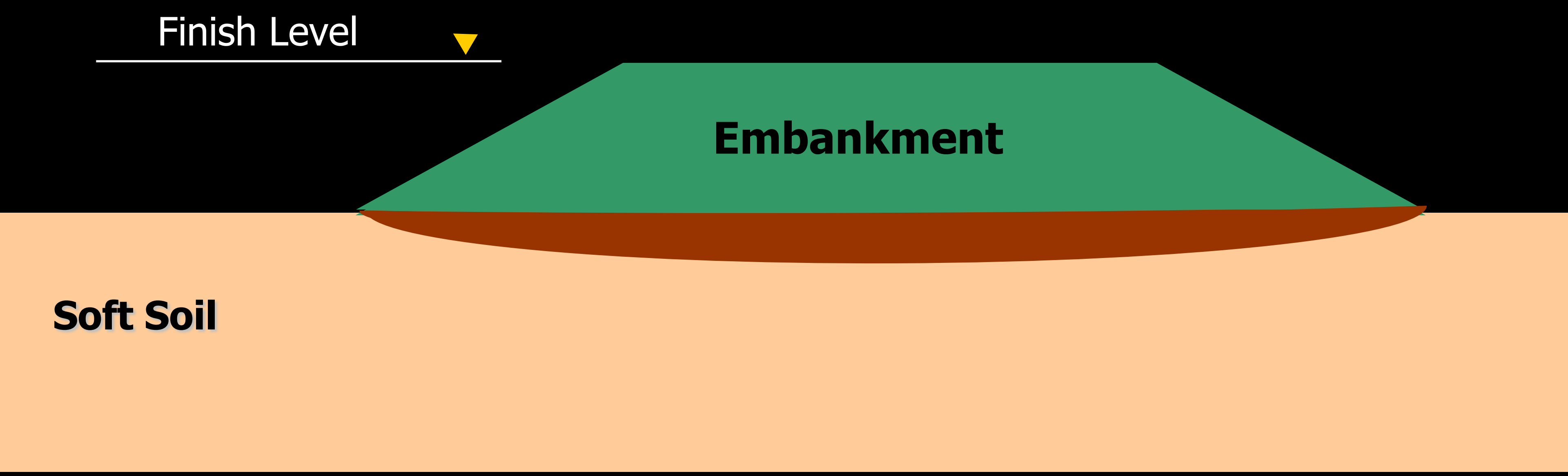


Surcharge/Preloading

Temporary Surcharge

- Subject to higher pressure than Permanent Load.
- Achieve higher initial rate of settlement + reduce long-term settlement.
- Large portion of fill left behind.

Temporary Surcharge



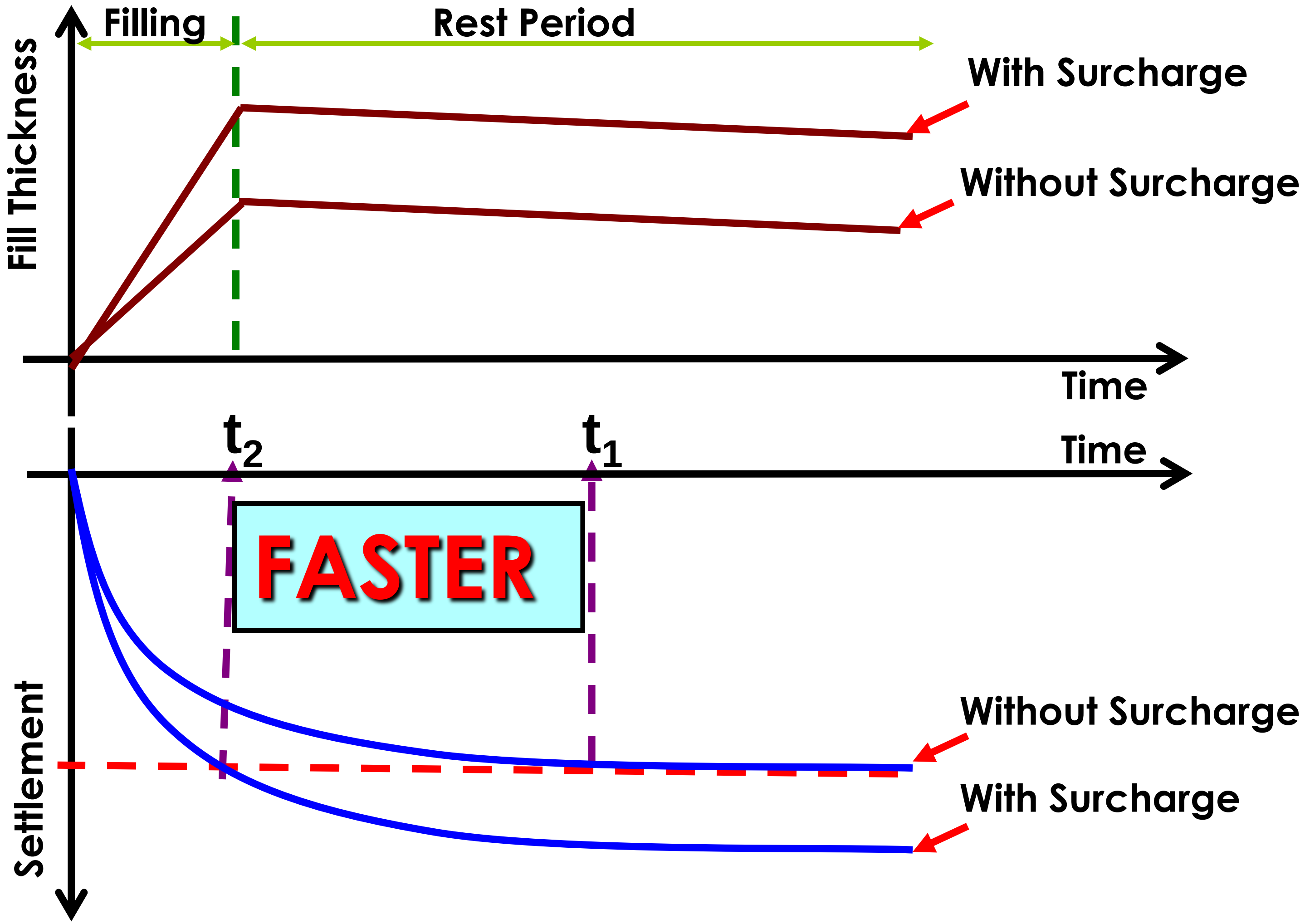
Advantages:

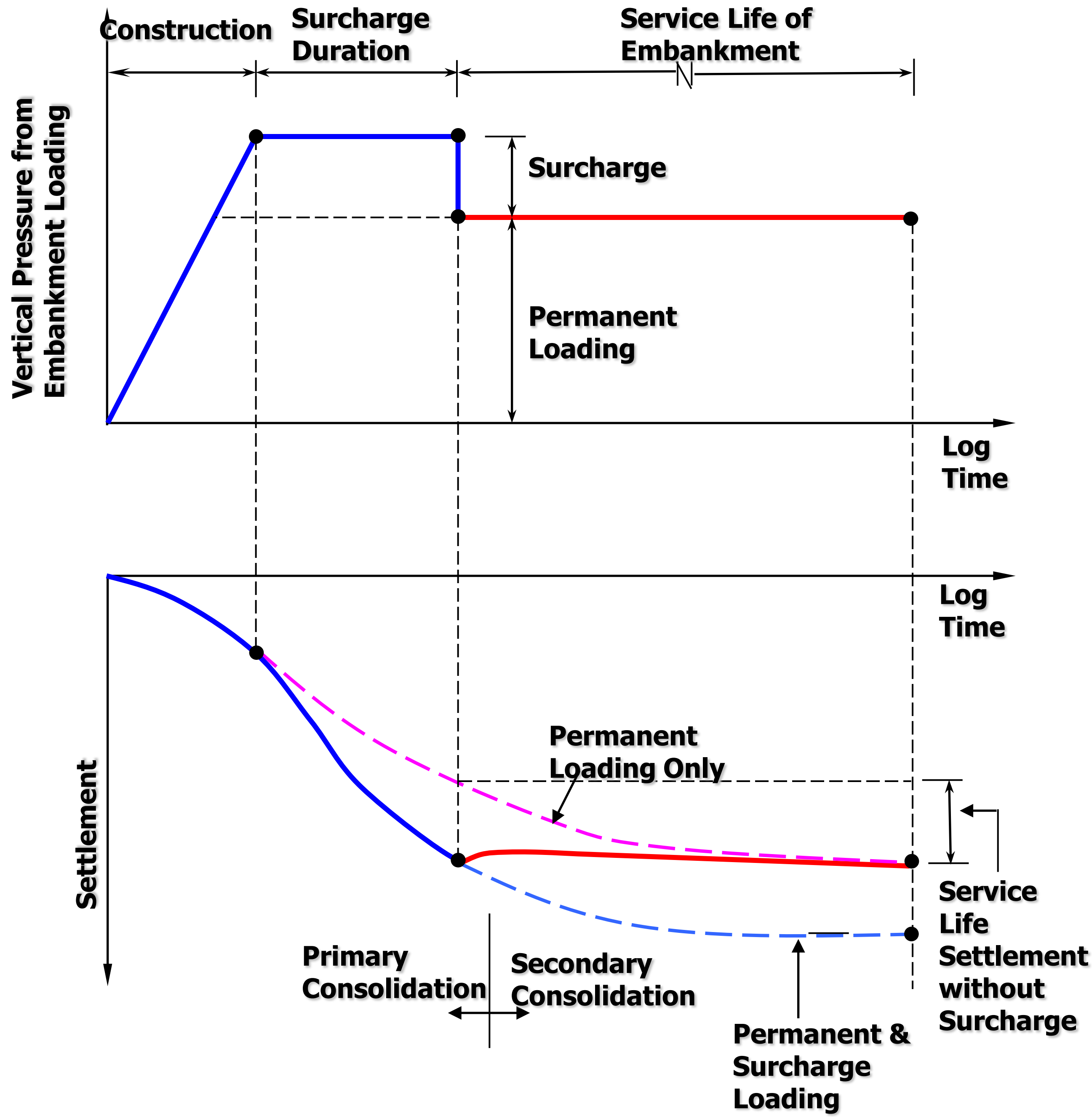
- ✓ Major settlement has taken place before construction

Disadvantages:

- ✓ Long consolidation time for very thick soft soil layer
- ✓ Controlled rate of preloading to prevent failure
- ✓ Extra fill to be disposed

Surcharging




Construction
Surcharge Duration
Service Life of Embankment
Vertical Pressure from Embankment Loading
Surcharge
Permanent Loading
Log Time
Log Time
Settlement
Permanent Loading Only
Service Life Settlement without Surcharge
Primary Consolidation
Secondary Consolidation
Permanent & Surcharge Loading


10 DEC


25 MAR 2009

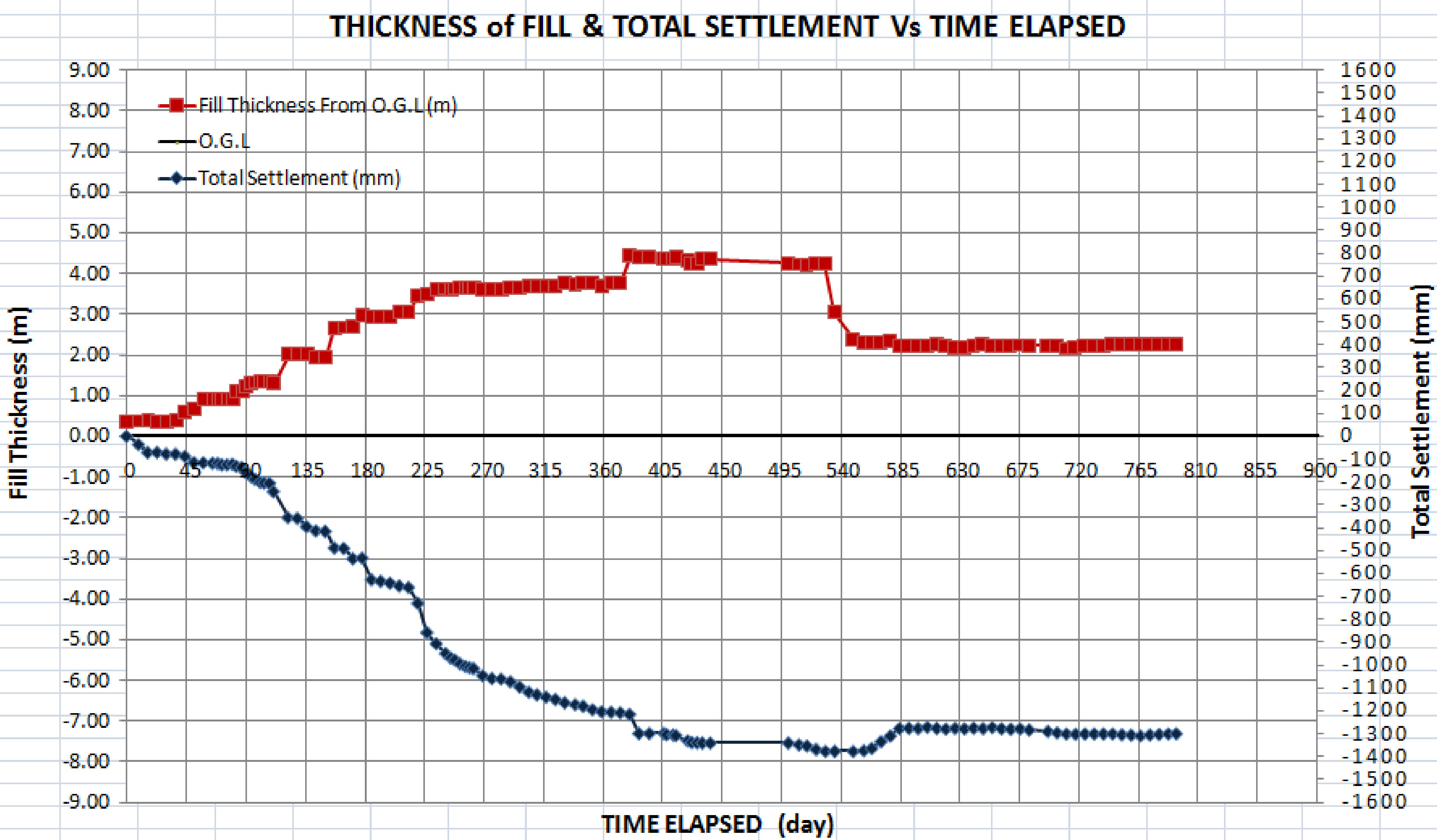
Staged Loading

Staged Loading

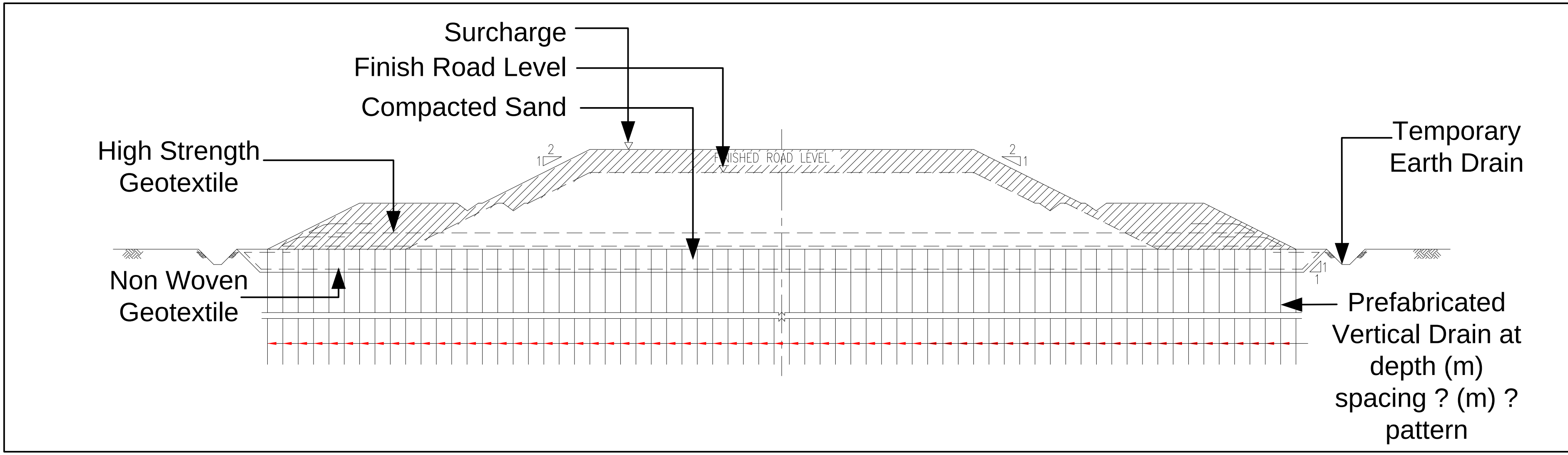
- Allows gain in strength (time for consolidation) before next stage
- Rate of Loading = Gain in Strength
- Longer Time of Construction

- Usually used with Vertical Drains
- Require Close Monitoring & Coordination

Settlement Plate Monitoring Chart For N3/S8/CH80,275



Prefabricated Vertical Drains (PVD)



PVD with Surcharge

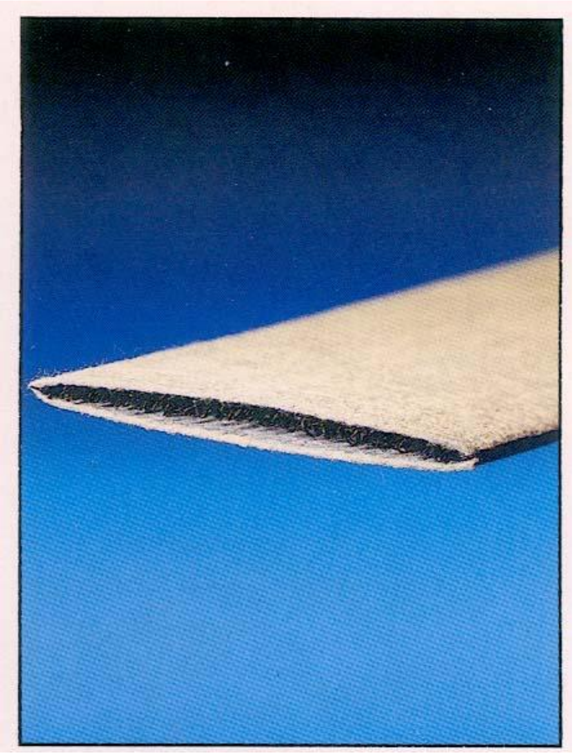
Prefabricated Vertical Drains (PVD)

- Commonly used to accelerate the rate of consolidation and is use in conjunction with surcharging

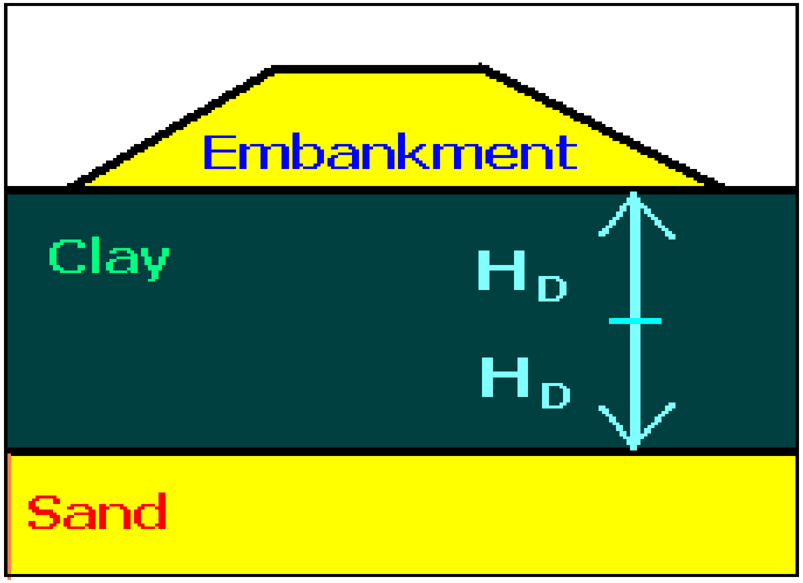
- Successfully used worldwide

- Cost effective (RM1.10 to 1.30 per m)

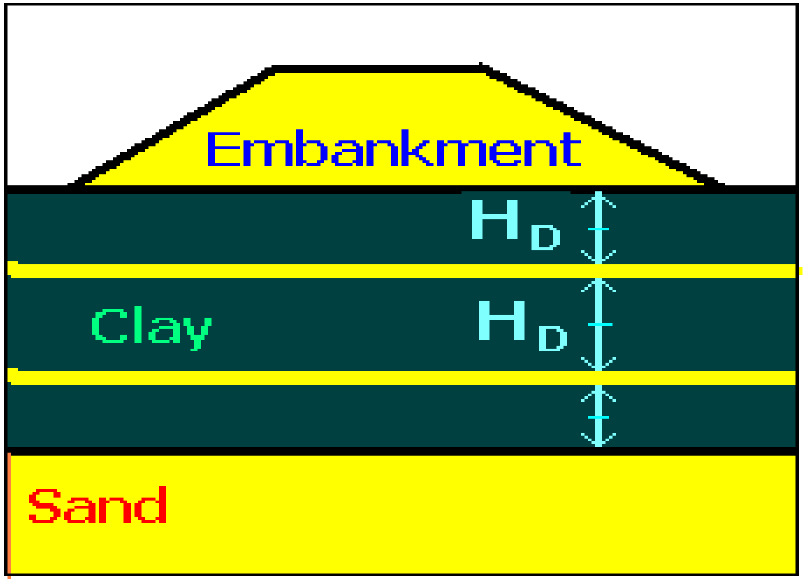
- PVD will not improve the subsoil shea
time of installation



Drainage Path for Consolidation

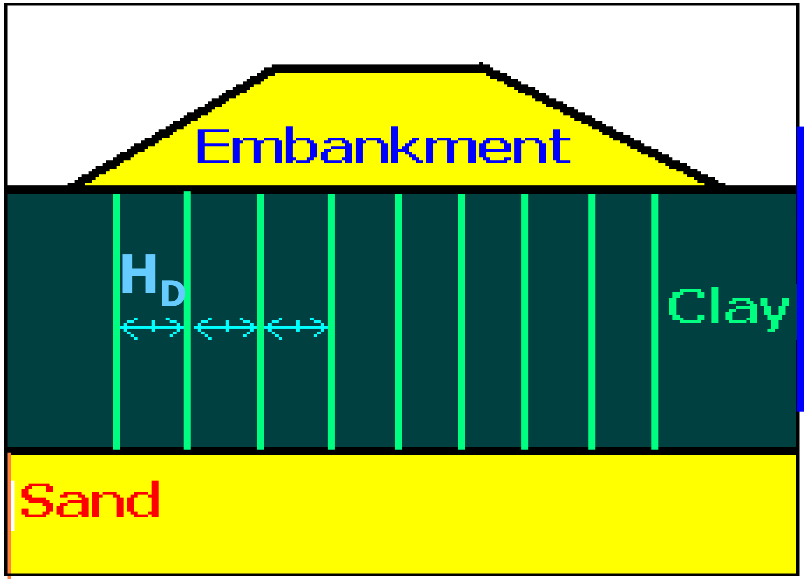


Thick Clay Layer



Intermediate Sand Layer

$$t \propto H_D^{\,2}$$



Vertical Drains

H_D	1m	10m
t	1	100

100 times faster!

How it works?

Terzaghi's Theory of Consolidation:

$$t = \frac{T_v H_D^{\,2}}{c_v}$$

Where t = Time required for full consolidation (year)

T_v = Time factor

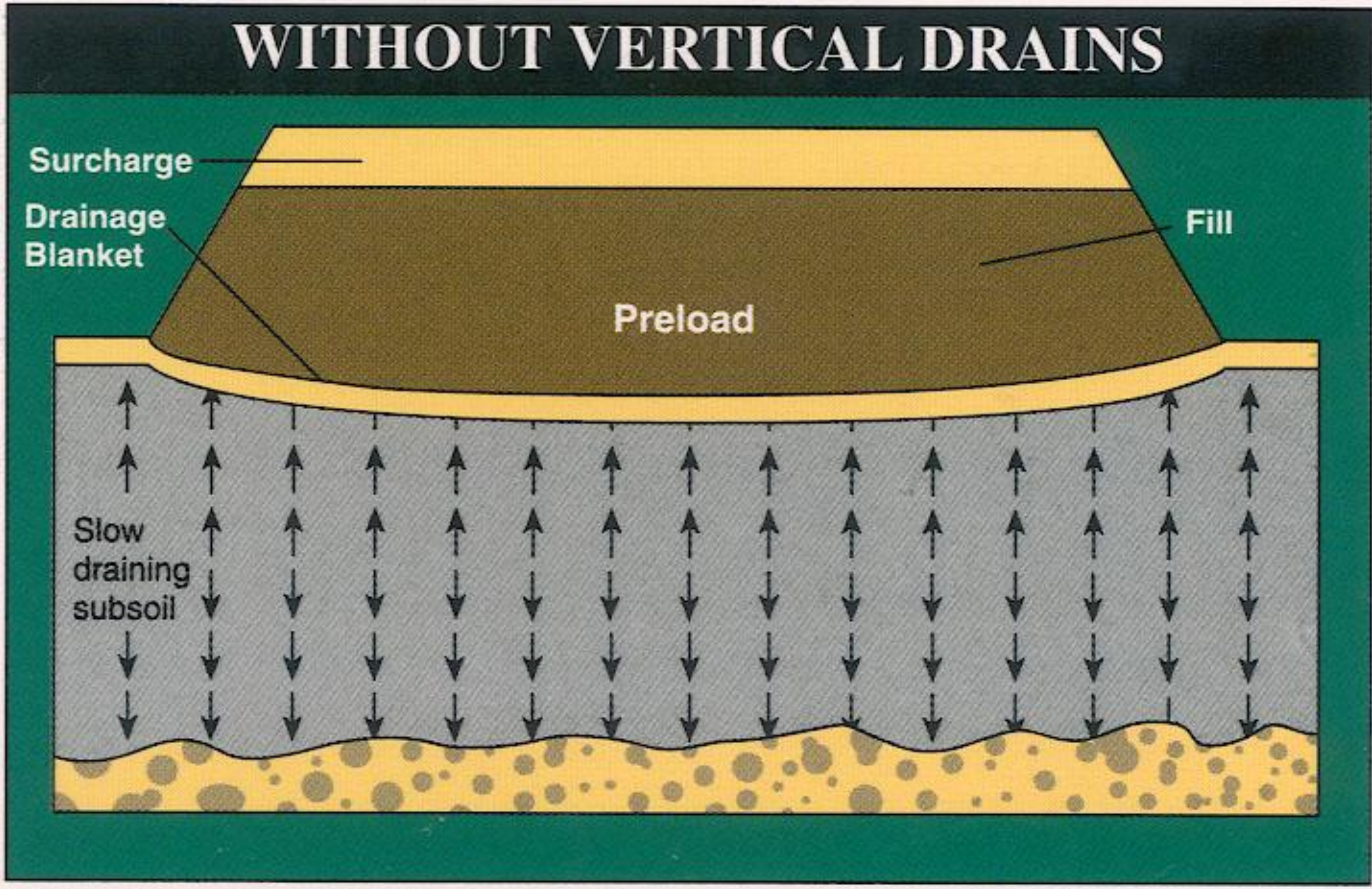
H_D = Drainage path length (m)

c_v = Coefficient of consolidation (m^2/year)

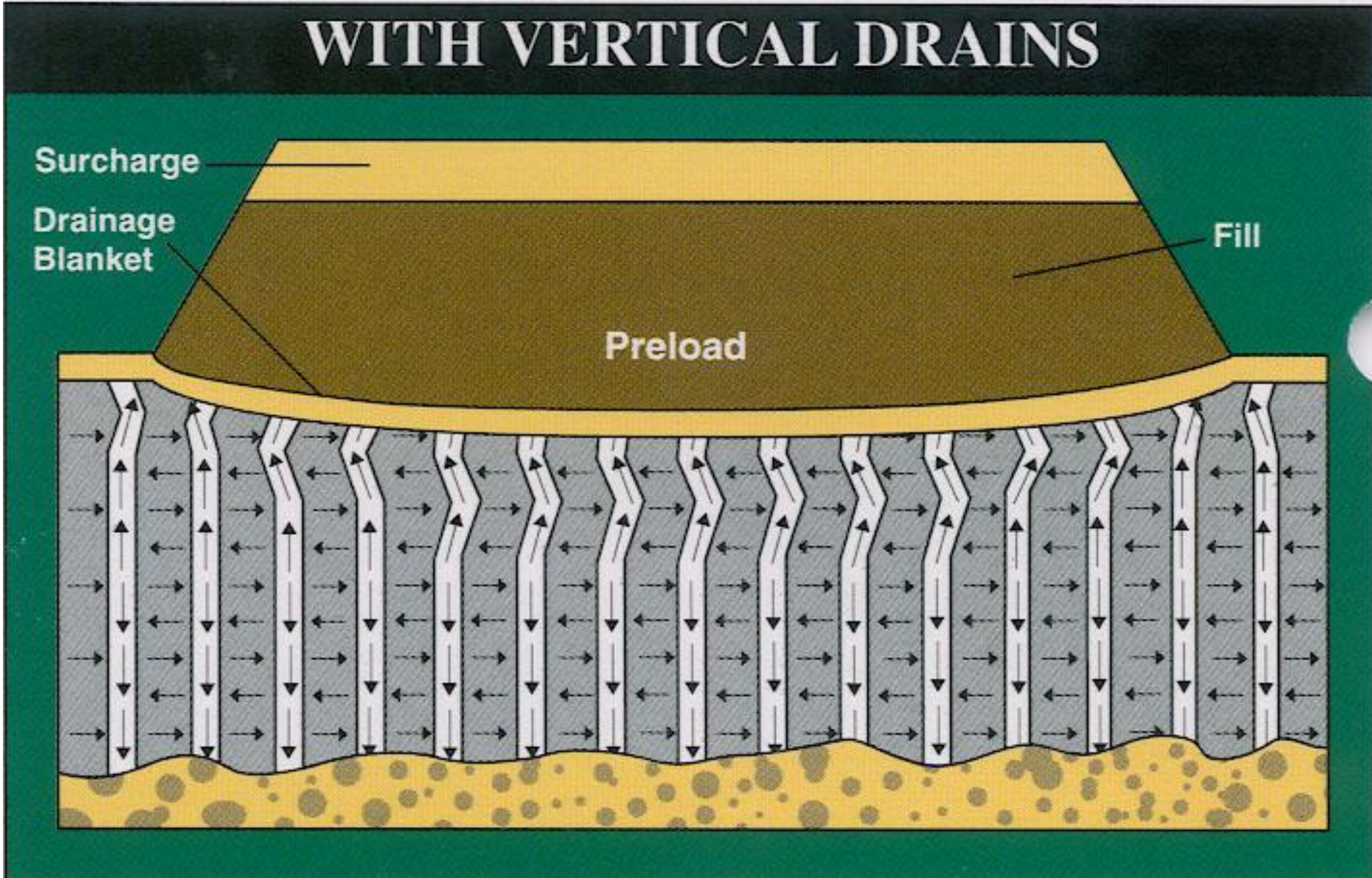
$$t \propto H_D^{\,2}$$

Ex.

H_D	10m	1m
t	$\frac{100}{c_v}$	$\frac{1}{c_v}$
		100 times faster



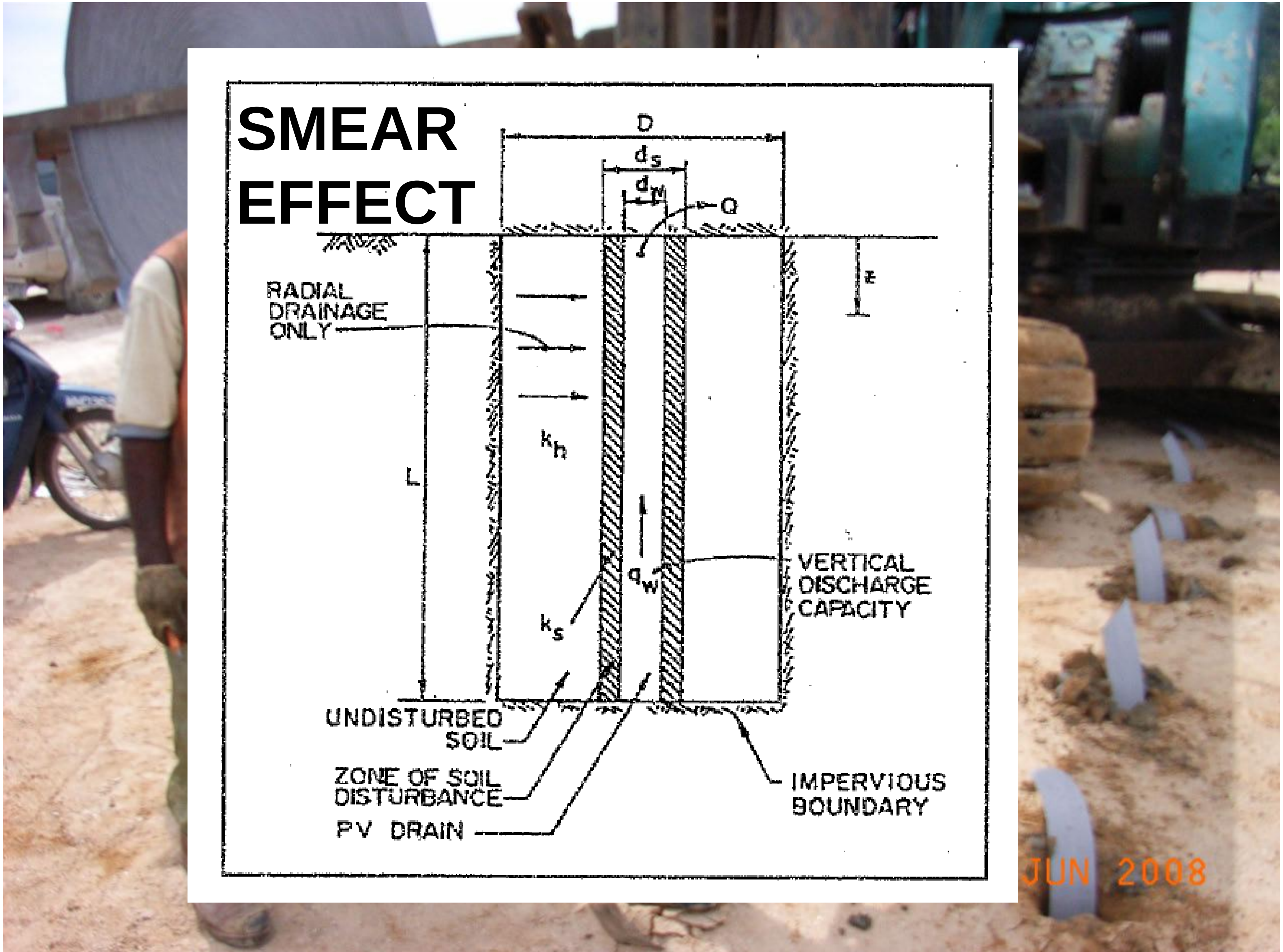
Without inserting PVD, dissipation of excess pore pressure is a slow process.



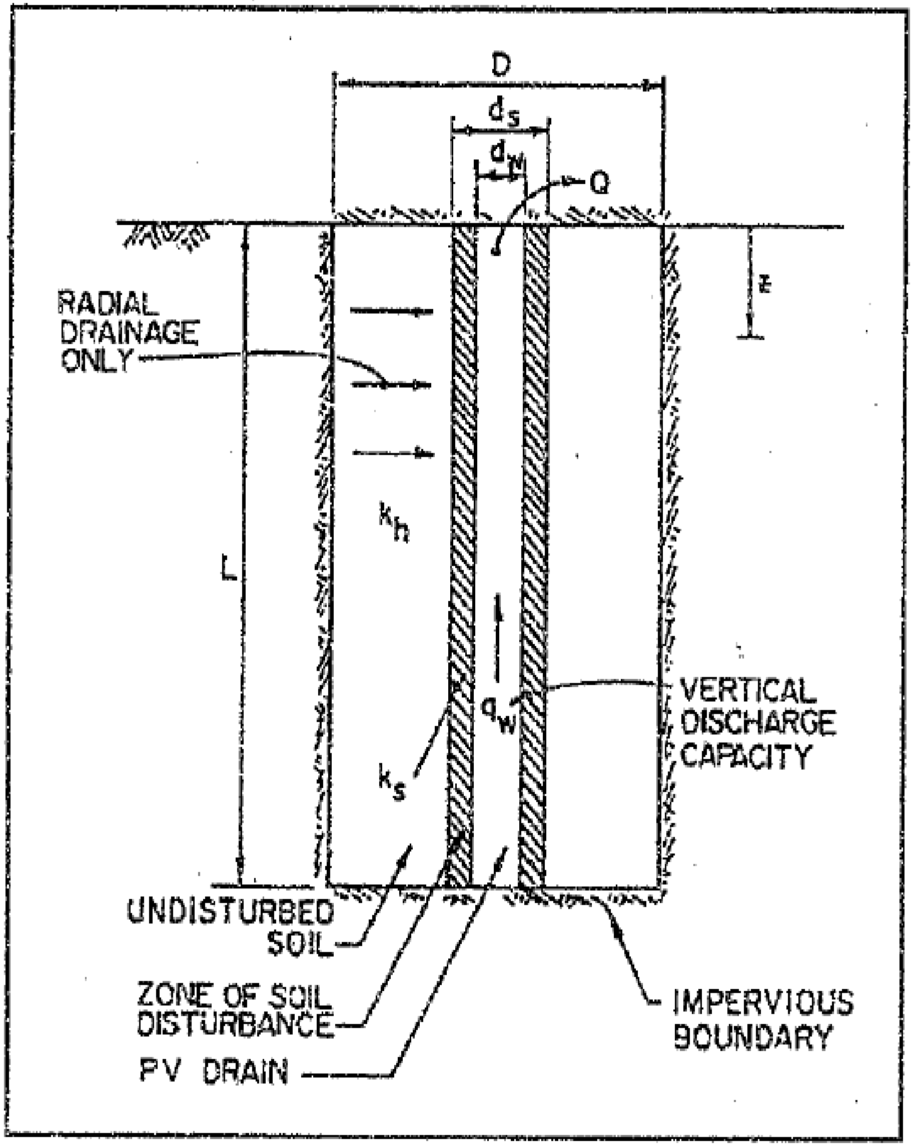
With PVD the excess pore pressure dissipates quickly through shorter drainage paths.


