DEEP EXCAVATIONS IN MALAYSIA THE STATE OF THE ART

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Lecture material from experience gained
in
analysis, design and construction of more than 50 deep excavation projects with embedded retaining structures.

Cases presented are all designed and (mostly) constructed by the authors

TYPES OF EMBEDDED WALLS AND BRACING SYSTEMS

- SHEET PILES
- SOLDIER PILES
- ***CONTIGUOUS BORED PILES***
- ***SECANT PILES***
- ***DIAPHRAGM WALLS***

LECTURE MATERIAL

TYPES OF EXCAVATION SUPPORTS

- *Cantilever (plane strain) CBP or diaphragm wall – no external bracing.*
- *Circular diaphragm wall – no external bracing – supported by hoop (compressive) stresses induced by inward movement of wall.*
- *Top – down construction with floor slabs as bracing.*
- *Horizontal steel struts with pre-stressing.*

TYPES OF EXCAVATION SUPPORT

- *Diaphragm wall or CBP with permanent passive soil nails as reducers of lateral forces*
- *Soil cement mix or jet grout with or without embedded wall*
- *Temporary pre – stressed ground anchors*
- *Combinations of the above*

Characteristics of major urban centres

Kuala Lumpur where most of the basement excavations are. Maximum depth of excavation about 25 m.

- *Granite residual soils*
- *Kenny Hill formation in places with alluvium or tin tailings over it*
- *Alluvium or tin tailings over karst limestone*

URBAN CENTRES

Kuala Lumpur

- Alluvium and tin tailings – normally consolidated often sandy
- Granite residual soils and Kenny Hill Formation – exhibit characteristics of over--consolidated soils – less settlements due to drawdown of ground water

URBAN CENTRES

Kuala Lumpur

- *Walls inevitably not designed as total seepage cut offs*
- *Hilly terrain can result in uneven basement retaining wall heights and imbalanced lateral loads on building*

URBAN CENTRES

Penang

- *In Georgetown – about 6 m of soft clay over deep seated granite wash (Penang Piedmont wash) – silty sand. K = 10^{-5} m/sec*

- *Prangin Mall basement excavation resulted in draw-down and consolidation settlement affecting surrounding brick houses to a distance of 100 m – problem resolved with 28 m sheet pile cut off.*

URBAN CENTRES

Penang

- *Penang high court extension (centre of historical Penang) – 28 m deep sheet pile effective as total seepage cut – off.*
- *Diaphragm walls have been used outside George town area – Bayan Baru deep sewage pumping station*

URBAN CENTRES

Kelang and coastal areas

- *Deep seated soft clays*
- *Building basements generally 1 to 1½ levels – mostly sheet pile supports*
- *Deep excavations for pumping stations – circular arrangement of diaphragm walls without external bracings*

URBAN CENTRES

Malacca

- *Relatively few basement excavations*
- *Recent case of soil – cement mix block in soft clay for 1 ½ level basement excavation without an embedded wall – paper to presented by Yee*

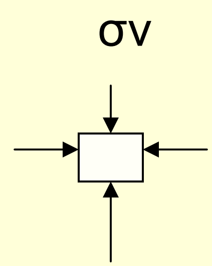
URBAN CENTRES

Johor Baru

- *Deepest basement – 5 levels*
- *Diaphragm wall with high pre-stressed anchors with “tube –a – manchette” grouting*
- *Older Alluvium with characteristics of an over consolidated clay*

SOIL MECHANICS OF AN EXCAVATION WITH PARTIAL SEEPAGE CUT – OFF WALL

CHANGES IN STRESSES AND PORE PRESSURES



σv – small changes Δ σv = 0

σh – reduces Δ σh = <u>negative</u>

Δu = B(Δ σh + A(Δ σv – Δ σh)
B = 1 A = 0.5 for OC clay

Δu = 0.5Δ σh = <u>negative</u>

PORE PRESSURES IN FRONT OF WALL LESS THAN BACK OF WALL.
HIGH EFFECTIVE STRESSES IN FRONT OF WALL AT END OF EXCAVATION

σv – reduces Δ σv = <u>negative</u>
σh – small increase Δ σh = 0

Δu = B(Δ σh + A(Δ σv – Δ σh)
B = 1 A = 0.5 for OC clay

Δu = 0.5 Δ σv = <u>negative</u>

GROUND WATER DRAWDOWN

- Ground water drawdown as excavation proceeds – transient seepage condition
- After completion of the excavation a transient seepage condition occurs for some time (depending on the k value) before reaching a steady state flow condition.
- Even at steady state condition, recharge conditions can result in transient states.

SUM EFFECT ON PORE PRESSURES

FRONT OF WALL

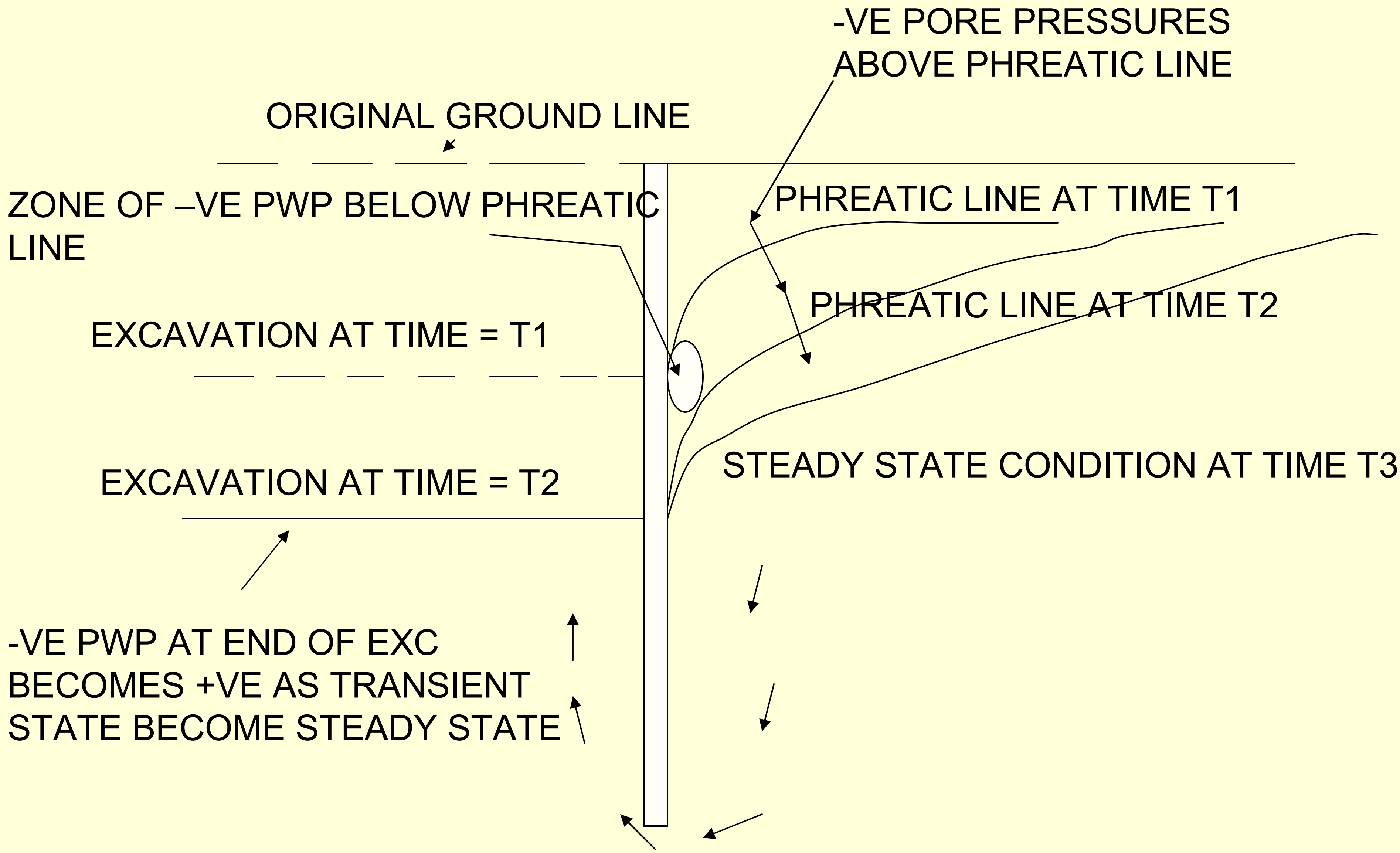
- *Immediately at end of excavation, negative pore pressures in front of wall along excavation boundary due to reduction in vertical stresses*
- *Over time as conditions move from transient to steady state, flow will cause negative pore pressures at boundary to be zero. Positive pore pressures below excavation boundary*
- *Therefore effective stresses highest at end of excavation*

SUM EFFECTS ON PORE PRESSURES

BEHIND WALL

- *The pore pressures above the drawn - down phreatic line will be negative and remain negative over time unless there is an external recharge (unless sandy and gravely; u = 0.0)*
- *It is possible to have localized negative pore pressures <u>immediately behind the wall below the phreatic line</u> due to reduction in lateral pressure from excavation and wall movements. These localized negative pore pressures are temporary and dissipate quickly due to flow from the surrounding positive pore pressure region.*

SUM EFFECTS OF PORE PRESSURES



NEGATIVE PORE PRESSURE DOES NOT MEAN DE-SATURATION

- *Clays are able to support suction of many atmospheres without de-saturating.*
- *If largely fine grain, can sustain suctions of several atmospheres without de-saturating.*
- *In clays, de-saturation occurs at - 400 kPa.*
- *In SAGE CRISP analysis, mostly less than*

-100 kPa above phreatic line.

- *Therefore clayey soils above phreatic line remains saturated even though pore pressures negative*

EFFECTS OF WALL INSTALLATION

SOIL BEHAVIOUR DURING WALL INSTALLATION

Measurements in the UK and the work of C.W.W. Ng and Lings have shown:

- *Marked decrease in lateral stresses during diaphragm wall installation but such decrease accompanied by small movements*
- *The reduced lateral stresses from installation results in relatively low strut forces*
- *The influence of diaphragm wall installation extends to distances of 15 m perpendicular to the wall face*

MEASURED LATERAL EARTH PRESSURES REDUCED EARTH PRESSURES ATTRIBUTED TO INSTALLATION EFFECTS

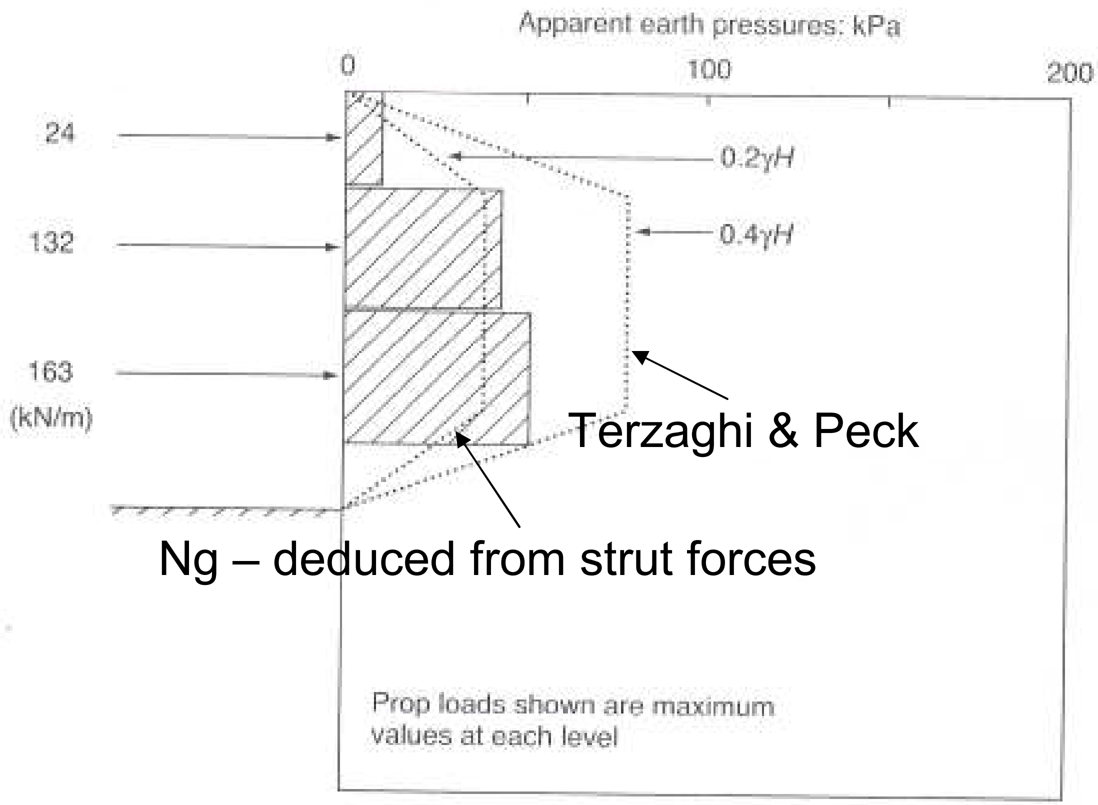


Fig. 2.26 Comparison of measured and Peck's (1969) design earth pressures at Lion Yard (after Ng, 1998)

REDUCTION IN LATERAL PRESSURES DUE TO WALL INSTALLATION (Ng)

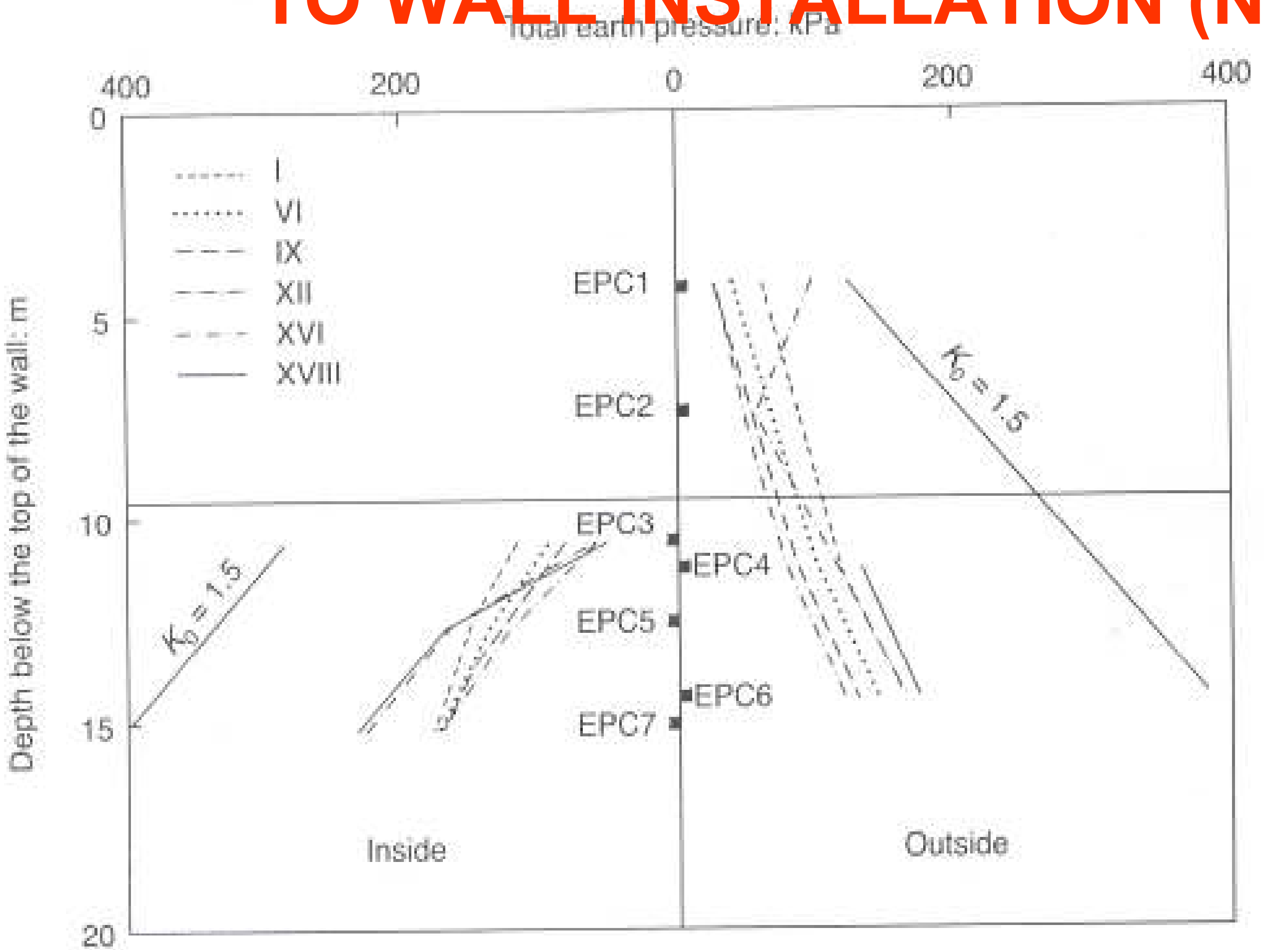


Fig. 2.25 Total lateral pressure during and after construction at Lion Yard (after Ng, 1998)

MOVEMENTS DURING INSTALLATION

CHAN S.F. AND Yap T.F.(1992)

Measurements of settlement of nearby building (Raffles Hotel) on shallow foundations in Singapore

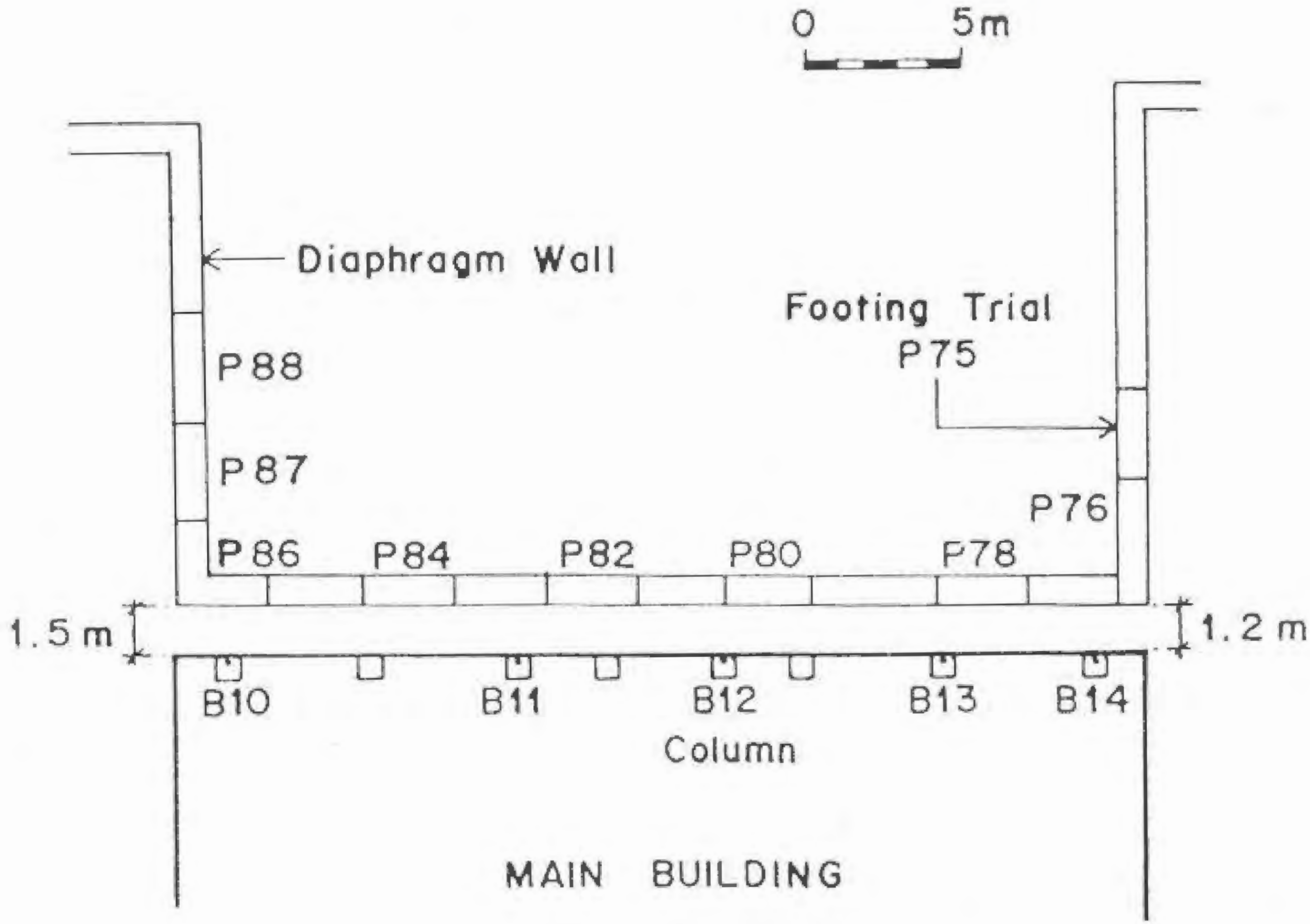


Fig. 3 -- Diaphragm wall adjacent to
Main Building.

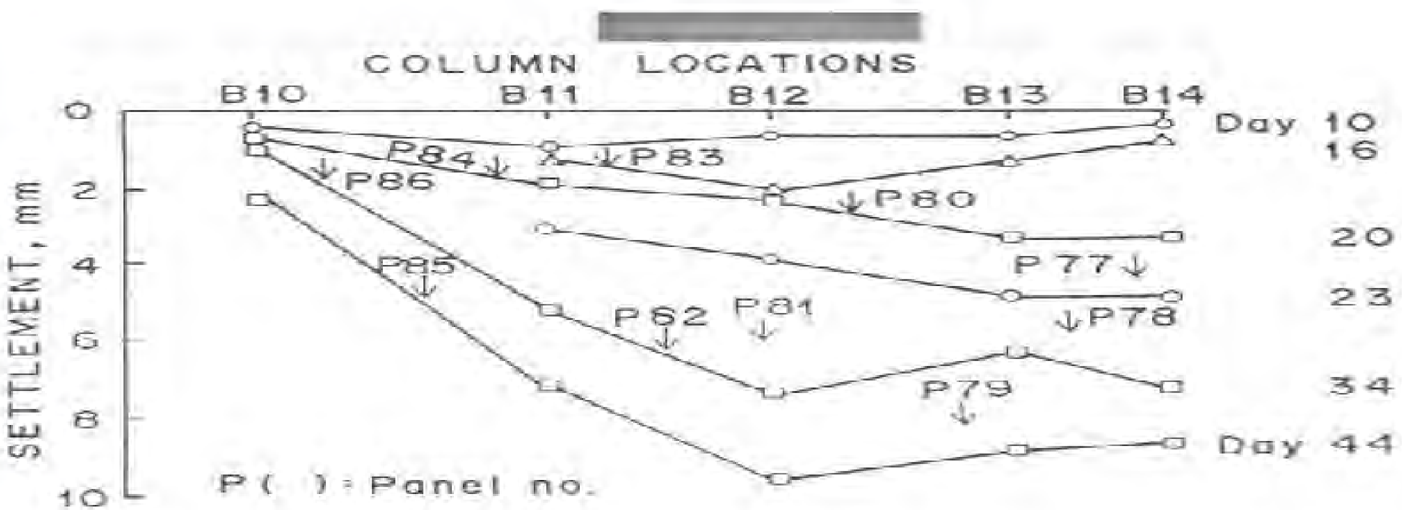


Fig. 9 -- Settlement of Main Building.

MINIMIZING SETTLEMENT DUE TO INSTALLATION

Methods of reducing settlement:

(i) Reduce length of each panel to be installed to a minimum of 2.8m

(ii) Minimize time of installation of each panel

(iii) No trench excavation near newly completed panel for 12 hours

(iv) Arrange panel construction sequence – each column near end of each panel

(v) Raise head of slurry to 0.5 m above ground level

METHODS OF ANALYSIS AND DESIGN

METHODS OF ANALYSIS FOR DESIGN OF WALL

Two methods commonly in use:

(1) SUBGRADE REACTION METHODS

- WALLAP, FREW

(2) FINITE ELEMENT METHODS

PREFERRED.SHOULD BE ABLE TO SIMULATE TRANSIENT SEEPAGE AND NEGATIVE PORE PRESSURES

- SAGE CRISP, GEOSOIL, PLAXIS

PROBLEMS OF USING COMMERCIAL FINITE ELEMENT ALGORITHMS

- BLACK BOX
- MAIN PROBLEM IS LACK OF USER UNDERSTANDING OF THE COMPLEX ALGORITHMS, ACCURACY, CORRECTNESS AND LIMITATIONS. NEED TO HAVE PROGRAMMED FINITE ELEMENTS AND CONSTITUTIVE LAWS TO BE ABLE TO UNDERSTAND.
- NEED TO HAVE A GOOD GRASP OF TIME DEPENDENT COUPLED EFFECTIVE STRESS BEHAVIOUR AND CONTINUUM MECHANICS – CHANGING PORE PRESSURES AND EFFECTIVE STRESS WITH TIME.
- NEED TO MOVE AWAY FROM THE RESTRICTIVE MIND SET OF UNDRAINED AND DRAINED ANALYSIS