2007/07/16 12:12


THE EXPOSED GRAVEL OR CRUNSHER RUN SHALL ALWAYS BE MAINTAINED TO ENSURE WATER FROM THE VERTICAL DRAINS CAN DISCHARGE OUT EFFECTIVELY.
150mm CUT-OFF LENGTH
1m
0.5m
0.2m
E.G.L.
0.5m
0.3m
500mm THK. SAND BLANKET
GRAVEL OR CRUSHER RUN
PREFABRICATED VERTICAL DRAINS
PREFABRICATED DRAIN AT HORIZONTAL SPACING OF 5m
28 AUG 2008



SMEAR
EFFECT
D
d_s
d_w
Q
z
RADIAL
DRAINAGE
ONLY
k_h
L
q_w
VERTICAL
DISCHARGE
CAPACITY
k_s
UNDISTURBED
SOIL
ZONE OF SOIL
DISTURBANCE
PV DRAIN
IMPERVIOUS
BOUNDARY
JUN 2008



d_s/d_w = 2 to 7

Bergado (1992)

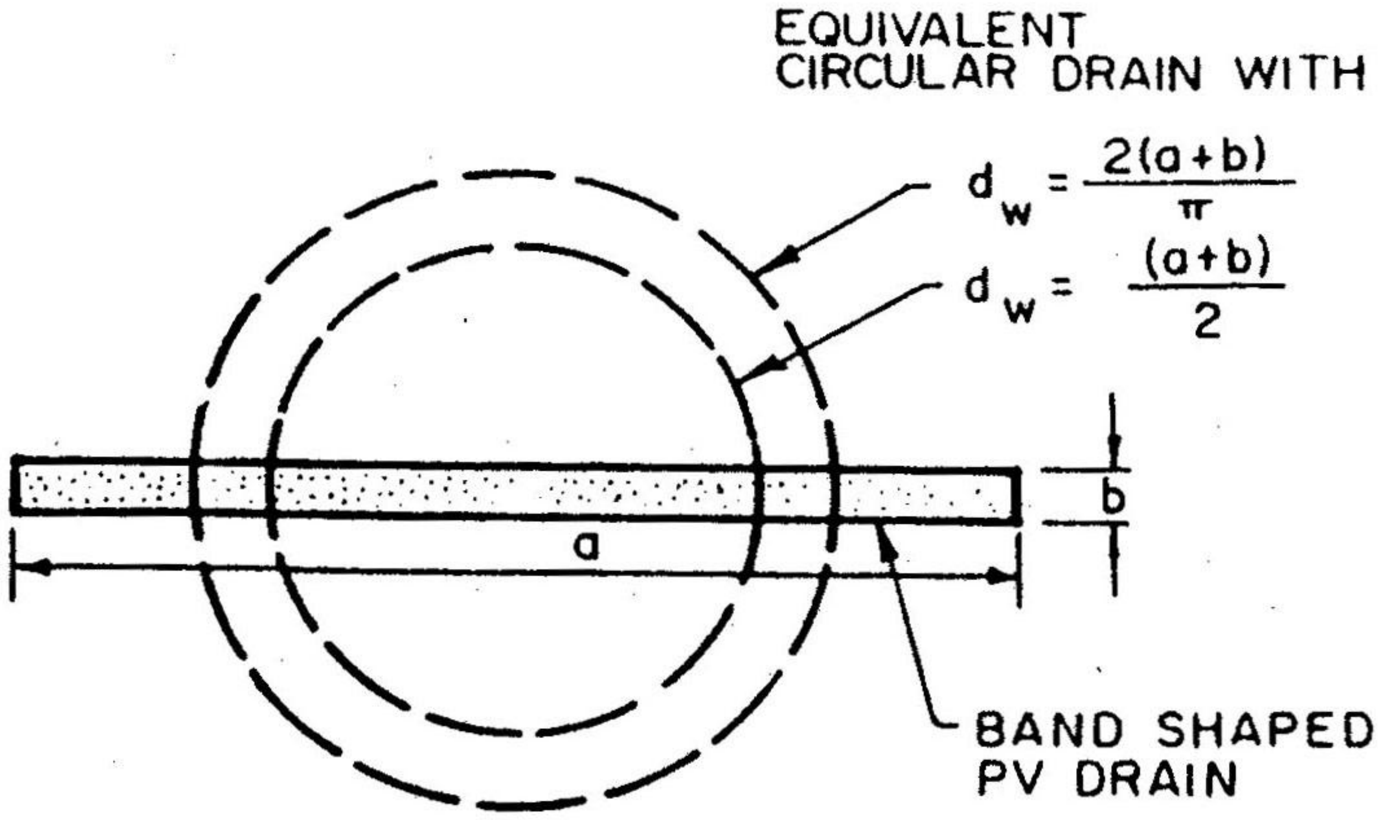
Permeability Ratio

kh : Horizontal Permeability of Undisturbed Soil

ks : Horizontal Permeability at Smear Zone of Prefabricated Drain

PI	kv(m/yr)	kh/ks
30	0.02	4-8
37~57	0.003	2-3
45~65	0.003	1.5-2

PREFABRICATED VERTICAL DRAIN (PVD)



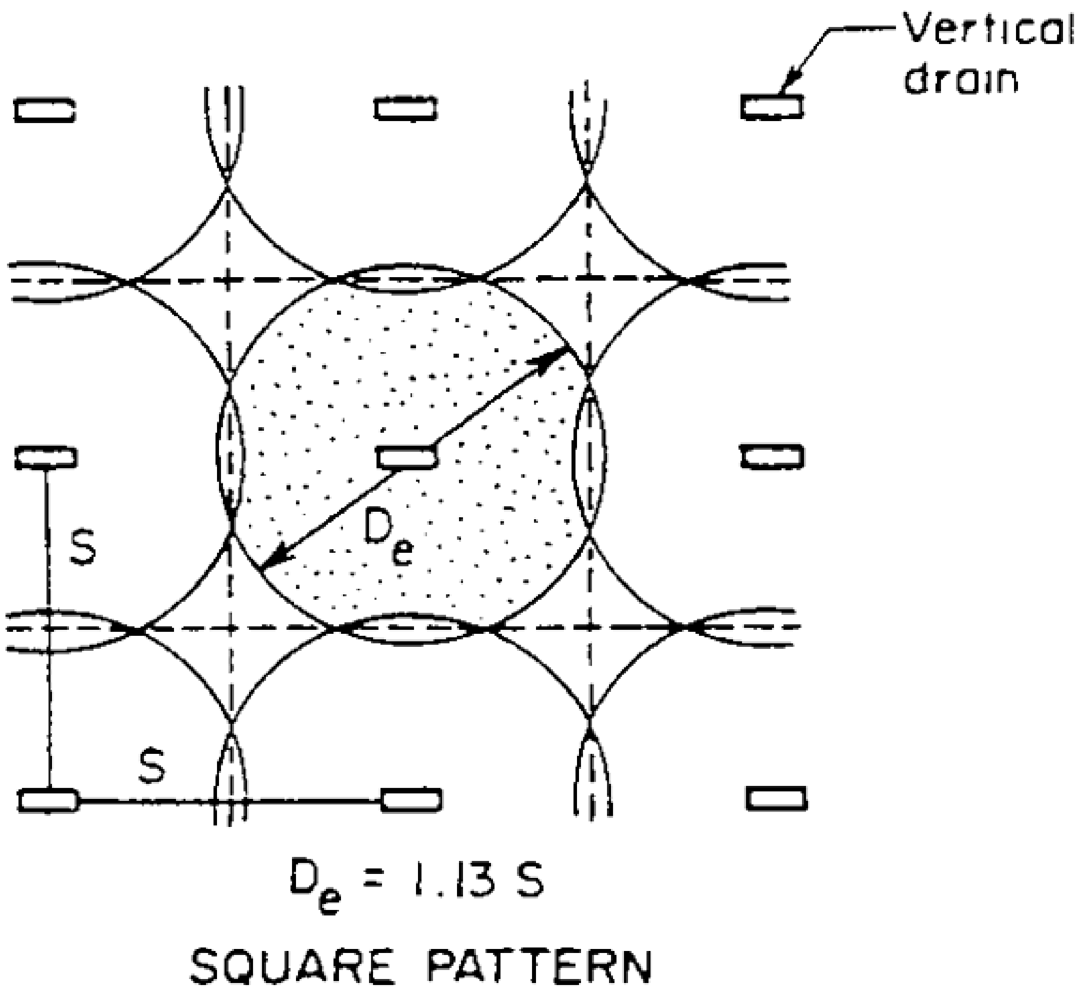
Wick Drains : **Wide = 95 ~ 100mm**

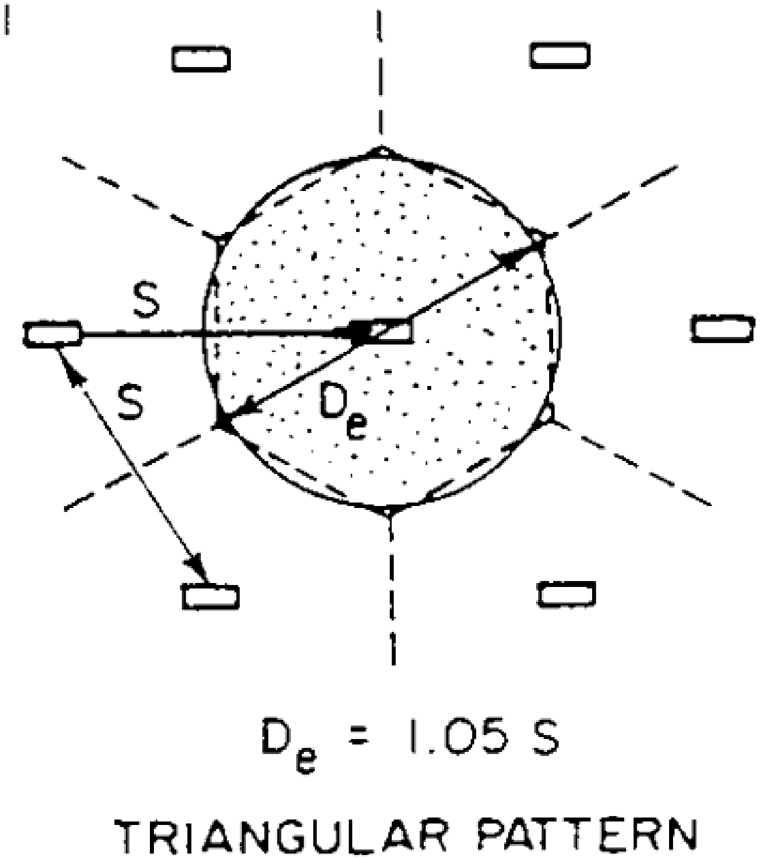
Thick = 3 ~ 4 mm

→Equivalent Diameter, d_w = 62 ~ 66mm

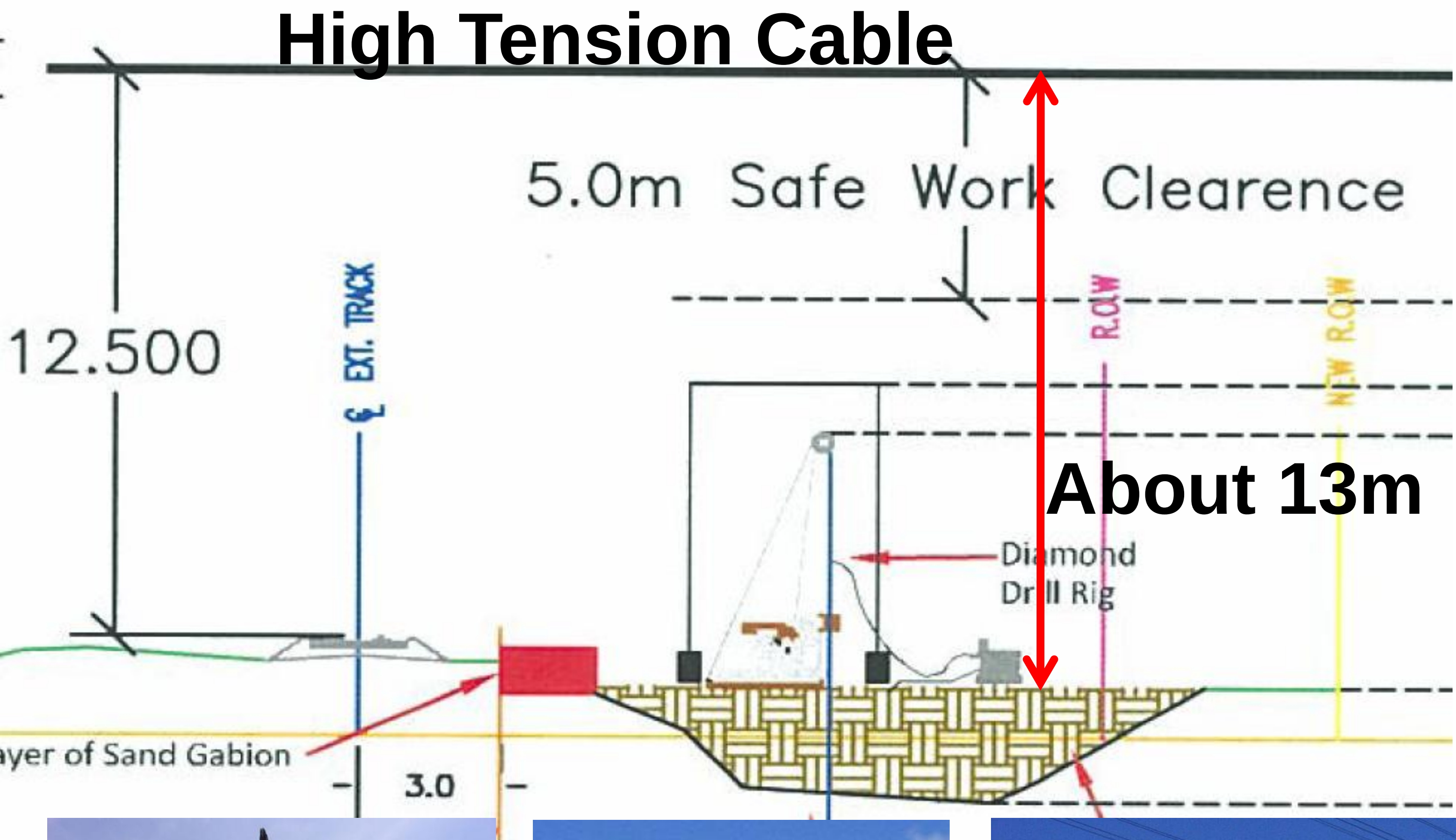
Some use 50mm (Hansbo, 1979)

Equivalent Cylindrical

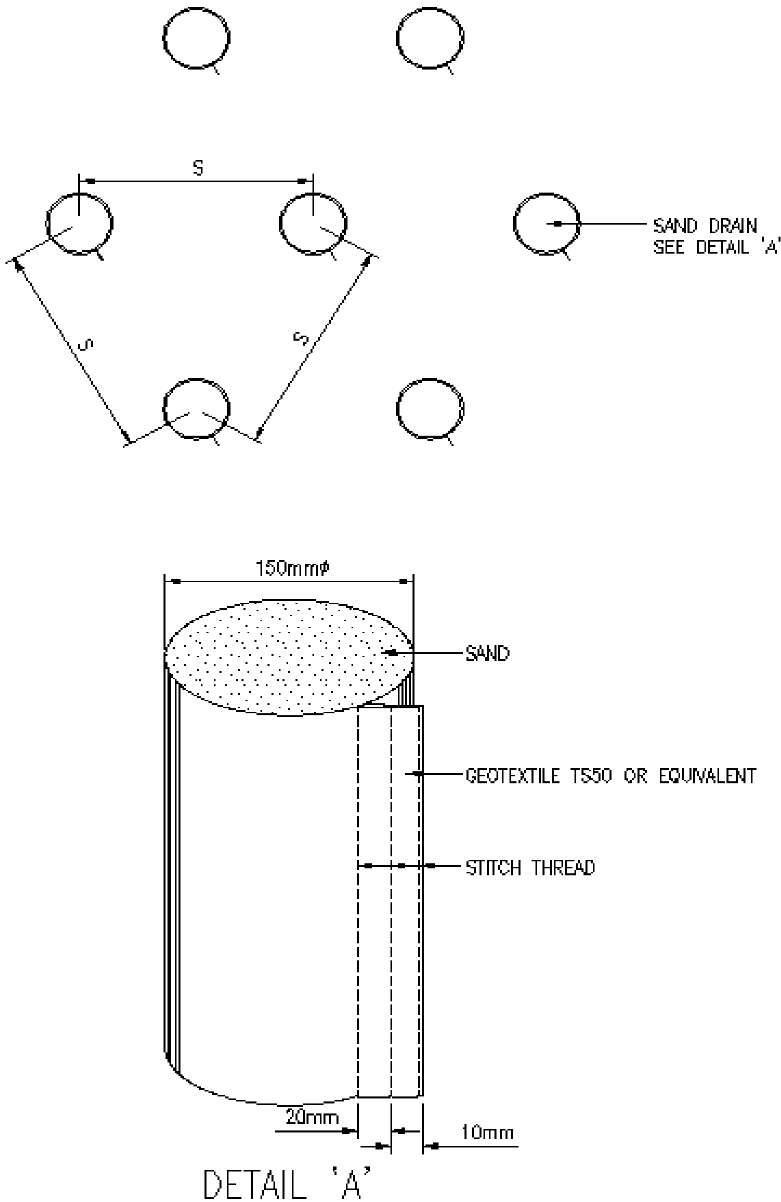




PVD can not penetrate material with SPTN value more than 7


High Tension Cable
5.0m Safe Work Clearence
12.500
℄ EXT. TRACK
R.O.W
NEW R.O.W
About 13m
Diamond Drill Rig
ayer of Sand Gabion
3.0


25 MAR


S
S
S
SAND DRAIN
SEE DETAIL 'A'
150mmφ
SAND
GEOTEXTILE TS50 OR EQUIVALENT
STITCH THREAD
20mm
10mm
DETAIL 'A'


ISUZU
25 MAR 2009


25 MAR 2009

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Installation Sequence

- Position Rig at Drain Location
- Place Anchor on Drain End
- Penetrate Mandrel to Desired Depth
- Withdraw Mandrel
- Cut Drain Material Above Drainage Blanket

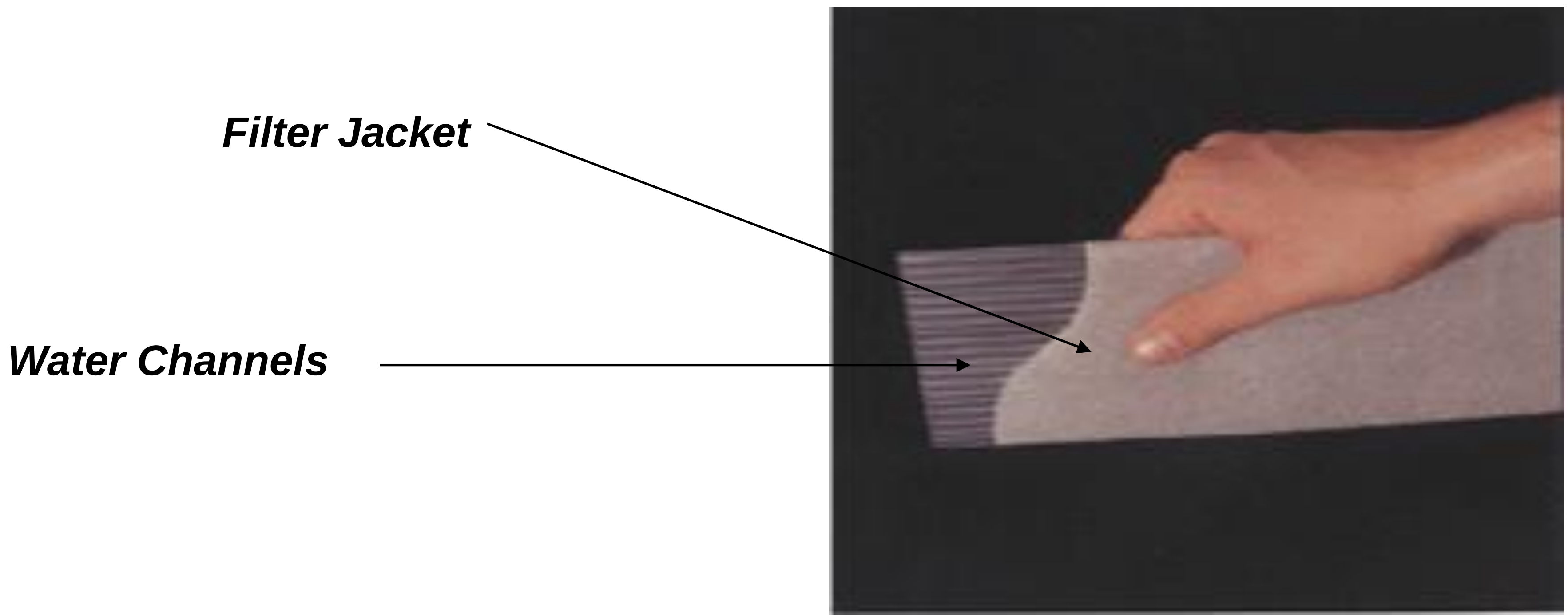
Core

- high quality flexible polypropylene

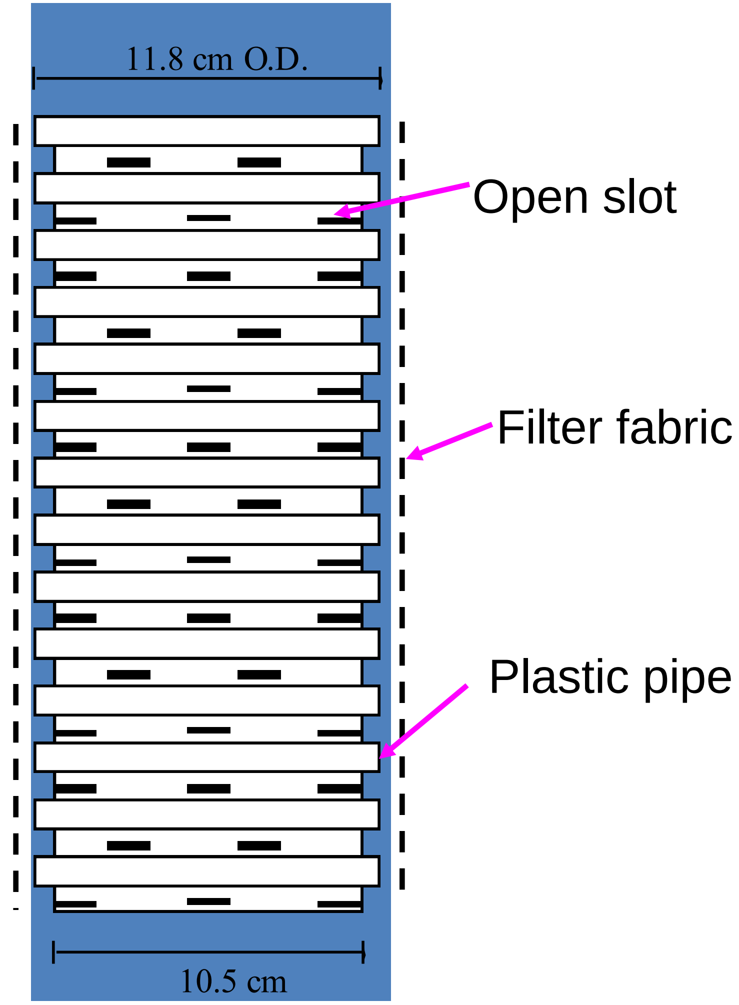
allows a large flow of water in the longitudinal direction via preformed water channels on both sides of the core.

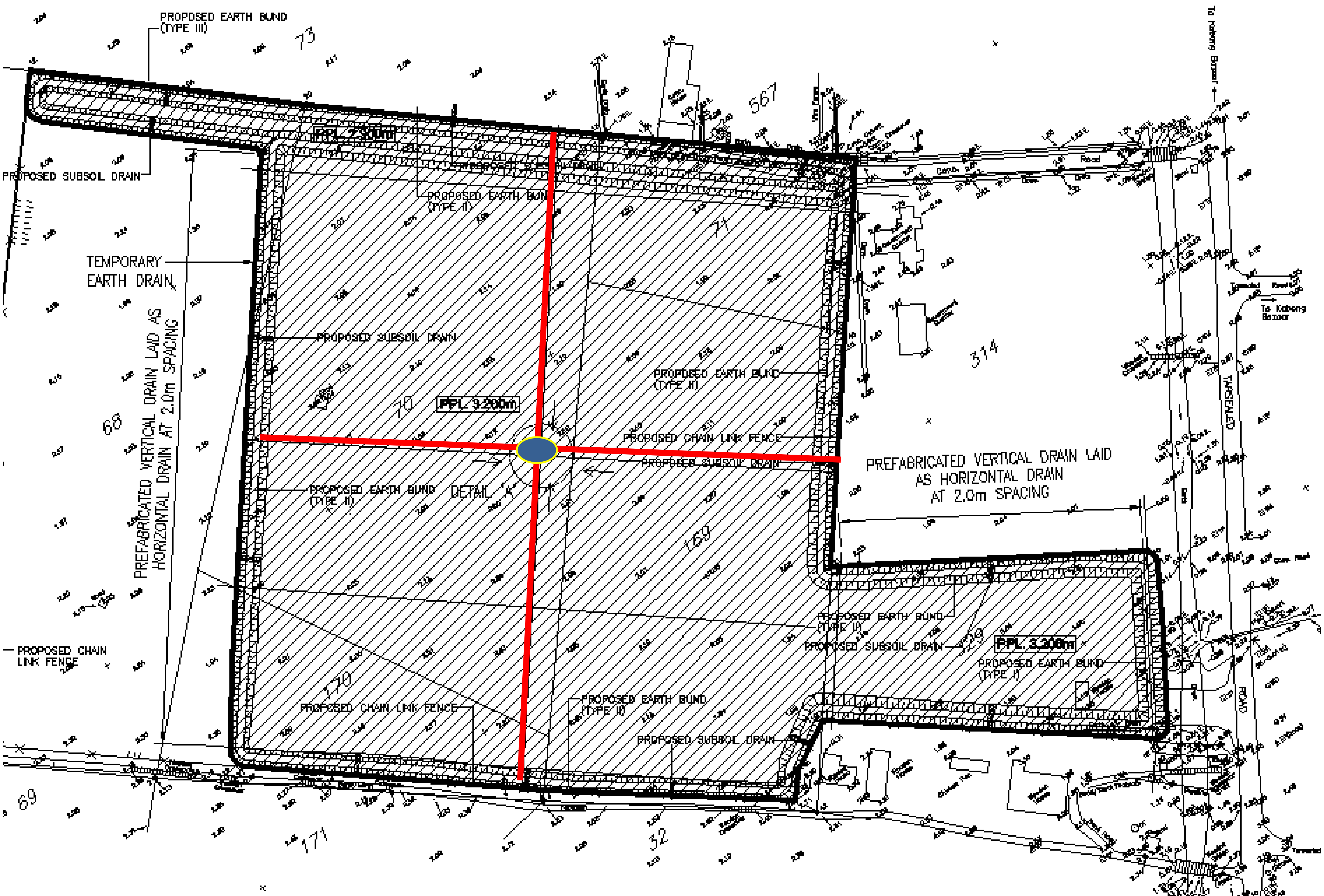
geotextile filter jacket

- tightly wrapped in a geotextile filter jacket to filter out the smaller soil particles, preventing the core from getting clogged.

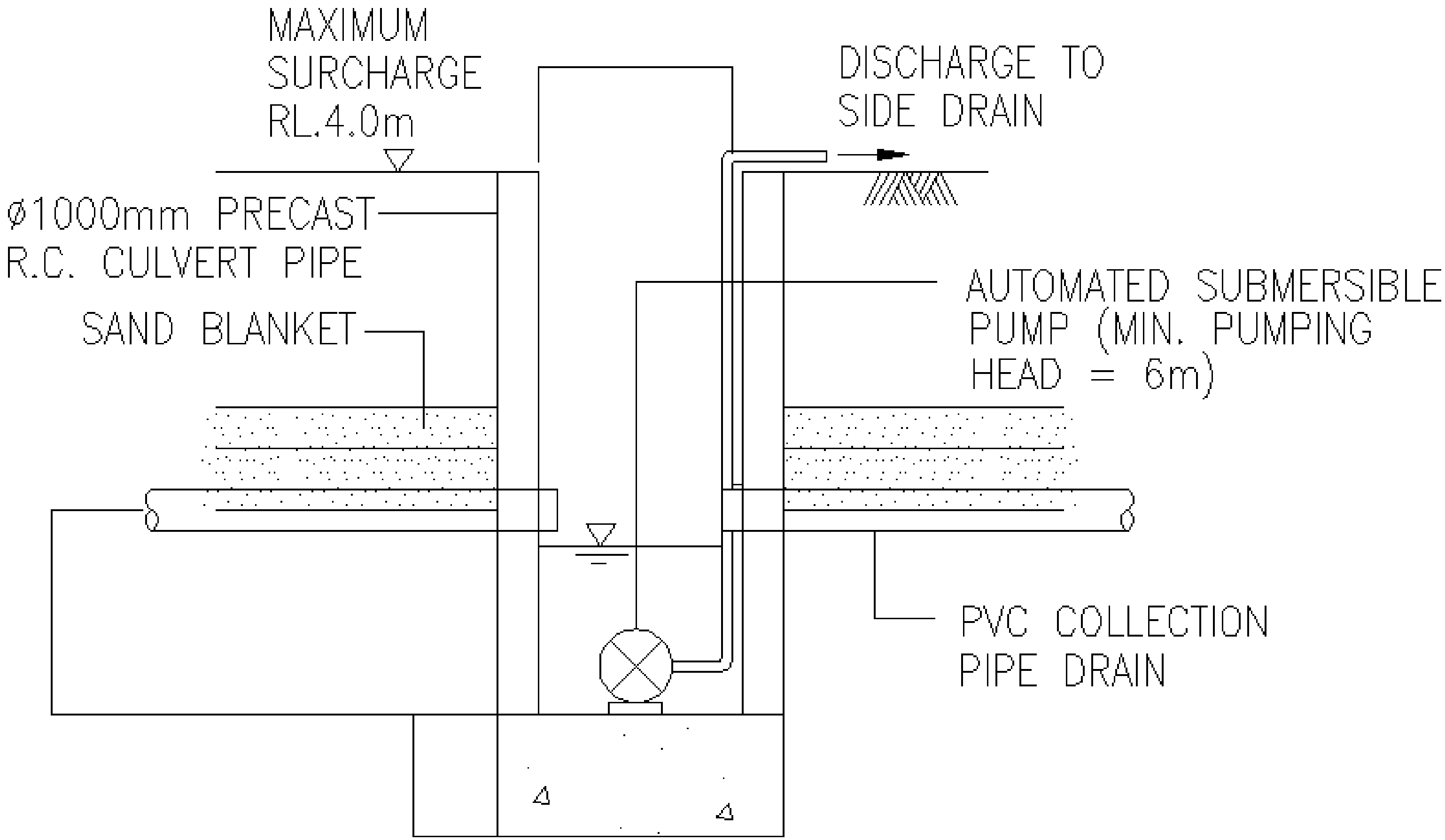


Prefabricated Drains





PROPOSED EARTH BUND
(TYPE III)
PROPOSED SUBSOIL DRAIN
TEMPORARY
EARTH DRAIN
PREFABRICATED VERTICAL DRAIN LAID AS
HORIZONTAL DRAIN AT 2.0m SPACING
PROPOSED EARTH BUND
(TYPE II)
PROPOSED SUBSOIL DRAIN
PPL 3.200m
PROPOSED EARTH BUND
(TYPE II)
PROPOSED CHAIN LINK FENCE
PROPOSED SUBSOIL DRAIN
PROPOSED EARTH BUND
(TYPE II)
DETAIL 'A'
PREFABRICATED VERTICAL DRAIN LAID
AS HORIZONTAL DRAIN
AT 2.0m SPACING
PROPOSED EARTH BUND
(TYPE II)
PROPOSED SUBSOIL DRAIN
PPL 3.200m
PROPOSED EARTH BUND
(TYPE II)
PROPOSED CHAIN
LINK FENCE
PROPOSED CHAIN LINK FENCE
PROPOSED EARTH BUND
(TYPE II)
PROPOSED SUBSOIL DRAIN
To Kabong
Bazaar



DETAIL 'A'

TEMPORARY DRAINAGE SUMP

Geotextile
BASAL REINFORCEMENT

Basal Reinforcement

- To enhance embankment stability against failure
- Strength will deteriorate when exposed to sunlight
- The primary direction (MD) shall be perpendicular to the proposed track
- Geotextile WHOLE LENGTH across the embankment SHALL BE ONE PIECE (DO NOT ALLOW JOINTS)
- Design strength = 0.5 x ultimate strength

TENCATE
Polyfelt

QUALITY
ISO/IEC 17025
Accredited
Laboratory
GAI-LAP-45-02
SAMM NO. 207
ASSURED

Polyfelt WX Reinforcing Geotextile

Properties of Polyfelt WX Reinforcing Geotextile

Property		Unit	WX 100/50	WX 200/50	WX 300/50	WX 400/50	WX 600/50	WX 800/100
Characteristic short term tensile strength	MD	kN/m	100	200	300	400	600	800
Characteristic short term tensile strength	CD	kN/m	50	50	50	50	50	100
ISO 10319, ASTM D4595, AS 3706.2								
Strain at short term strength	MD	%	10	10	10	10	10	10

$$T_d = \frac{T_c}{f_c . f_d . f_e . f_m}$$

where,

T_d is the long term design strength of the reinforcement at the required design life,

T_c is the characteristic short term tensile strength of the reinforcement,

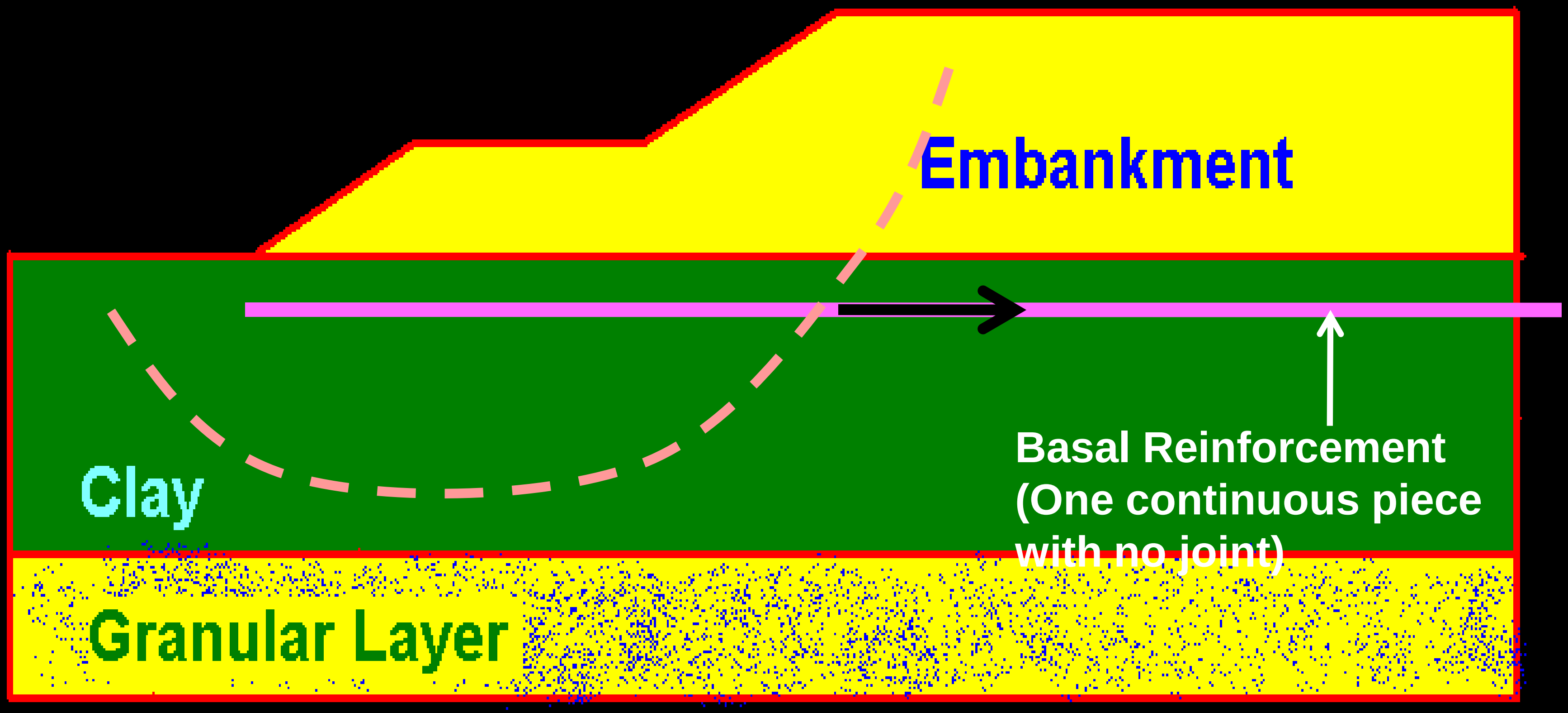
f_c is the partial factor relating to creep effects over the required design life of the reinforcement,

f_d is the partial factor relating to the installation damage of the reinforcement,

f_e is the partial factor relating to environmental effects on the reinforcement,

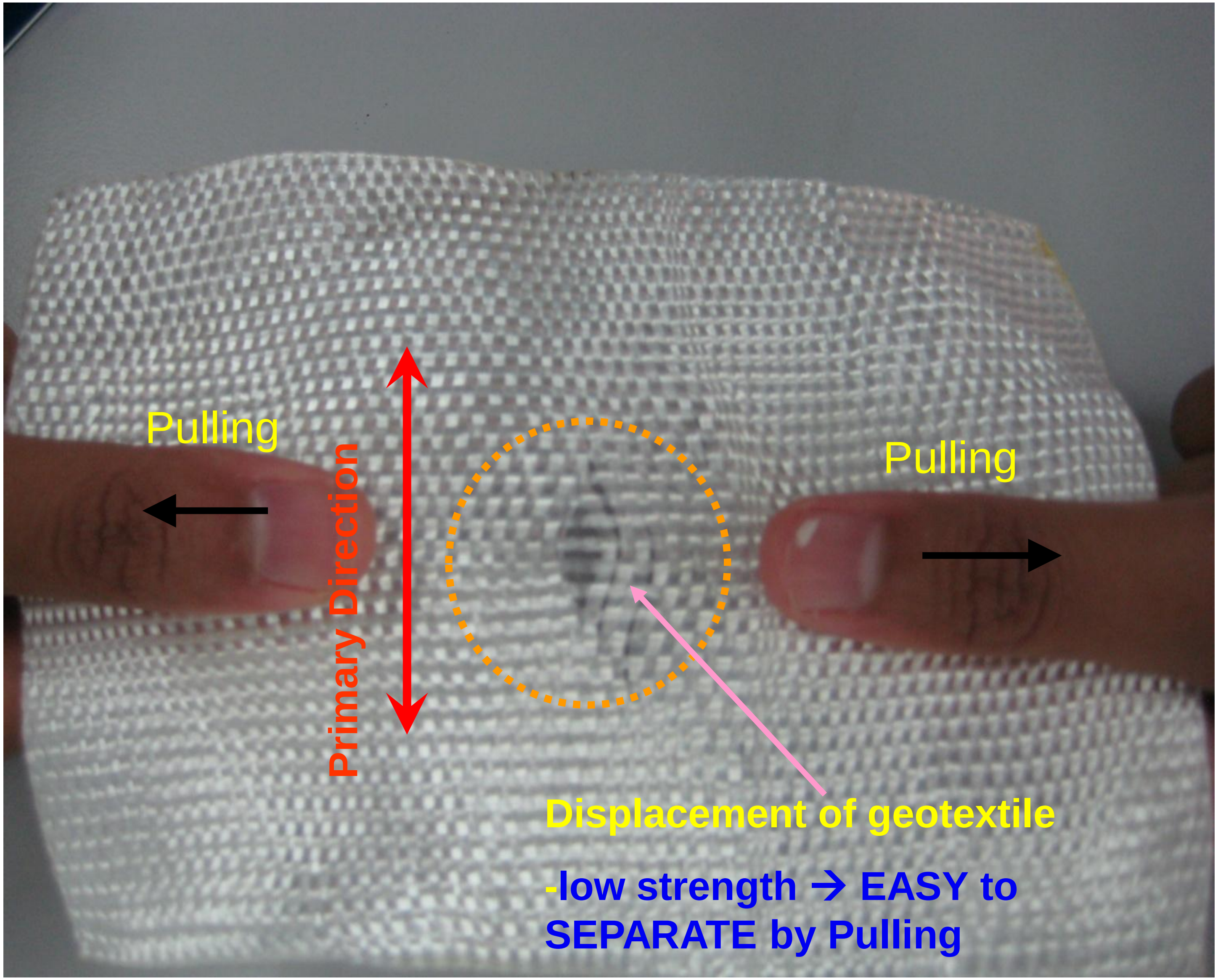
f_m is the partial factor relating to consistency of manufacture of the reinforcement.