COMPARISONS OF COMMERCIAL FE PROGRAMS

PROF. LEE FOOK HOU (NUS) – private communications

COMPARED SAGE CRISP, PLAXIS AND ABAQUS AGAINST ANALYTICAL SOLUTIONS FOR SEVERAL CONDITIONS

(i) CAVITY EXPANSION PROBLEMS – SIMPLEST STRESS FIELDS

(ii) EMBEDDED WALL EXCAVATION

CAVITY EXPANSION Cu MATERIAL

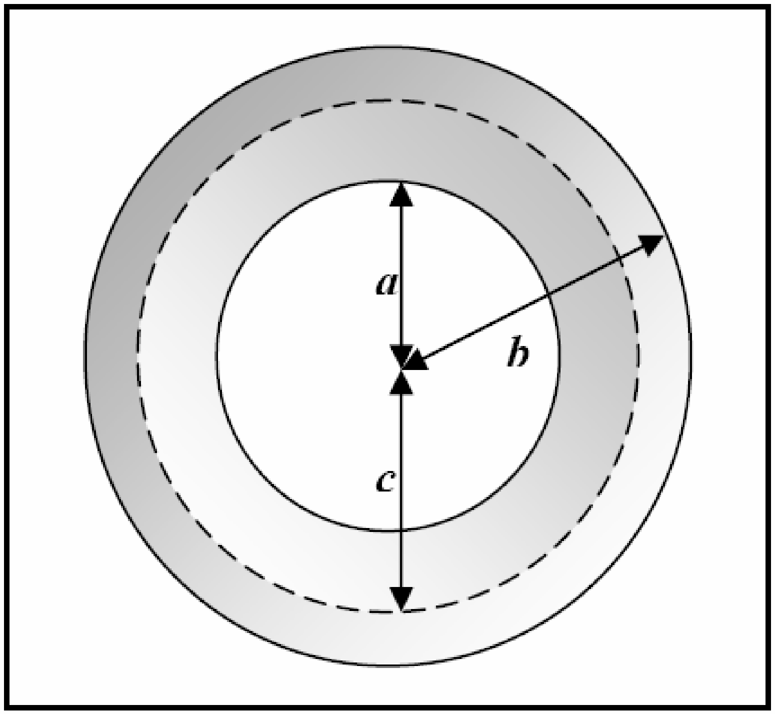


Figure 1 Cavity Expansion of a thick wall cylinder with plastic zone *c*

CAVITY EXPANSION MODEL

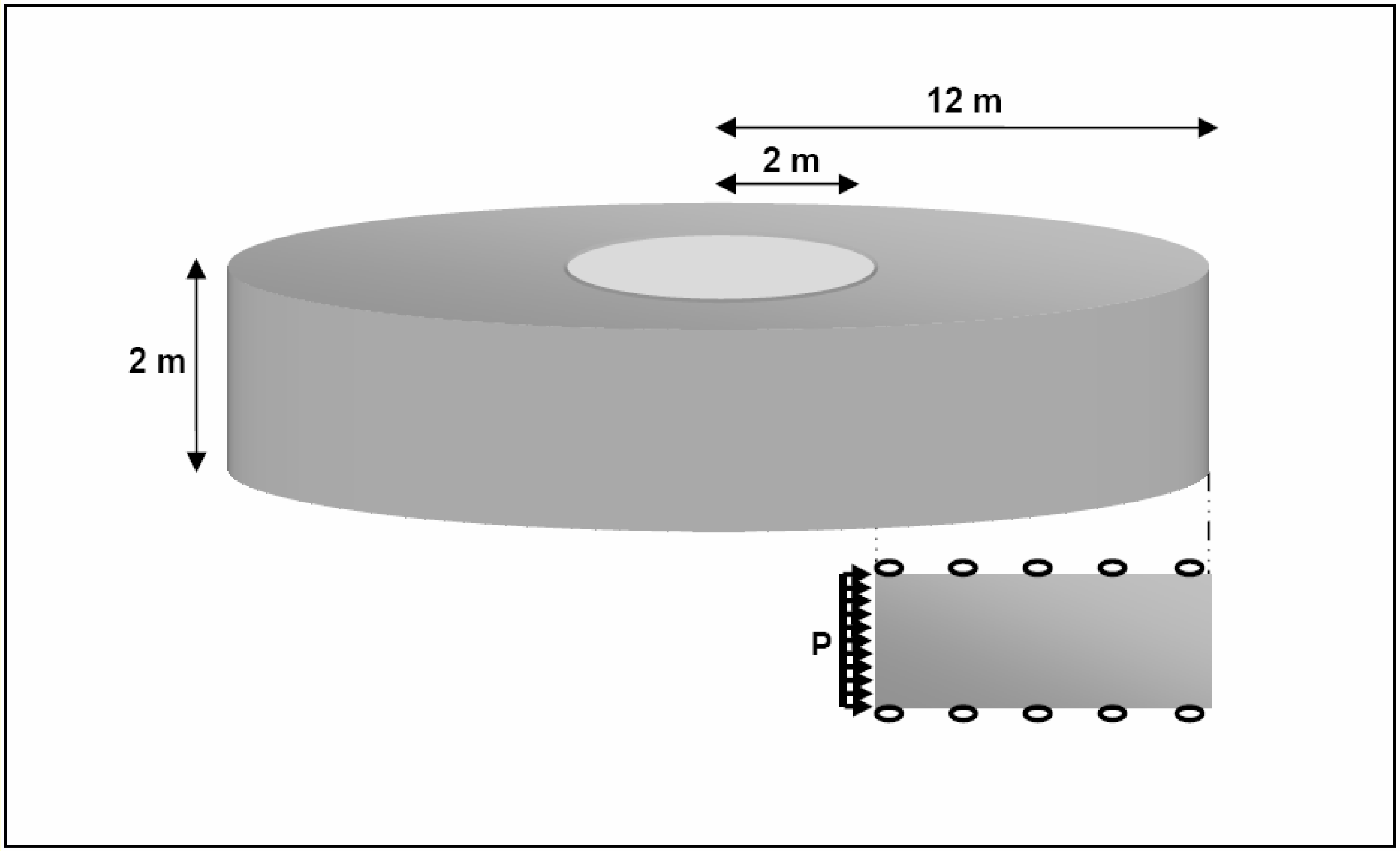


Figure 4 Thick wall cylinder

DISPLACEMENT CONTROL

Trial 1

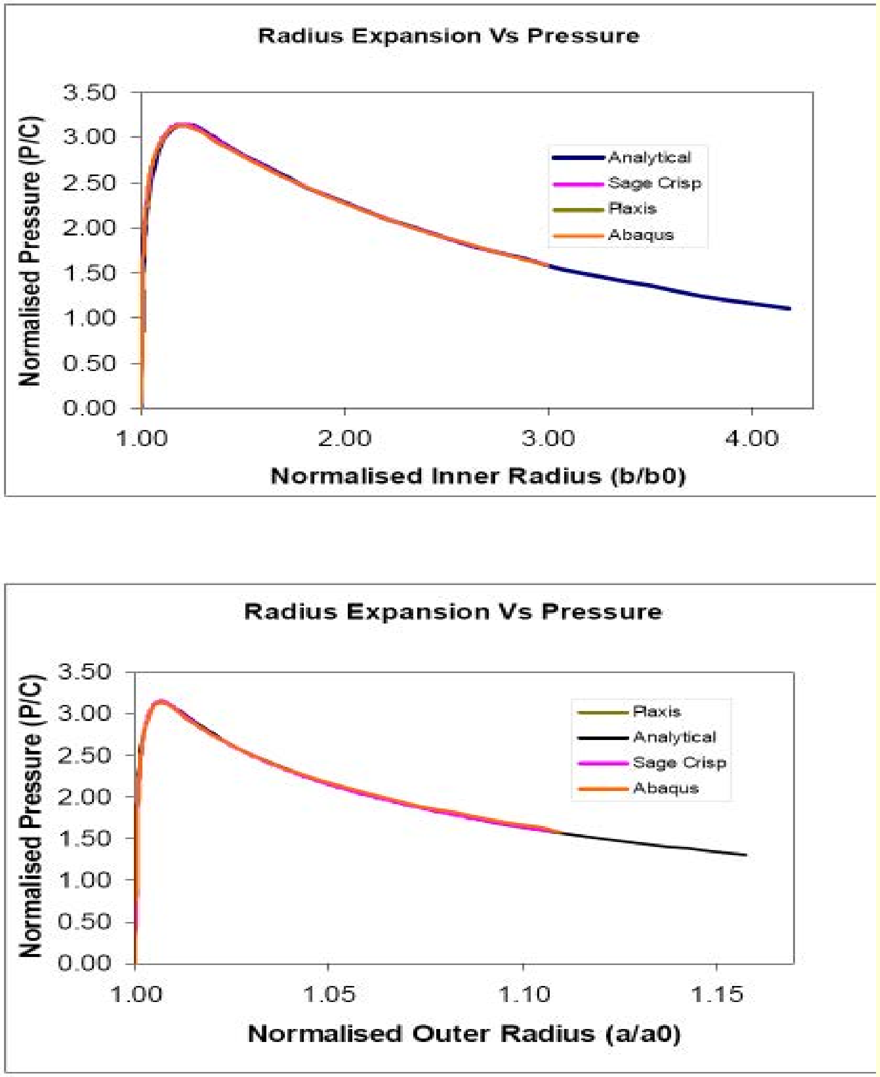


Figure 7 Displacement controlled analysis

PLAXIS OVER PREDICTS ULTIMATE LOAD FOR LOAD CONTROL

Trial 2

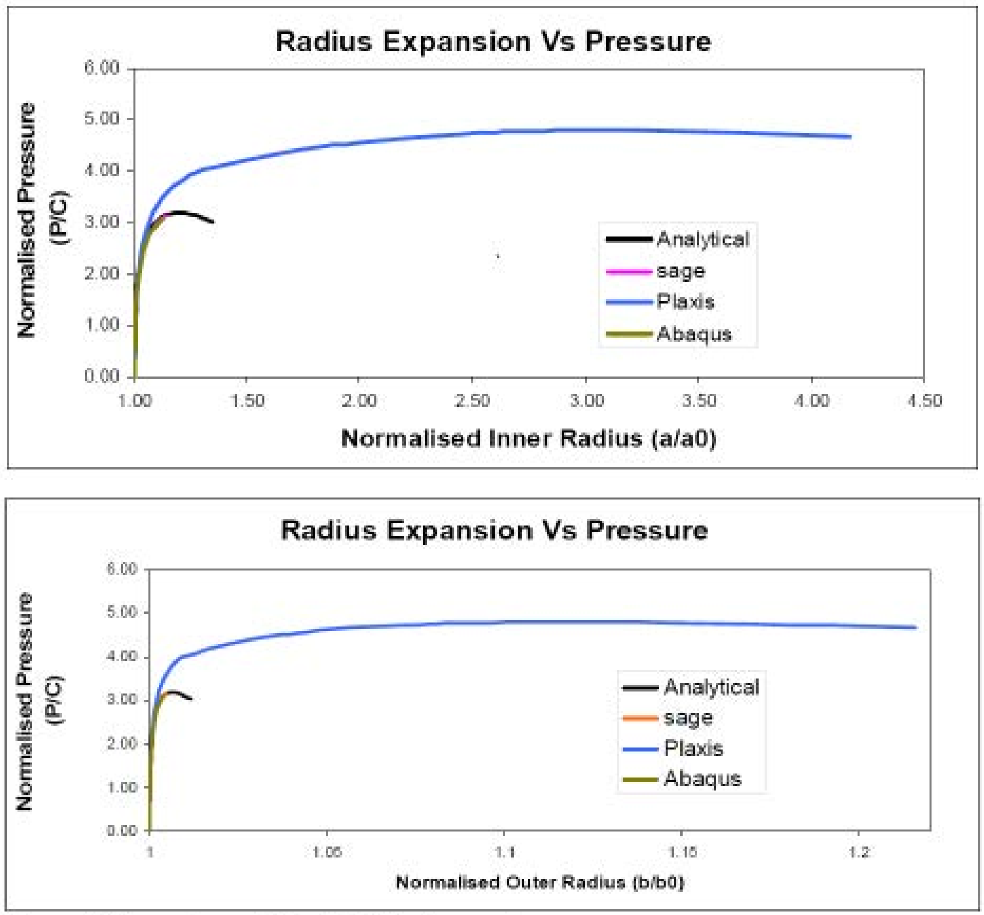
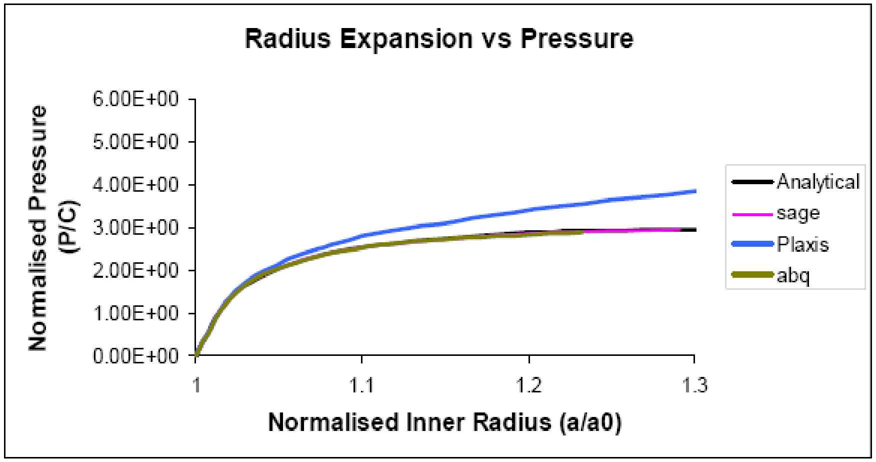


Figure 9 Comparison of Load – Displacement curves

PLAXIS OVERPREDICTS TRUE SOLUTION FOR LOAD CONTROL

<u>Trial 5 as an example.</u> (Parameters include **c=200 KPa, v=.3, and φ=0**)



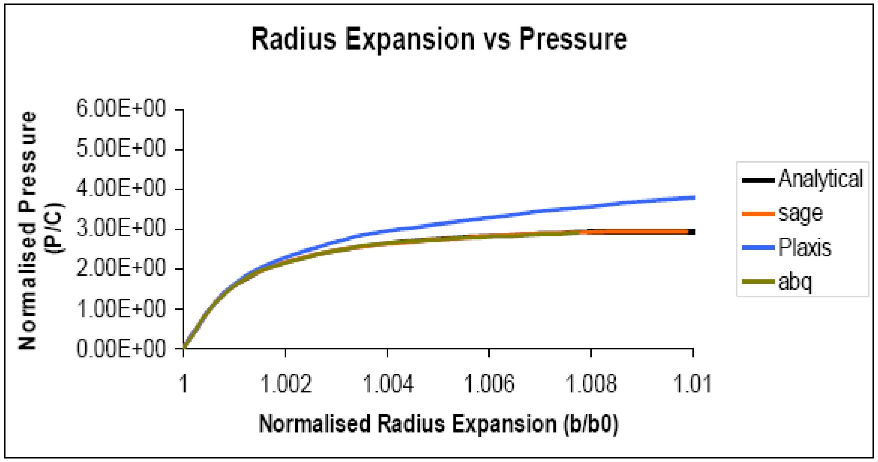


Figure 13 showing results similar at the collapse displacement of the Sage crisp and Abaqus.

NUS ANALYSIS OF CANTILEVER EMBEDDED WALL

DIFFERENCES IN BENDING MOMENTS AND DEFLECTIONS BETWEEN SAGE CRISP AND PLAXIS +/- 20 %

DEEPER EXCAVATIONS – LARGER DIFFERENCES – LESS STABLE CONDITIONS – GREATER YIELDING AND NON-LINEARITY

PLAXIS 6 NODED TRIANGLES GAVE SIGNIFICANT ERRORS IF UNDRAINED CONDITIONS ASSUMED

SAGE CRISP - PLAXIS

Several projects:

- Author's analysis with SAGE CRISP < 75 mm wall movements.
- Checker's analysis with PLAXIS > 200 mm
- Measurements lateral wall movements < 75 mm
- *Uncertain if problem with checker or PLAXIS*

PLAXIS AND SAGE CRISP HANDLES SEEPAGE FLOW DIFFERENTLY

PLAXIS

- Starts by calculating steady state condition
- Uexc = Initial – steady state
- -ve pwp zones changed to very low permeability.
- -ve pwp not allowed to develop
- Low permeability zones assigned very low –ve pwp
- Lots of twiddling – compromise on equilibrium
- Transient seepage analysis ???

SAGE CRISP

- Does not twiddle
- Entire continuum a flow domain
- Solves for effective stress and hydraulic equilibrium
- Transient and steady state seepage and consolidation solved
- -ve pwp allowed to develop without twiddling
- Purely directed at achieving equilibrium.
- Numerical procedures consistent with mathematical equations

SOIL MODELS

COMMONLY IN USE:

- MOHR COULOMB (LINEAR ELASTIC – PLASTIC) for residual soils and sandy soils
- MODIFIED CAM CLAY for soft clay

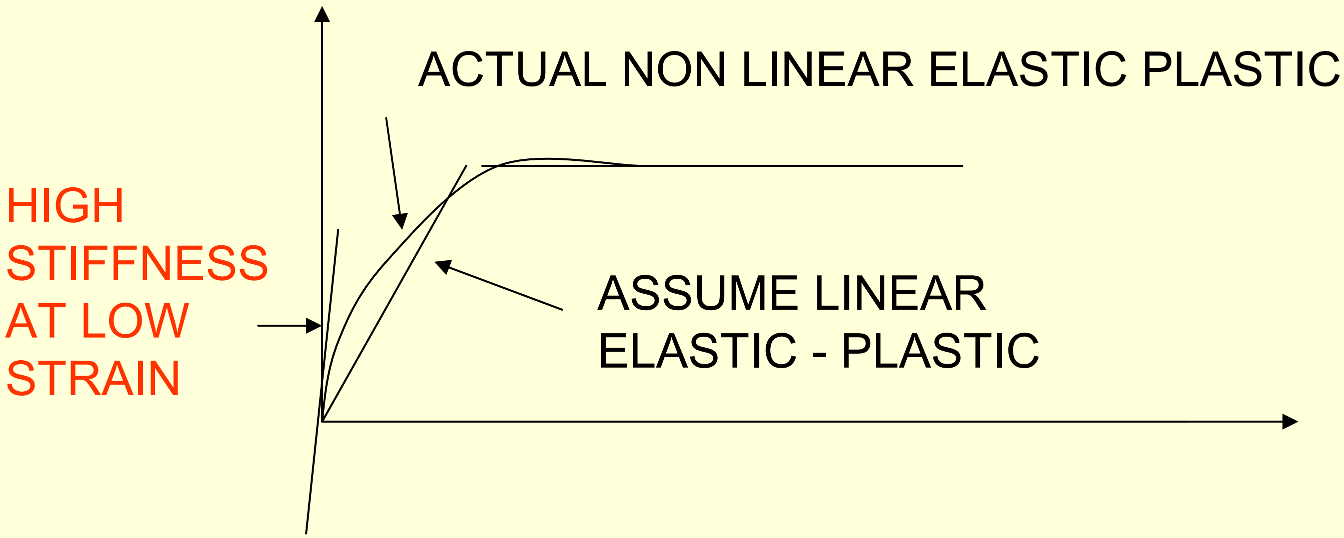
ABOVE MODELS <u>ATTRACTIVE</u> BECAUSE NUMBER OF PARAMETERS ARE RELATIVELY SMALL. THEREFORE CORRELATIONS WITH FIELD TESTS EASIER TO ESTABLISH

SOIL MODELS

- More complex models like Kondner's hyperbolic function with yield surfaces can be used to simulate the low strain – high stiffness effects.
- However such models require a larger number of parameters
- Therefore greater difficulty in relating to usual field test results
- Therefore more uncertainties

SOIL MODELS

- BUT SIMPLE MODELS (elastic – plastic) DO HAVE DISADVANTAGES.
- IMPORTANT - HIGH STIFFNESS AT VERY LOW STRAIN NOT MODELED



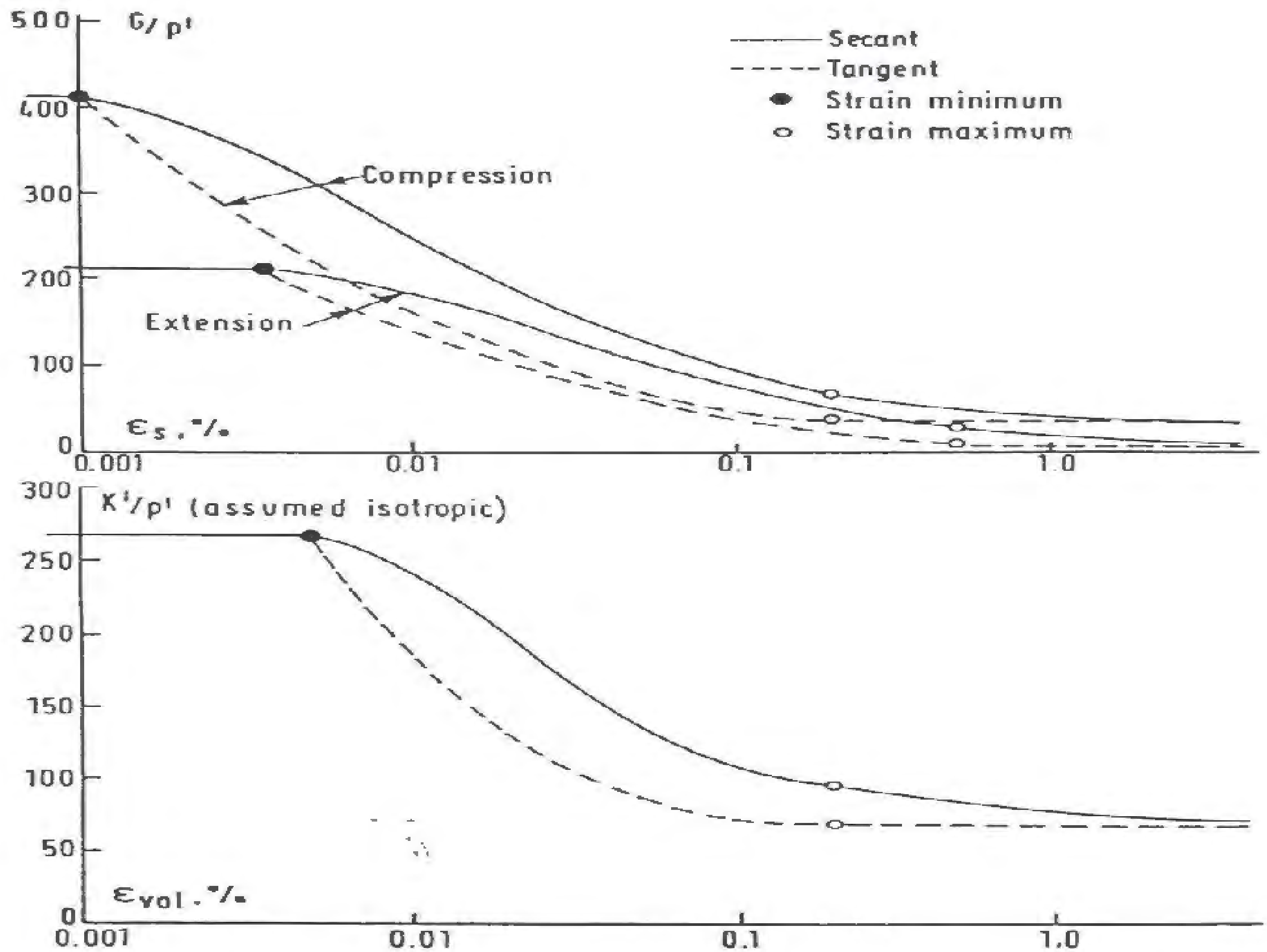


Figure 11. Non-linear stiffness relationships for intact London clay at Morgan Place.

(1975). The surface settlement map shown on Figure 14 illustrates the overall picture: the limited length of

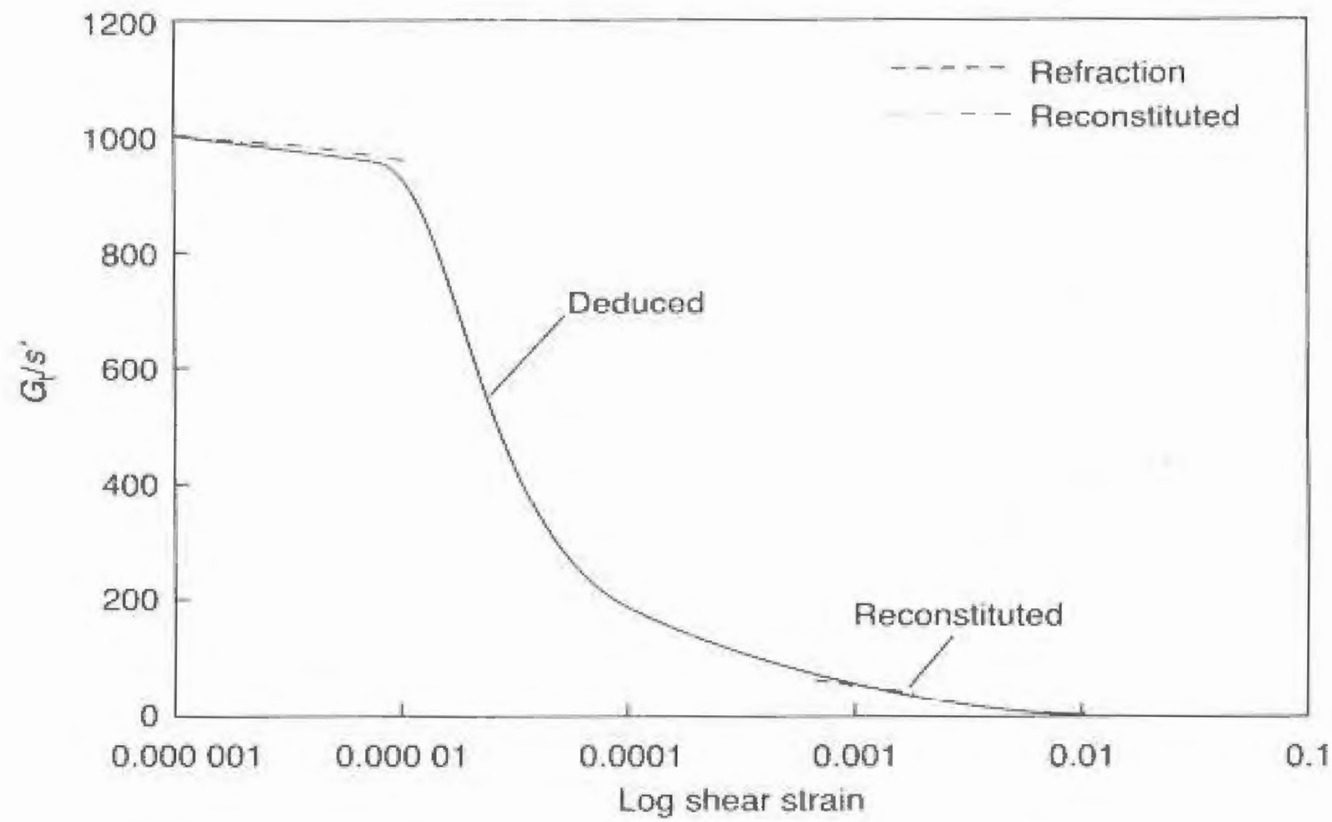


Fig. 2.67 Deduced normalized stiffness–strain relationship for Gault Clay (after Ng and Lings, 1995)

USING SIMPLE MODELS

- Mohr Coulomb over-predicts movements at very low strain areas (toe of wall).
- Because of assumption of average linear stiffness over elastic stress range. AVERAGE STIFFNESS LOWER THAN THE HIGHER STIFFNESS AT LOW STRAINS.

- Resolve deficiency by judiciously impose higher stiffness modulus in the known low strain zones to get realistic answers.
- E= 2 to 3N (MPa) behind wall above excavation level and E = 7 to 9N (MPa) in front of embedded part of wall

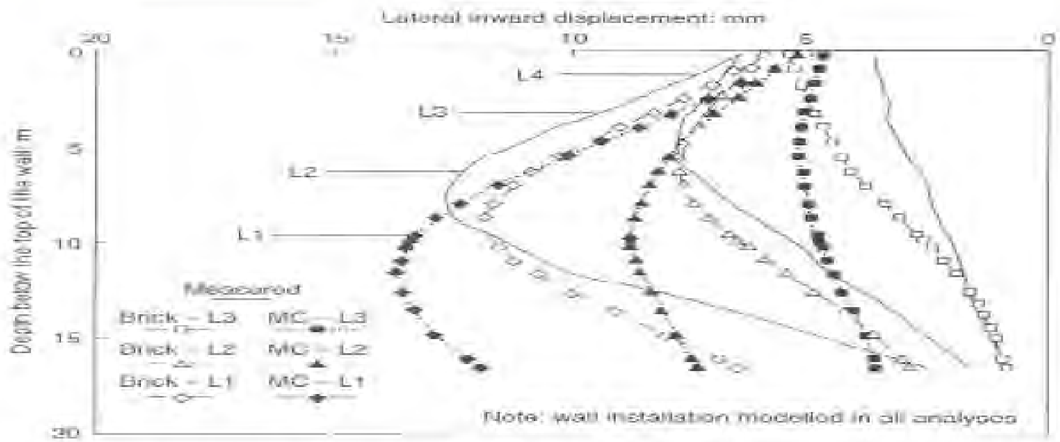


Fig. 2.68 Comparison of computed lateral inward displacements using Brick and Mohr–Coulomb (MC) models (after Ng and Lings, 1995)

WISH – IN – PLACE WALL

Invariably virtually all F.E. analyses adopt a wish – in – place wall where a beam element is just placed against the finite element mesh.

Because of the difficulties:

- In simulating the actual process of excavation with support fluid;
- The replacement with concrete stresses

This means that stress reduction due to wall installation not simulated

WISH – IN – PLACE WALL

If actual Ko of OC soil (commonly 2 to 3 for residual sedimentary and granite soils) is used with WISH–IN-PLACE walls :

- Over – estimate the wall deflections
- Over – estimate the strut or anchor forces

Over come this inadequacy by deliberately using lower Ko

When using Wish-in-place walls: Satisfactory to use Ko < 1 in highly OC clays (with Ko $= 2$ to 3) as a way of simulating lateral stress reduction due to installation.

MUST MOVE ON

Meanwhile we must move on while we await the HOLY GRAIL of perfect models that can easily be related to SPT and perfect algorithms that are easy to understand.

LATERAL MOVEMENTS OF WALL AND SETTLEMENT BEHIND WALL

From Clough and O' Rourke (1990)

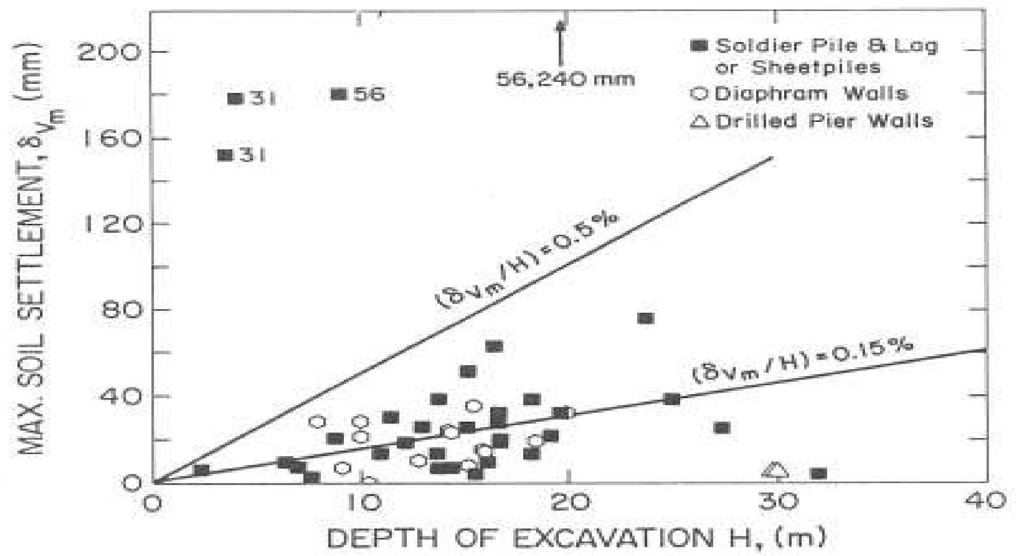
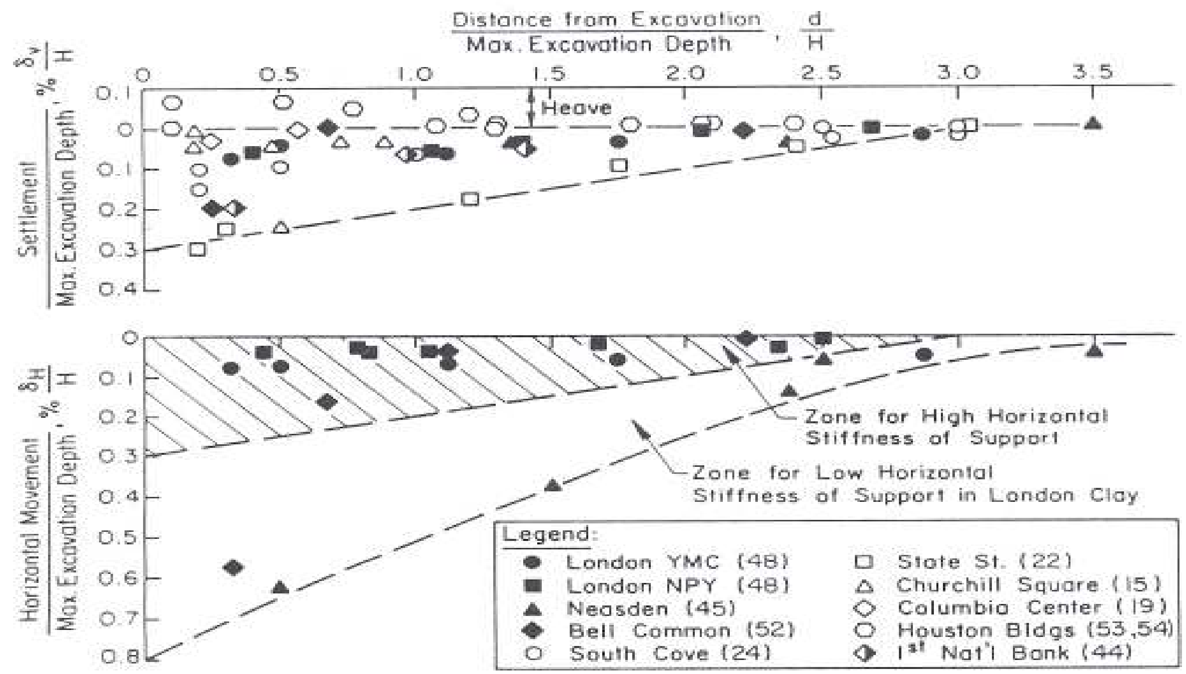


Figure 3. Observed Maximum Soil Settlements in the Soil Retained by Insitu Walls.

MAXIMUM SOIL SETTLEMENT VERSUS DEPTH OF EXCAVATION



SETTLEMENT AND WALL MOVEMENT NORMALZED AGAINST EXCAVATION DEPTH AGAINST DISTANCE BEHIND WALL

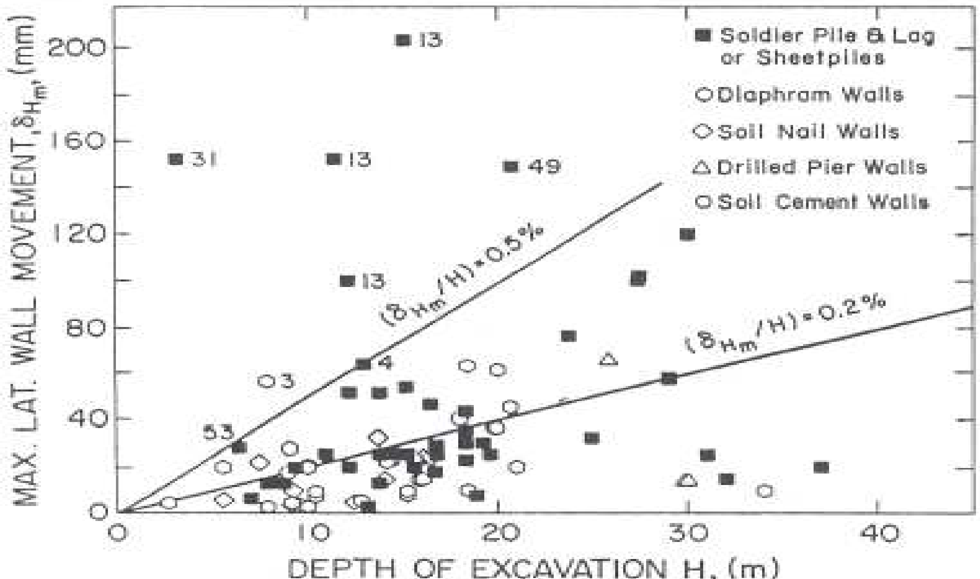


Figure 2. Observed Maximum Lateral Movements for Insitu Walls in Stiff Clays, Residual Soils and Sands.

MAXIMUM WALL LATERAL MOVEMENT AGAINST DEPTH OF EXCAVATION

TECHNIQUES OF BASEMENT CONSTRUCTION

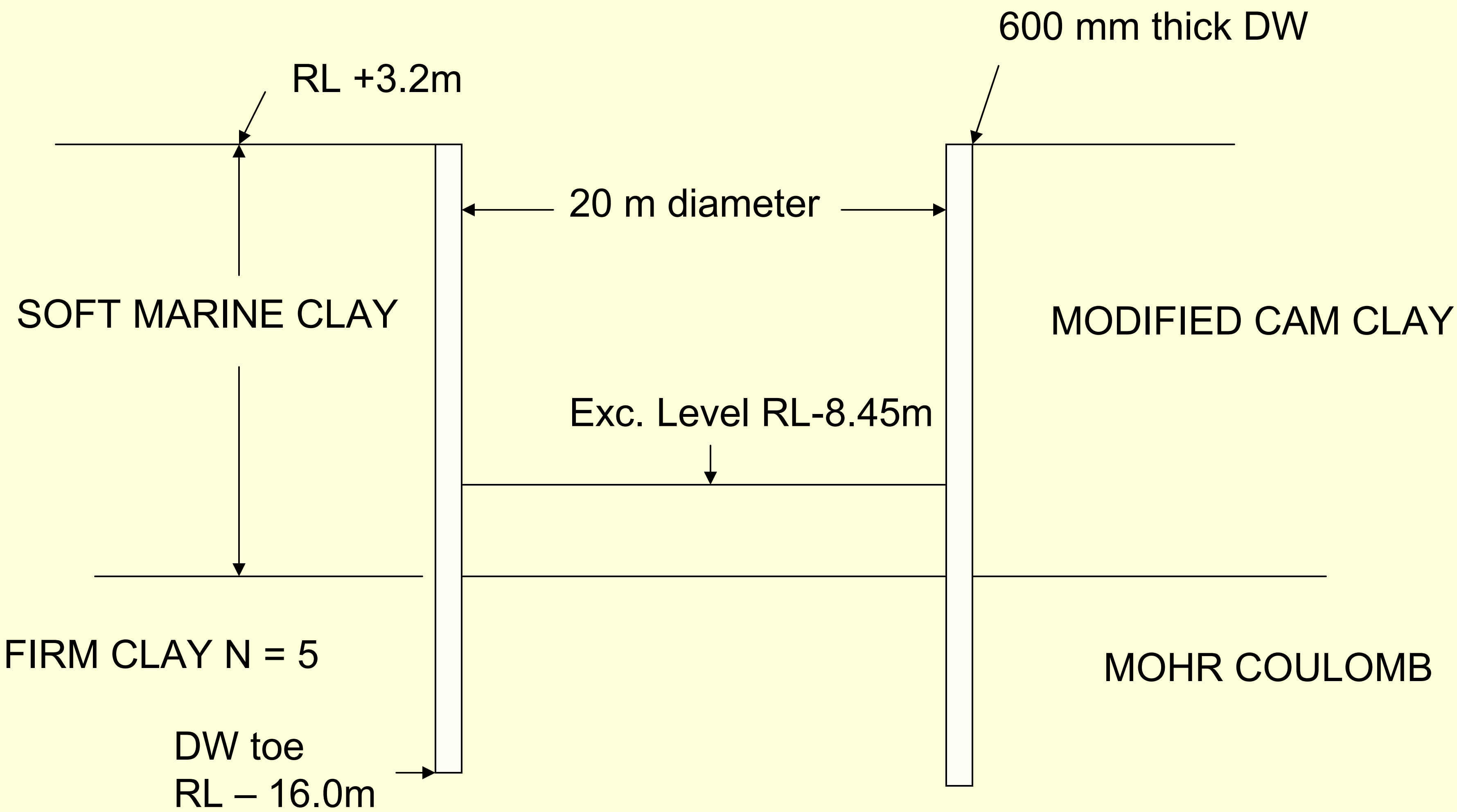
case histories

(FROM OUR OWN DESIGN – CONSTRUCTION)