Basal Reinforcement

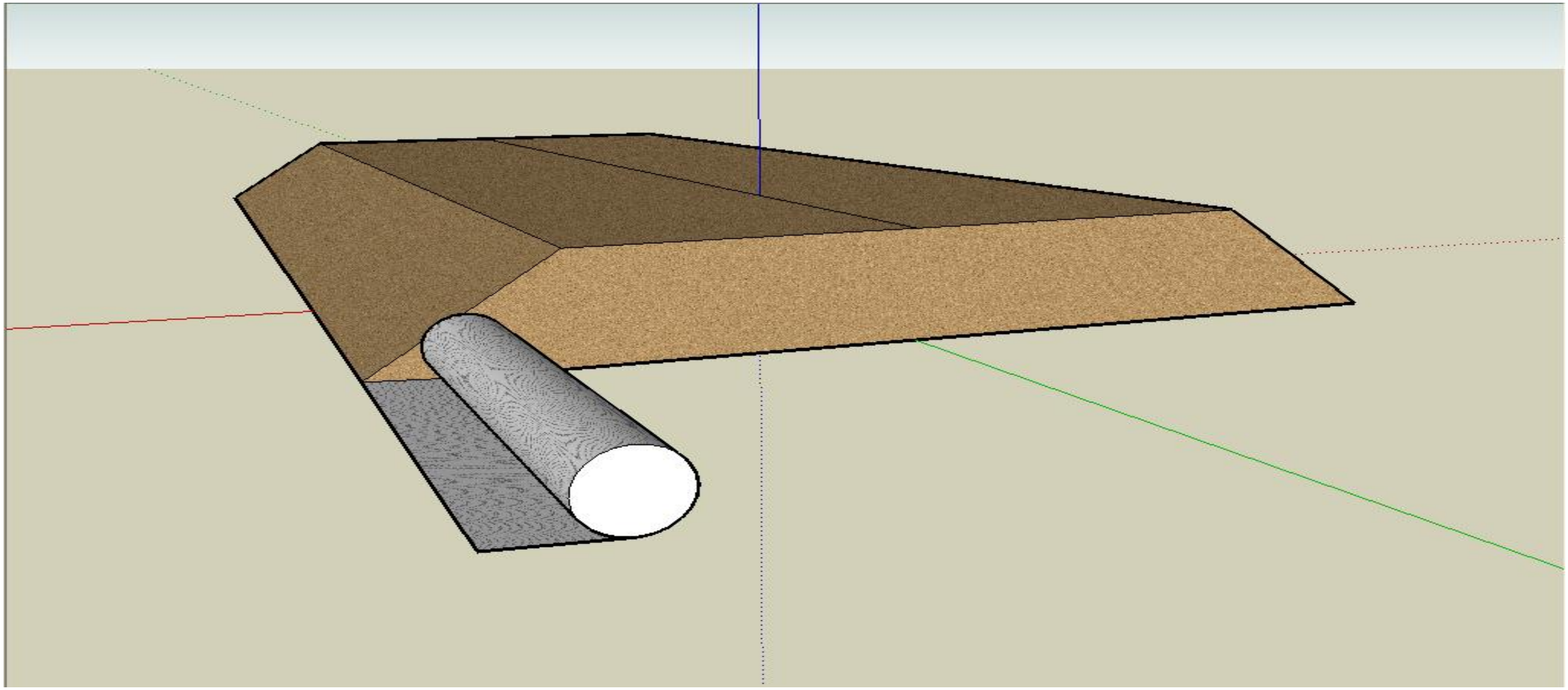


Basal Reinforcement

Basal Reinforcement



Step 1 – Lay basal reinforcement



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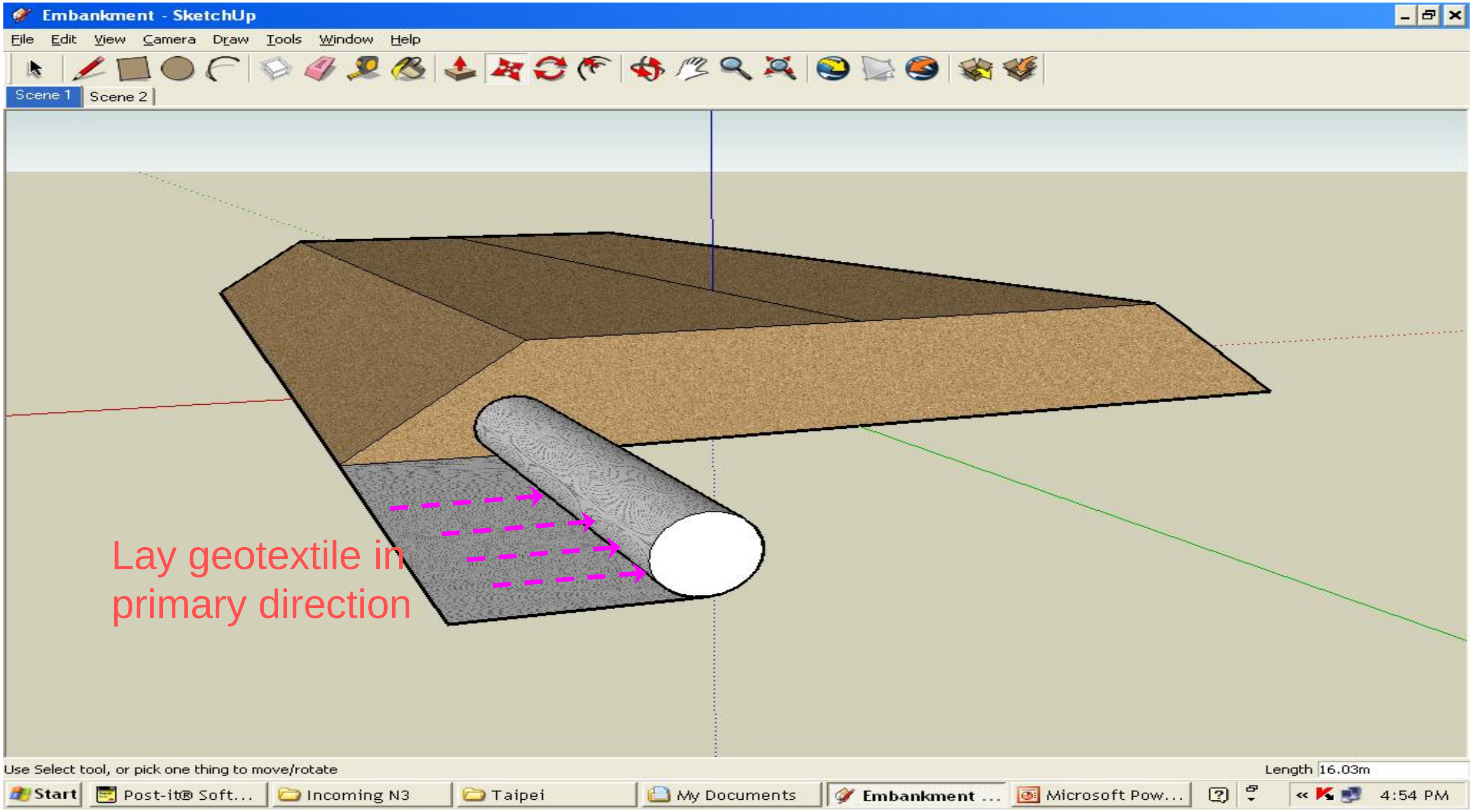

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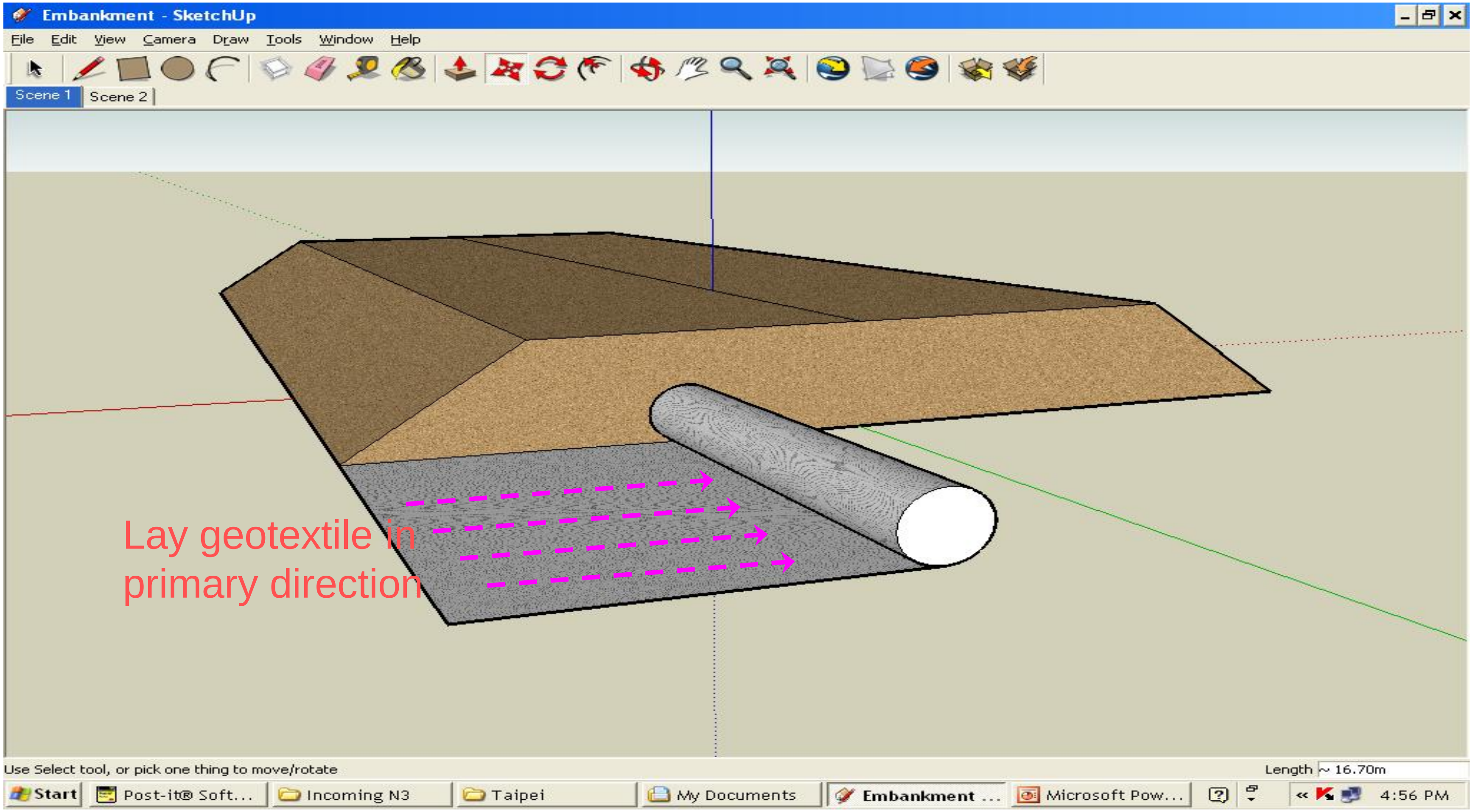

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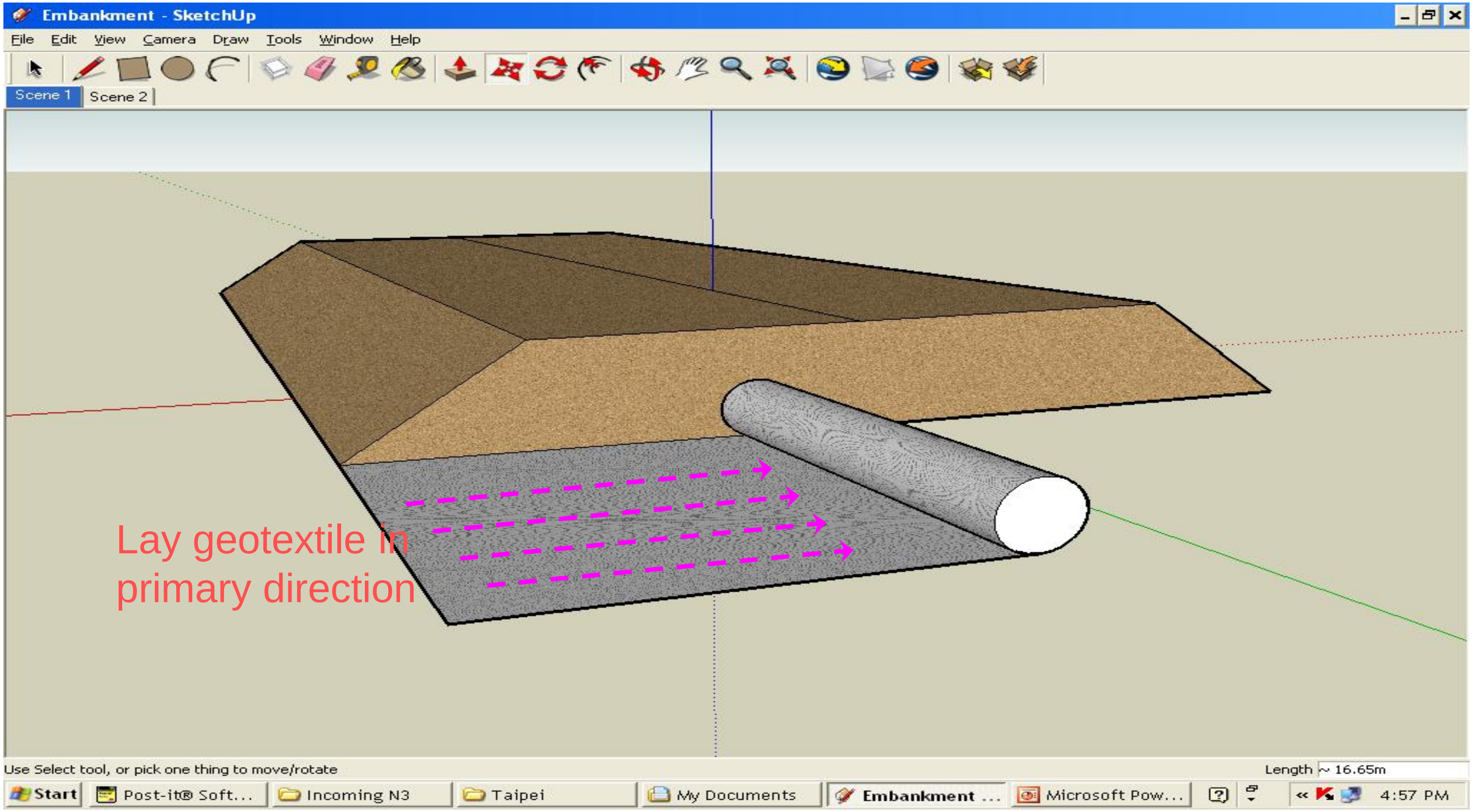

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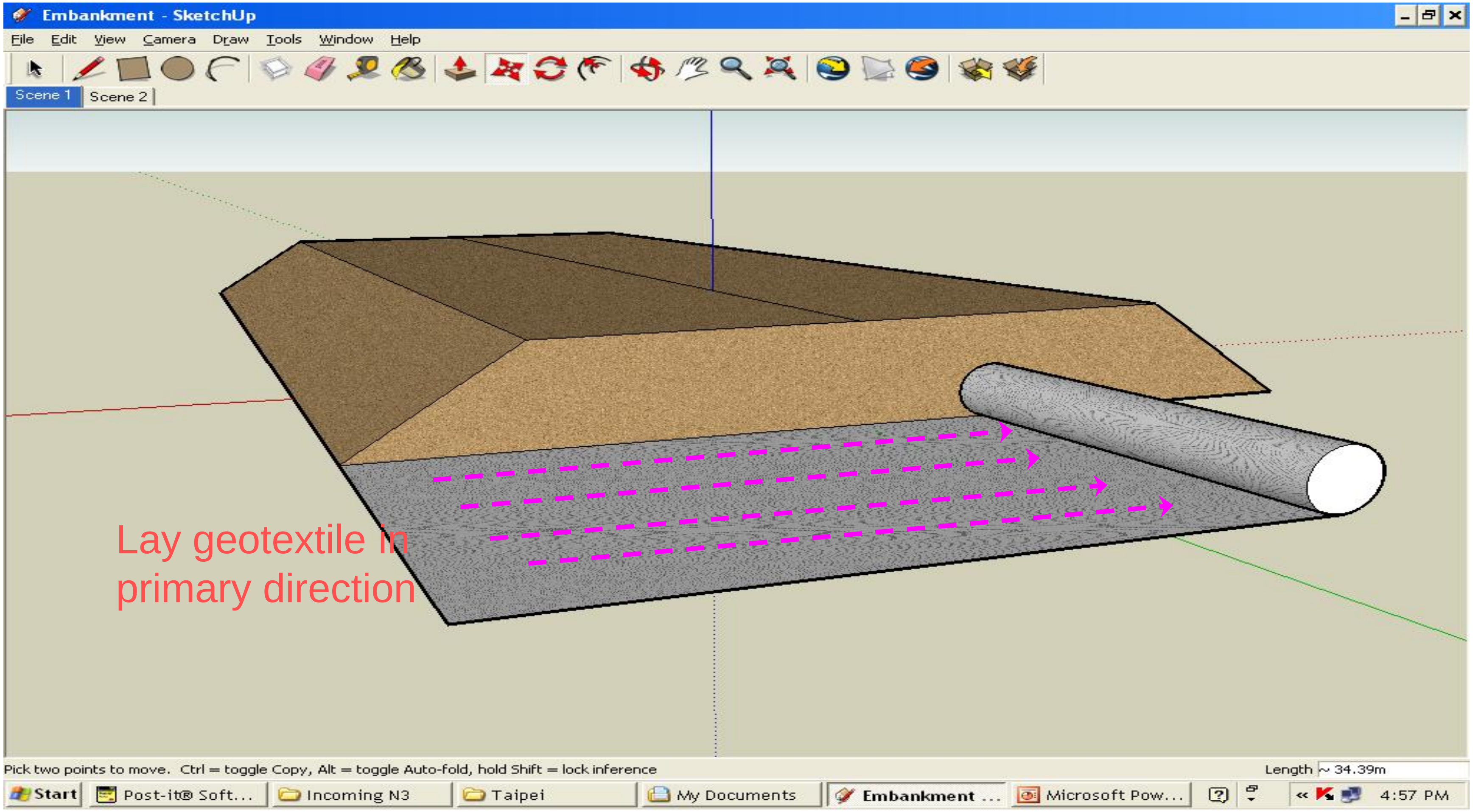

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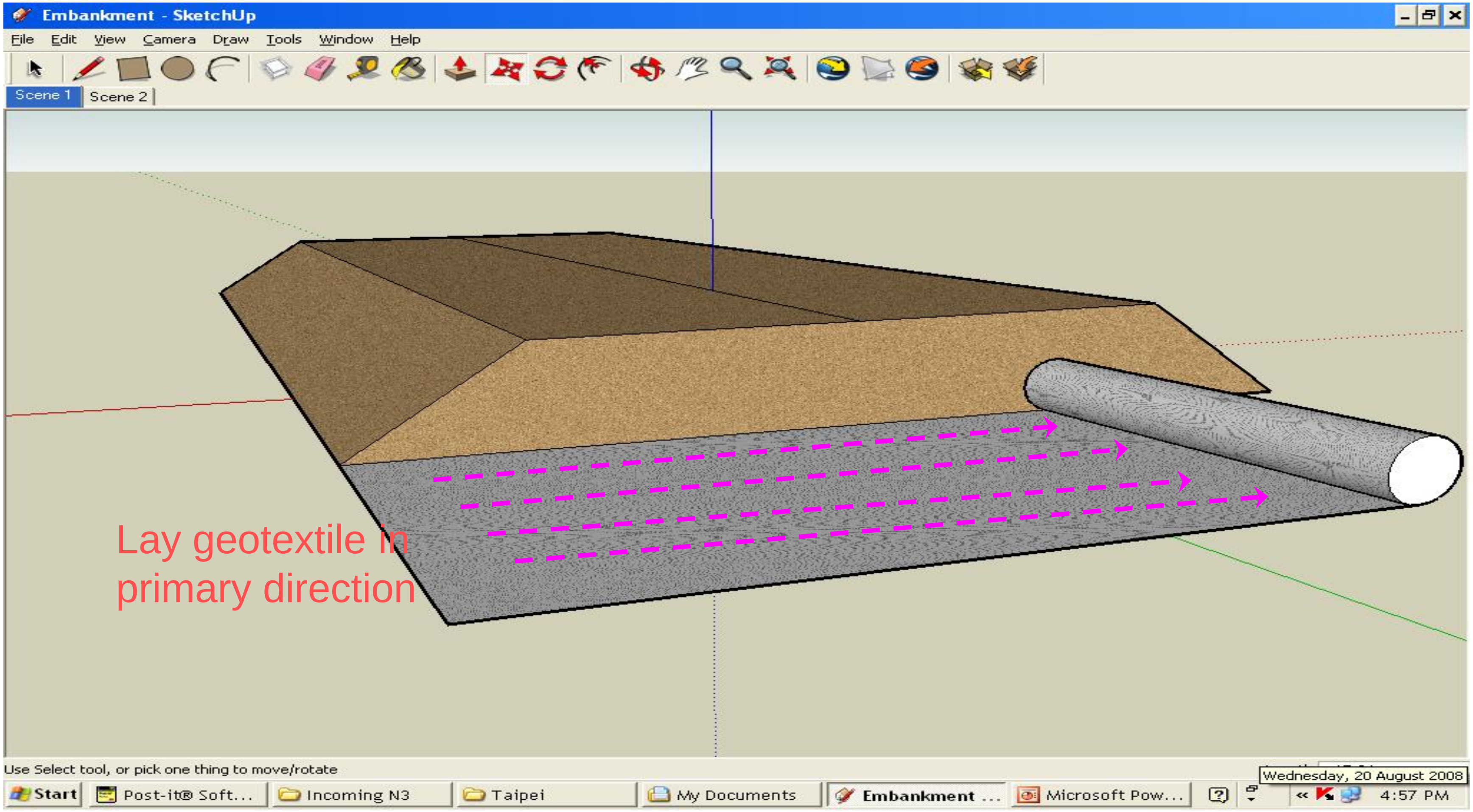
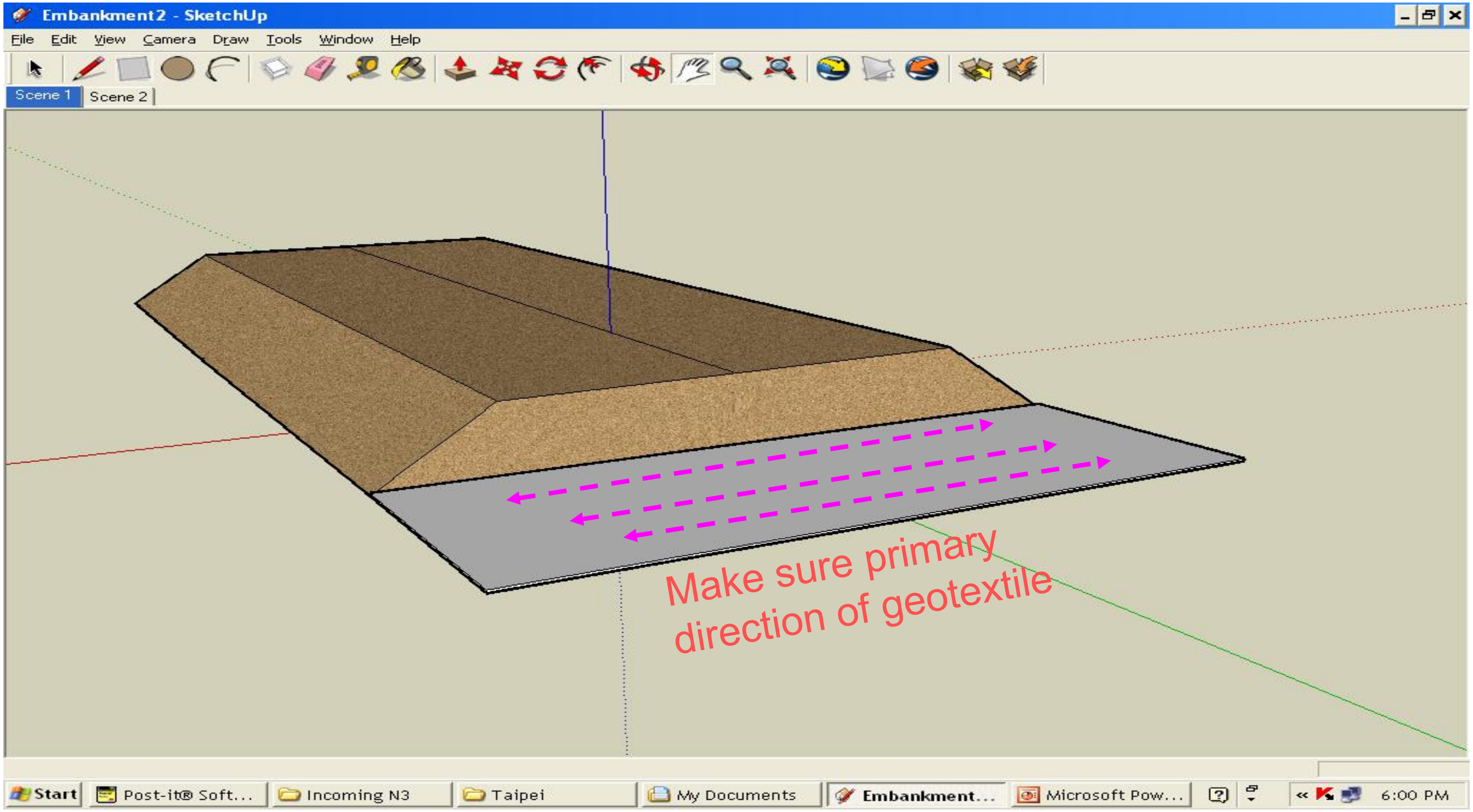
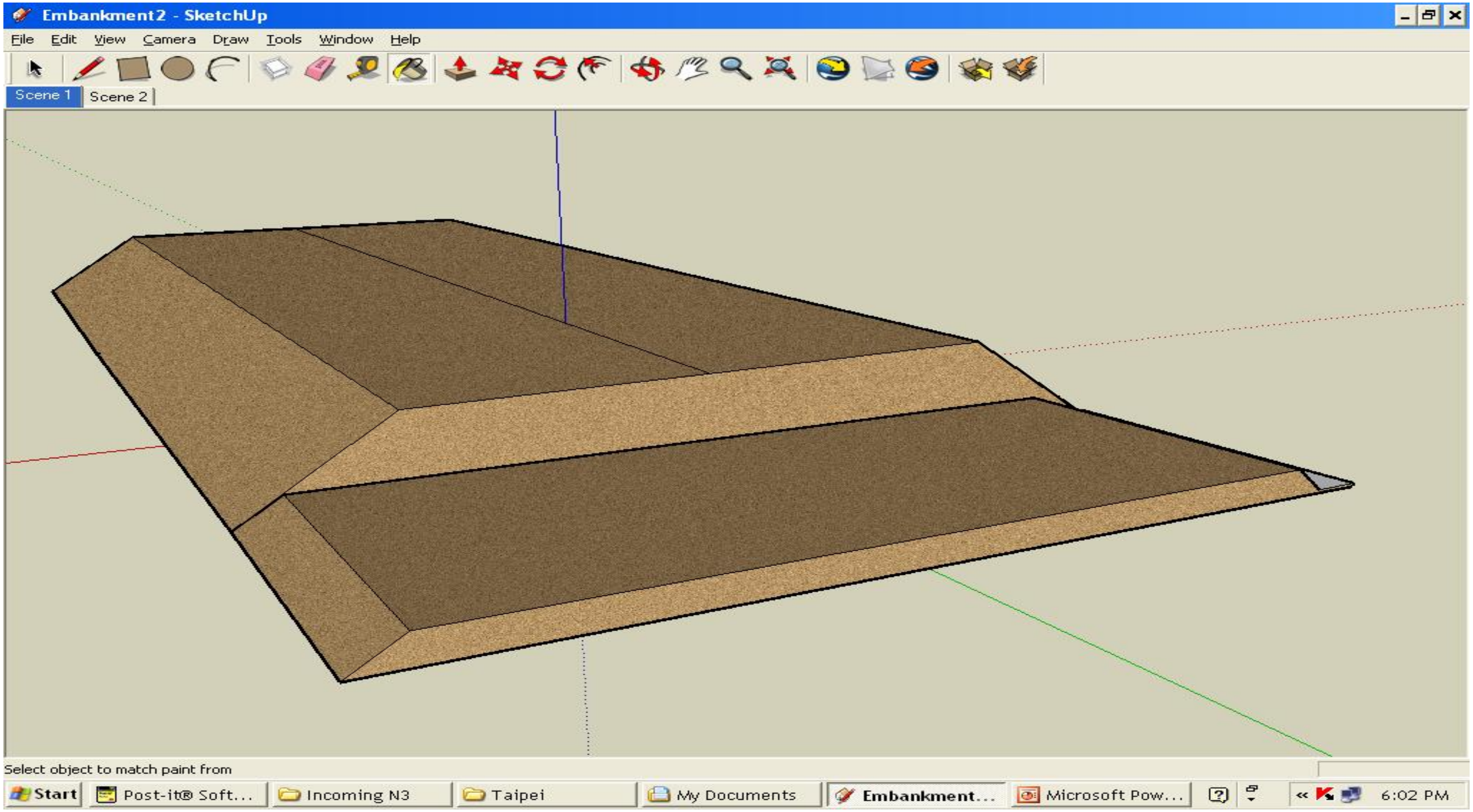


Step 1 – Finished lay basal reinforcement



Step 2 –Fill with appropriate material and proper compaction



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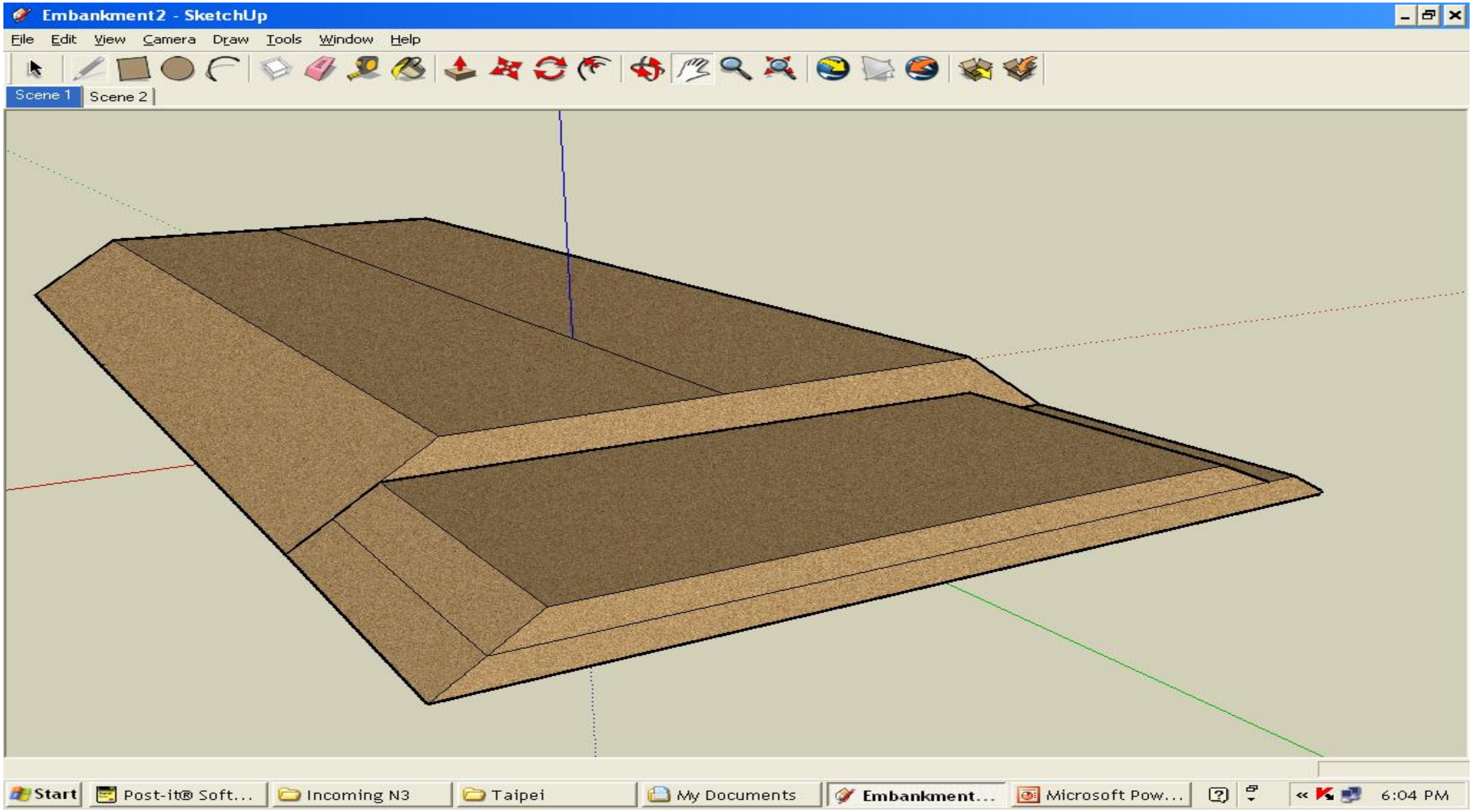

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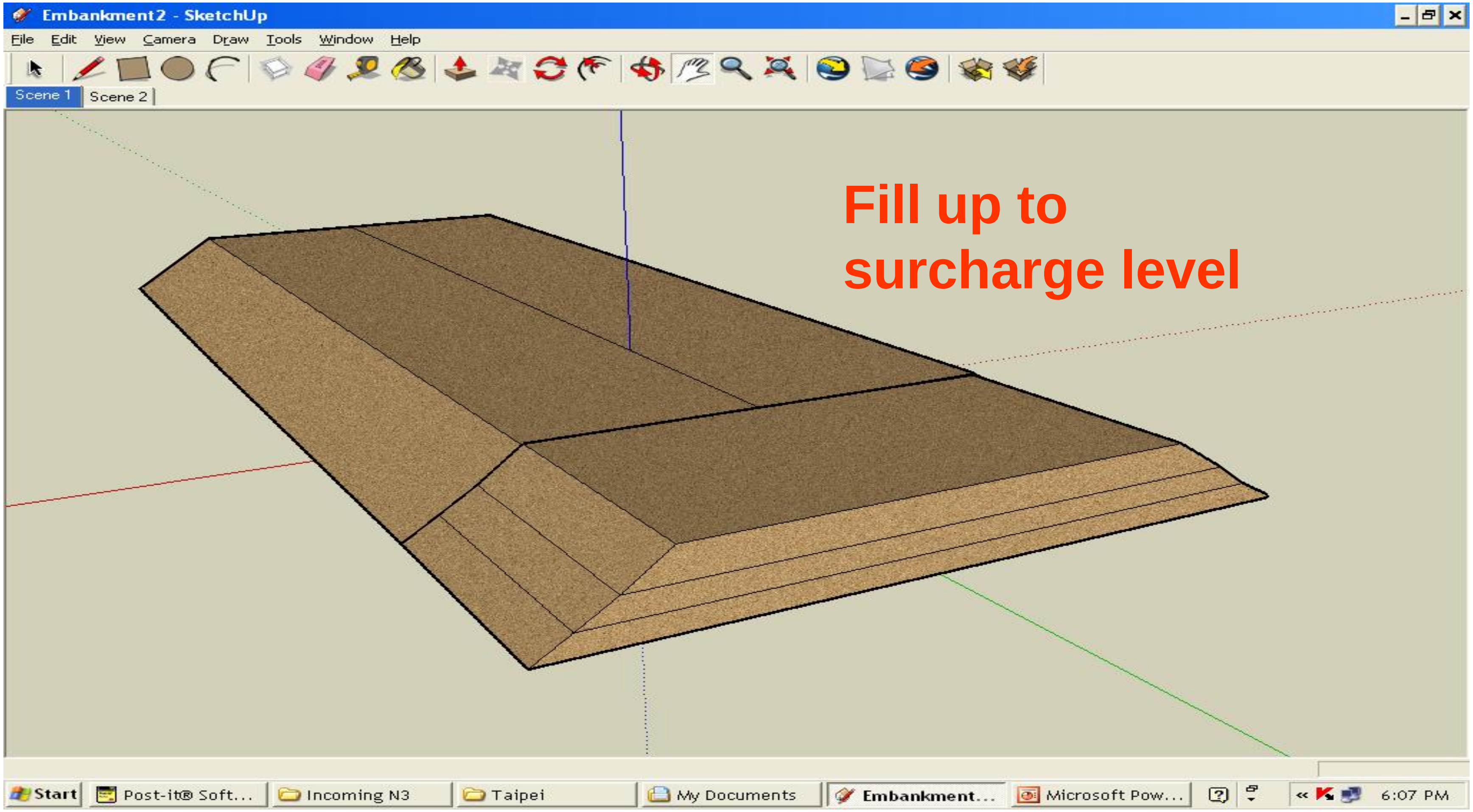
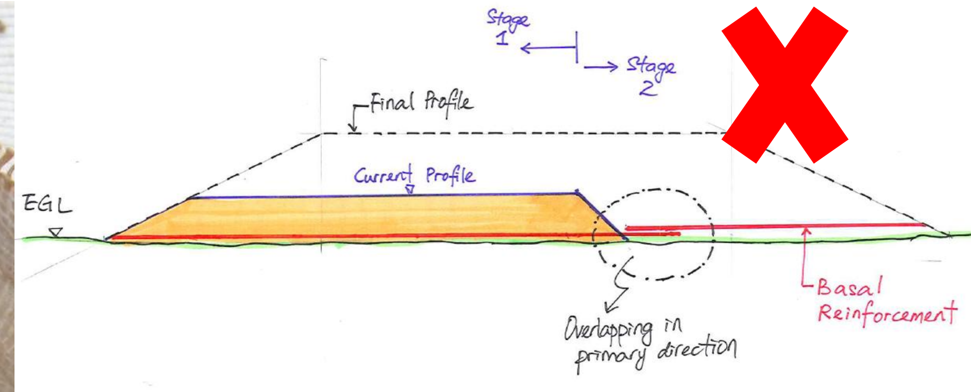
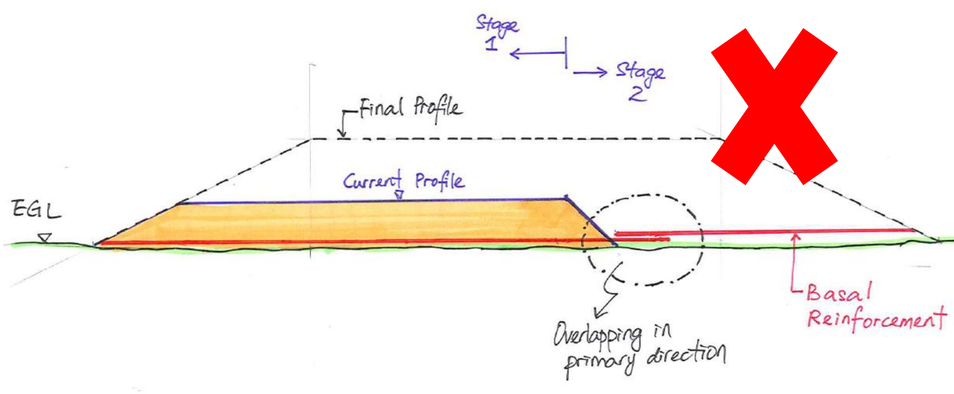




WRONG !!!!

Basal reinforcement SHALL NOT be connected by stitching in Primary Direction.



WRONG !!!!

Basal reinforcement <u>SHALL NOT</u> be connected by stitching in Primary Direction.

Good Practice (proper cover)

- GOOD !
- Proper storage of basal reinforcement – covered with plastic sheet

BAD Practice (No proper cover)

- BAD !!!
- Improper storage of basal reinforcement and the basal reinforcement also exposed to sunlight prior to installation
- Cause loss of Strength (BAD)

A layer of basal reinforcement with strength of 400kN/m

2 layers of basal reinforcement with strength of 200kN/m

200kN/m + 200kN/m = 400kN/m????

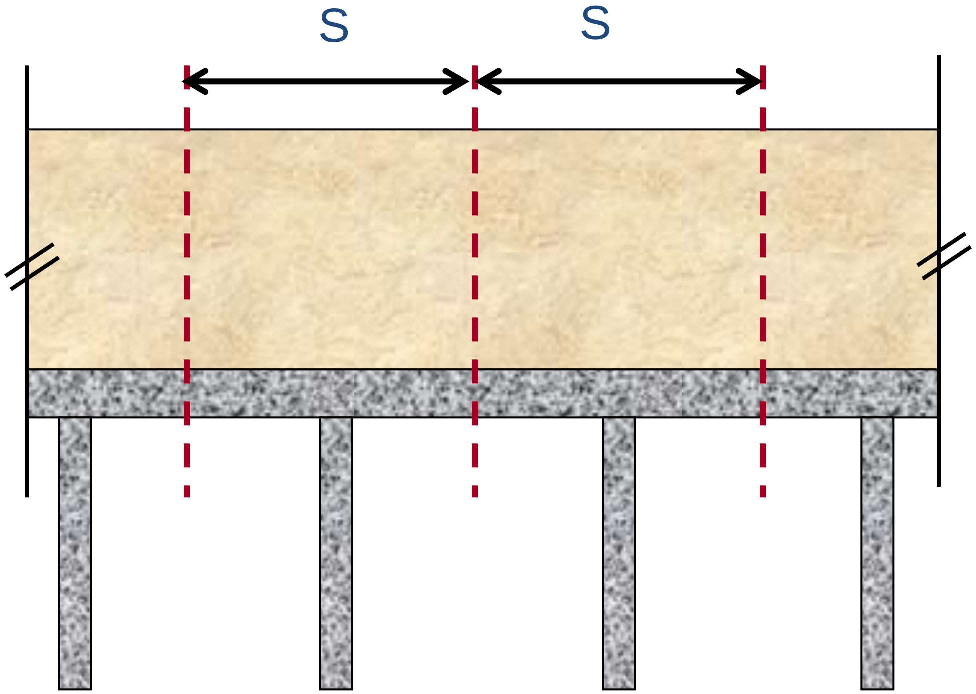
Piled Embankment

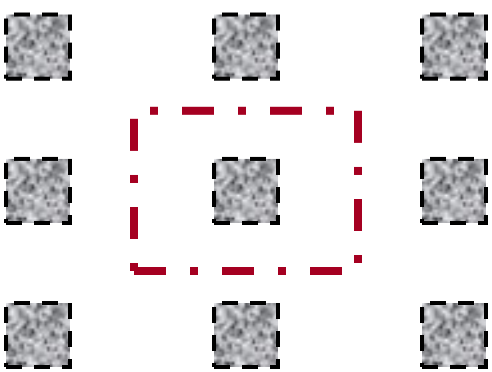
Piled Embankment

- Design philosophy

  - Design as a type of ground treatment works

- Embankment filling can be fast.

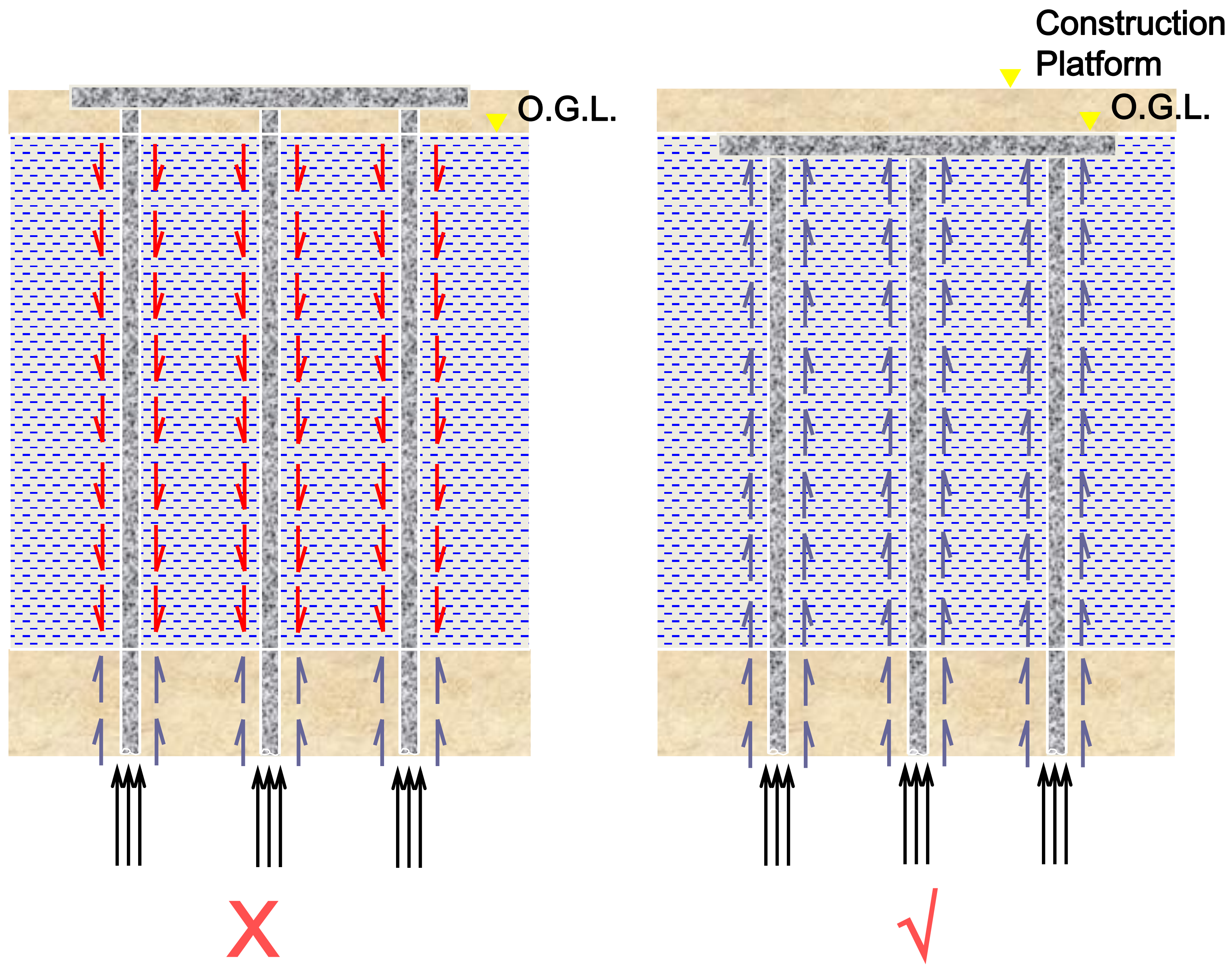




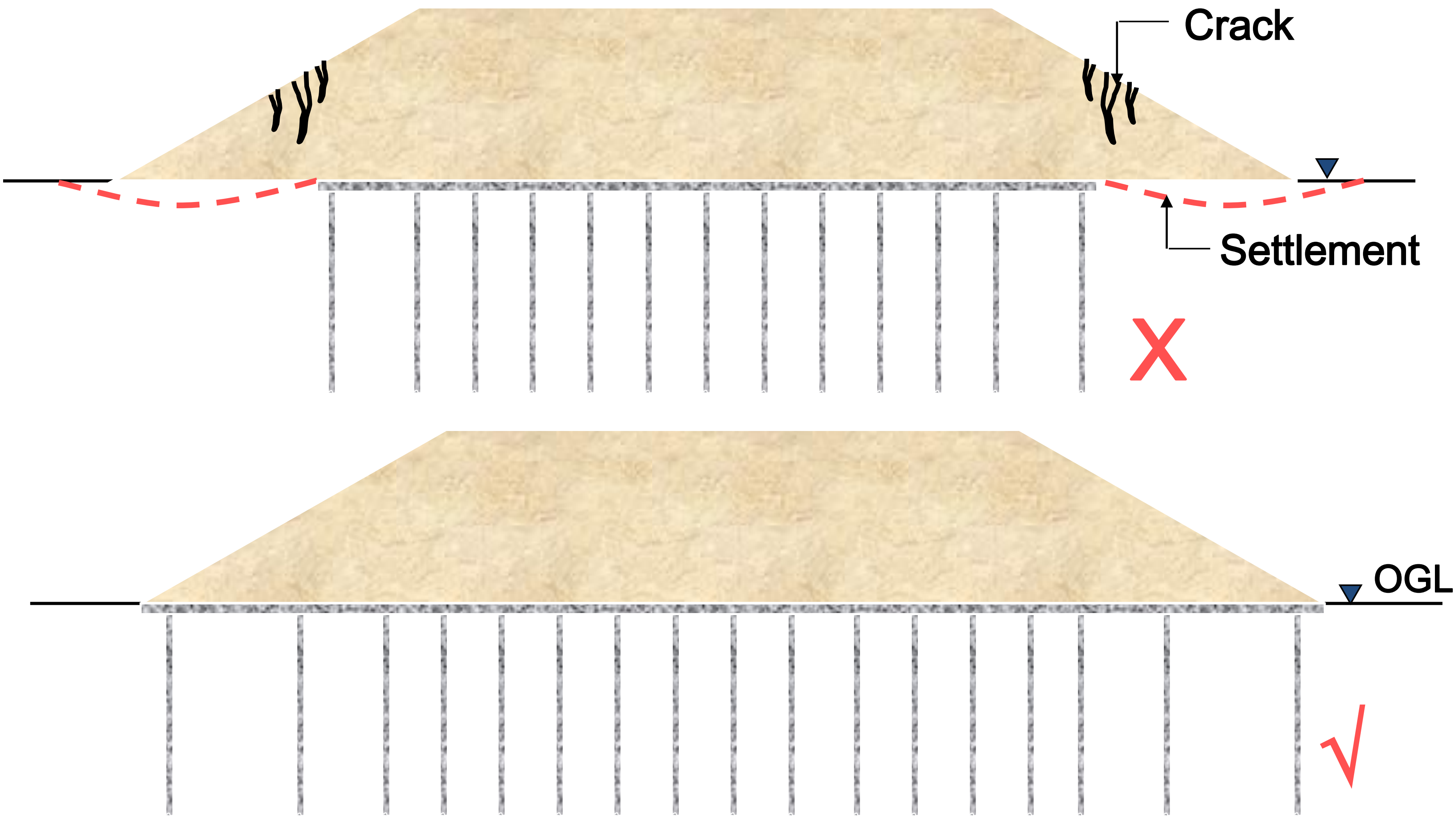
Plan View

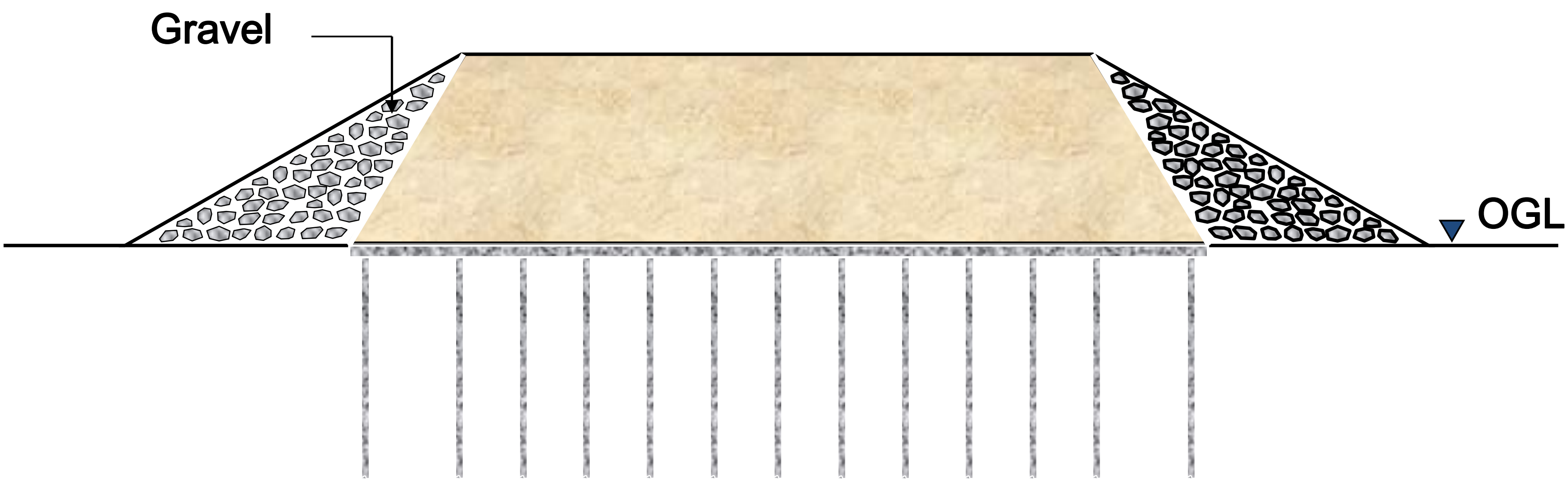
$$S^2 = \frac{\text{Pile Capacity}}{(\text{Fill Weight} + \text{Surcharge} + \text{Slab Self Weight})}$$

Things to Take Care in Piled Embankment Design



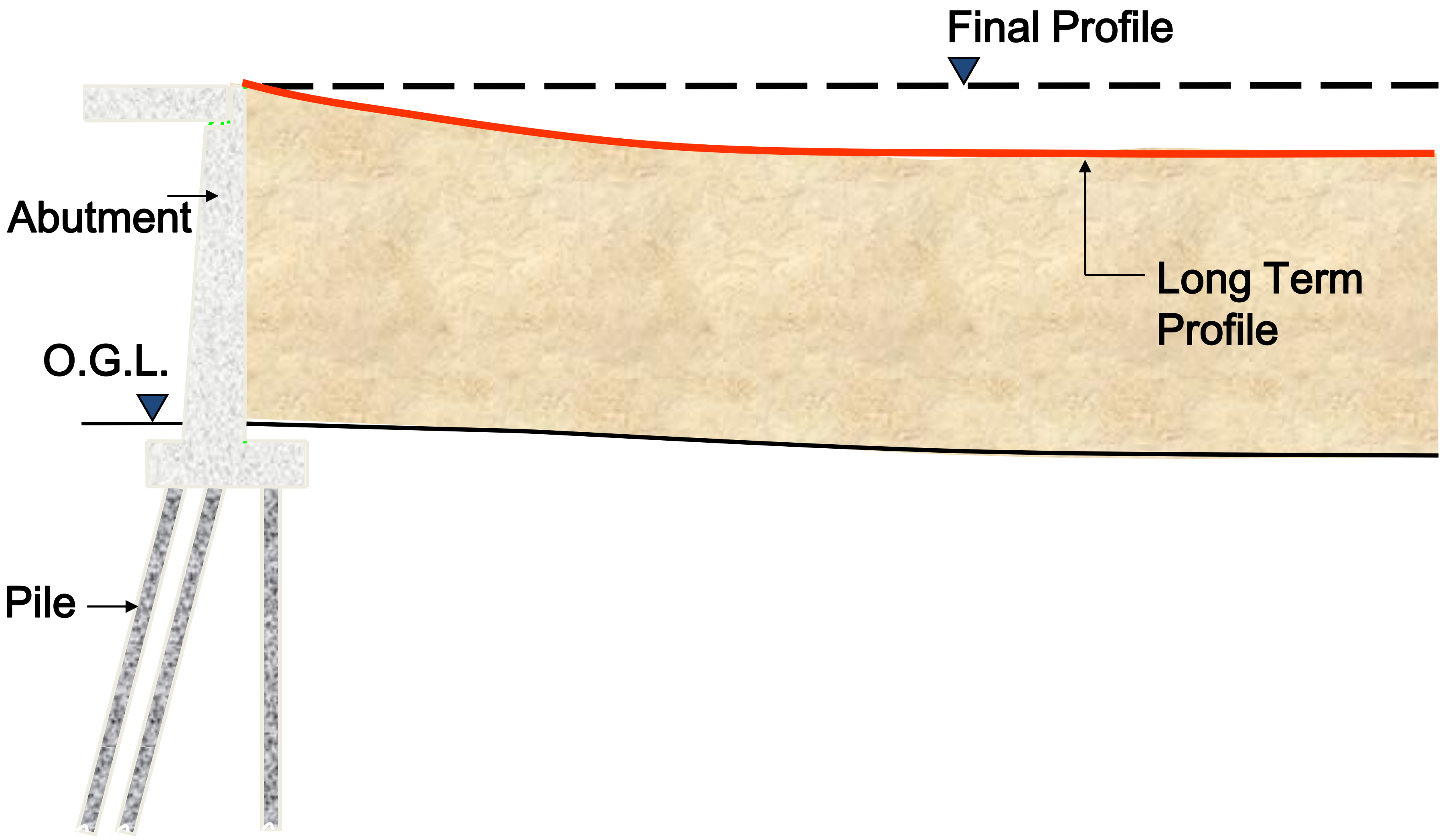
O.G.L.
Construction
Platform
O.G.L.
X
√


Crack
Settlement
X
OGL
√

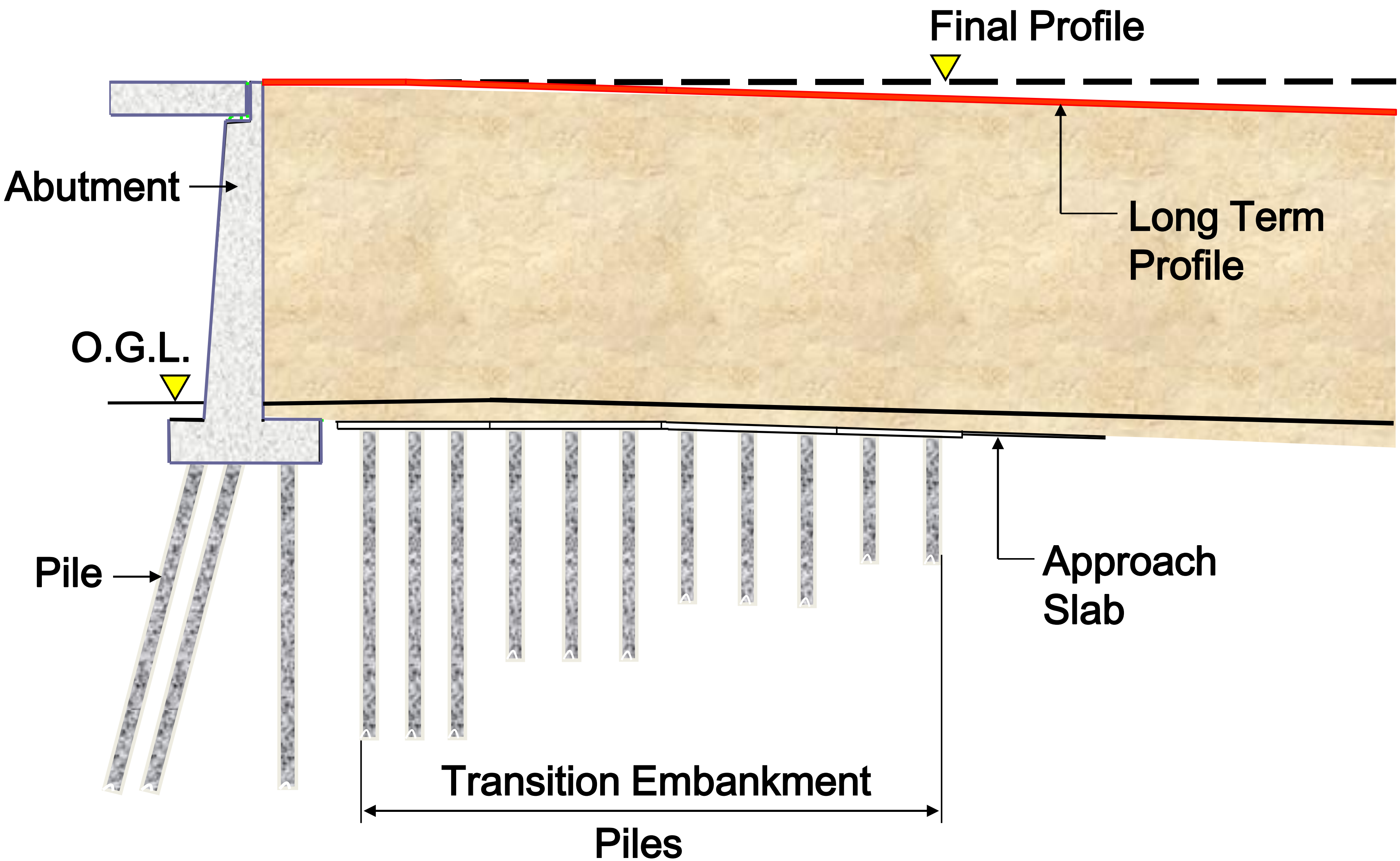

Gravel
OGL

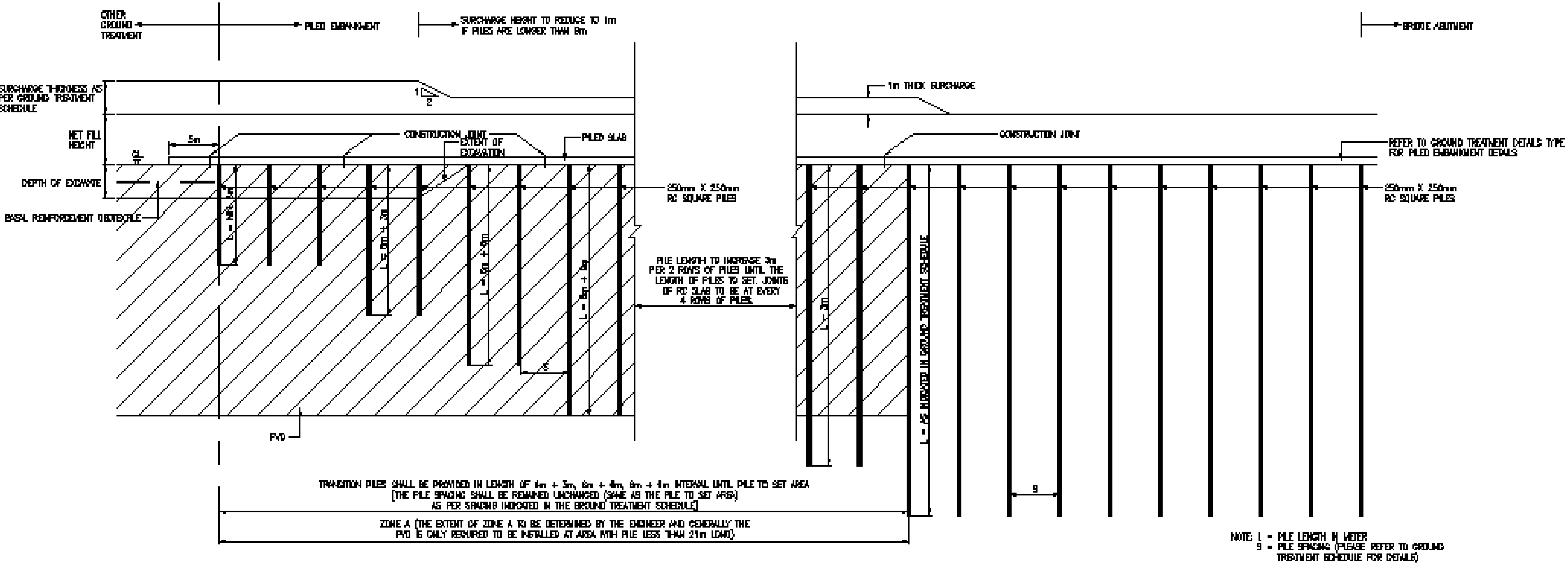
Must do proper curing → ALWAYS WET (with WATER)

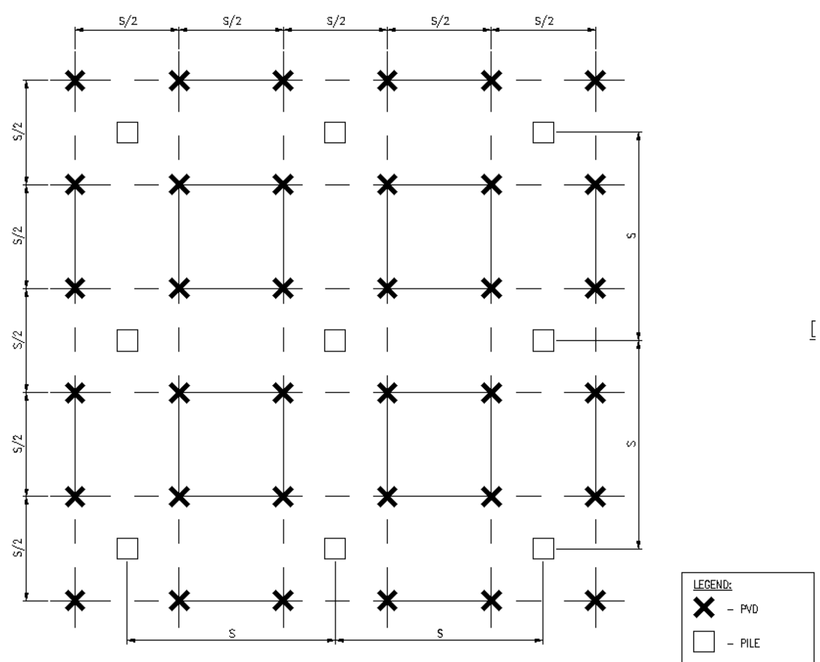
“spot-curing” of concrete slab



Final Profile
Abutment
Long Term
Profile
O.G.L.
Pile


Final Profile
Abutment
Long Term
Profile
O.G.L.
Pile
Approach
Slab
Transition Embankment
Piles





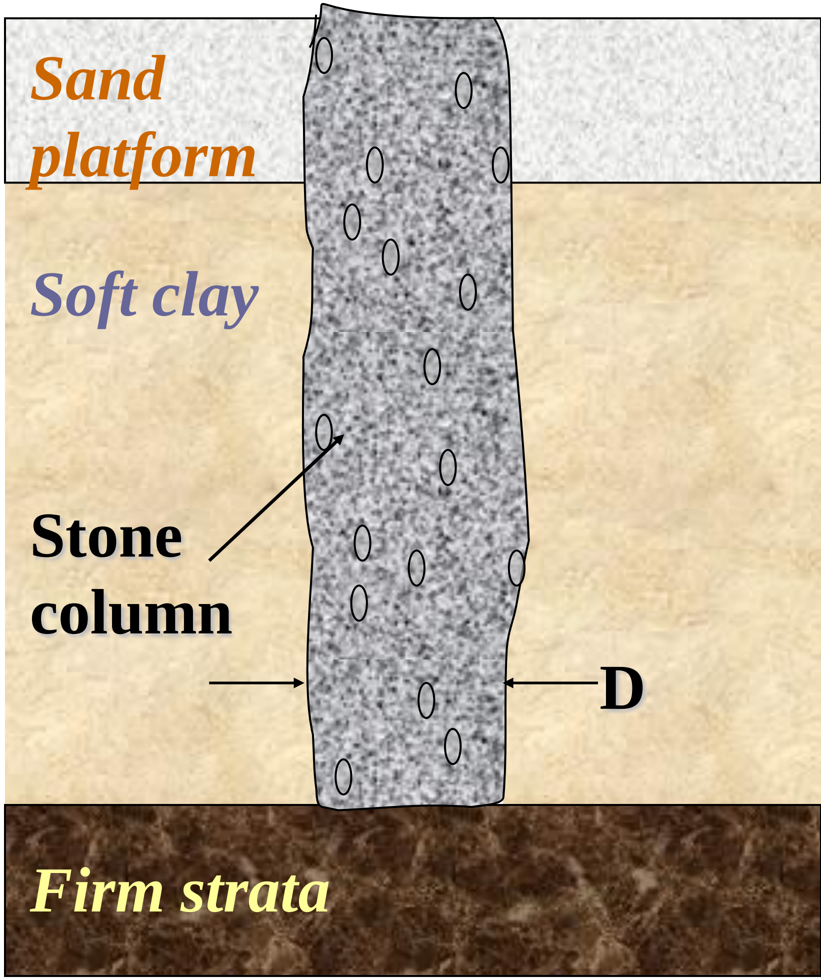
PLAN VIEW OF PVD AND PILE ARRANGEMENT AT ZONE A

Stone Column

Stone Column

The Principle

- Stone Columns
  = Granular Pile
  = Vibro Replacement
- Involves partial replacement of unsuitable subsoil with compacted column of stones or aggregates