CIRCULAR ARRANGEMENT OF DIAPHRAGM WALLS IN SOFT MARINE CLAY

NO EXTERNAL BRACINGS

PULAU INDAH SEWAGE PUMPING STATION
IN
SOFT MARINE CLAYS



ESTIMATED MAX HOOP STRESS = 5 MPa

ESTIMATED MX BENDING MTM = 90 kN - m

CIRCULAR DIAPHRAGM WALL, PULAU INDAH

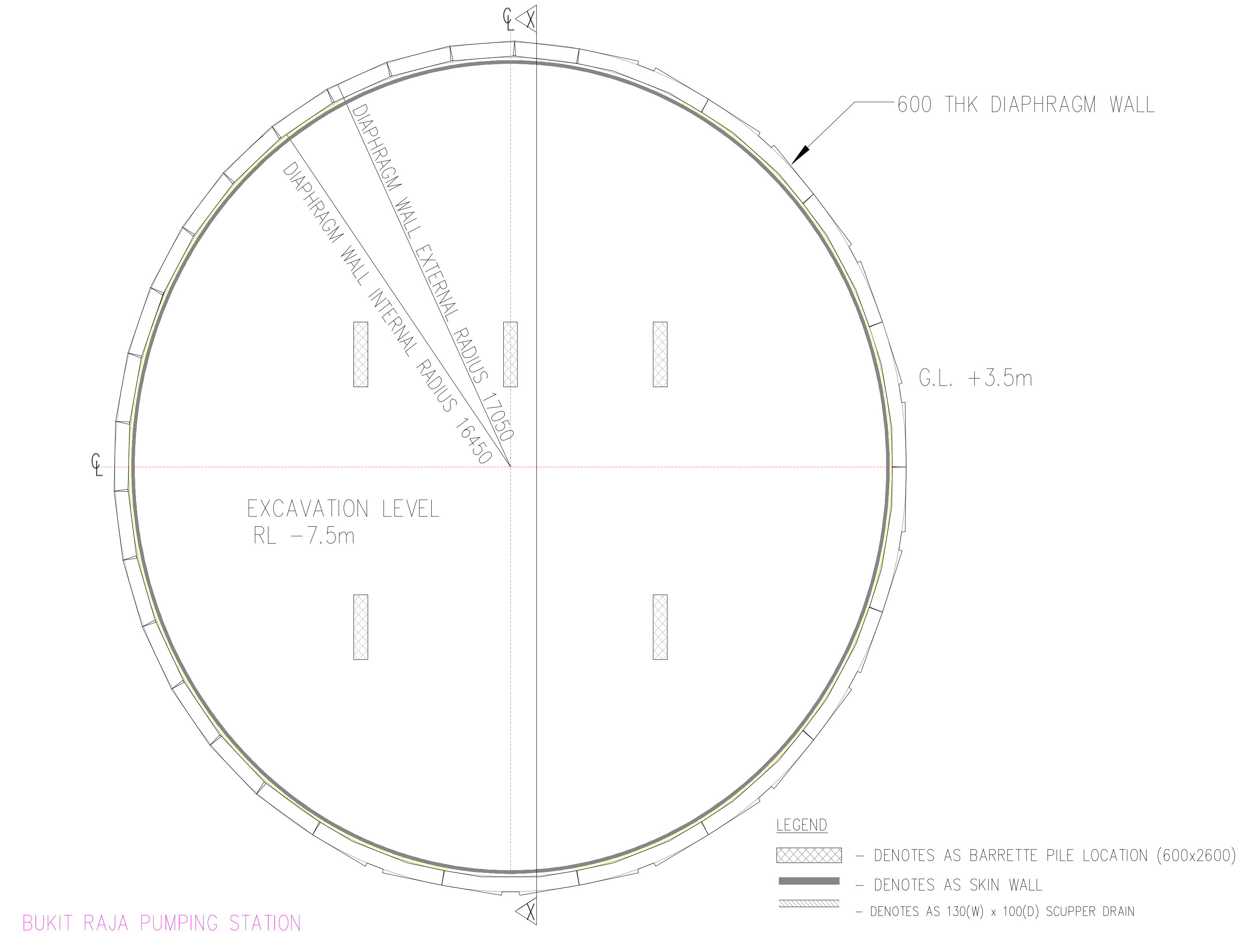
CIRCULAR DIAPHRAGM WALL, PULAU INDAH

BUKIT RAJA SEWAGE PUMPING STATION

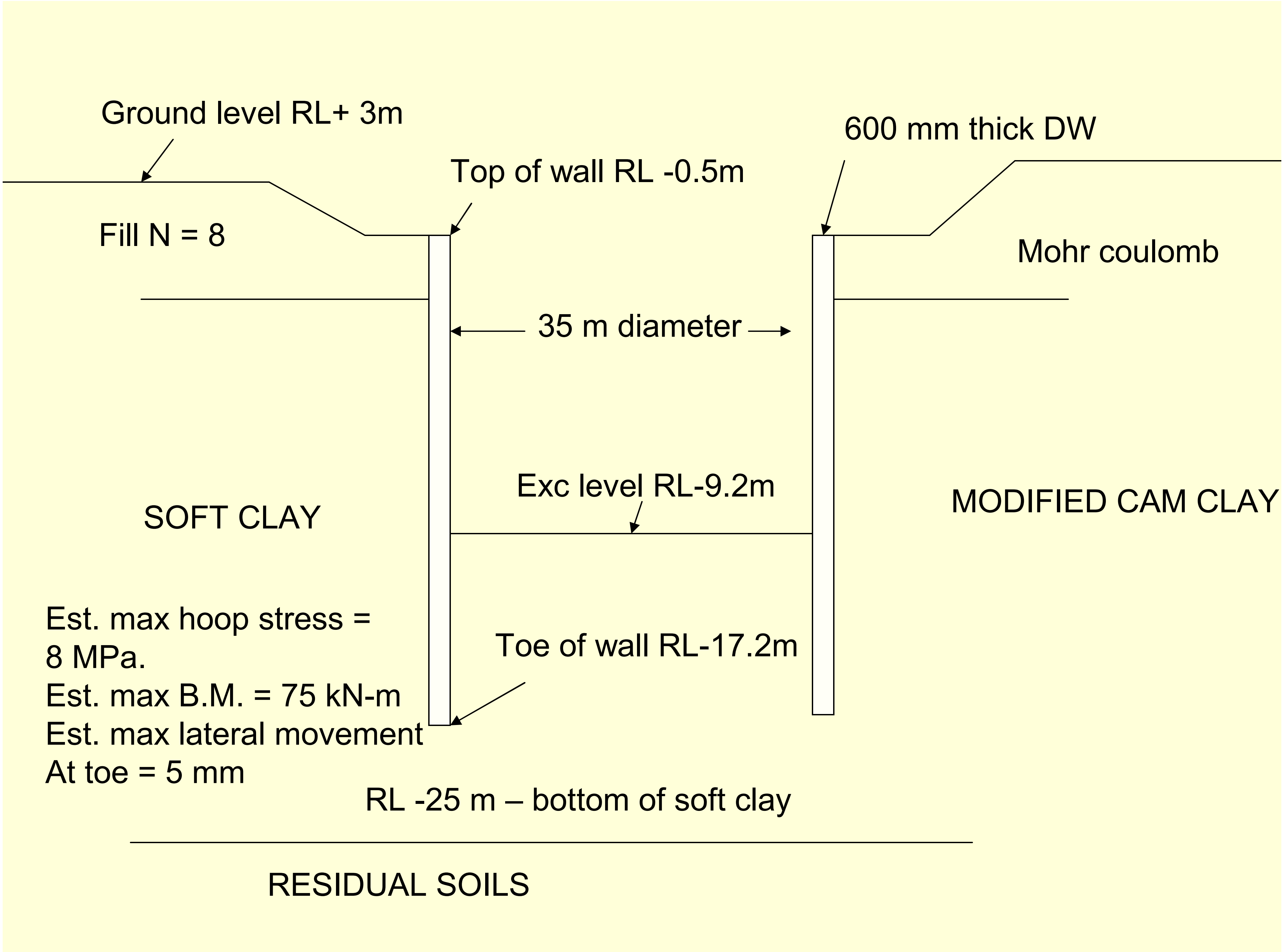
DEEP SEATED SOFT MARINE CLAYS

remedial works for failed sheet piles

BUKIT RAJA

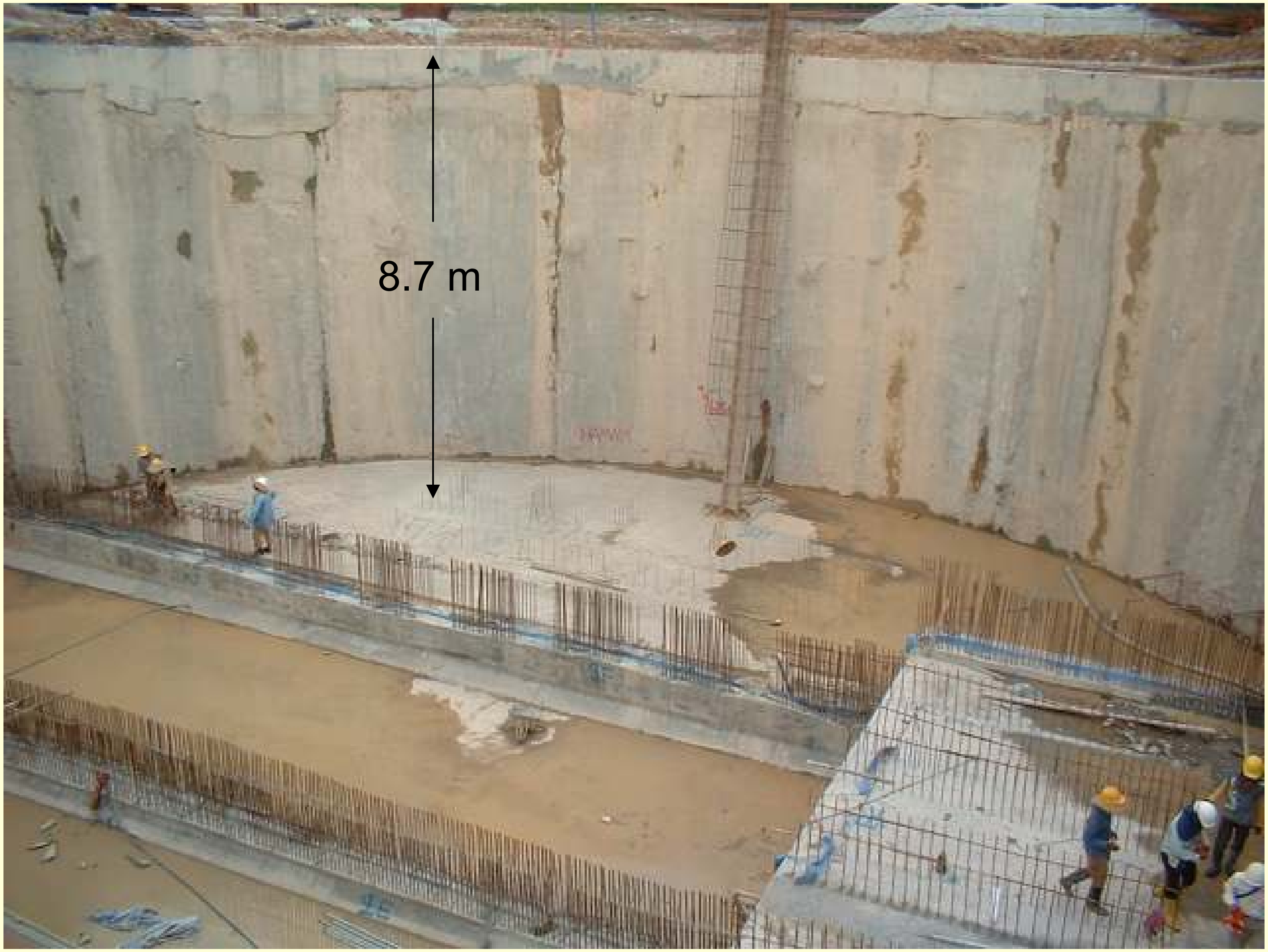


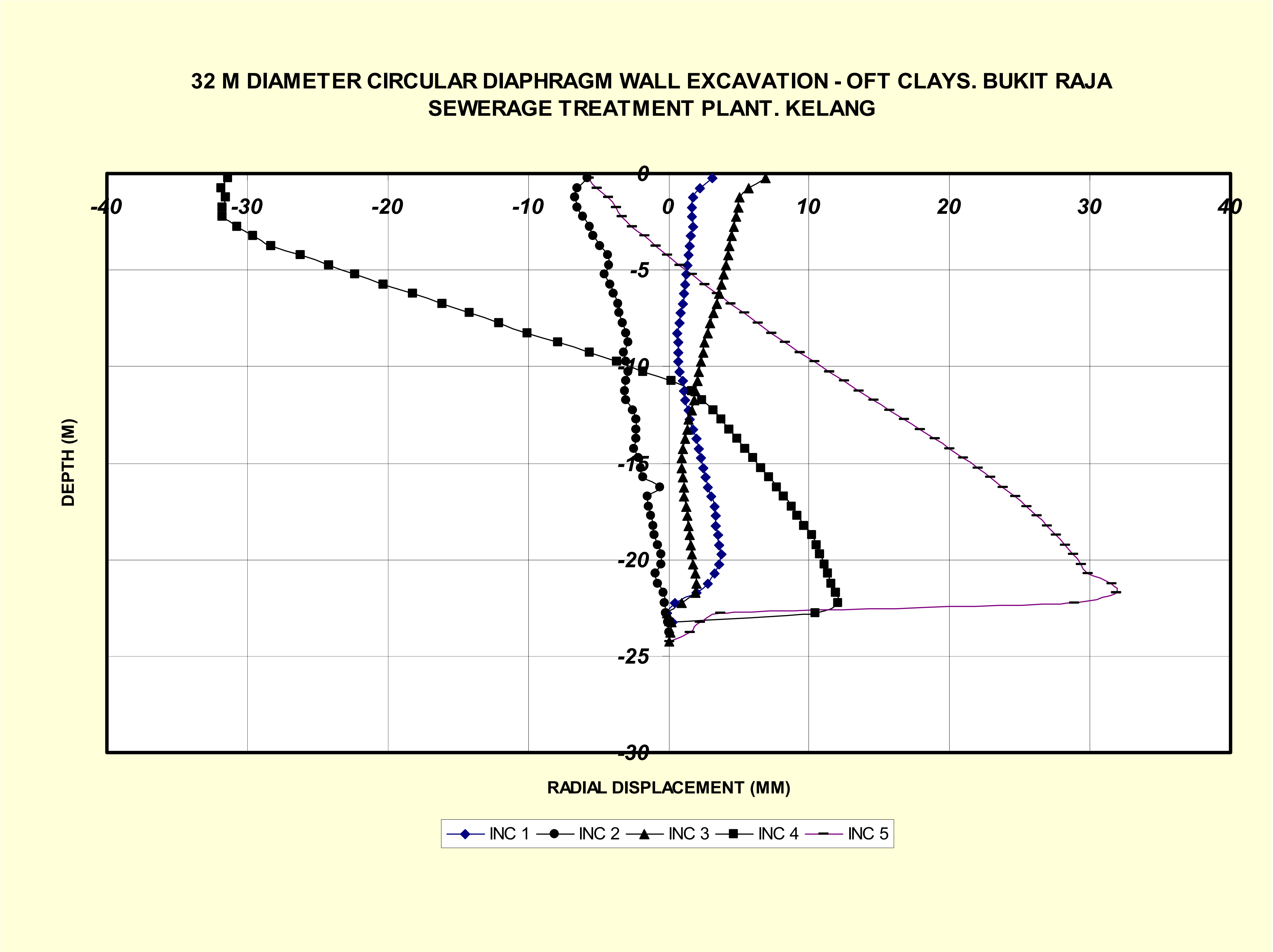
600 THK DIAPHRAGM WALL
DIAPHRAGM WALL EXTERNAL RADIUS 17050
DIAPHRAGM WALL INTERNAL RADIUS 16450
G.L. +3.5m
EXCAVATION LEVEL
RL -7.5m
X
X
LEGEND
- DENOTES AS BARRETTE PILE LOCATION (600x2600)
- DENOTES AS SKIN WALL
- DENOTES AS 130(W) x 100(D) SCUPPER DRAIN
BUKIT RAJA PUMPING STATION


Ground level RL+ 3m
600 mm thick DW
Top of wall RL -0.5m
Fill N = 8
Mohr coulomb
35 m diameter
Exc level RL-9.2m
SOFT CLAY
MODIFIED CAM CLAY
Est. max hoop stress = 8 MPa.
Est. max B.M. = 75 kN-m
Est. max lateral movement At toe = 5 mm
Toe of wall RL-17.2m
RL -25 m – bottom of soft clay
RESIDUAL SOILS

CIRCULAR DIAPHRAGM WALL, BUKIT RAJA

BUKIT RAJA CIRCULAR DIAPHRAGM WALL




32 M DIAMETER CIRCULAR DIAPHRAGM WALL EXCAVATION - OFT CLAYS. BUKIT RAJA SEWERAGE TREATMENT PLANT. KELANG
DEPTH (M)
RADIAL DISPLACEMENT (MM)
-40 -30 -20 -10 0 10 20 30 40
0 -5 -10 -15 -20 -25 -30
INC 1
INC 2
INC 3
INC 4
INC 5

CANTILEVER EMBEDDED WALLS

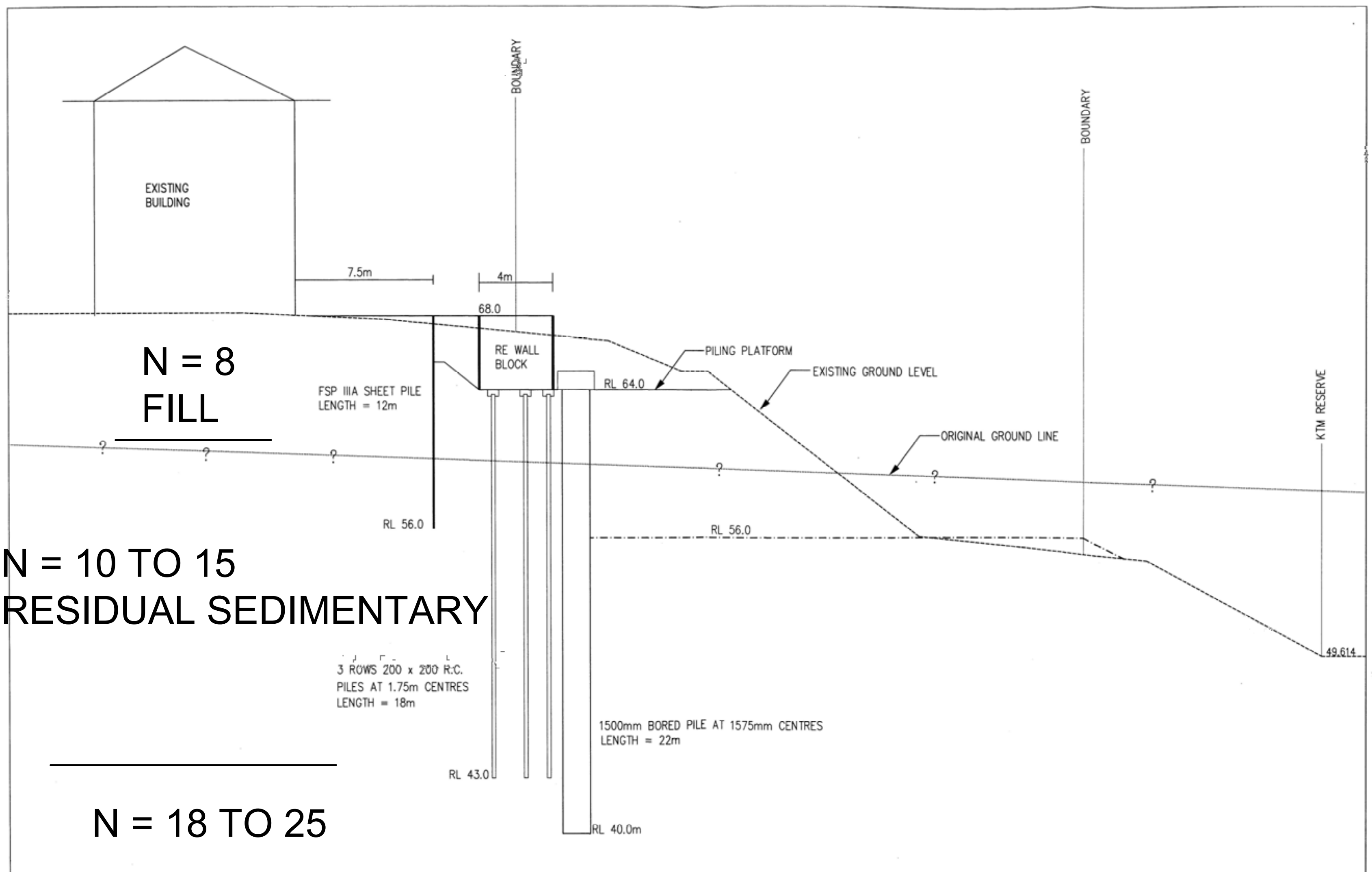
(CBP, DIAPHRAGM WALLS, SECANT PILES)