- Usually completely penetrates the weak strata

Stone Column

Function

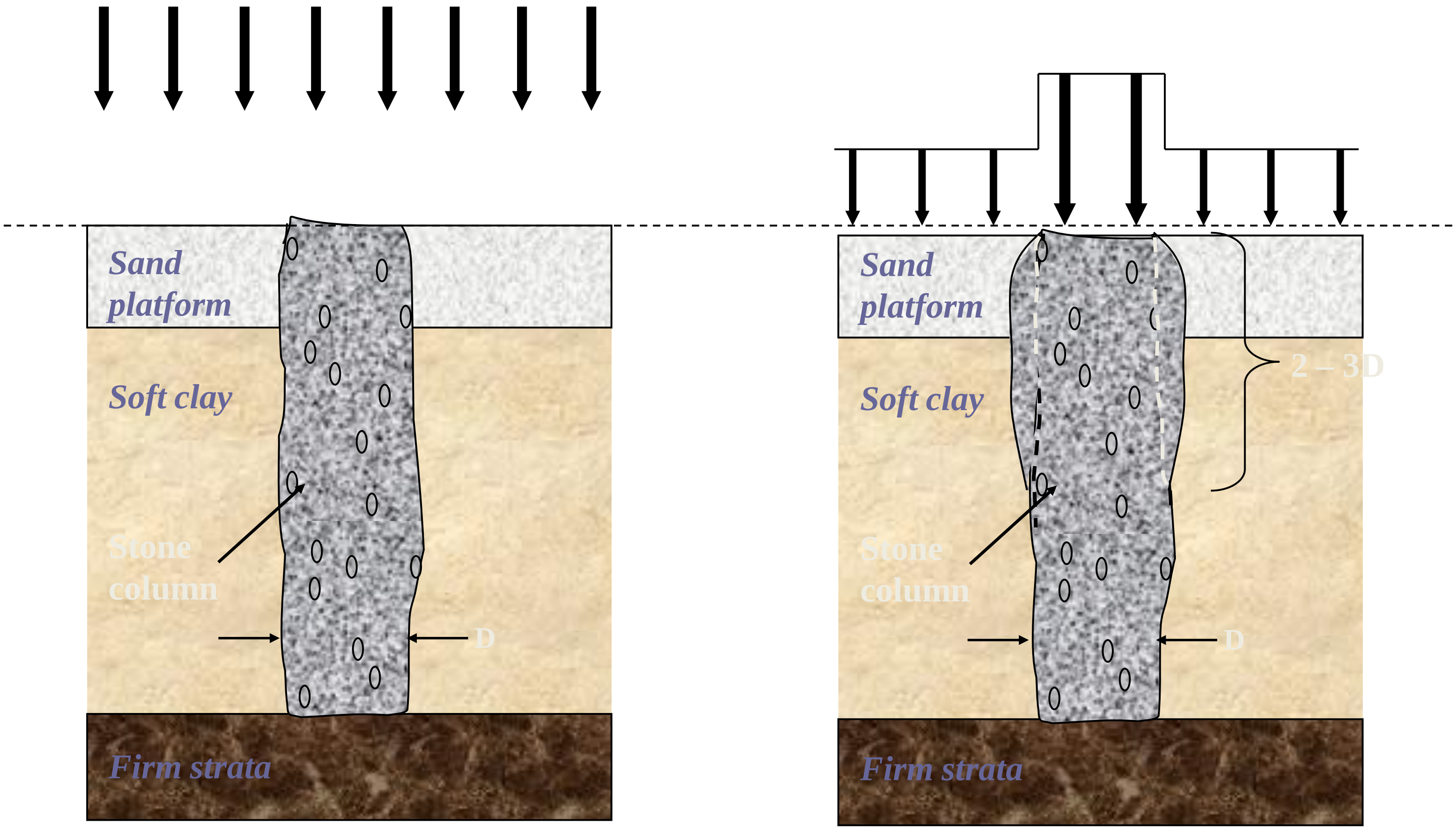
- Provide bearing capacity / strengthening immediately upon installation
- Reduce settlement
- Increase the rate of consolidation
- Facilitate subsoil drainage

- Diameter: 0.8m - 1.2m, most common is 1.0m

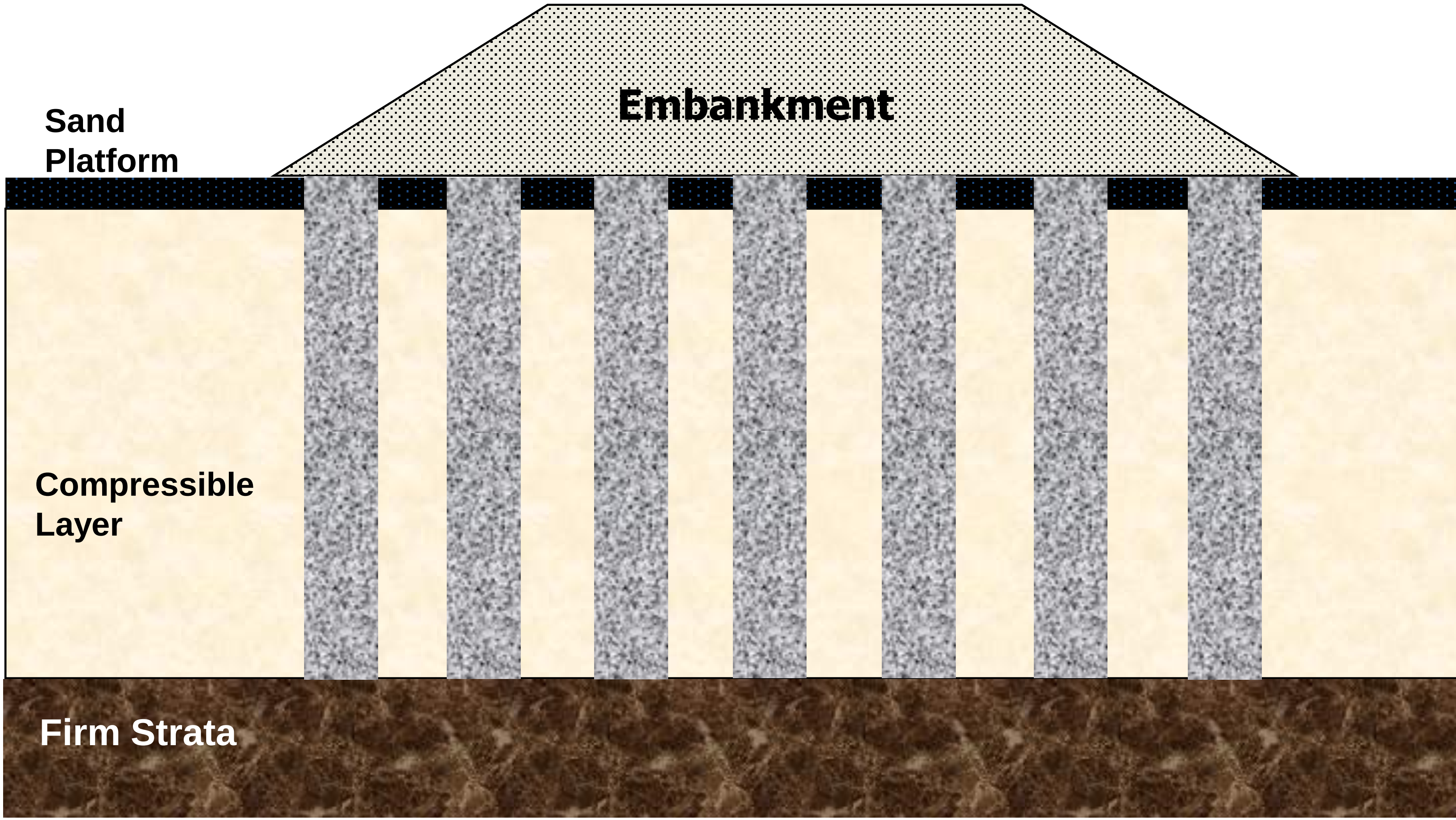
Stone columns

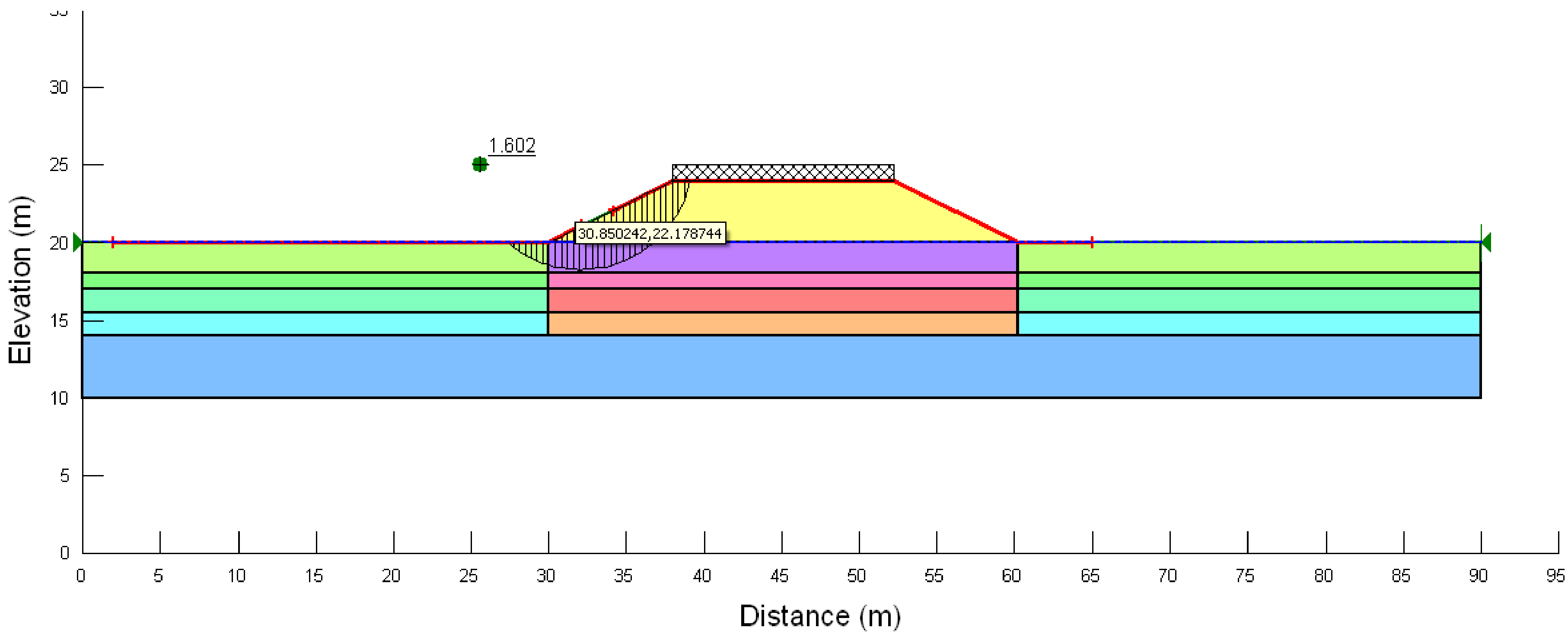
- To model as composite soil
- Not suitable for undrained shear strength less than 10kPa
- Adequate fill height is required to prevent “mushroom” effect = large differential settlement ➔ <u>more than 2.5m high</u>
- Availability of aggregate
- Filling speed must be controlled
  to prevent Failure

MECHANISM OF STONE COLUMN



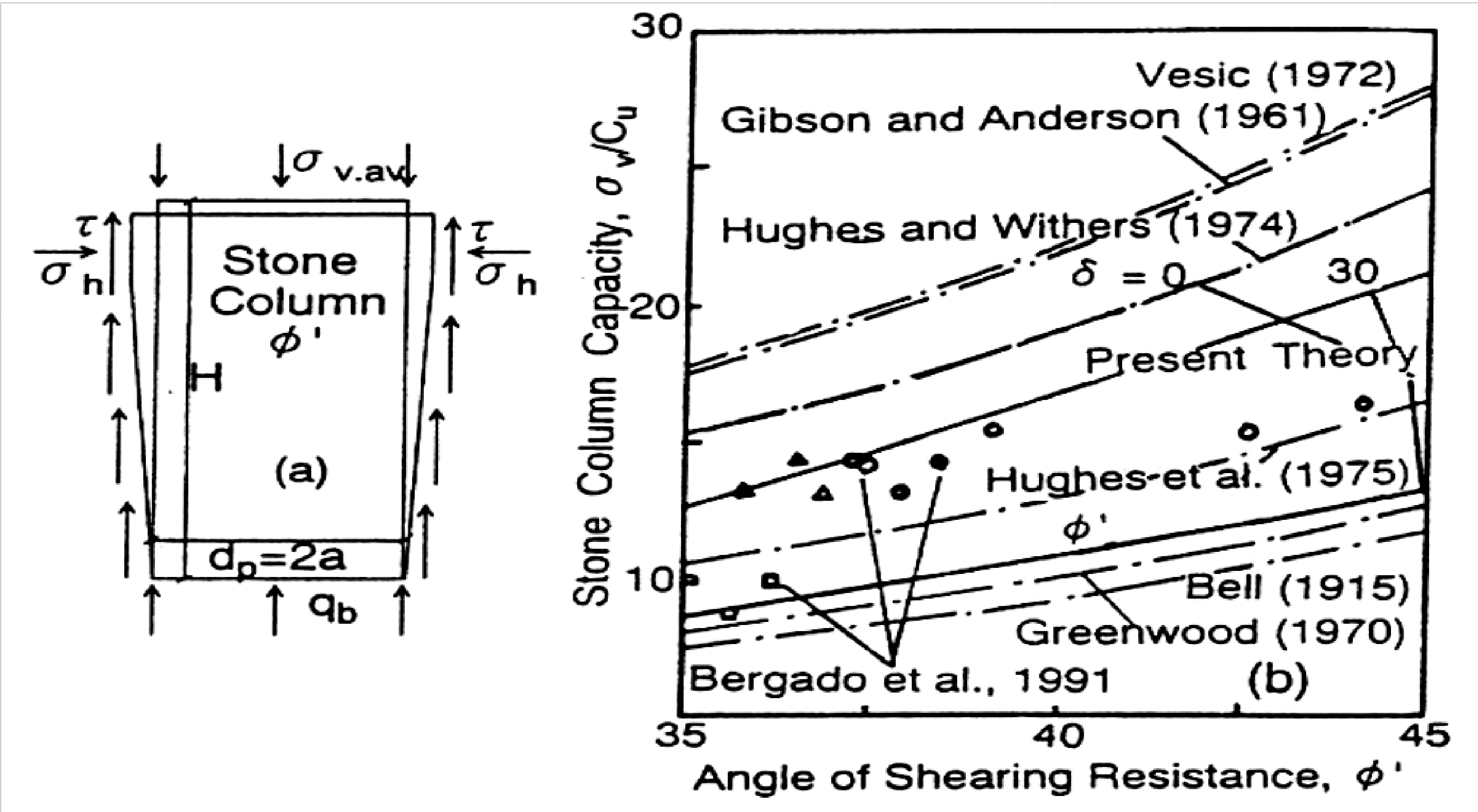
Stone Column





1.602
30.850242,22.178744
Elevation (m)
Distance (m)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95

Bulging & General Shear

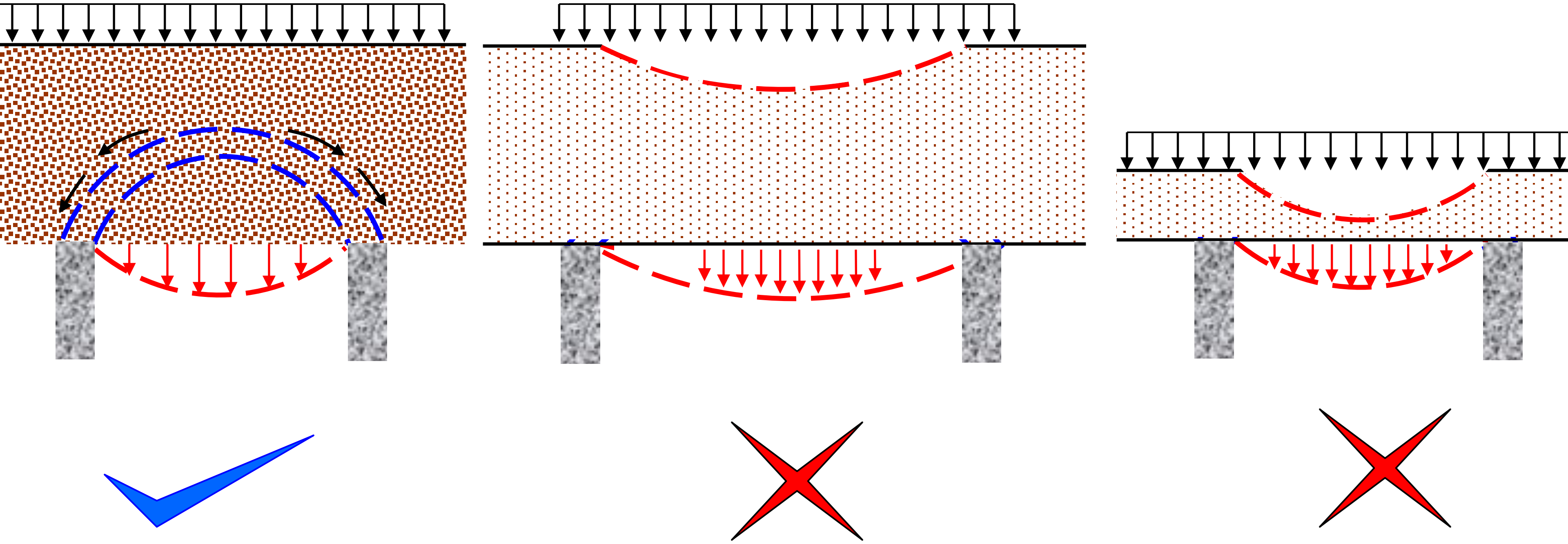


Soil Arching

Large pile spacing

Unsuitable fill materials

Inadequate fill thickness

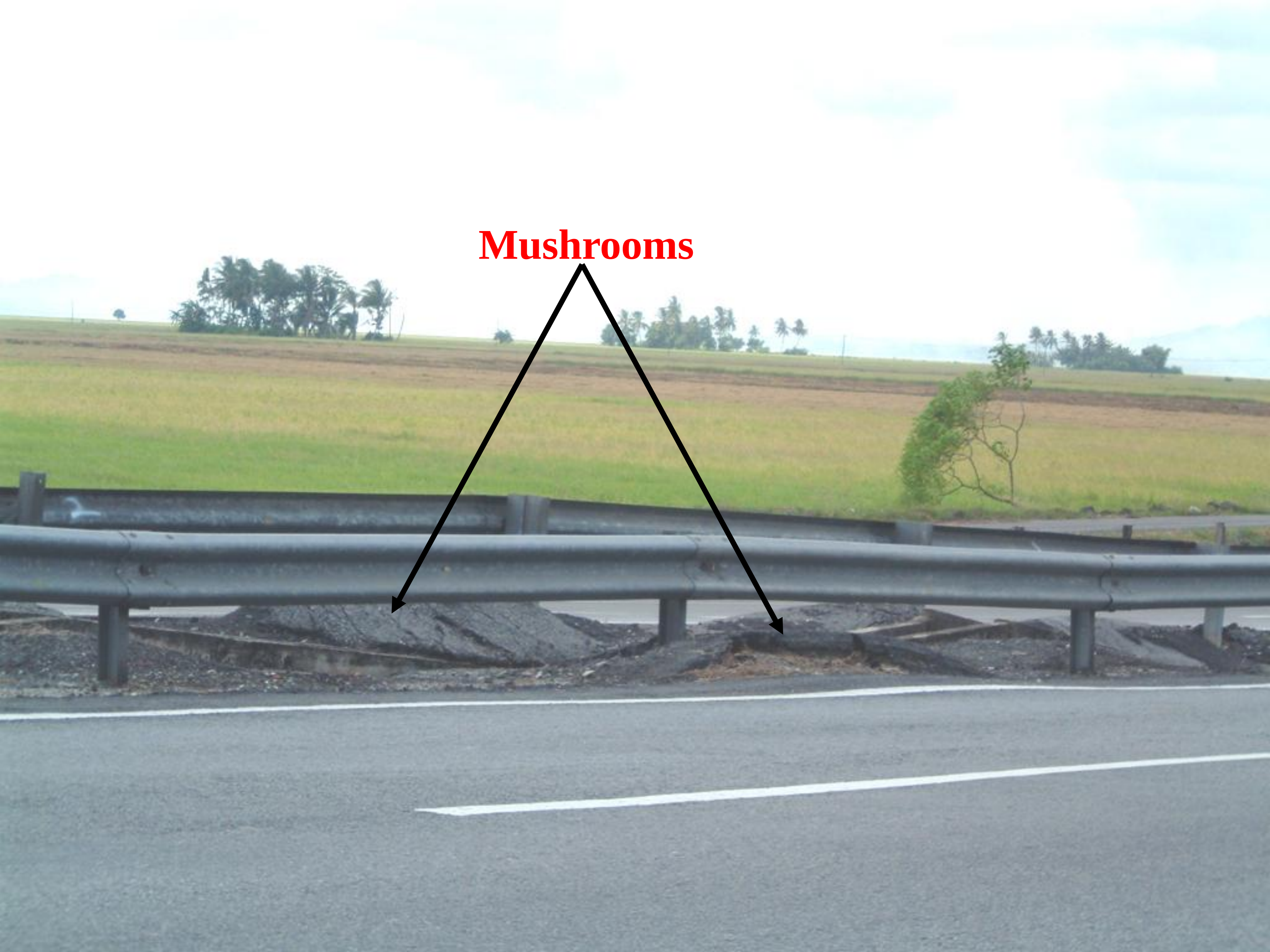


Mushroom Effect

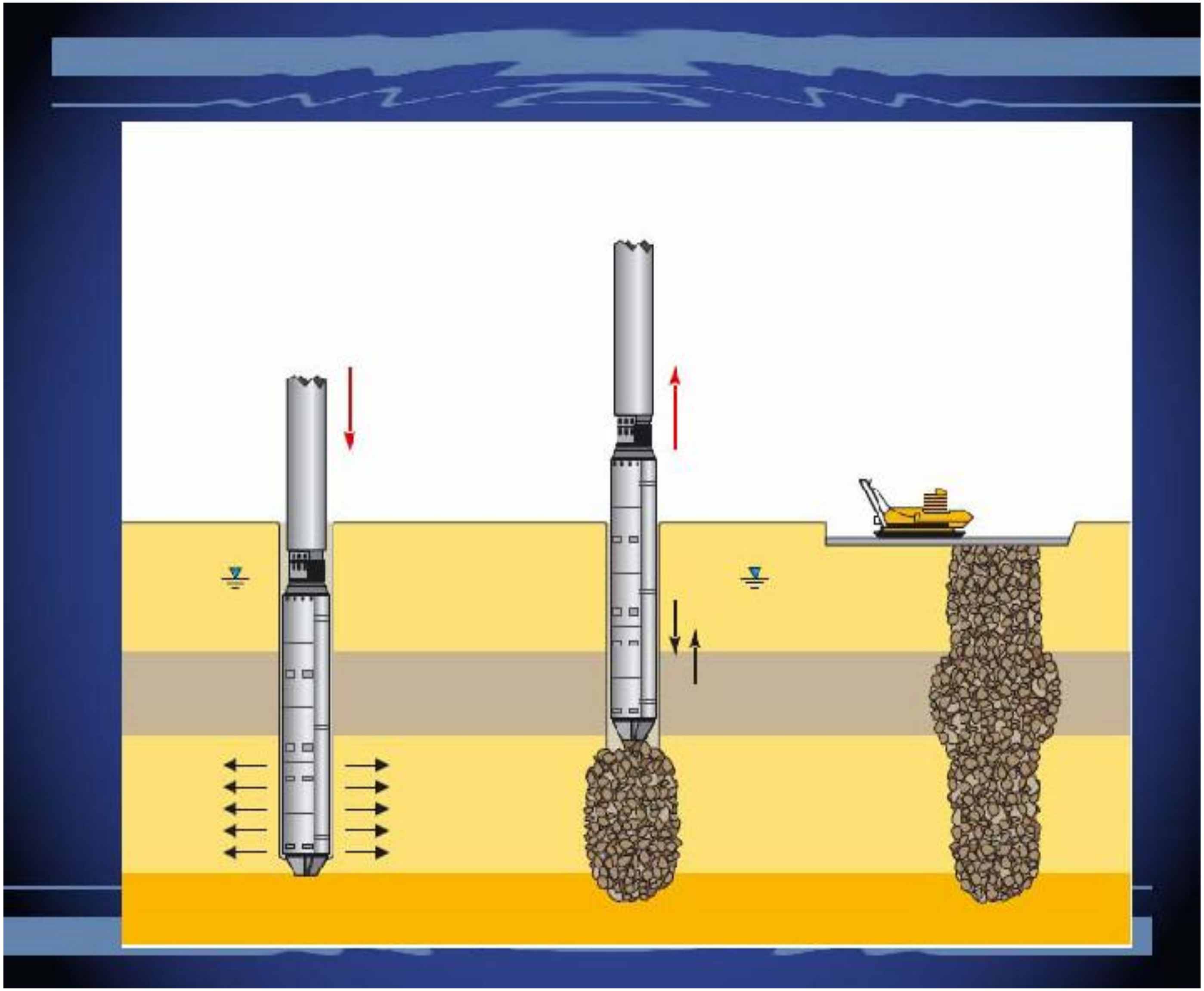
Fig. 7. 'Mushrooms' and undulating surface on expressway.

Fig. 8. Differential settlement observed after excavation to a depth of about 300mm for construction of remedial works.

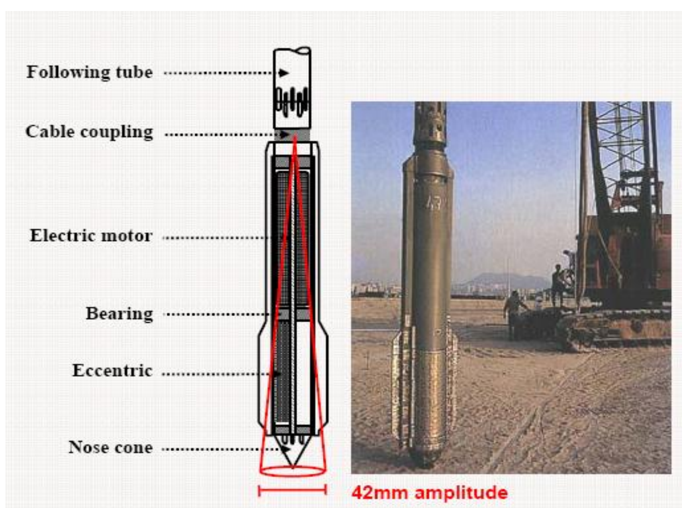
MAIN


Mushrooms

VIBRO STONE COLUMN



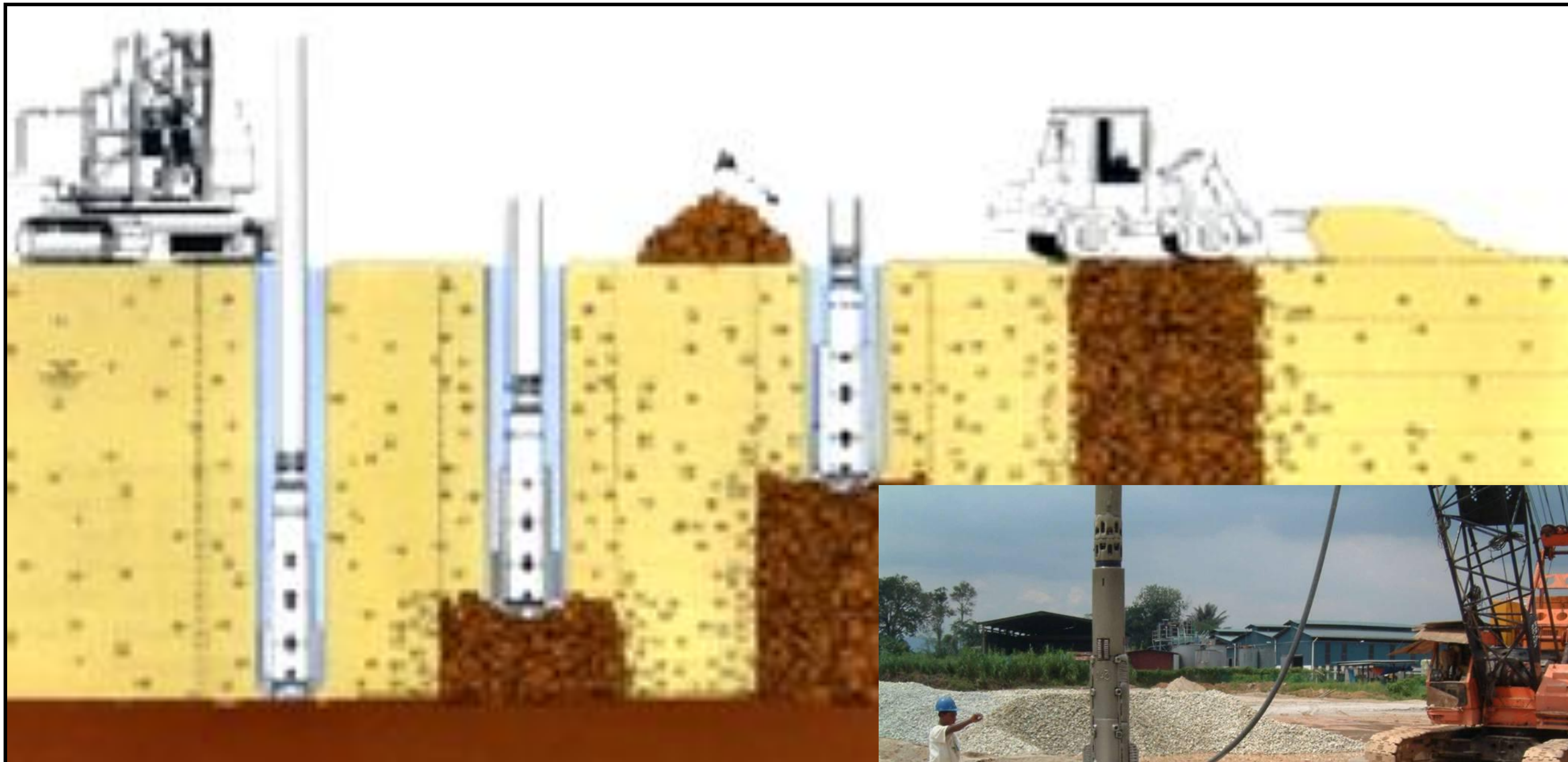
VIBRO STONE COLUMN



Vibroflot Used to Create Circular Hole and Compacting the Filled Gravel

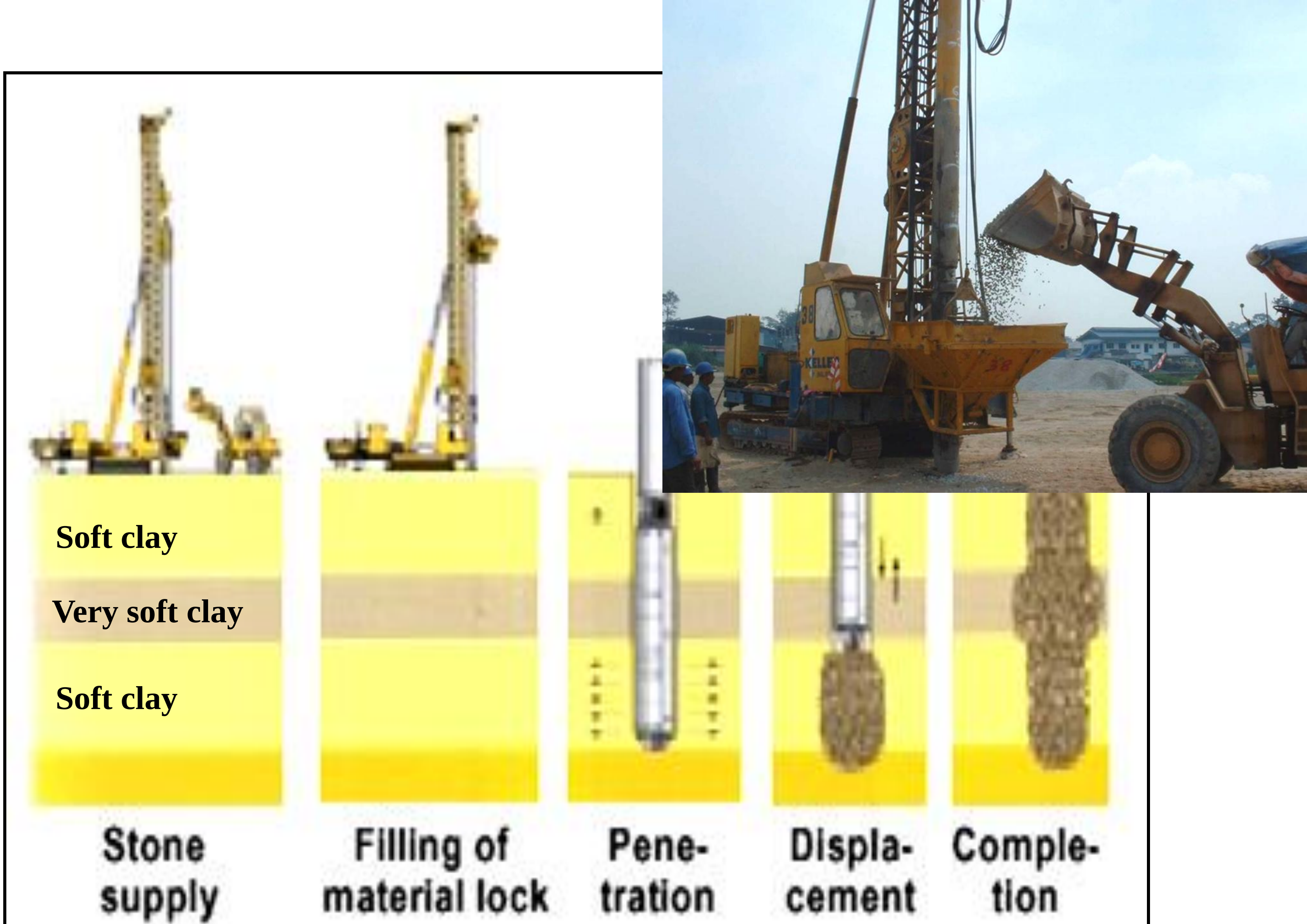
VIBRO STONE COLUMN

Vibro replacement at Jelutong Expressway



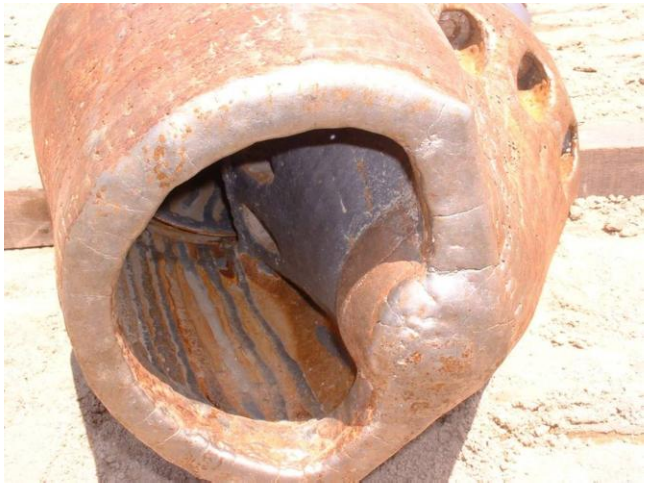
Schematic of wet top feed method

Stone Column: Wet Method



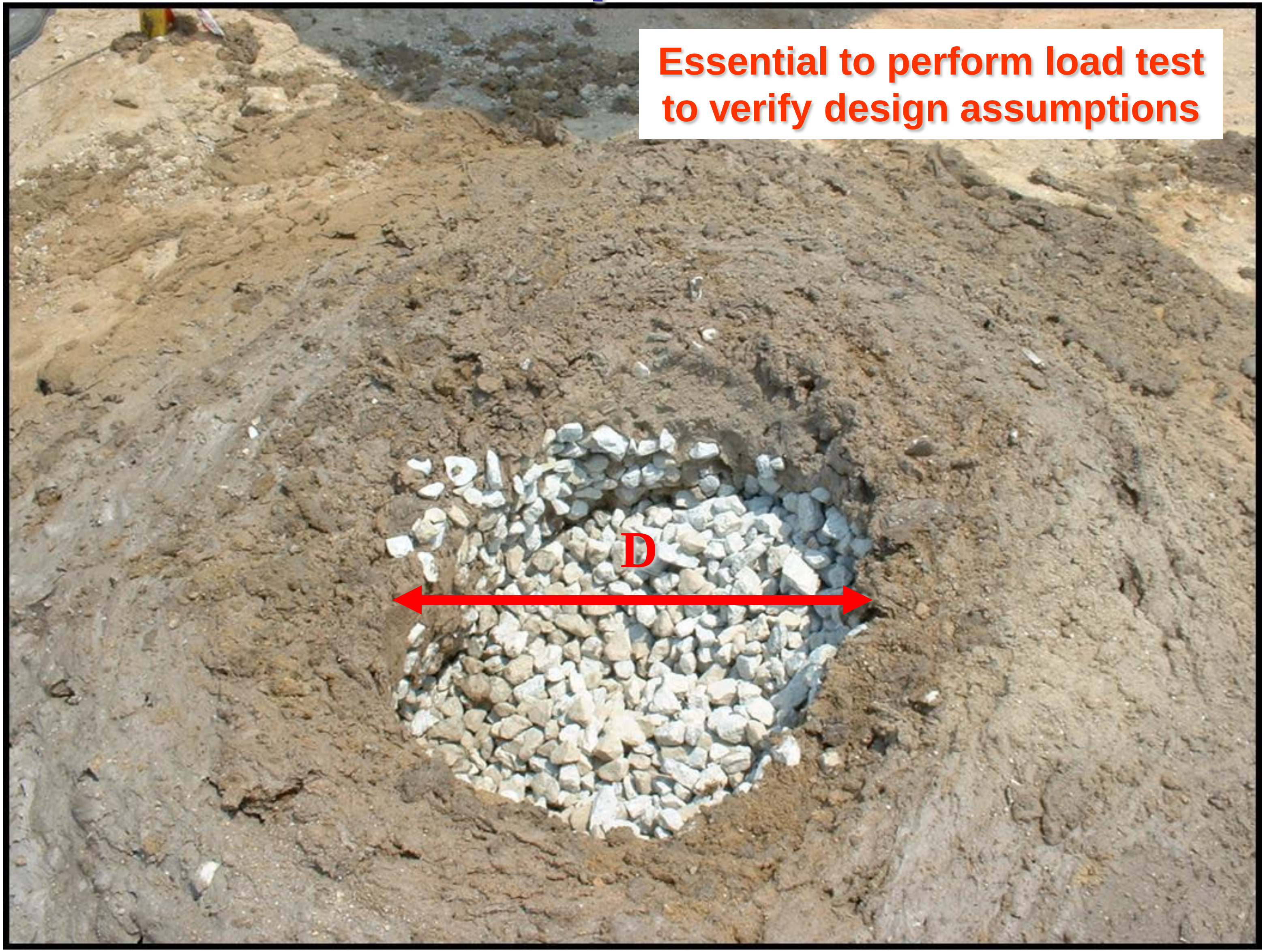
Schematic of dry bottom feed method

Stone Column: Dry Method



Stone Column

Completed stone column



Wet Method	Dry method
Very soft to firm soils	Firmer soils
High ground water table	Low ground water table
Give larger diameter columns	Give smaller diameter columns
Angular stones & larger size (25-70mm)	Rounded stones & smaller size (10-35mm)
Requires large quantities of water which must later be disposed off without causing pollution	Much cleaner

Terminate at stiff layer typically N => 10

DYNAMIC COMPACTION

Definitions

- Process of systematically tamping the ground surface with a heavy weight dropped from height.
- It is used to improve the bearing capacity of a wide range of materials, generally loose fills.
- Sometimes referred to as heavy tamping or pounding, dynamic pre – compression or dynamic consolidation.

Applications

- Can be applied to improve ground to depths 15m or so, usually on site of 5000m2 or greater area.
- Used mainly to compact sands, silty sands, hydraulic fill and silty clay fills.

DYNAMIC COMPACTION

Limitations

Adverse Situation	Possible Difficulty
➢Very soft clay (Su < 30 kN/m²)	➢Insufficient resistance to transmit tamper impulse
➢High groundwater level	➢Need to dewater and consider possible effects of subsequent recovery in water level
➢Vibration effects (may be worse if groundwater level is high)	➢Distance from closest structure to be of the order of 30m or more
➢Clay surface	➢May be inadequate for heavy cranes and unsuitable for imprint backfilling
➢Clay fills	➢May be subject to collapse settlement if inundated later
➢Flying debris	➢Precautions for site and public safety
➢Voided ground below treated ground	➢Treatment may not reach the voided zone or may make it less stable
➢Biologically degrading material	➢Compaction may create anaerobic conditions and regenerate or change the seat of biological degradation

DYNAMIC COMPACTION

Construction

- Typically, weights of 5 – 20 tonnes are used with drops of up to about 20m.
- Weight are often mass concrete or steel plates welded together and are usually about 2m square.
- A layer of granular fill, typically 0.3 – 1.0m thick is placed over the site first.
- The weight is dropped on a square grid of about 5 – 10m.
- 5 – 10 blows are applied to each imprint in each pass of the weight.
- The aim is to produce a crater about 0.5 – 2m deep.
- Groundwater may have to be lowered to ensure that it does not enter the imprints.
- Each imprint are backfilled after each pass of the weight.
- The process is repeated until the required induced settlement of the site is achieved.
- Induced settlements can range from 0.5 – 2.0m depend on the ground and the type of improvement that is needed.
- Alternatively, the process may be controlled by achieving specified minimum or average in – situ properties determined by penetration tests, either SPT or CPT.

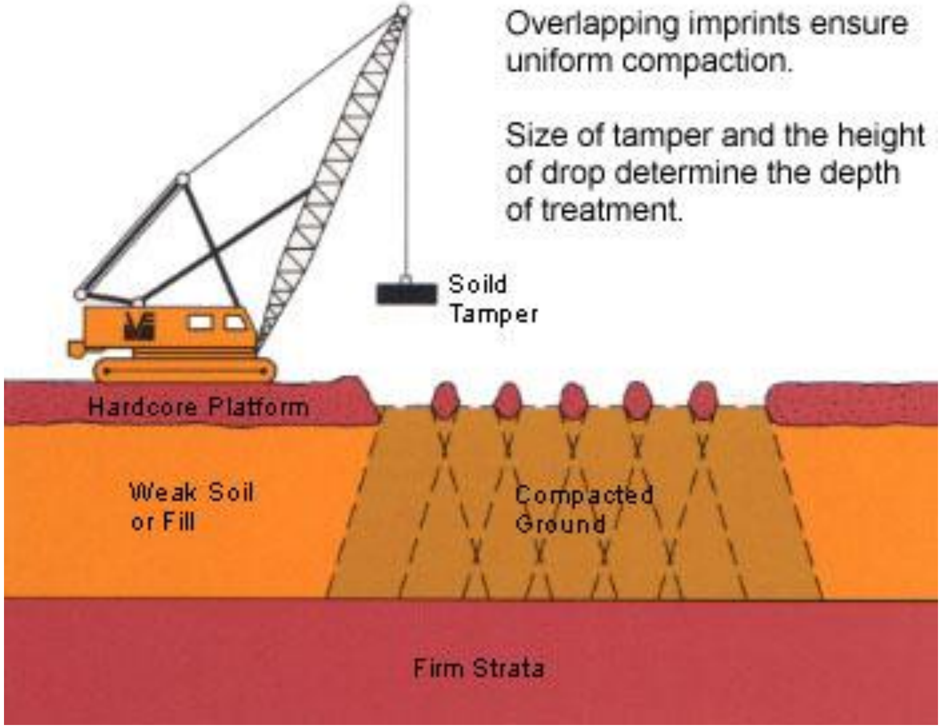
DYNAMIC COMPACTION

Controls

- Controls in positioning and careful dropping of the tamper.
- To note and record the energy (number of drops) imparted at each imprint and the quantity of imported fill to make up the general site level.
- Vibration or noise monitoring is necessary.
- Indicators of the improvement achieved might be in terms of :
- A depth of lowering of the site surface (or the volume required to maintain the original level)
- Comparative changes in penetration test resistances
- Large scale loading tests.

DYNAMIC COMPACTION

DYNAMIC COMPACTION



Pounder (Tamper)
Mass = 5-30 tonne
Drop = 10-40 m

Main Considerations for Ground Treatment

- Technical Suitability
- Practicality and Availability of material
- Cost effectiveness
- Time effectiveness – shorter construction time
- Soil and groundwater conditions

Ranking of Treatment Method

Method	Cost	Time	Priority
Modification of Embankment Geometry	v.low	v.short	1
Soft Soil Replacement	v.low	long	2
Surcharging	low	v.long	4
Staged Construction	low	v.long	3
Surcharge + Vertical Drains	medium	medium	5
Geosynthetics Reinforcement	medium	short	6
Piled Embankment	high	medium	7
Lightweight Fills	high	v.short	9
Vacuum Preloading	v.high	short	8
Stone Column	v.high	long	10
Jet Grouting	v.high	long	11

SUMMARY

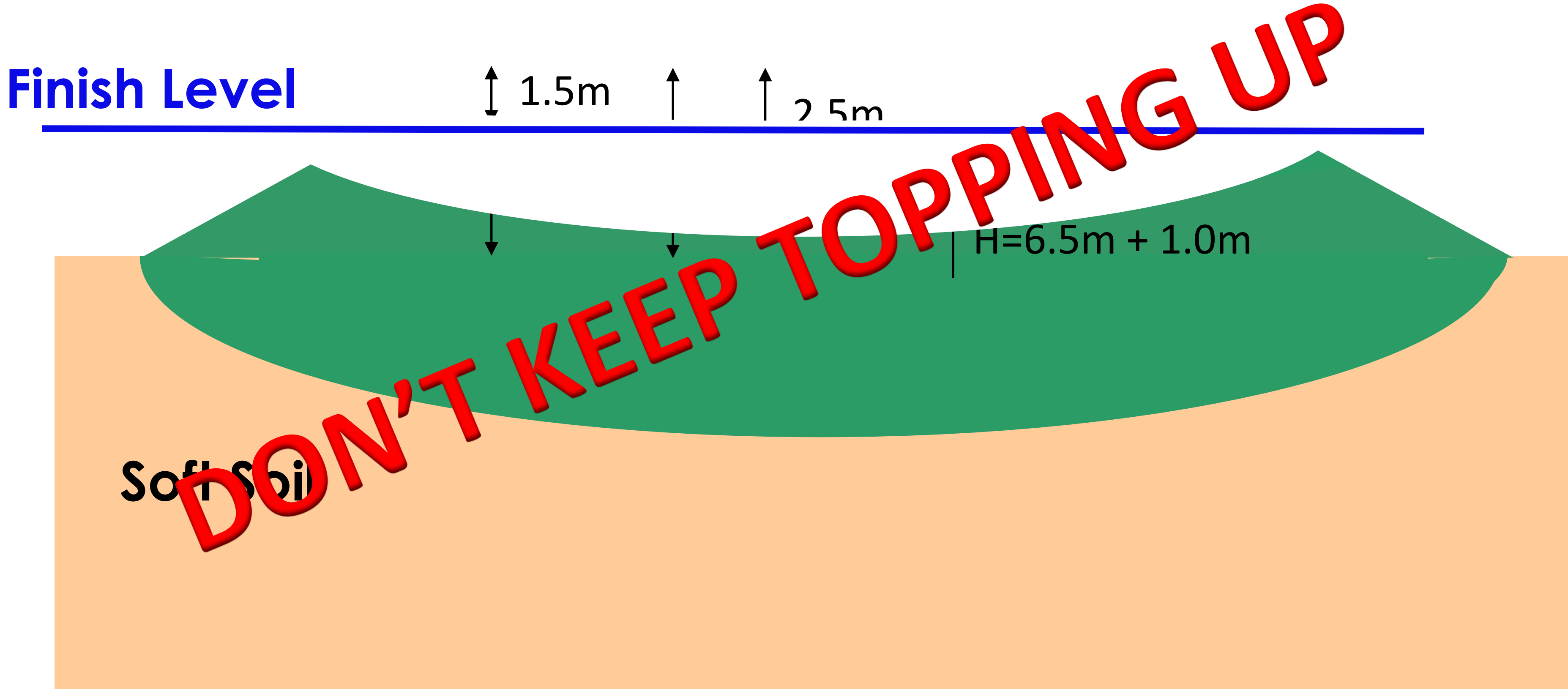
Successful Ground Treatment

- ✓ Awareness of Project Requirements + Specification
- ✓ Knowledge on the site & subsoil conditions
- ✓ Proper Geotechnical Design
- ✓ Full time proper supervision
- ✓ Careful and proper monitoring

Concept of Settlement Analyses

- Misunderstanding on Concept
- Lead to never ending process

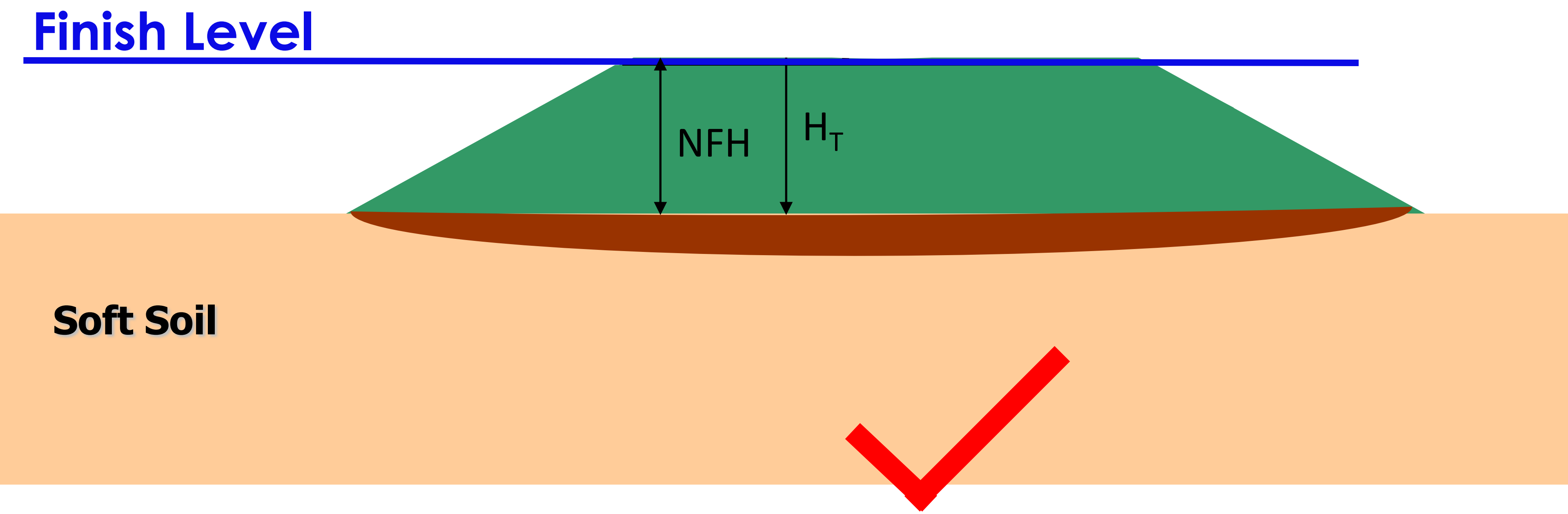
Wrong Concept of Settlement Analysis



Implication

- Not Solving Problem

Design of Embankment



Involve Iterative Process

Settlement Calculation

Settlement Calculations

Total Settlement (ρ_T) =

Immediate Settlement (ρ_i) – not time related

+

Primary Consolidation Settlement (ρ_c)

+

Secondary Compression (ρ_s)-creep

Compression and Consolidation

Immediate Settlement

Still Settling after >800 years

Settlement Calculations

- Immediate Settlement (ρ_i) – not time related
- Primary Consolidation Settlement (ρ_c)
- Secondary Compression (ρ_s)

Immediate Settlement (ρ_i)

"Immediately" after loading.

$$\rho_i = \sum \frac{1}{E_U}(I \cdot q)dh$$

(Craig, R.F., "Soil Mechanics, 6th Edition", 1997)

Immediate Settlement (ρ_i)

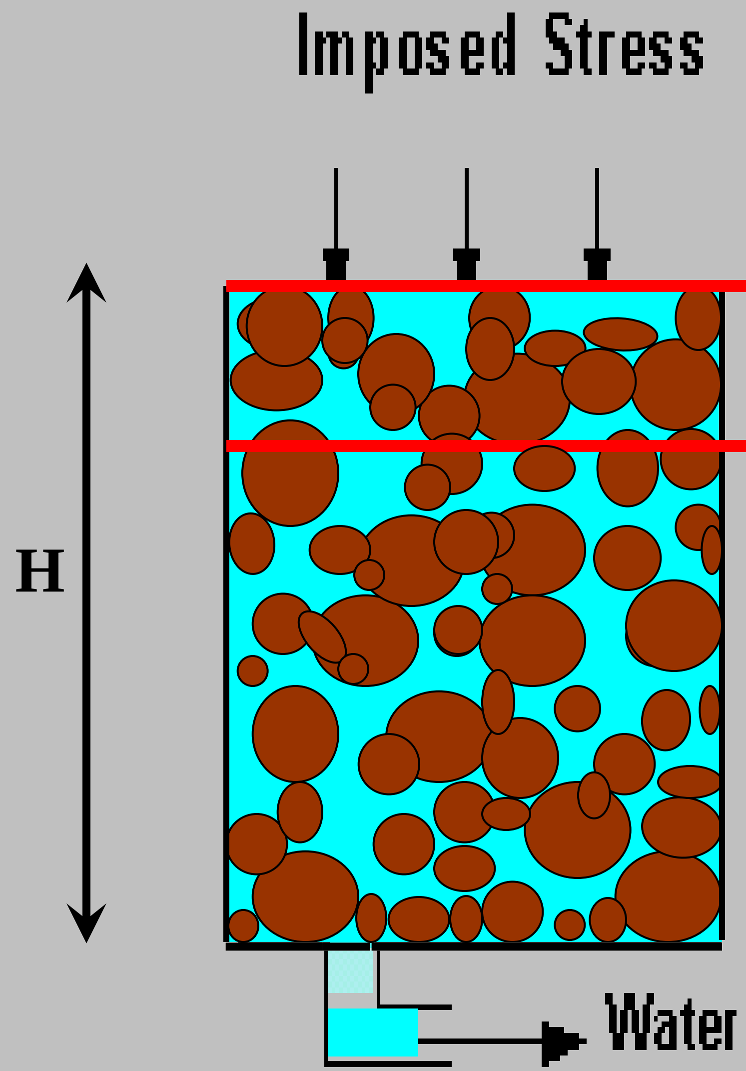
q = Applied Stress / Pressure on the subsoil (kPa)

dh = thickness of each layer (m)

E_u = Undrained Young's Modulus of the subsoil (kPa)

I = Influence factor (can refer to Osterberg Chart)

Consolidation Mechanism



Concept of Consolidation

Reduction in **volume-saturated soil**

Drainage of **pore water**

Induced by **increase in stress**

Increase in **effective stress**

Primary Consolidation Settlement (ρ_c)

During consolidation - After certain time

$$\rho_c = \sum_{i=1}^{n}[\frac{C_r}{1+e_o}\log\frac{\sigma'_{vc}}{\sigma'_{vo}} + \frac{C_C}{1+e_o}\log\frac{\sigma'_{vf}}{\sigma'_{vc}}]H_i$$

(Tan, Y.C., & Gue, S.S., "Design & Construction Control of Embankment over Soft Cohesive Soils", 2000)

Primary Consolidation Settlement (ρ_c)

ρ_c = Consolidation Settlement Magnitude (m)

σ'_{vo} = Initial vertical effective stress

σ'_{vf} = Final vertical effective stress = $\sigma'_{vo} + \Delta\sigma'_v > \sigma'_{vc}$

σ'_{vc} = Preconsolidation Pressure / Yield Stress

H_i = Initial thickness of incremental soil layer,i of n.

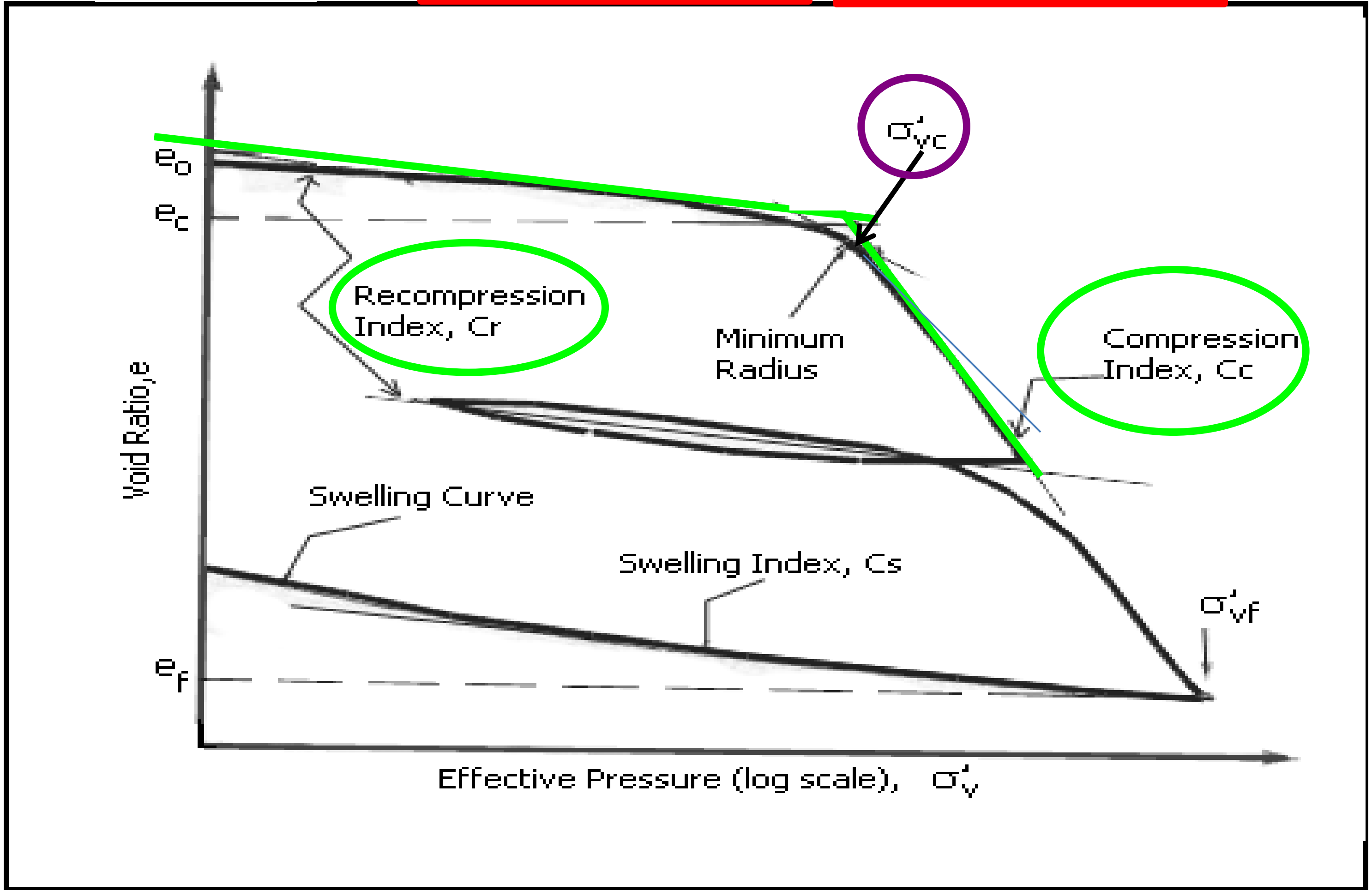
e_o = Initial voids ratio

C_C = Compression Index

C_r = Recompression Index

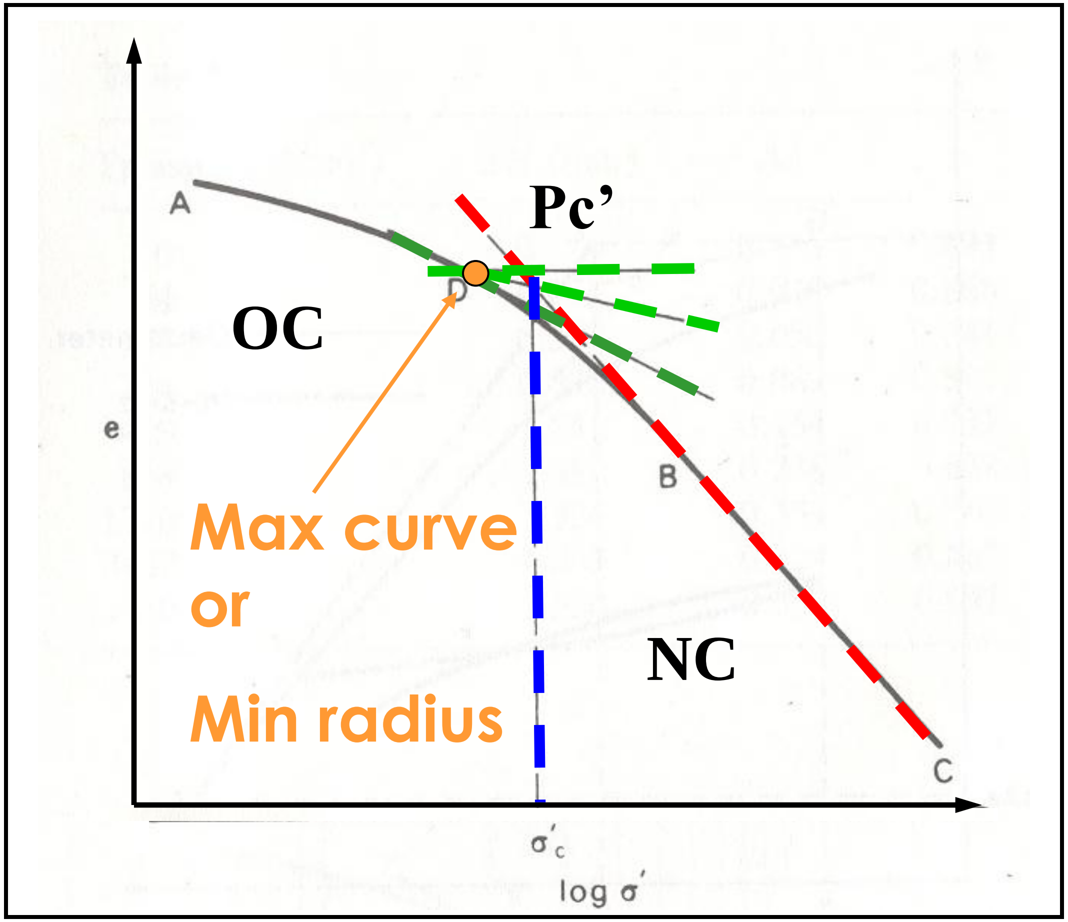
Terminology of Oedometer Curve

$$\rho_c = \sum_{i=1}^{n}\left[\boxed{\frac{C_r}{1+e_o}\log\frac{\sigma'_{vc}}{\sigma'_{vo}}} + \boxed{\frac{C_C}{1+e_o}\log\frac{\sigma'_{vf}}{\sigma'_{vc}}}\right]H_i$$



Over-Consolidated Material

Preconsolidation pressure is the **maximum effective stress, Pc'** that clay experienced in the **past**.



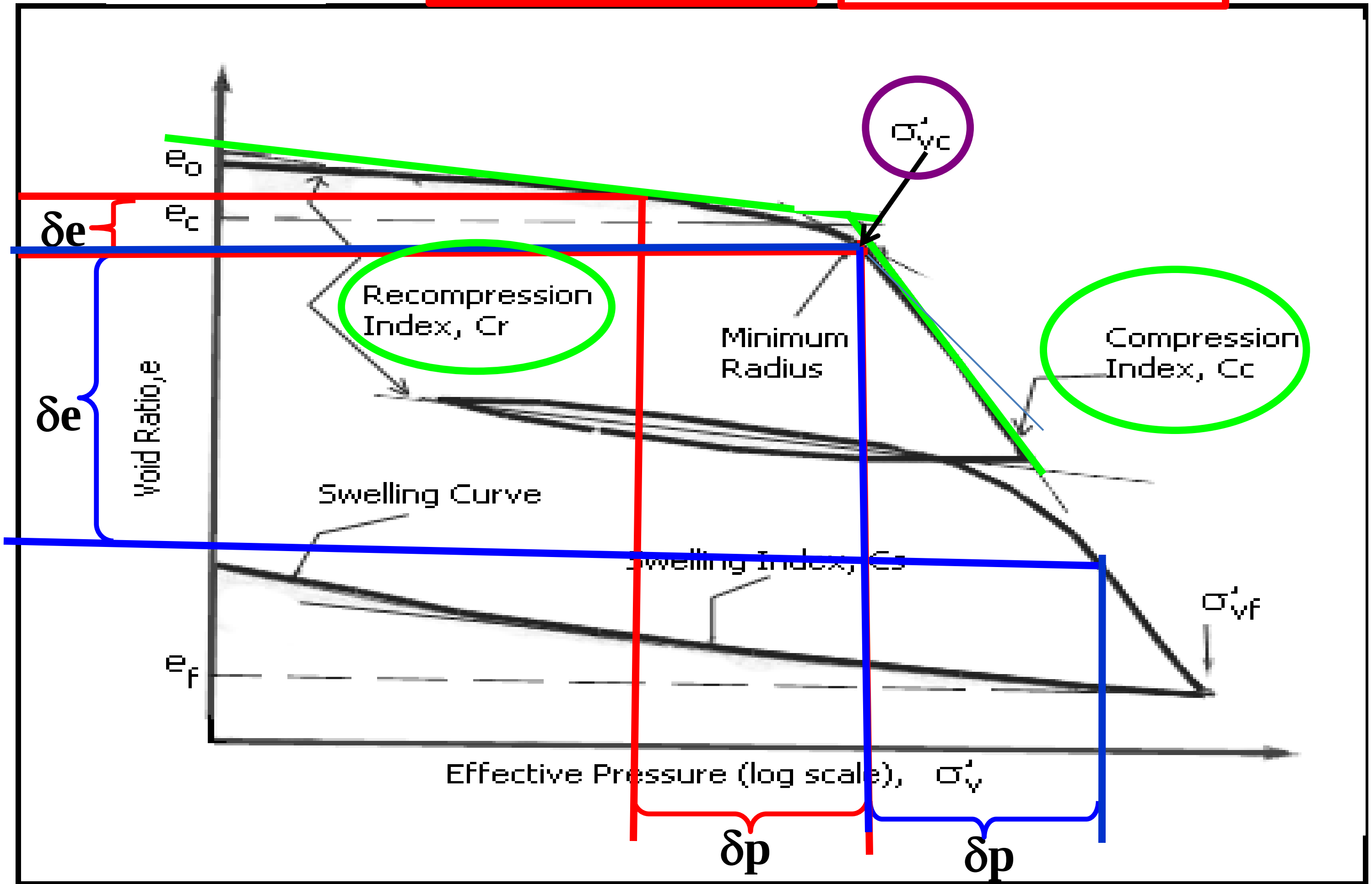
Application of Theory

- Pc’ > Po’ , Over consolidated Soil (OC)

- Pc’ = Po’ , Normal consolidated Soil (NC)

Terminology of Oedometer Curve

$$\rho_c = \sum_{i=1}^{n}\left[\boxed{\frac{C_r}{1+e_o}\log\frac{\sigma'_{vc}}{\sigma'_{vo}}} + \boxed{\frac{C_C}{1+e_o}\log\frac{\sigma'_{vf}}{\sigma'_{vc}}}\right]H_i$$



Secondary Compression (ρ_s)

Settlement after complete dissipation of excess pore pressure.

$$\rho_s = \sum_{i=1}^{n}[\frac{C_\alpha}{1+e_p}\log(t)]H_i$$

(Craig, R.F., "Soil Mechanics, 6th Edition", 1997)

Secondary Compression (ρ_s)

ρ_s = Secondary Compression Magnitude (m)

H_i = Initial thickness of incremental soil layer, i of n

e_p = Voids ratio at the end of primary consolidation

C_α = Secondary Compression Index

t = Time for calculation

Settlement Calculation

Settlement Calculation

$$C_v = T_v \, H_D^2 / t$$

where,

c_v = Coefficient of consolidation (m^2/year)

t = Time following application of loading(year)

H_D = Drainage path length (m)

T_V =Time factor

Coefficient of Consolidation

$$C_v = T_v H_D^2 / t$$

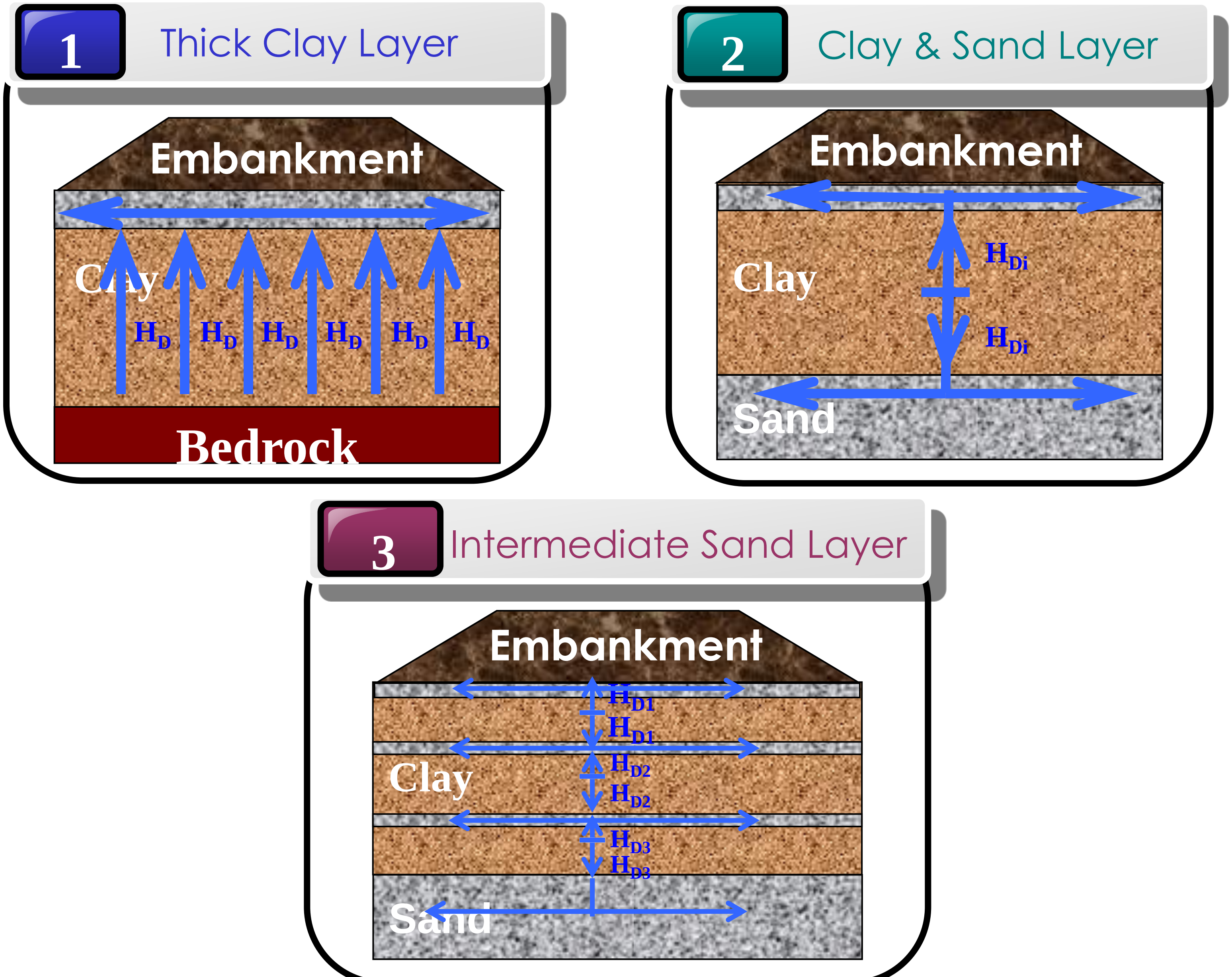
Rearrange, $t = T_v H_D^2 / C_v$

Therefore, $\mathbf{t \propto H_D^2}$

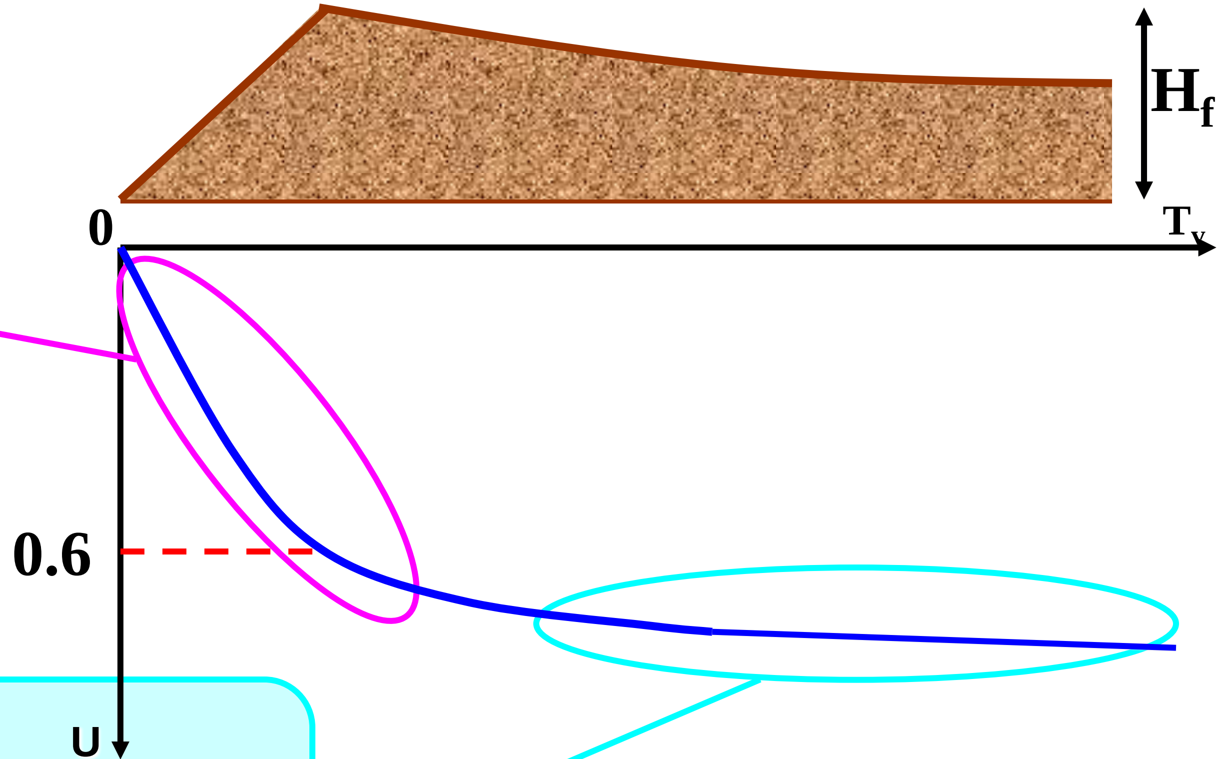
H_D	1	10
t	1	100

100 TIMES MORE

Consolidation Drainage Path



Degree of Consolidation



For U < 0.6

$$T_v = \frac{\pi U^2}{4}$$

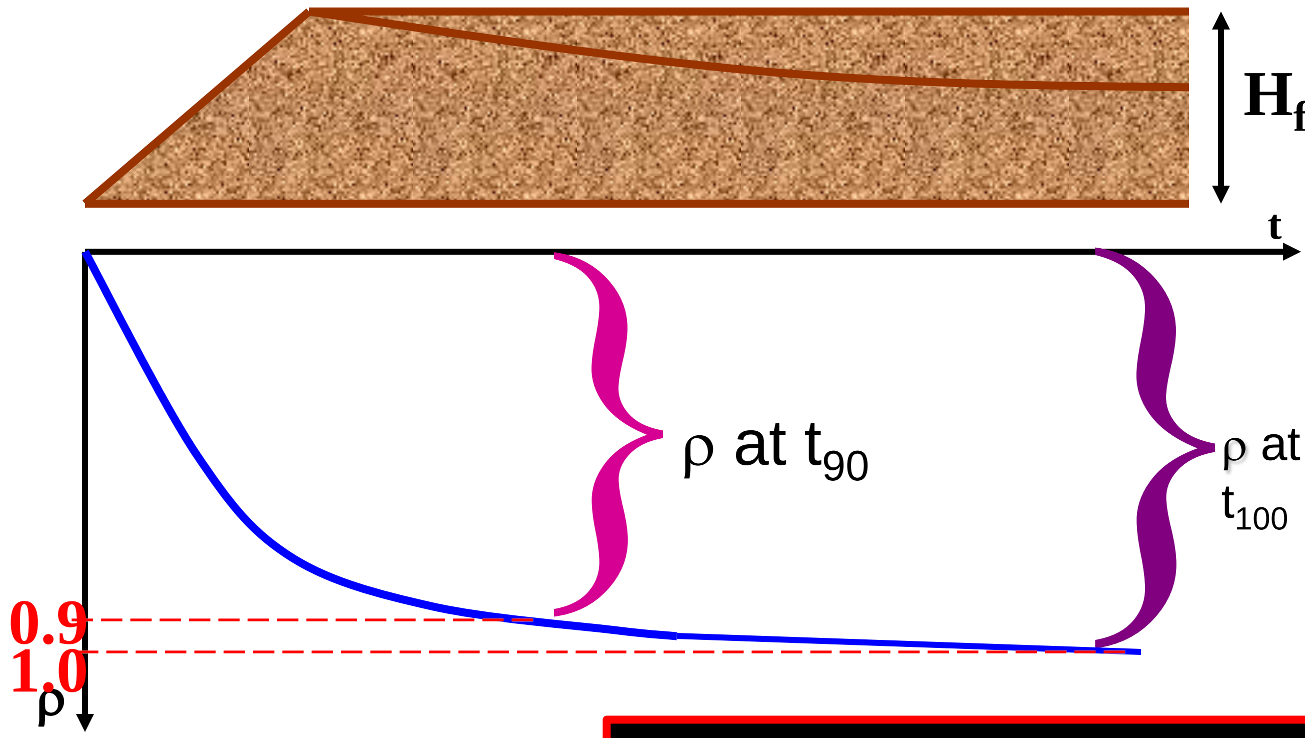
For U > 0.6

$$T_v = -0.933 \log(1-U) - 0.085$$

(Craig, R.F., "Soil Mechanics, 6th Edition", 1997)

Degree of Consolidation

To determine **settlement**, ρ at any instantaneous time.