FOR BASEMENT CONSTRUCTION

IN

RESIDUAL SOILS

ERL
EARLIEST CANTILEVER BORE PILE WALL, YEAR 2000



PROPOSED CONTIGUOUS BORED PILE WALL

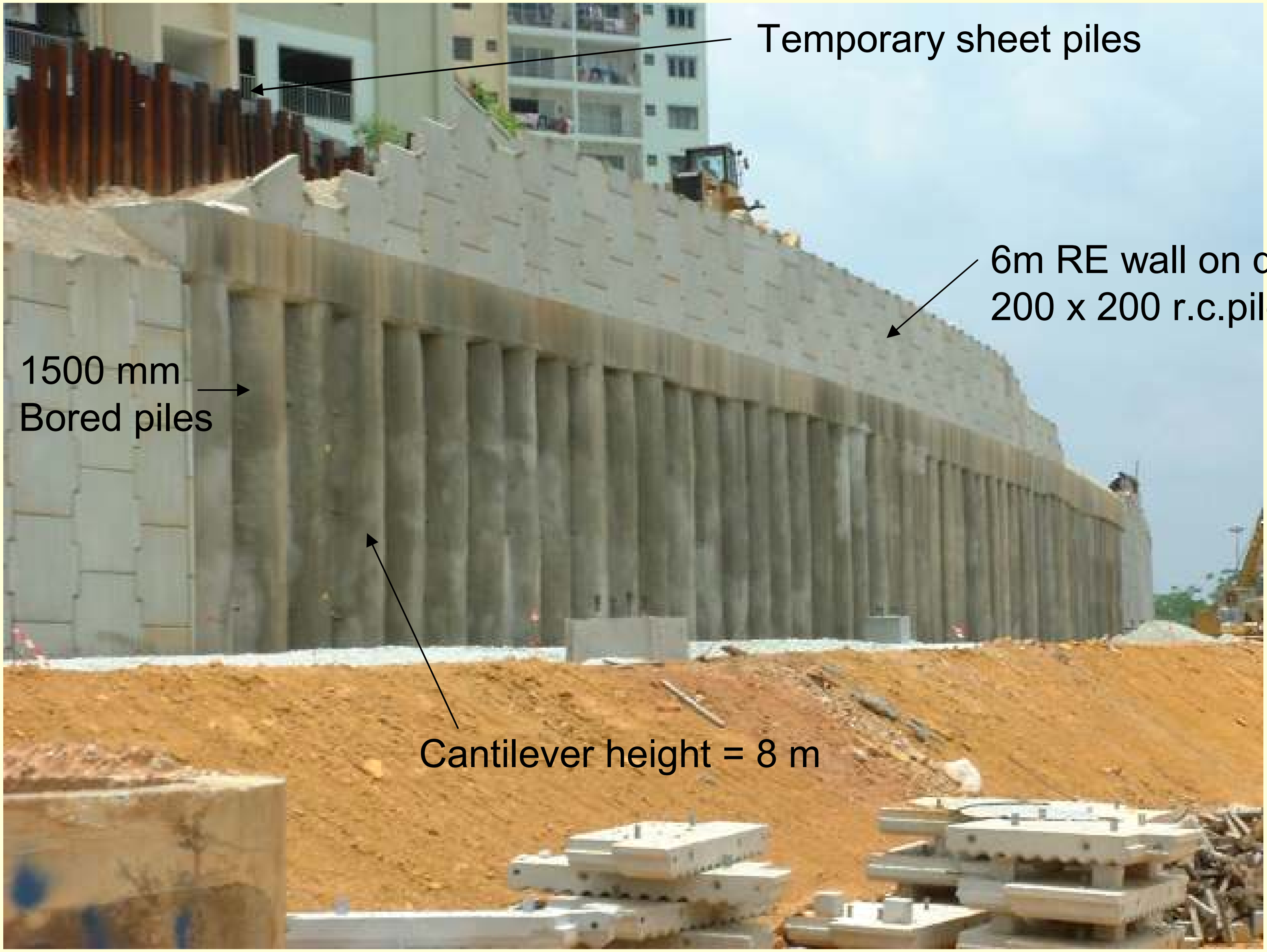
SCALE :- 1 : 200

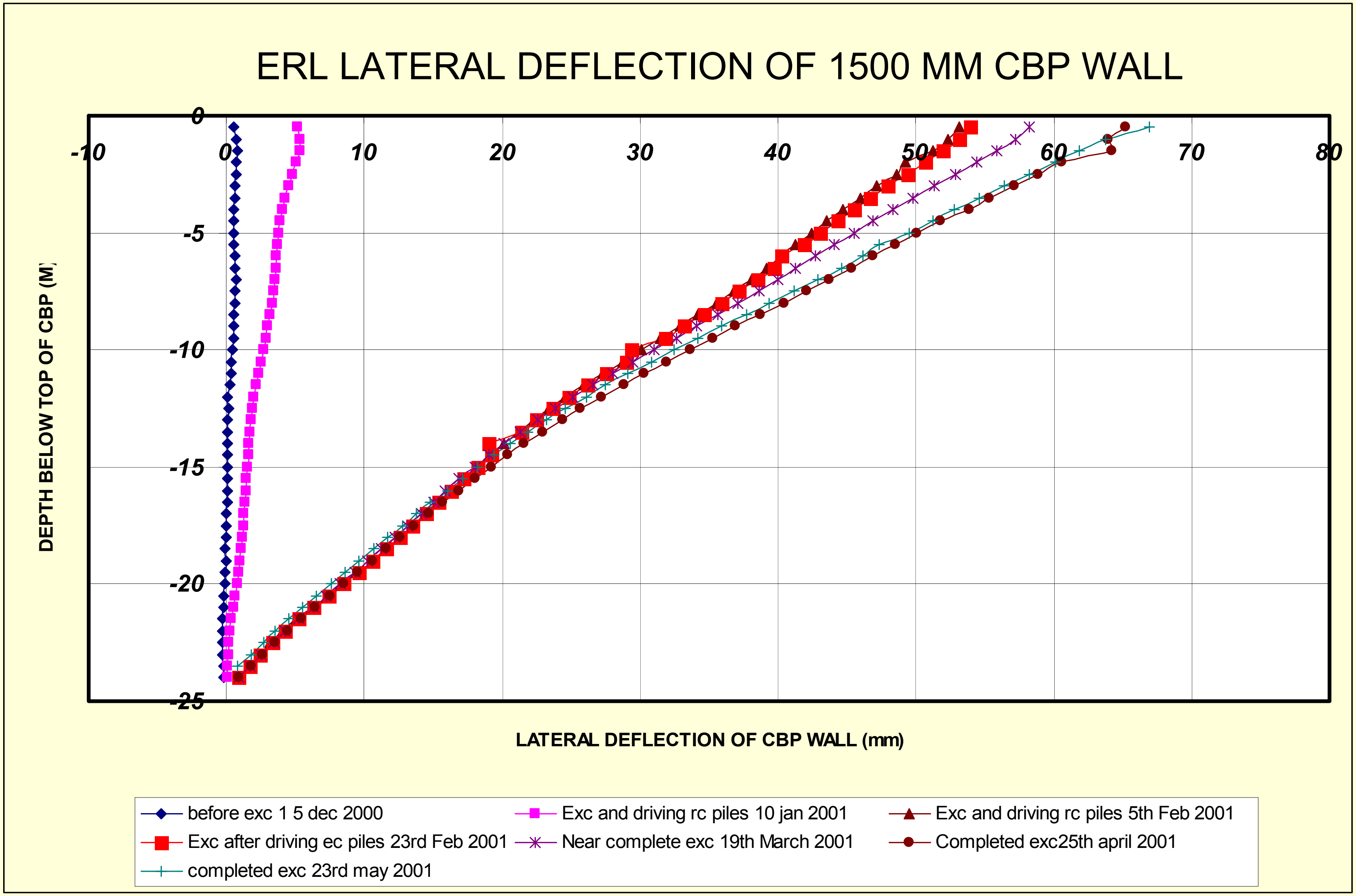
CANTILEVER CBP, ERL

CANTILEVER CBP. ERL

PILE DRIVING

CANTILEVER CBP ERL





ERL LATERAL DEFLECTION OF 1500 MM CBP WALL
0
-5
-10
-15
-20
-25
-10
0
10
20
30
40
50
60
70
80
DEPTH BELOW TOP OF CBP (M)
LATERAL DEFLECTION OF CBP WALL (mm)
before exc 1 5 dec 2000
Exc and driving rc piles 10 jan 2001
Exc and driving rc piles 5th Feb 2001
Exc after driving ec piles 23rd Feb 2001
Near complete exc 19th March 2001
Completed exc25th april 2001
completed exc 23rd may 2001

ERL MEASURED VS PREDICTED

- *WISH-IN-PLACE WALL. No account for movements due to pile driving. Estimated max deflection = 22 mm*
- *Measured total lateral deflection = 67 mm*
- *Movements due to pile driving = 53 mm*
- *Movements due to excavation = 67 – 53 = 14 mm*

LOT N SENTRAL, KL SENTRAL
CANTILEVER CBP(600mm) FOR BASEMENT AND RAFT CONSTRUCTION NEXT TO MONORAIL PIERS

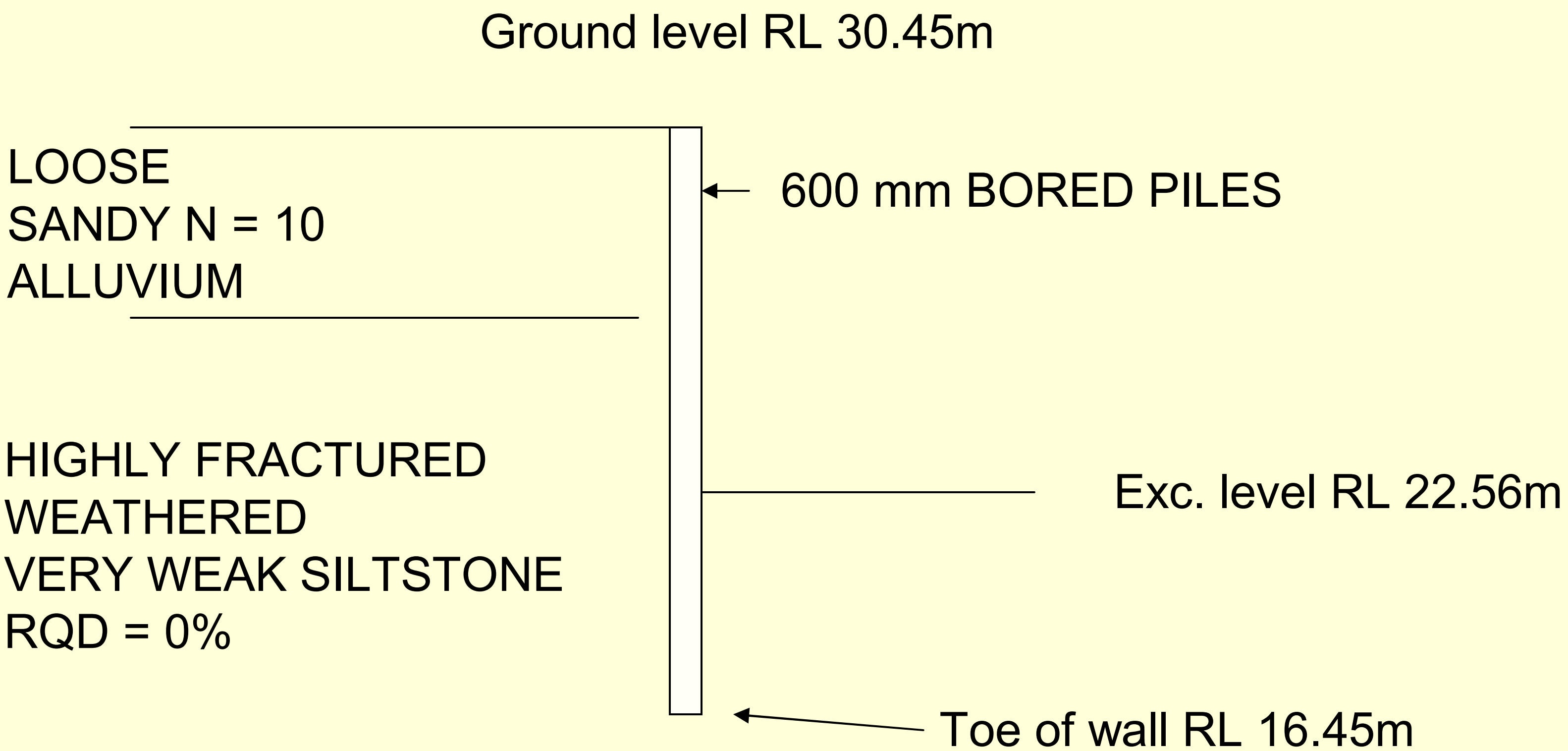
LOT N. SENTRAL, BRICKFIELDS

MONORAIL

TOP OF WALL RL+30.5m

600 mm Diameter CBP

EXC. LEVEL FOR RAFT RL +22.56m


Ground level RL 30.45m
LOOSE
SANDY N = 10
ALLUVIUM
600 mm BORED PILES
HIGHLY FRACTURED
WEATHERED
VERY WEAK SILTSTONE
RQD = 0%
Exc. level RL 22.56m
Toe of wall RL 16.45m

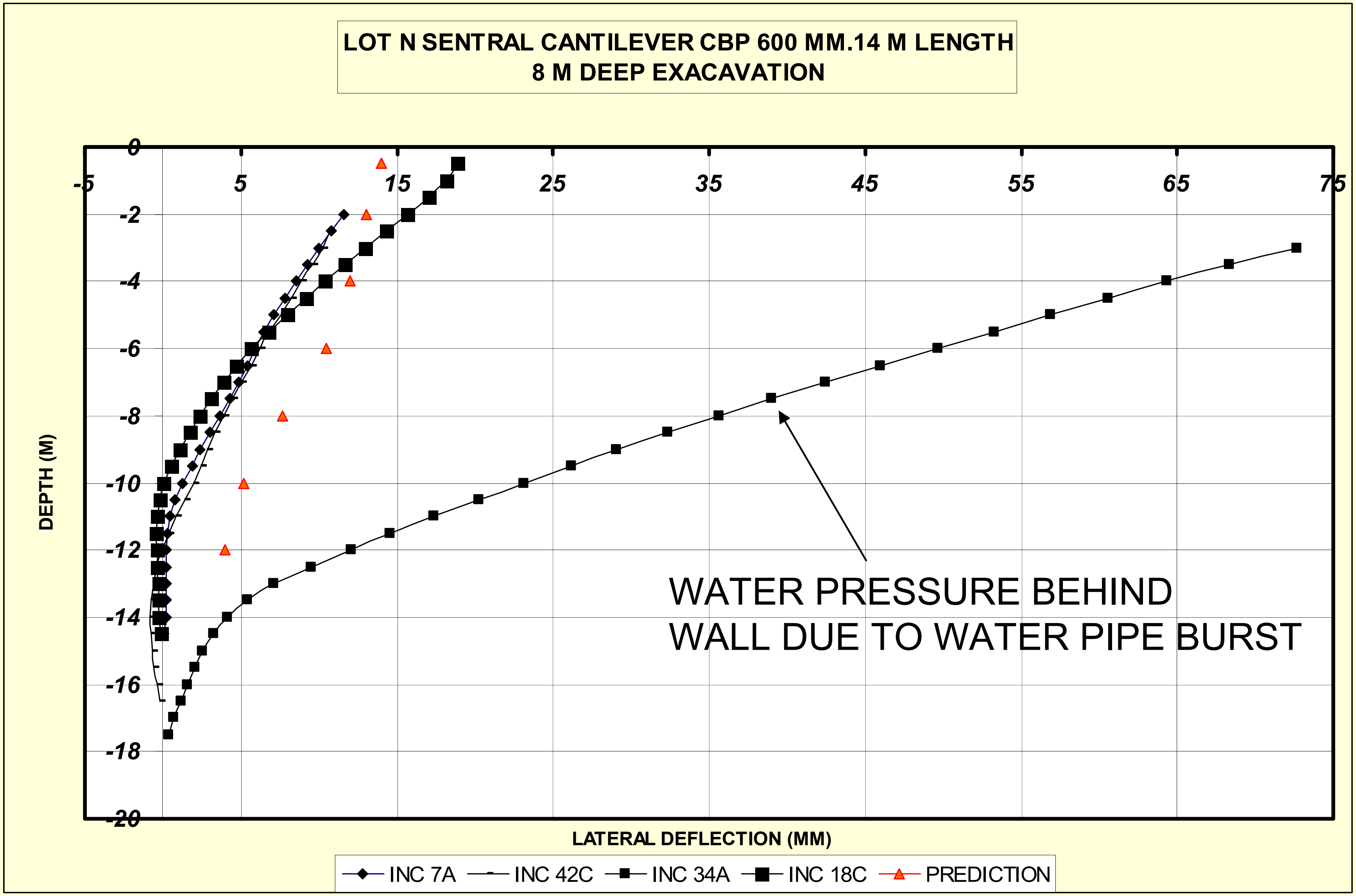
LOT N. SENTRAL

TOP OF
WALL
RL+30.45m

Sand N = 10

Weathered
siltstone

LIFT PIT
EXC.
RL 19.5 m



LOT N SENTRAL CANTILEVER CBP 600 MM.14 M LENGTH
8 M DEEP EXACAVATION
DEPTH (M)
LATERAL DEFLECTION (MM)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-5
5
15
25
35
45
55
65
75
WATER PRESSURE BEHIND WALL DUE TO WATER PIPE BURST
INC 7A
INC 42C
INC 34A
INC 18C
PREDICTION

CAHB
(IJM)
SECANT PILE WALL
SOCKETED INTO LIMESTONE
NEXT TO OLD HOUSES

CAHB. CANTILEVER SECANT PILE

CAHB. CANTILEVER SECANT PILE WALL

CBP (600mm) FOR PUTRAJAYA SMART SCHOOL
IMMEDIATELY ADJACENT TO RESIDENTIAL BUILDINGS

SMART SCHOOL, PUTRAJAYA

800 mm
CBP

Approx.
7 m

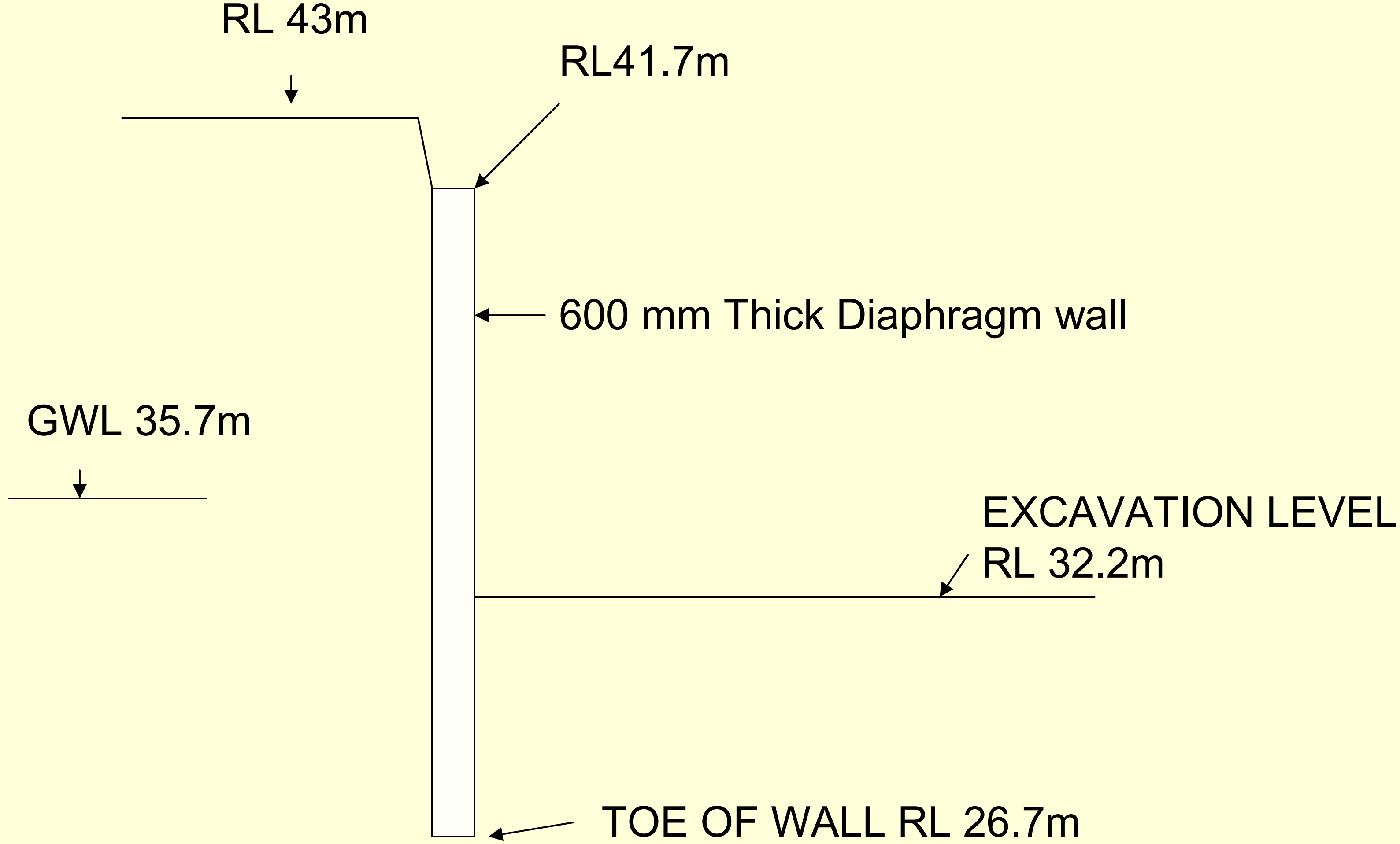
600 mm CBP
PUCHONG

STABLE FOR 3 YEARS
ADJOINING LAND OWNER CONSTRUCTED
HIGH FILL SLOPE
BEHIND WALL

WALL DEFLECTED 300mm BUT NO COLLAPSE

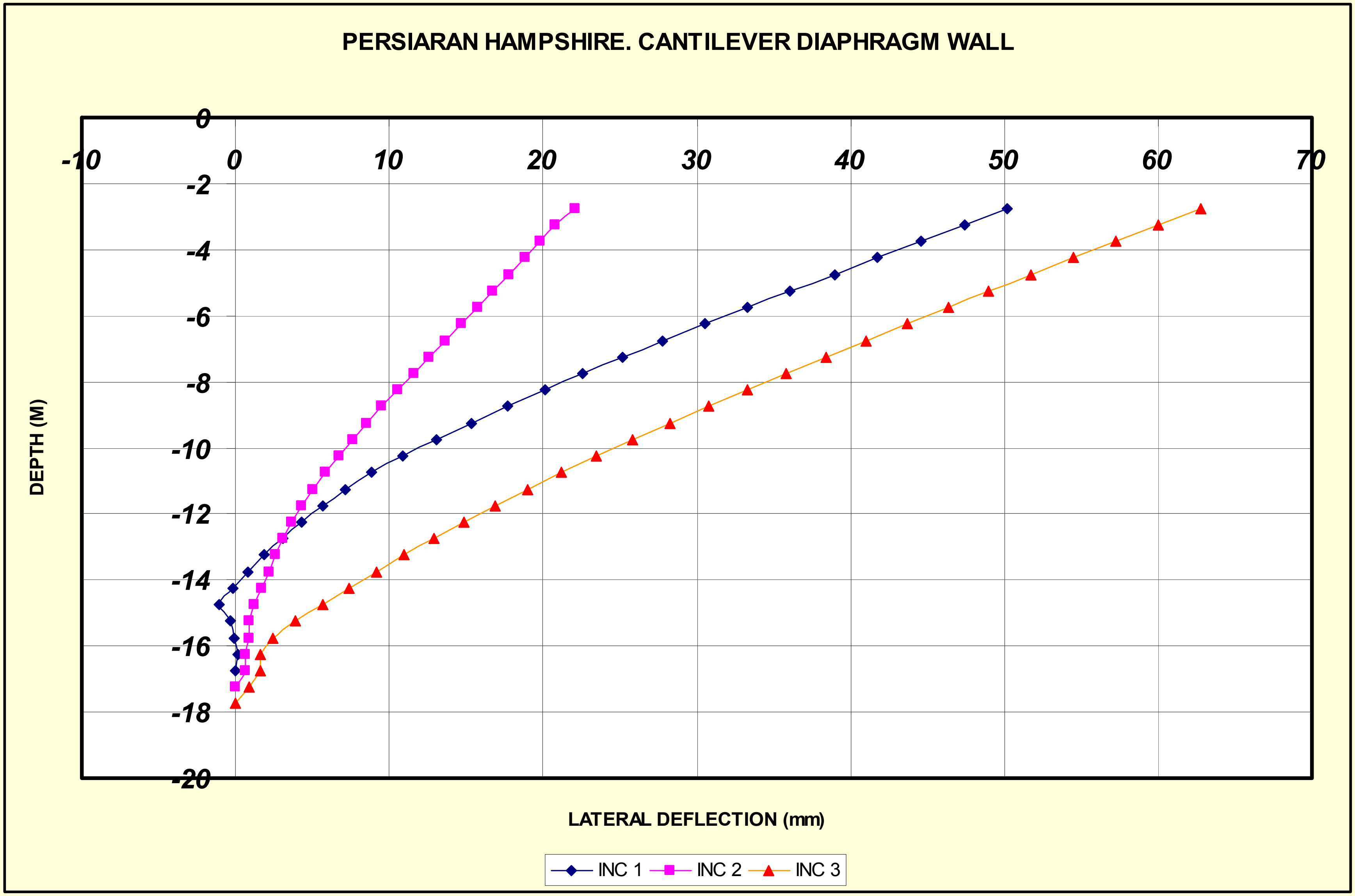
PUCHONG CBP. TILTED DUE TO CONSTRUCTION OF FILL SLOPE BEHIND

PERSIARAN HAMPSHIRE
CANTILEVER DIAPHRAGM WALL (600mm)

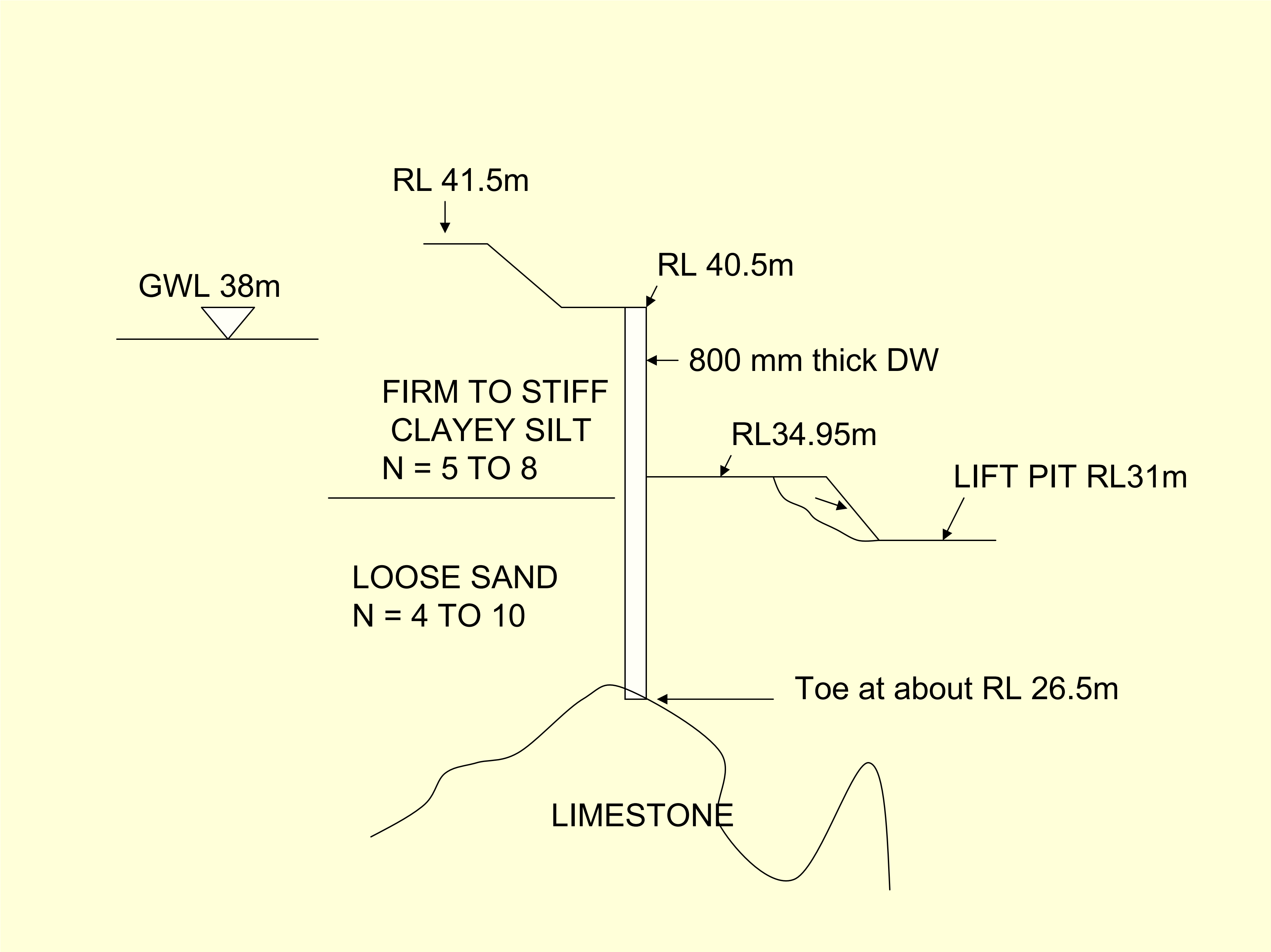


RL 43m
RL41.7m
600 mm Thick Diaphragm wall
GWL 35.7m
EXCAVATION LEVEL
RL 32.2m
TOE OF WALL RL 26.7m

CANTILEVER DIAPHRAGM WALL. PERSIARAN HAMPSHIRE

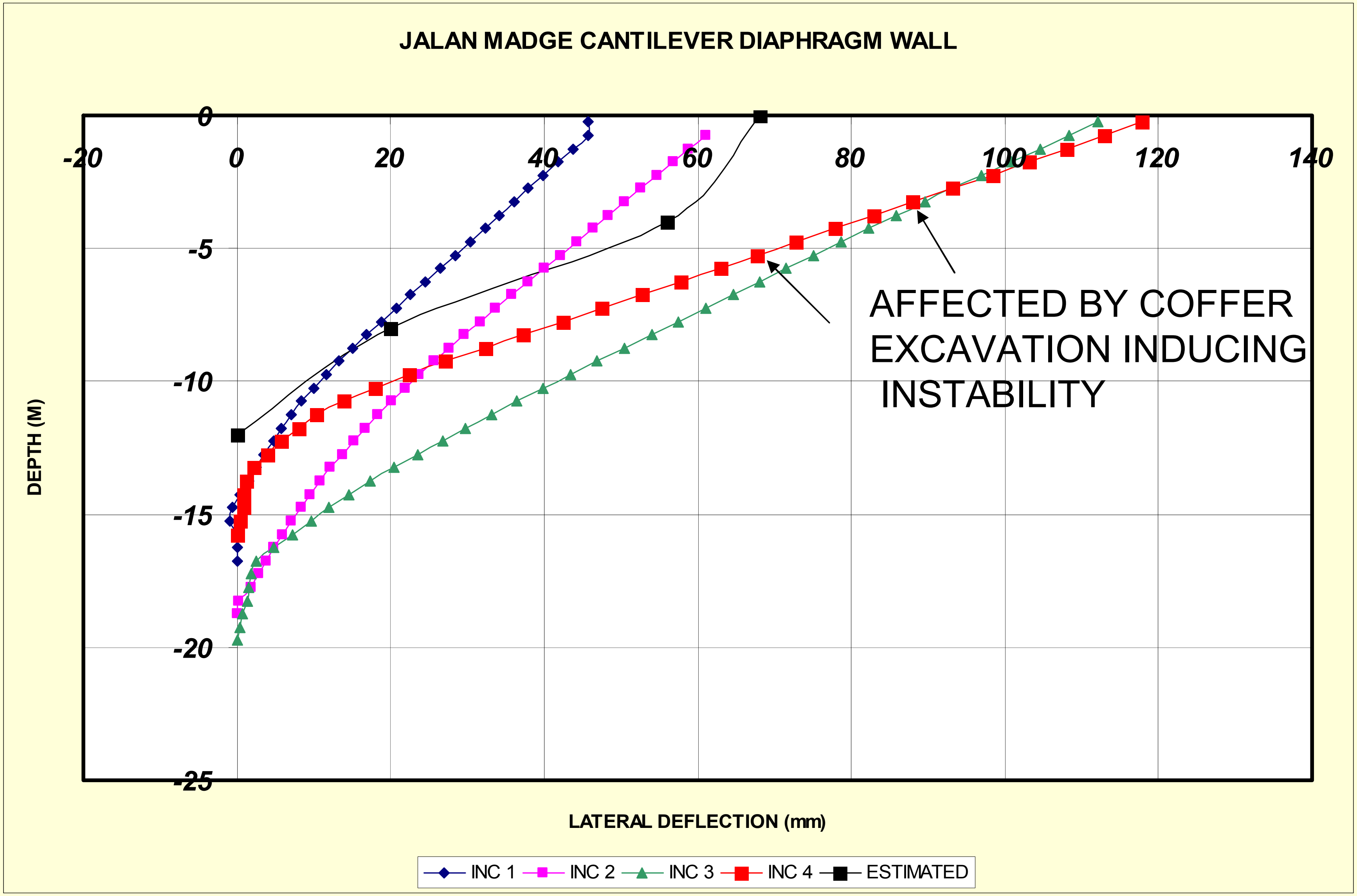

PERSIARAN HAMPSHIRE. CANTILEVER DIAPHRAGM WALL
-10
0
10
20
30
40
50
60
70
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
DEPTH (M)
LATERAL DEFLECTION (mm)
INC 1
INC 2
INC 3