Example :

At a site with 5m fill

ρ_T = 1500 mm

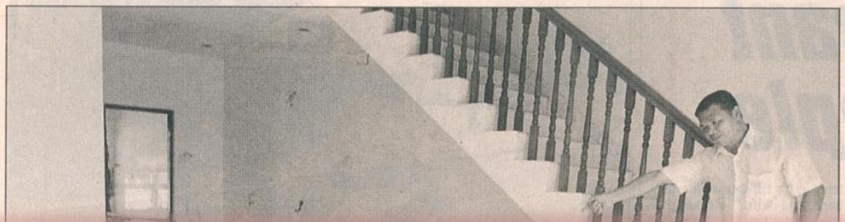
Degree of consolidation at year 5 = 90%

Settlement at year 5 = 0.9 x 1500 = **1350mm**

Can TOLERATE?

DO NOT AIM FOR 90% DEGREE OF CONSOLIDATION

Rebuild our houses, say owners



By KULDEEP S. JESSY

IPOH: Fourteen double-storey houses in Bandar Pengkalan Indah here have been sinking for the past 10 months and the halls of some of them now resemble ponds.

The two rows of houses are supported by thick iron beams while remedial work on the floors had caused the ceilings to drop lower than before.

Buyers' action committee

up to expectations, adding that the houses cost between RM95,000 and RM97,000 each and had a built-up area of 1,200 sq ft.

He said the residents had been servicing their bank loans of RM600 per month from the day they were handed the keys.

"They should tear down the houses and rebuild them. We want to know whether the houses are safe as water is

ffected houses in Bandar

to move out the furniture and belongings on the first floor for remedial work.

He said the work carried out on the houses so far was not

adding that the iron beams behind the houses were only temporary.

A total of 44 houses were built under the scheme.

SINKING SCHOOL GIVES PARENTS THE SHIVERS

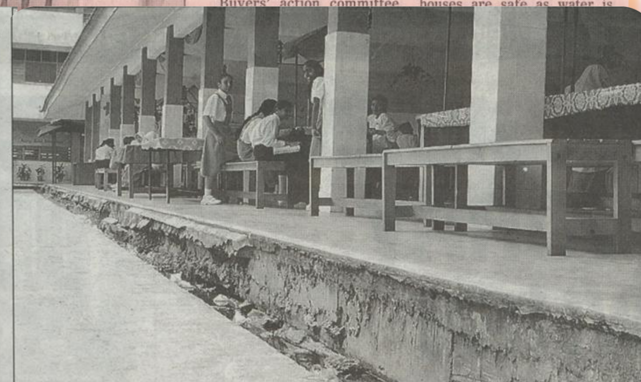
KUALA LUMPUR: The assembly area of Sekolah Menengah Kebangsaan Setapak Indah is sinking!

The area has sunk at least a metre from the surrounding area, most noticeably at the school canteen.

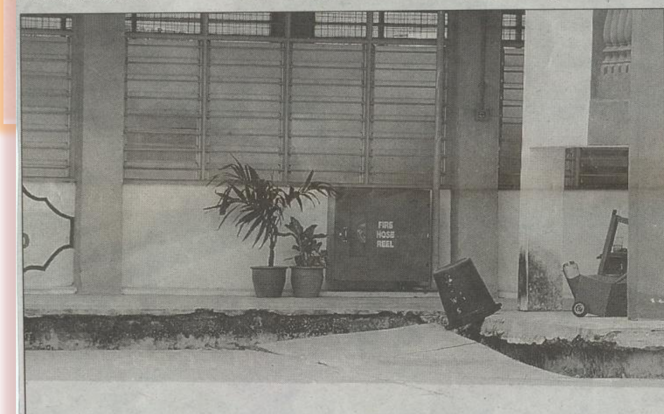
Understandably parents are worried and some called *The Malay Mail* to express their fear.

When *The Malay Mail* visited the school at noon yesterday, the principal, Mohd Noor Samat, said the Public Works Department (JKR) had been informed and work would begin next week.

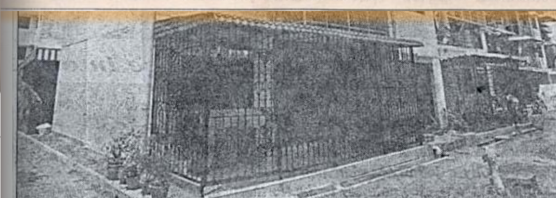
The Malay Mail understands that the issue had been brought up at the last Parent Teacher Association (PTA) meeting.



CAVING IN: The back part of the assembly area that has sunk



CRACKED: The front part of the assembly area



Block 28 is one of the 70 apartment blocks with cracks at the base of the block.

the office visited the school for the second time this week following our enquiry.

They were not available yesterday to comment on their findings and their next course of action.

During an earlier visit, our reporter saw numerous cracks at the canteen and school blocks.

The canteen floor had sunk a few centimetres and large cracks

FAILURE EVENTS IN MALAYSIA

Two drown after road collapses

■ By Roy Goh and Julia Chan
news@nst.com.my

PAPAR: A man and his son drowned while a university student is missing after a 25m stretch of road collapsed into a river yesterday.

The man and his son were travelling in a Perodua Kancil which plunged two metres into the Mandahan river about 8am.

The university student, meanwhile, had wanted to cross to the other side of the river later in the afternoon but was unable to do so due to the road collapse.

The student, who was riding a motorcycle, then tried to use a nearby railway bridge but lost his balance and fell into the river.

The road at Kilometre 16 Papar-Beaufort had caved in after floodwaters eroded the soil covering three box culverts placed across the river.

The culverts had been clogged with debris for several days, causing the water to seep through the soil at the side.

The victims were identified as Hussin Mastor, 50, a religious teacher from Skim Kepayan, Kuala Penyu, and his son, Razali Hussin, 22, a Universiti Malaysia Sabah undergraduate.

The missing university student is Zuhairy Abdul Wahab, in his 20s, from Kebatu, Beaufort.

The road collapse cut off links to Kuala Penyu, Membakut, Bongawan, Beaufort, Menumbuk and Sipitang.

The damaged road was also used by those travelling from Sarawak and Brunei.

FAILURE EVENTS IN MALAYSIA

TheStar MONDAY 19 September 2005

Bridge and water woes leave 800 families dry

KANOWIT: Some 800 families have been left dry after a major water main burst as a concrete bridge across Sungai Menyan here collapsed.

The families were from several villages and longhouse settlements in Pidai, Nibong, Tada, Sedaya and nearby areas.

Nobody was injured as the bridge, which was built in 1997, collapsed at about 3am on Saturday.

Villagers said they heard a loud sound and thought it was an explosion. They went to check and found that the bridge had given way.

State Assistant Minister for Housing Dr Soon Choon Teck, who carried out a site inspection, said a notice board was placed near the bridge, warning drivers of heavy vehicles against crossing it, when the bridge was found to be unstable a month ago.

The Public Works Department had planned to close the bridge to facilitate remedial works after discovering defects in one of the bridge's foundations.

A temporary bridge was under construction when the incident happened.

Dr Soon said the temporary bridge was expected to be ready by today.

The Sibu Water Board would lay a new water pipe to restore supply to the affected residents.

WRECKED: Residents inspecting the site of the broken bridge across Sungai Menyan in Kanowit yesterday.

FAILURE EVENTS IN MALAYSIA

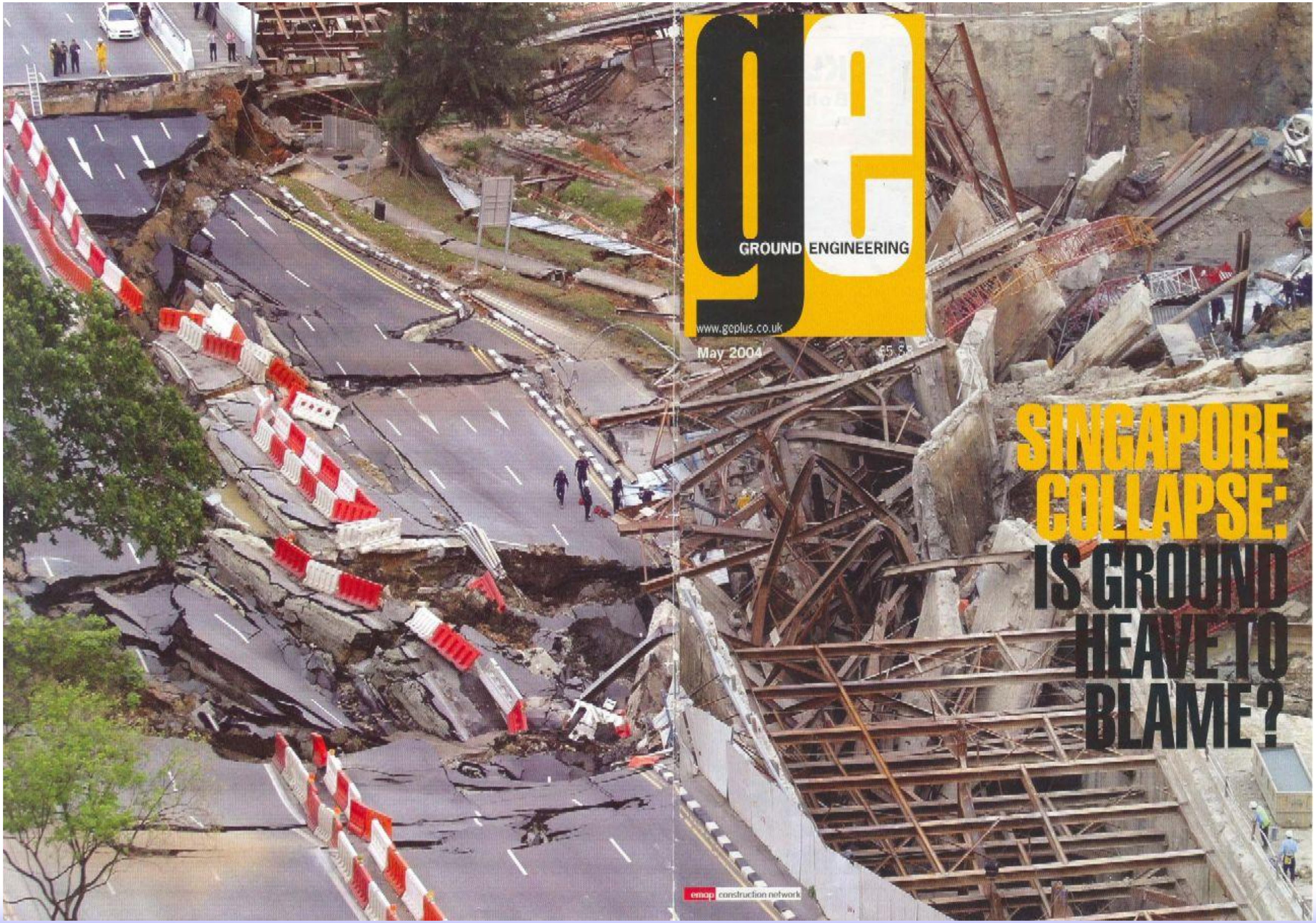
Bumpy journey

The new road linking Malacca and Johor only opened three months ago, but two major cave-ins had already occurred. The road is a short-cut to Sungai Rambai, Malacca, from Sungai Mati and links to the second Muar bridge. Heavy vehicles and bad weather have been blamed for the cave-ins. A Public Works Department spokesman said once the extent of the damage had been ascertained, repairs would begin. — NST picture by Chong Chee Seong

FAILURE EVENTS IN MALAYSIA

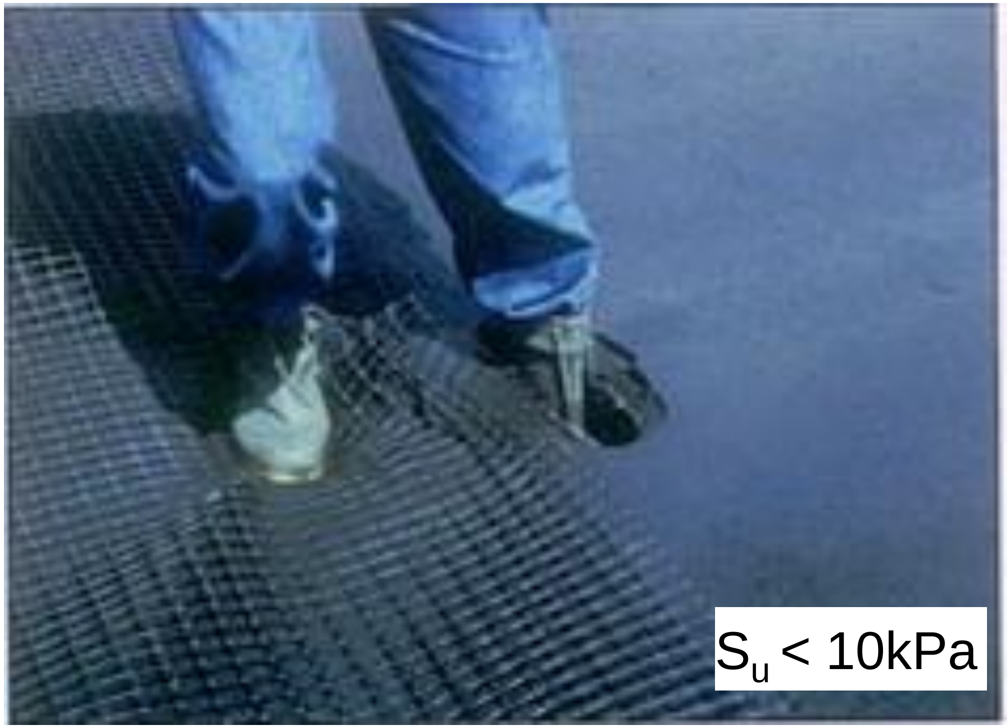
FAILURE EVENTS IN MALAYSIA

FAILURE EVENTS IN SINGAPORE



IDENTITY OF SOFT GROUND

IDENTITY OF SOFT GROUND



IDENTITY OF SOFT GROUND

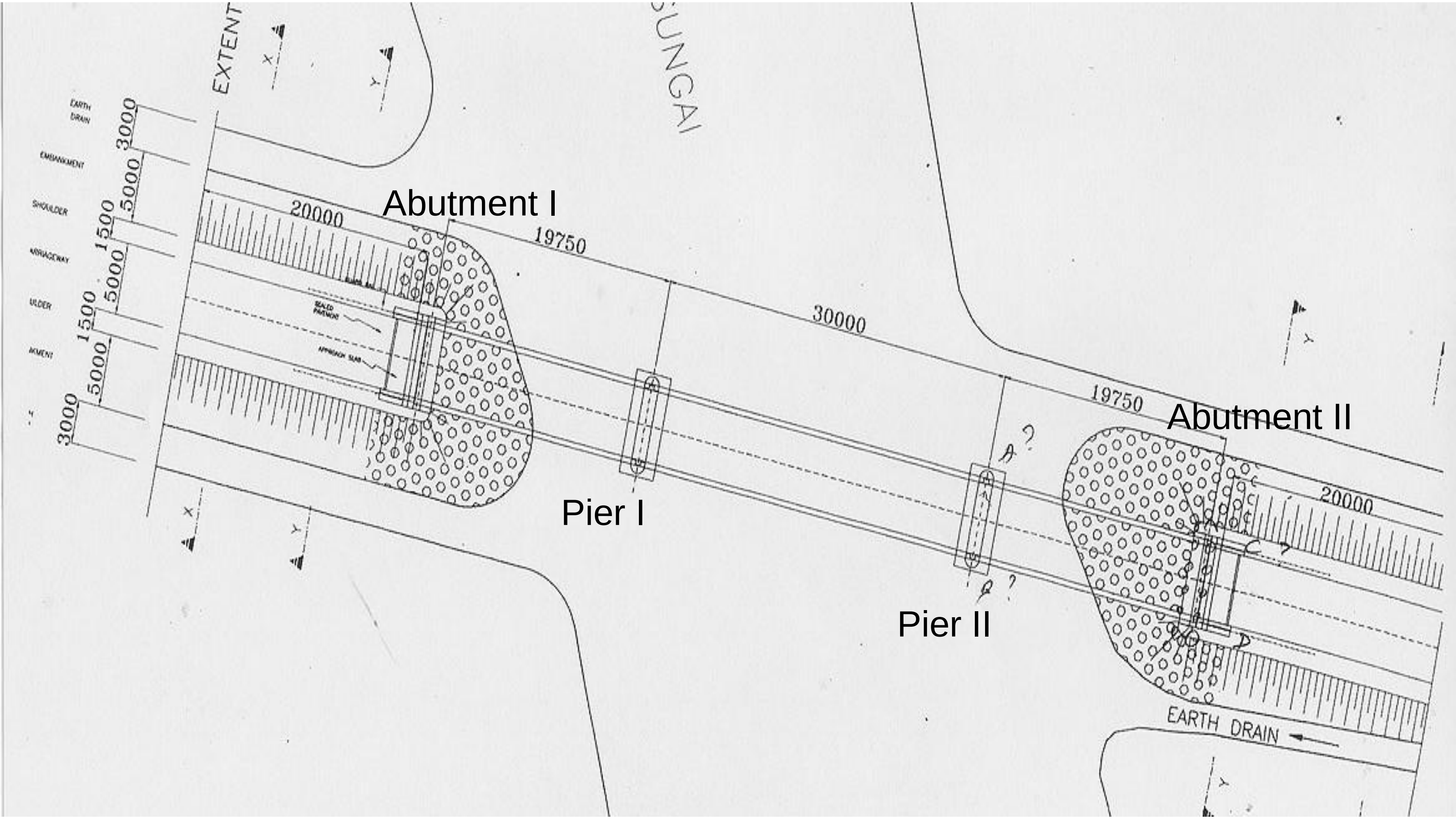
IDENTITY OF SOFT GROUND

VEGETATION

VEGETATION

Failure of Bridge Foundations and Approach Embankment

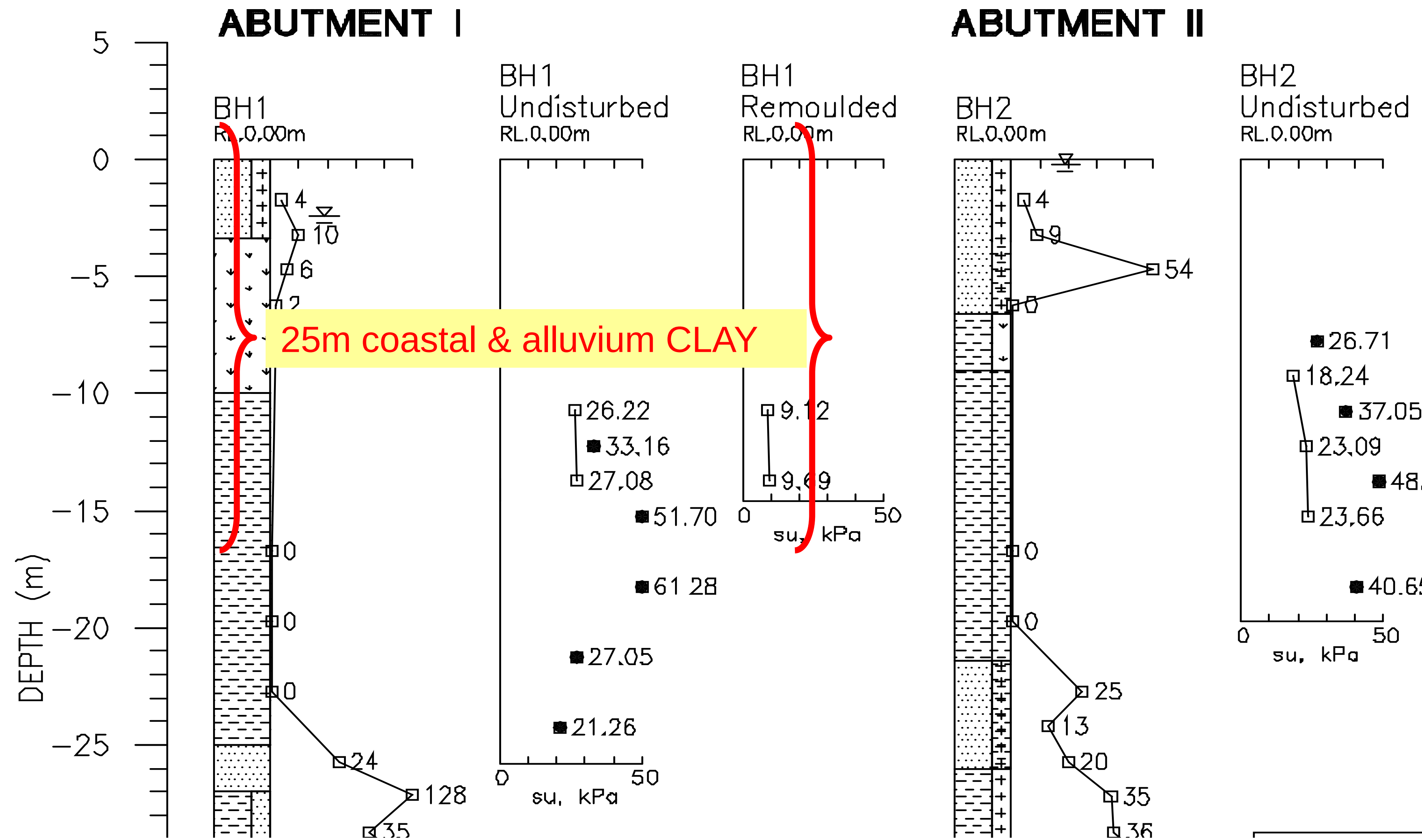
Overview



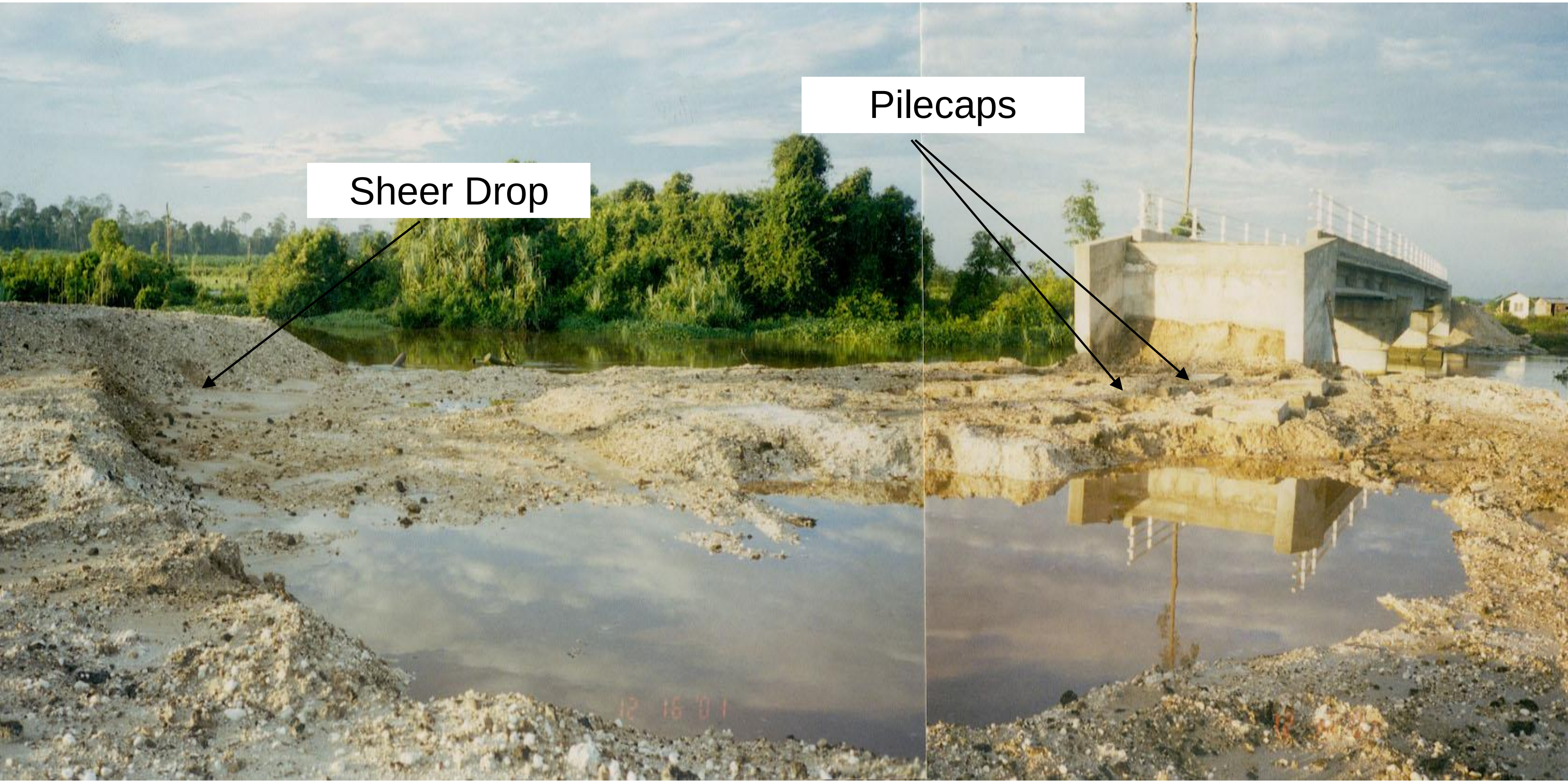
Abutment I
Abutment II
Pier I
Pier II
EXTENT
SUNGAI
3000
5000
1500
5000
1500
5000
3000
20000
19750
30000
19750
20000
EARTH DRAIN

Overview

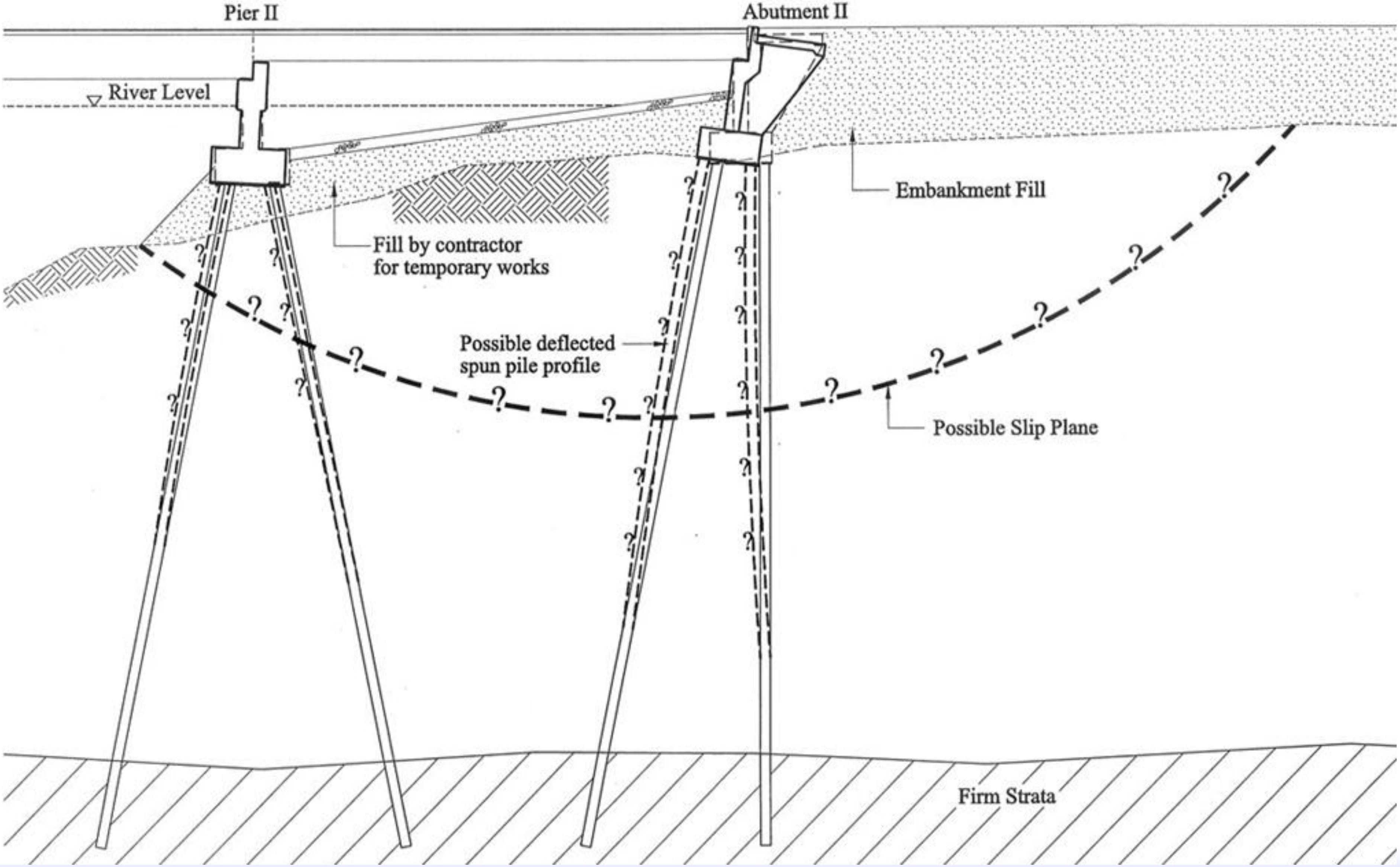
Subsoil Condition



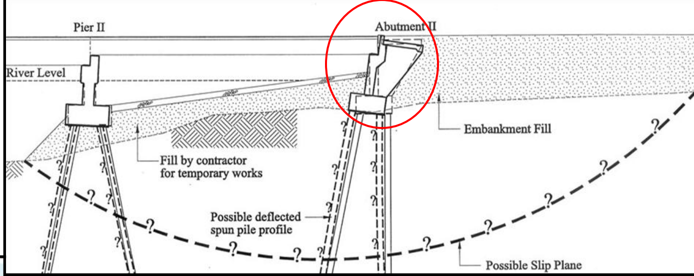
Sheer Drop

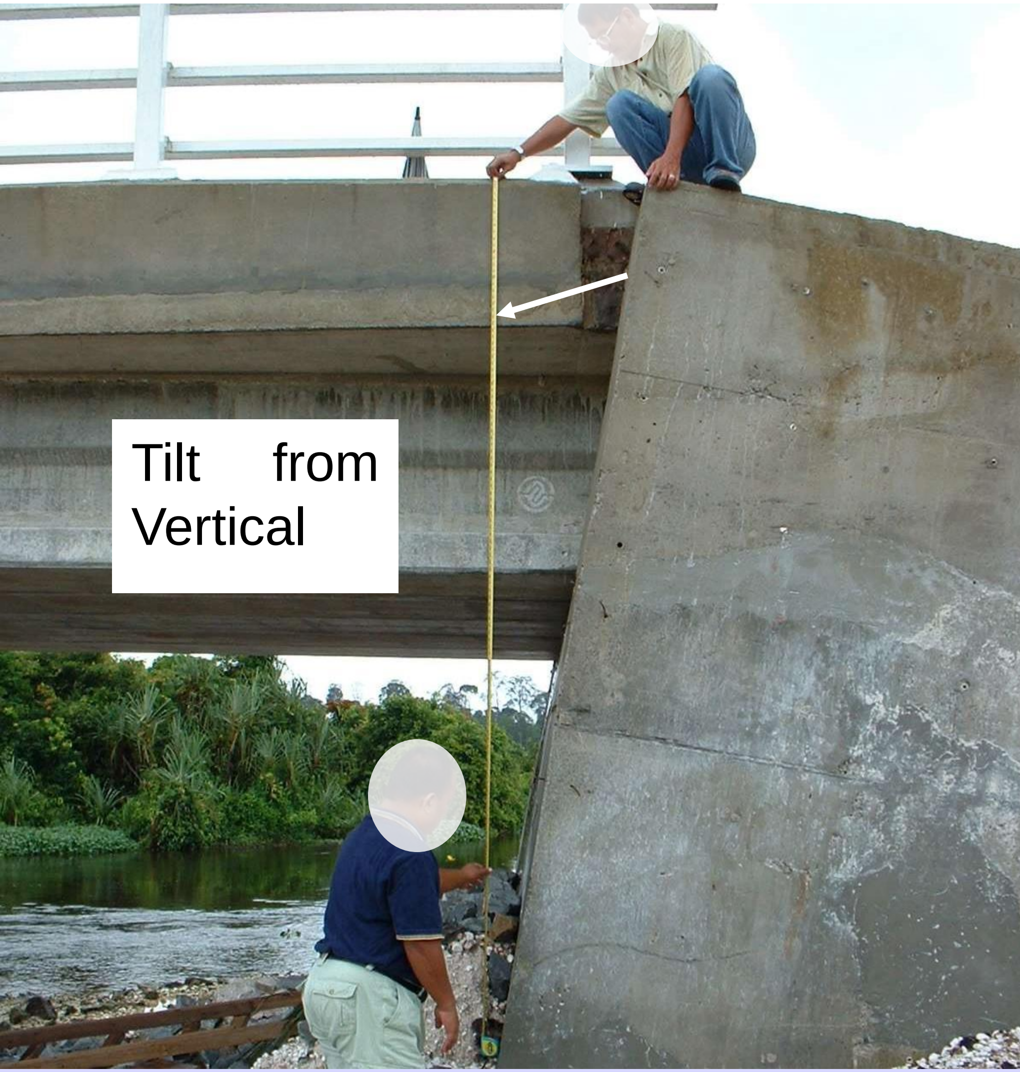


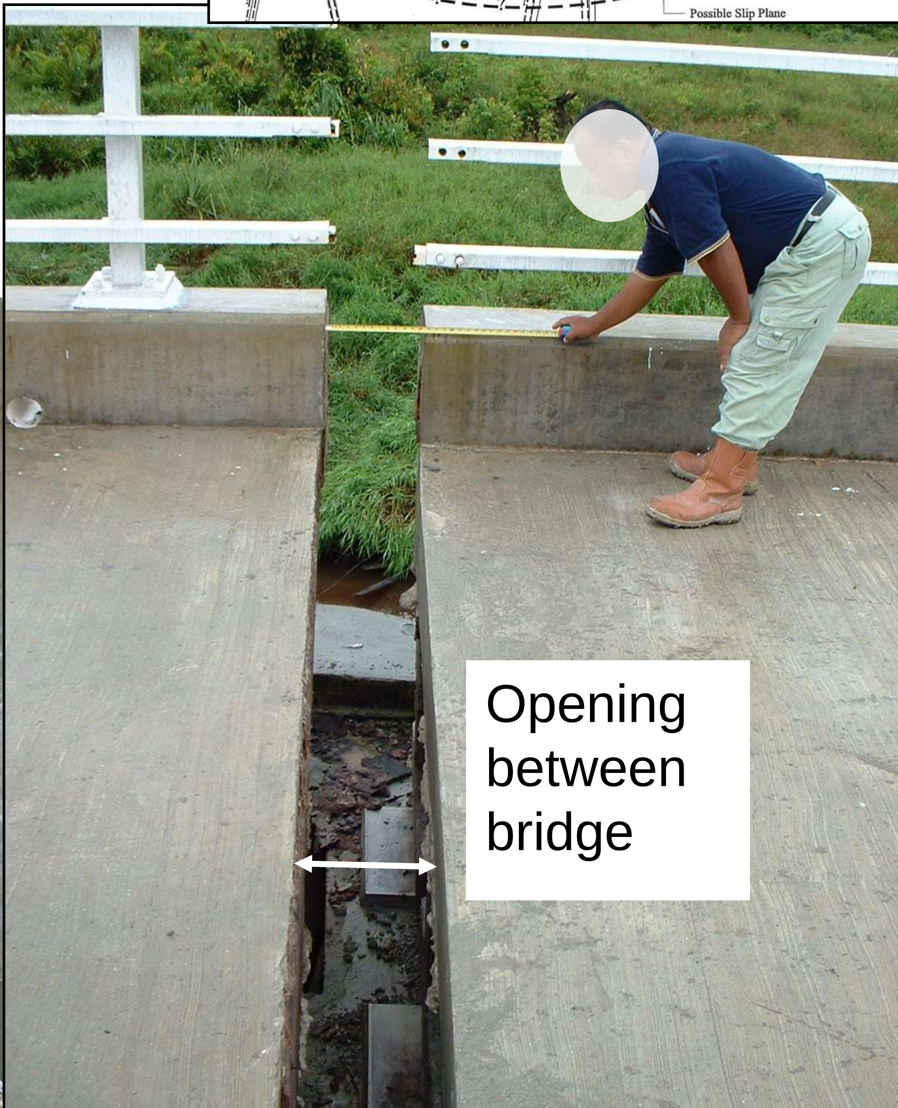
Slip Failure



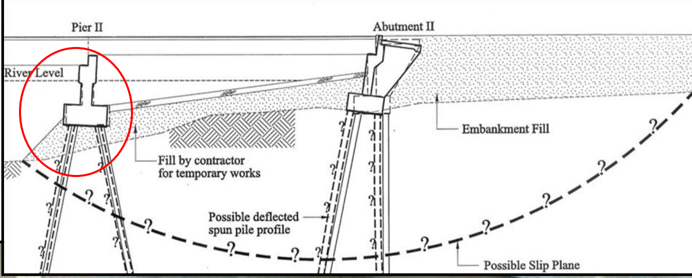
Tilted Abutment & Gap between Bridge Decks

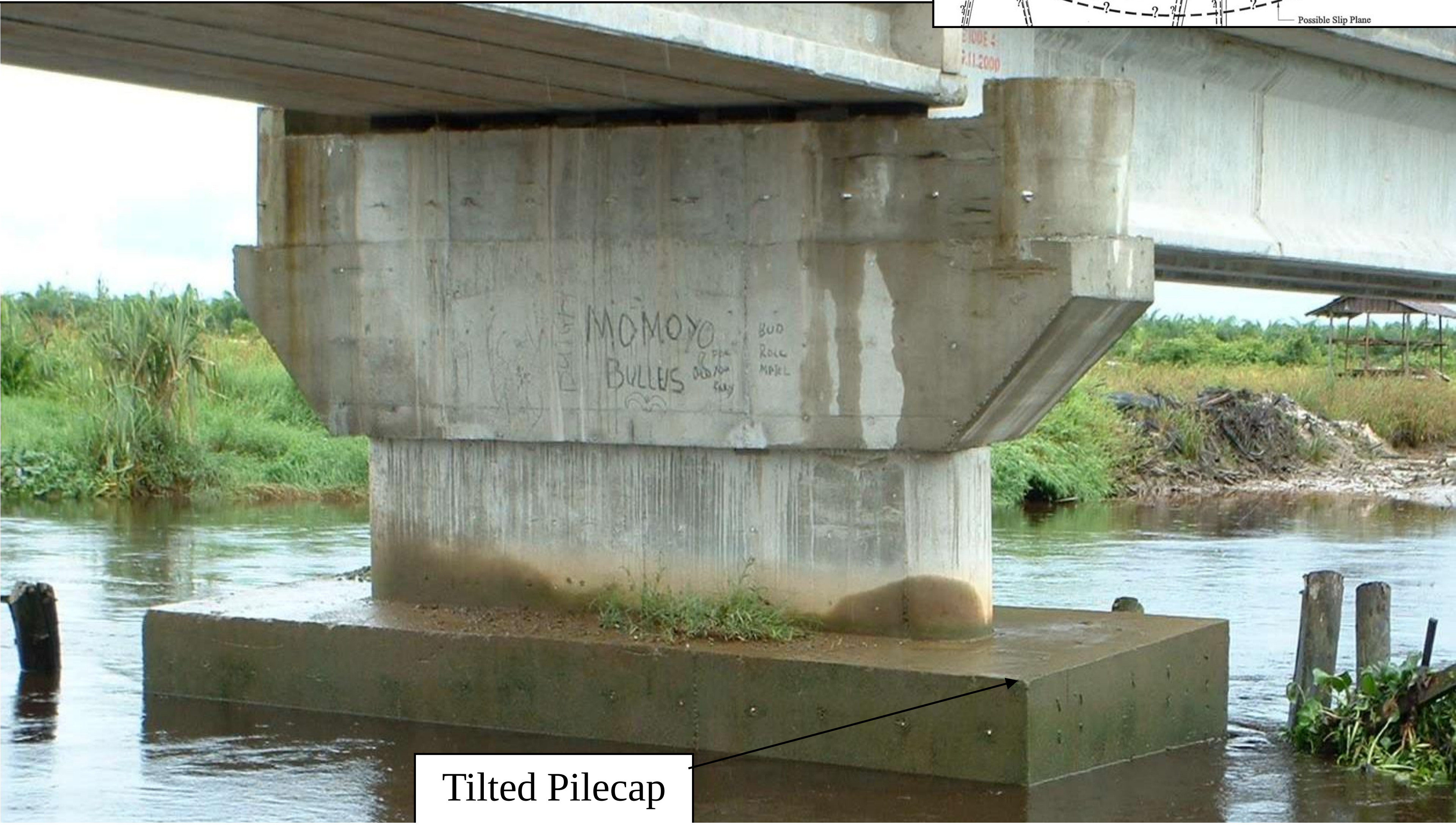






Pier II


Pier II
Abutment II
River Level
Embankment Fill
Fill by contractor
for temporary works
Possible deflected
spun pile profile
Possible Slip Plane


Tilted Pilecap

Slip Failure of Embankment

- At 25m behind Abutment II
- Abutment II :
  - Tilted 550mm on top
  - Angular distortion of 1/6
- 300mm gap between bridge decks

Geotechnical Investigation

- $H_{failure}$ @ 3m
- H_{Design} @ 5.5m

➔ NOT SAFE

HOW TO CHECK?

What Is The Critical Height?

Simple Calculation

$$H_{failure} = (N_c \times Su) / \gamma_{fill}$$

$N_c \approx 5$

$$H_{failure} = (5 \times Su) / \gamma_{fill}$$

e.g. :

When $Su = 10$ kPa ; $\gamma_{fill} = 18$ kN/m^3

$$H_{failure} = (5 \times 10)/ 18 = 2.8 \text{ m}$$

Lessons Learned

- Failures ← (temporary works)
  - Inadequate geotechnical design
  - Subsoil Condition
    (Lack of understanding)
  - Lack of construction control & supervision

Preventive Measures

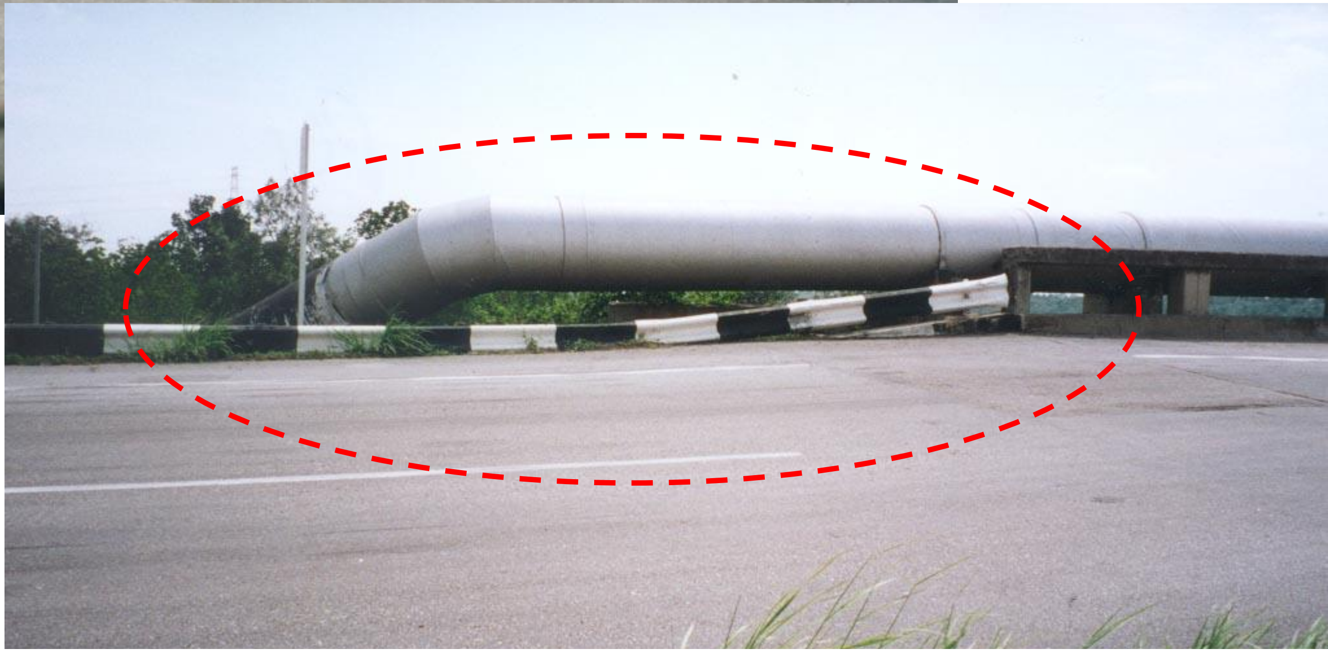
- Proper design and review
- Stability check of embankment & abutment
- Most critical :-

  During construction

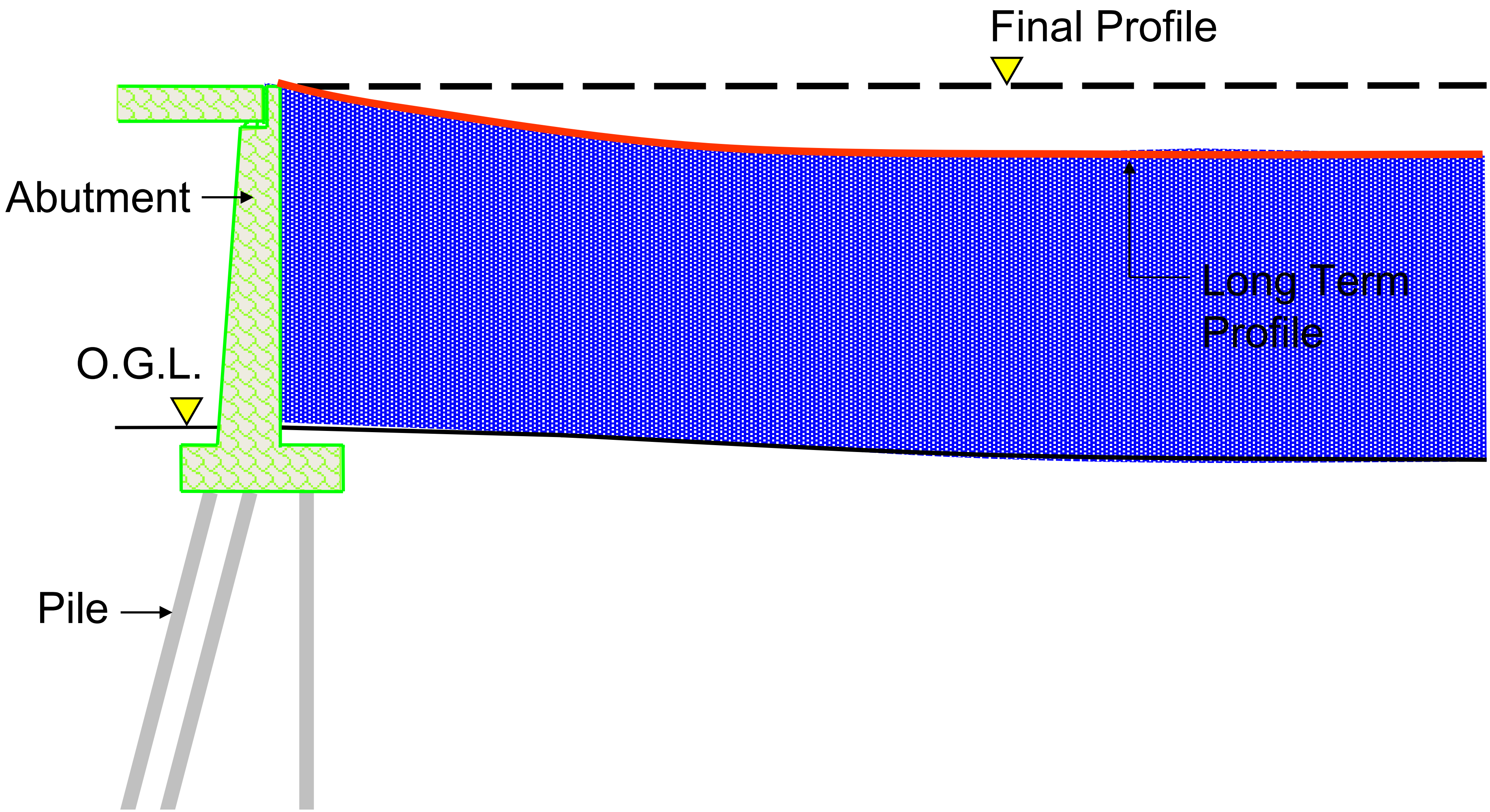
  (must check temporary works)
- Proper full-time supervision

  (with relevant experience & understand design assumptions)

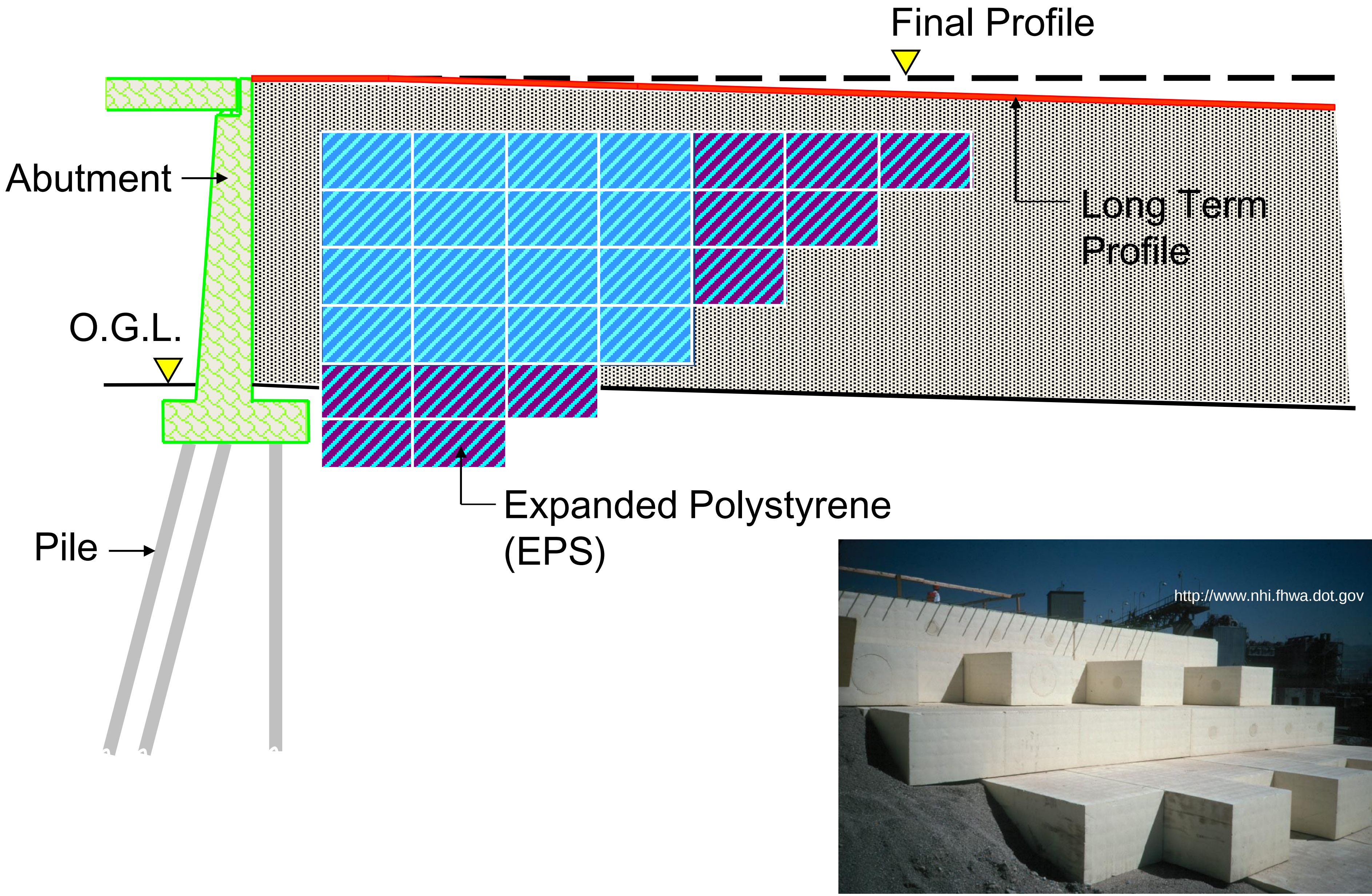
SETTLEMENT OF APPROACHES BRIDGES



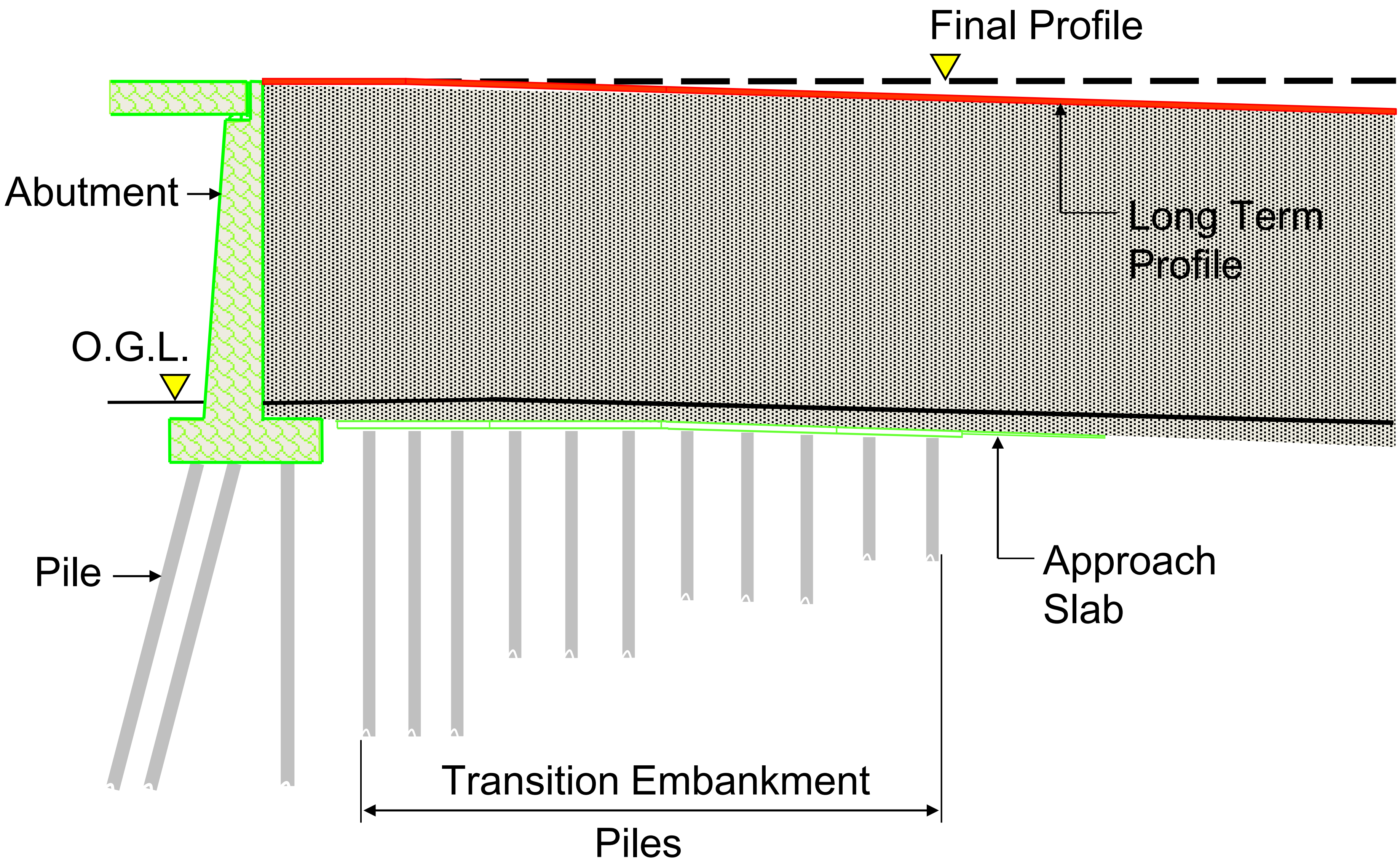
Typical Cross-Section



SOME SOLUTIONS TO THE PROBLEM



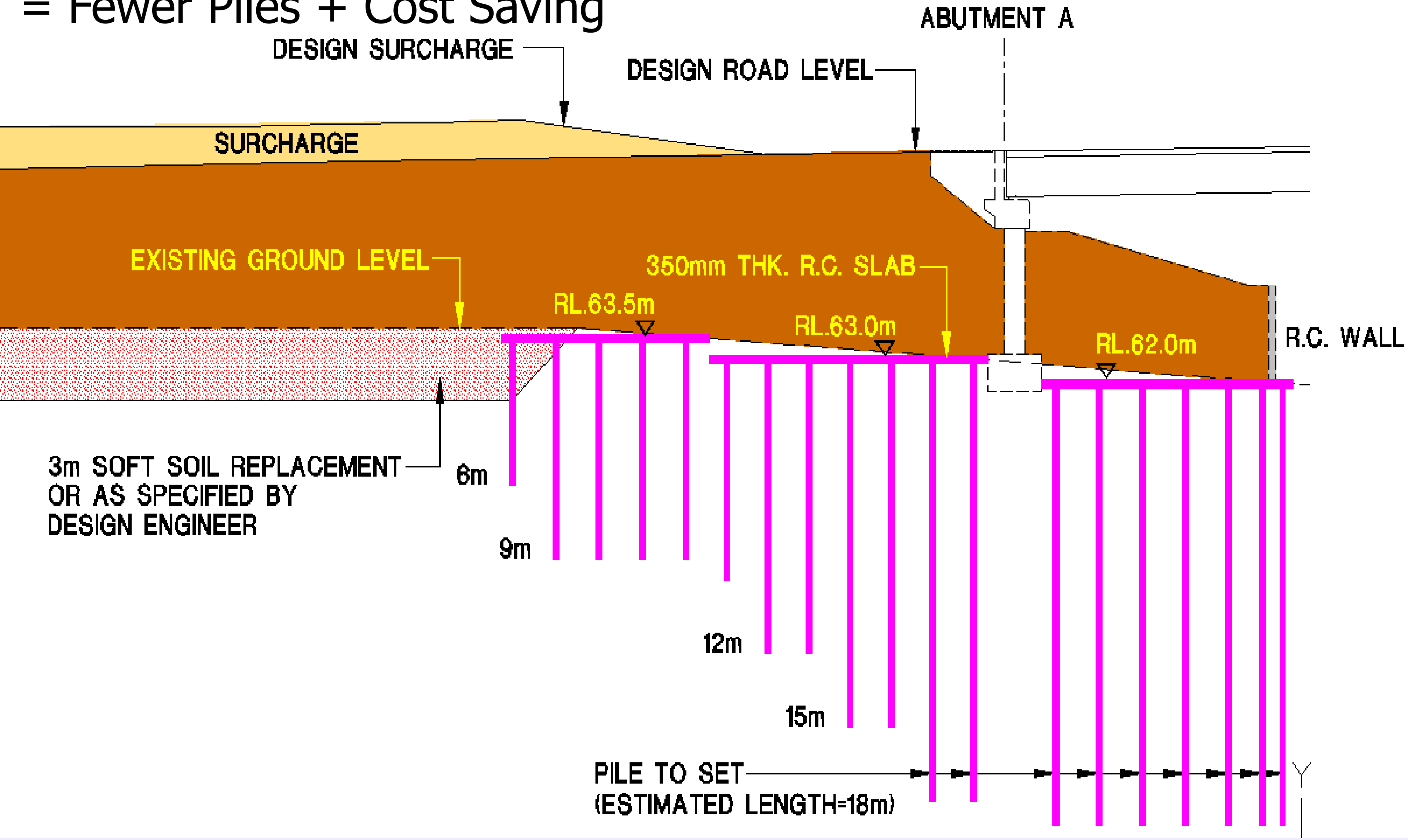
USE OF LIGHT WEIGHT MATERIAL



USE OF TRANSITION EMBANKMENT PILES

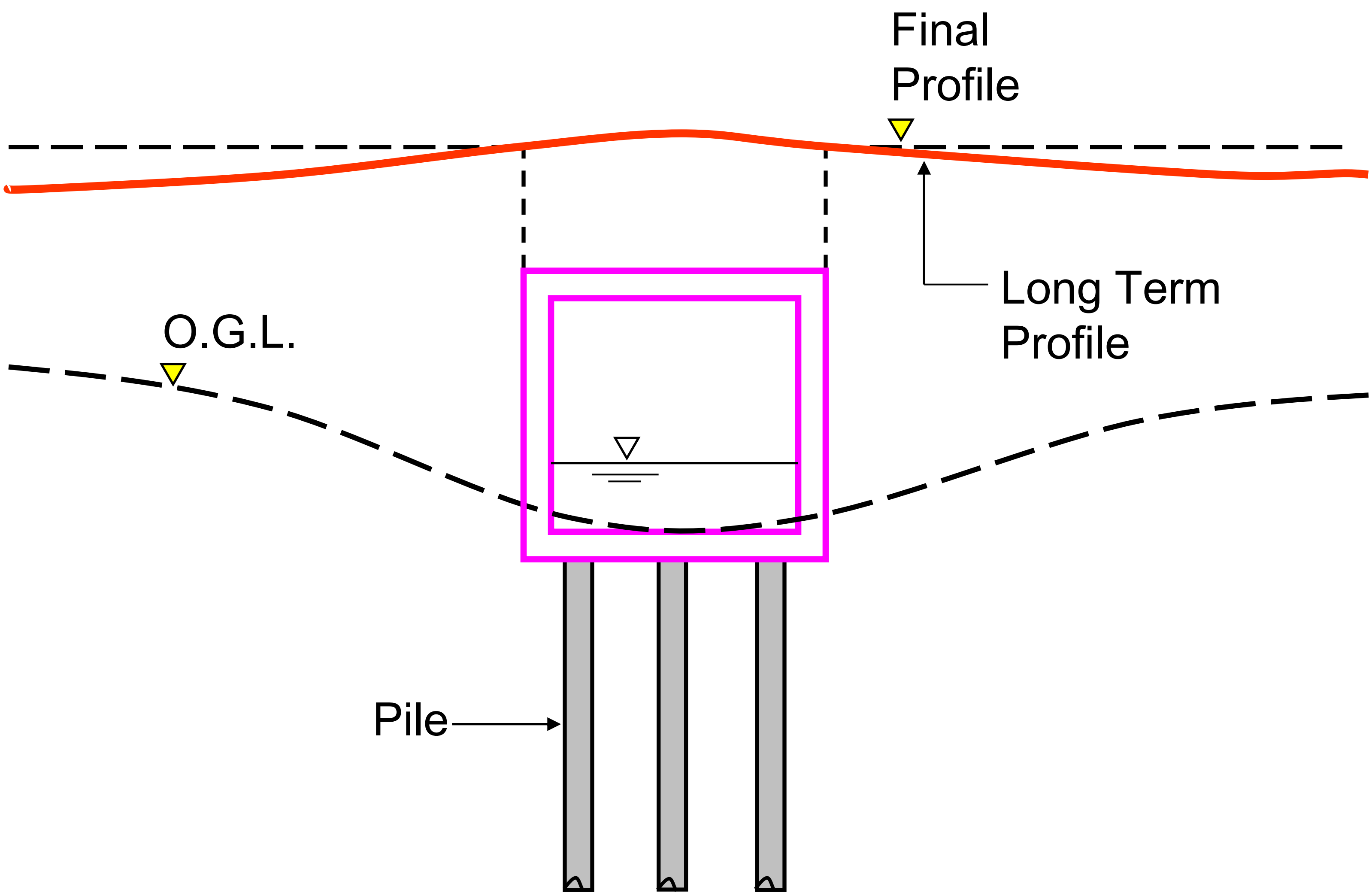
EXAMPLE (BERNAM JAYA)

Transition Piles + Surcharging
= Fewer Piles + Cost Saving



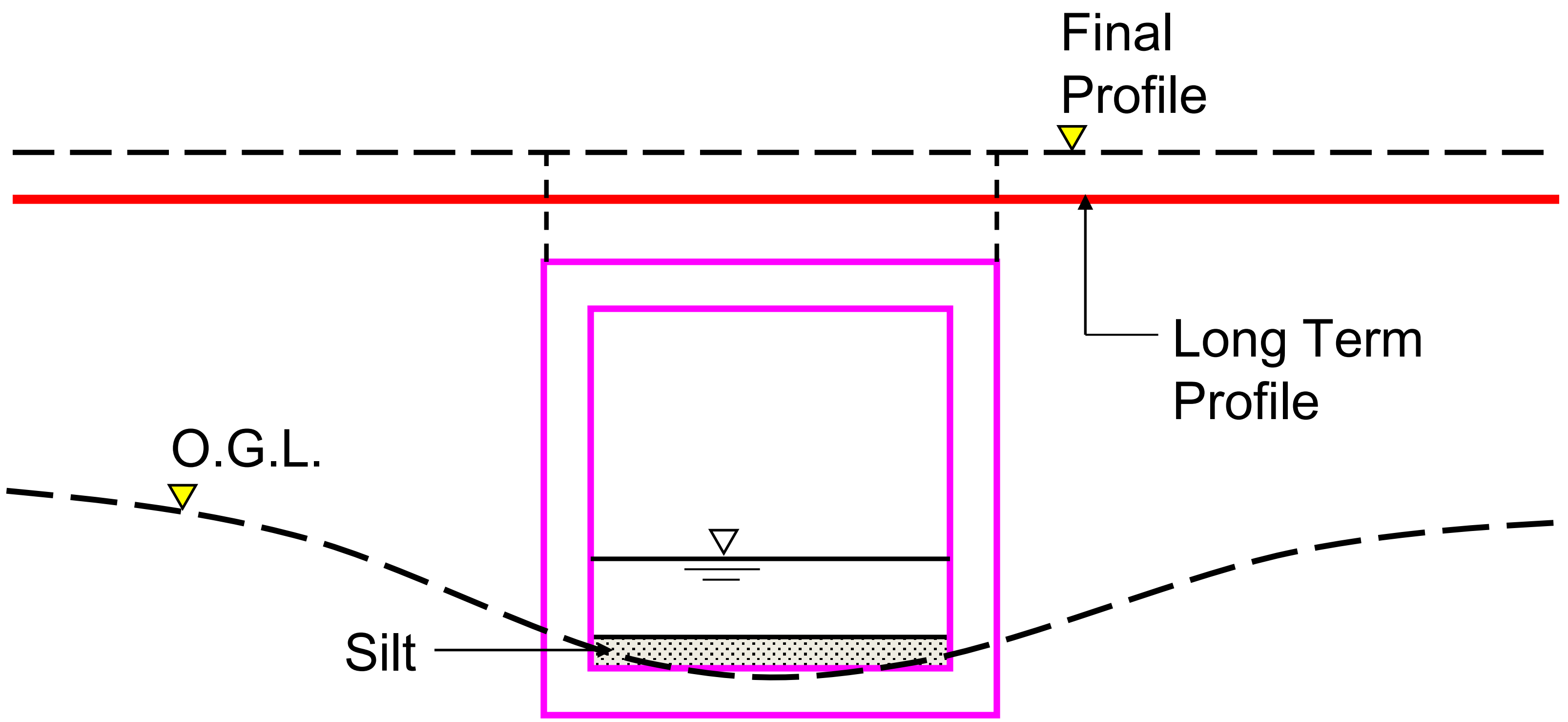
SETTLEMENT OF APPROACHES TO CULVERTS


'93 3 3

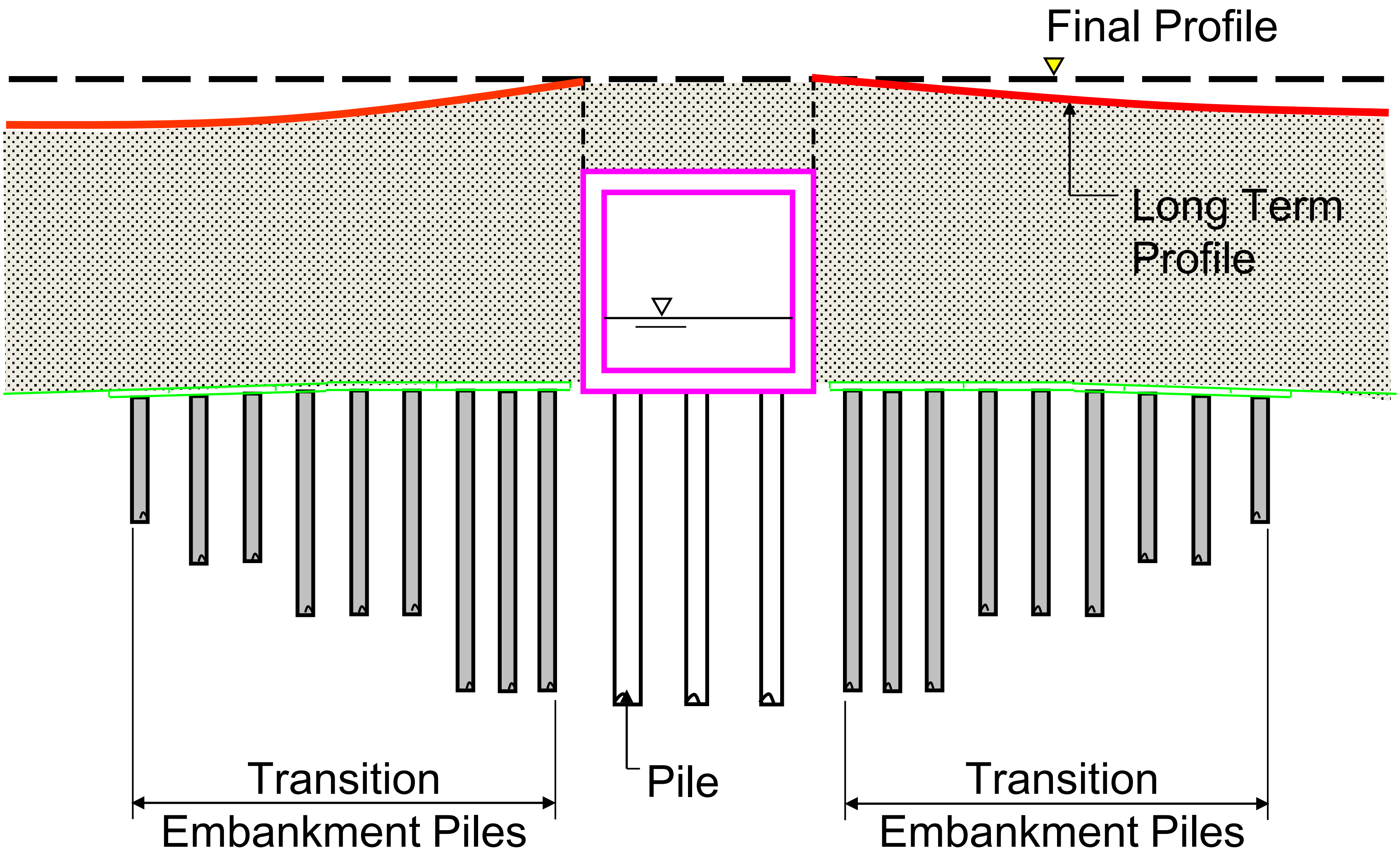


PILED CULVERT

SOME SOLUTIONS TO THE PROBLEM



ENLARGED CULVERT



TRANSITION PILES

Thank You