CANTILEVER DIAPHRAGM WALL (800mm), JALAN MADGE


RL 41.5m
RL 40.5m
GWL 38m
800 mm thick DW
FIRM TO STIFF
CLAYEY SILT
N = 5 TO 8
RL34.95m
LIFT PIT RL31m
LOOSE SAND
N = 4 TO 10
Toe at about RL 26.5m
LIMESTONE

CANTILEVER DIAPHRAGM WALL. JALAN MADGE

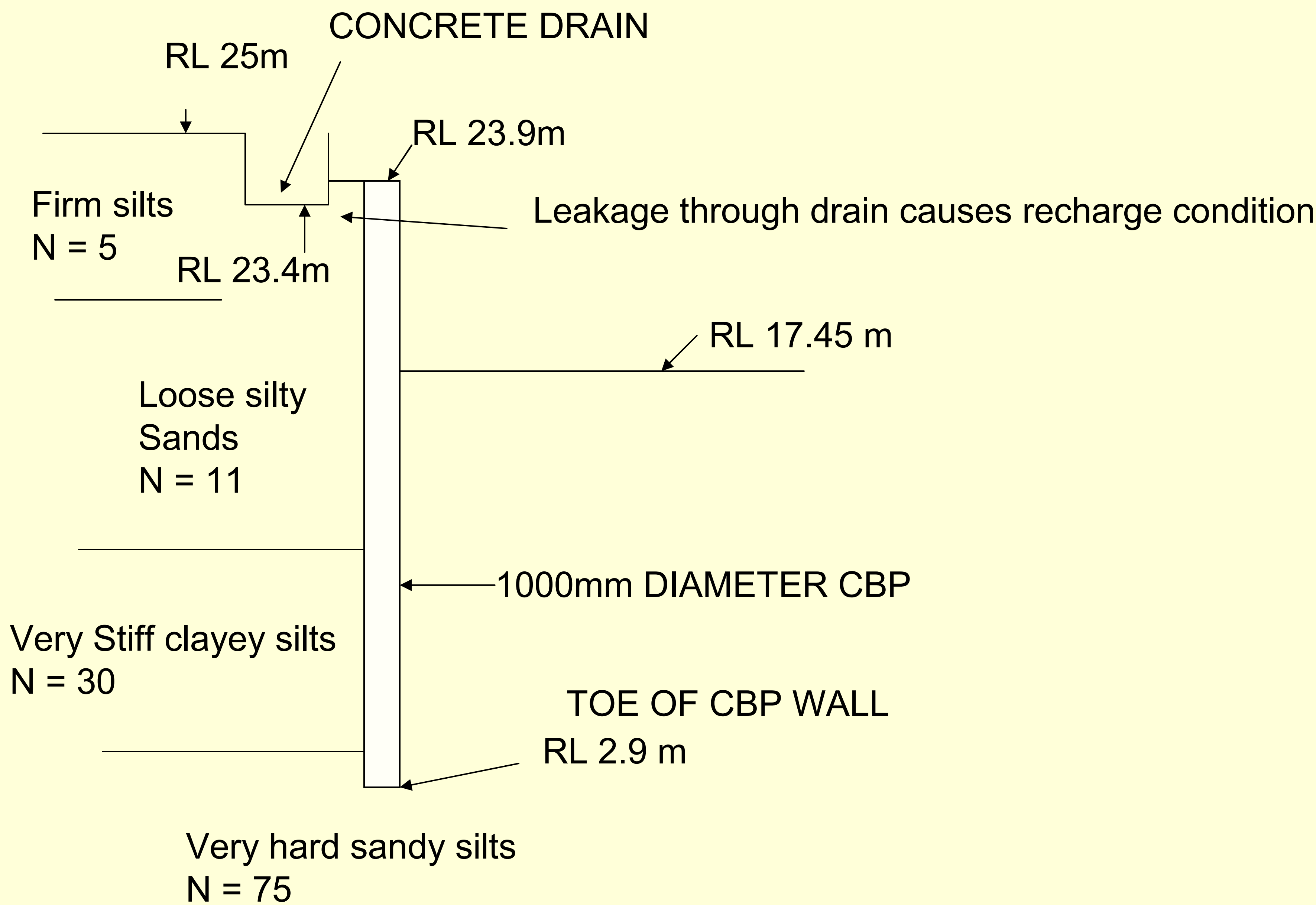
CANTILEVER DIAPHRAGM WALL. JALAN MADGE



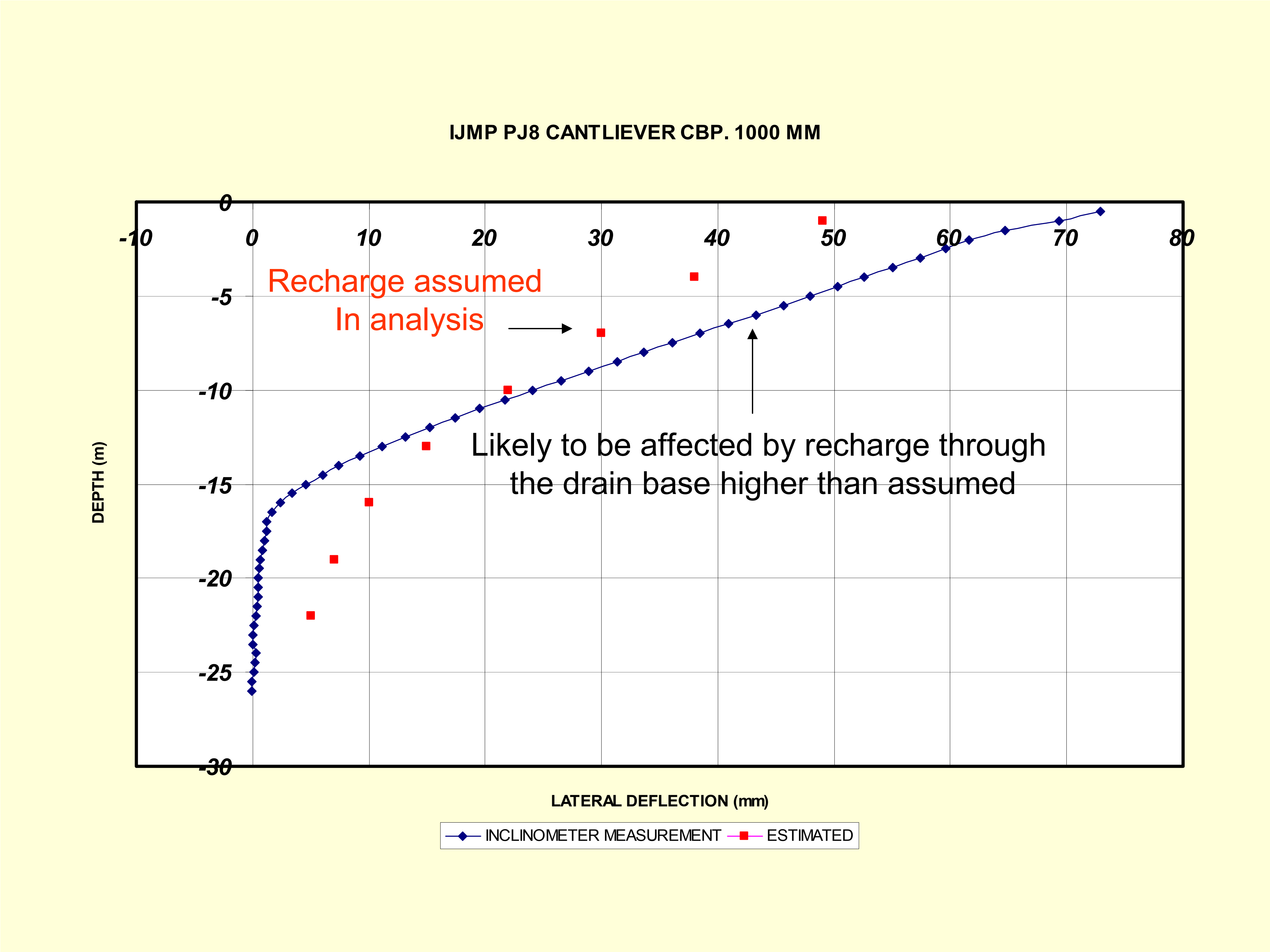
JALAN MADGE CANTILEVER DIAPHRAGM WALL
-20
0
20
40
60
80
100
120
140
0
-5
-10
-15
-20
-25
DEPTH (M)
LATERAL DEFLECTION (mm)
AFFECTED BY COFFER EXCAVATION INDUCING INSTABILITY
INC 1
INC 2
INC 3
INC 4
ESTIMATED

PJ8 (IJMP)

1000mm DIAMETER CBP
NEXT TO MONSOON DRAIN


CONCRETE DRAIN
RL 25m
RL 23.9m
Firm silts
N = 5
Leakage through drain causes recharge condition
RL 23.4m
RL 17.45 m
Loose silty
Sands
N = 11
1000mm DIAMETER CBP
Very Stiff clayey silts
N = 30
TOE OF CBP WALL
RL 2.9 m
Very hard sandy silts
N = 75

PJ8 CANTILEVER CBP



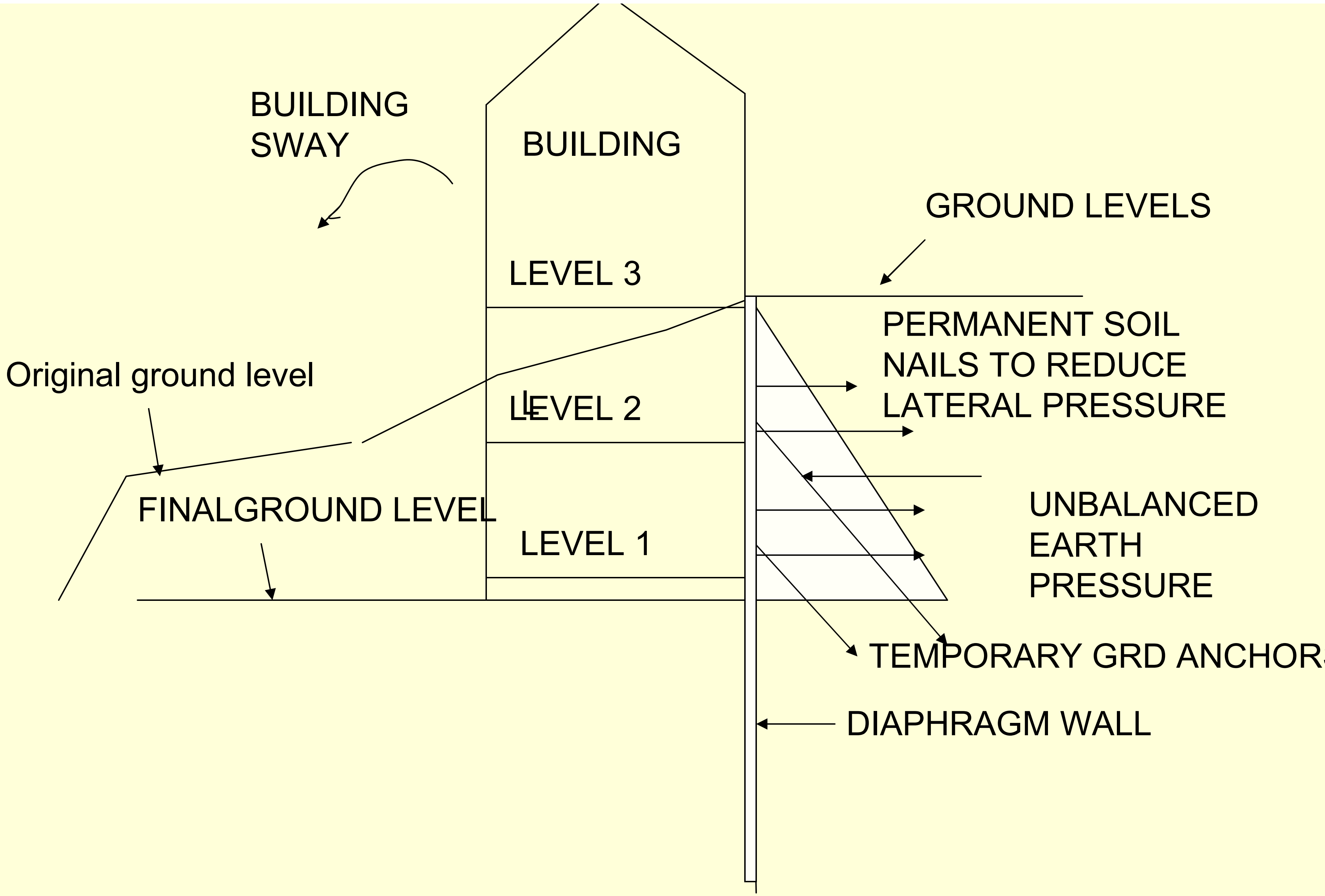
IJMP PJ8 CANTLIEVER CBP. 1000 MM
Recharge assumed In analysis
Likely to be affected by recharge through the drain base higher than assumed
DEPTH (m)
LATERAL DEFLECTION (mm)
INCLINOMETER MEASUREMENT
ESTIMATED
-10
0
10
20
30
40
50
60
70
80
0
-5
-10
-15
-20
-25
-30

ONE –MENERUNG (BANDARAYA DEVELOPMENT)
900 mm CBP
9M HIGH

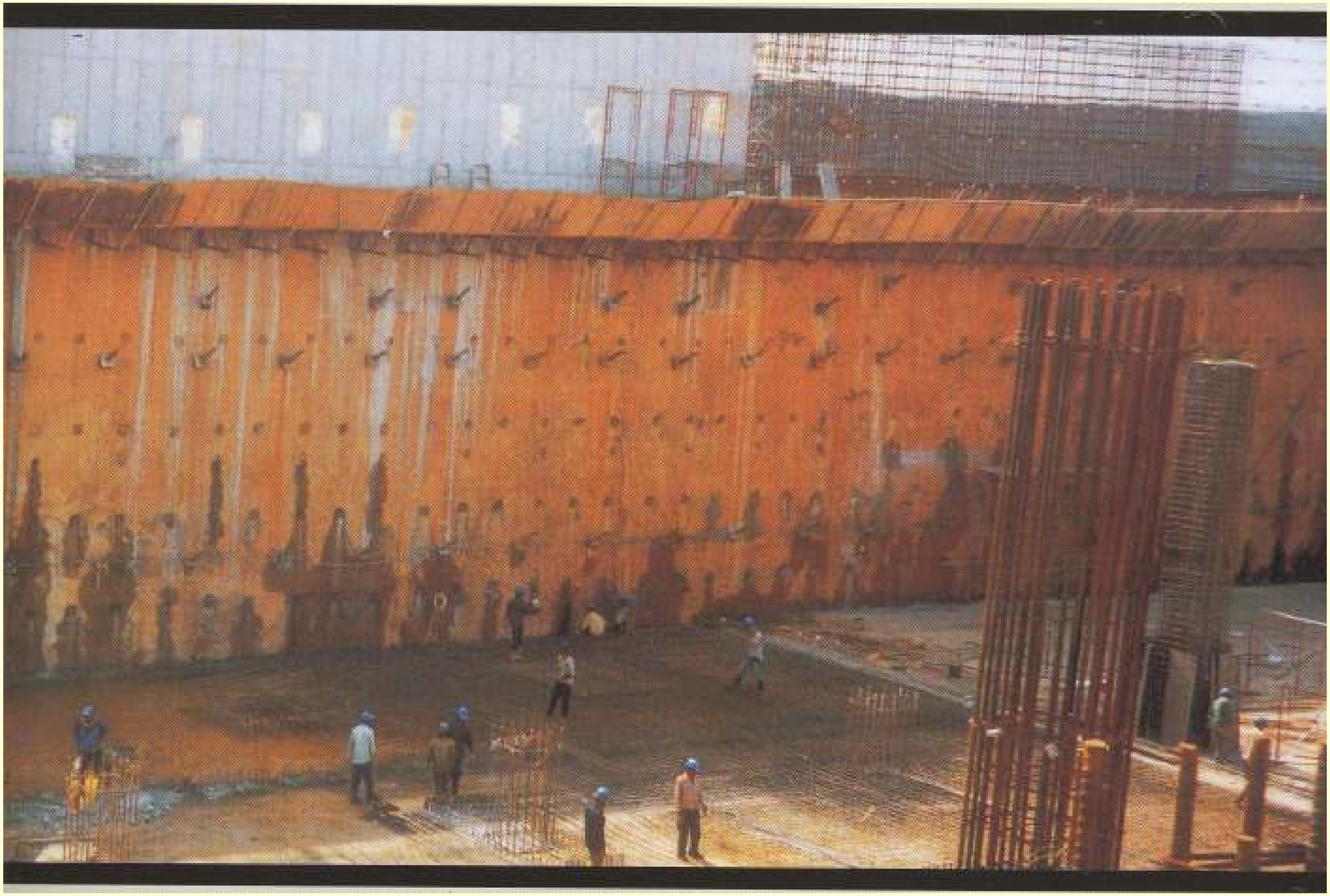
CANTILEVER CBP. ONE MENERUNG

UNBALANCED LATERAL LOADS ON BUILDINGS – WALL ON ONE SIDE

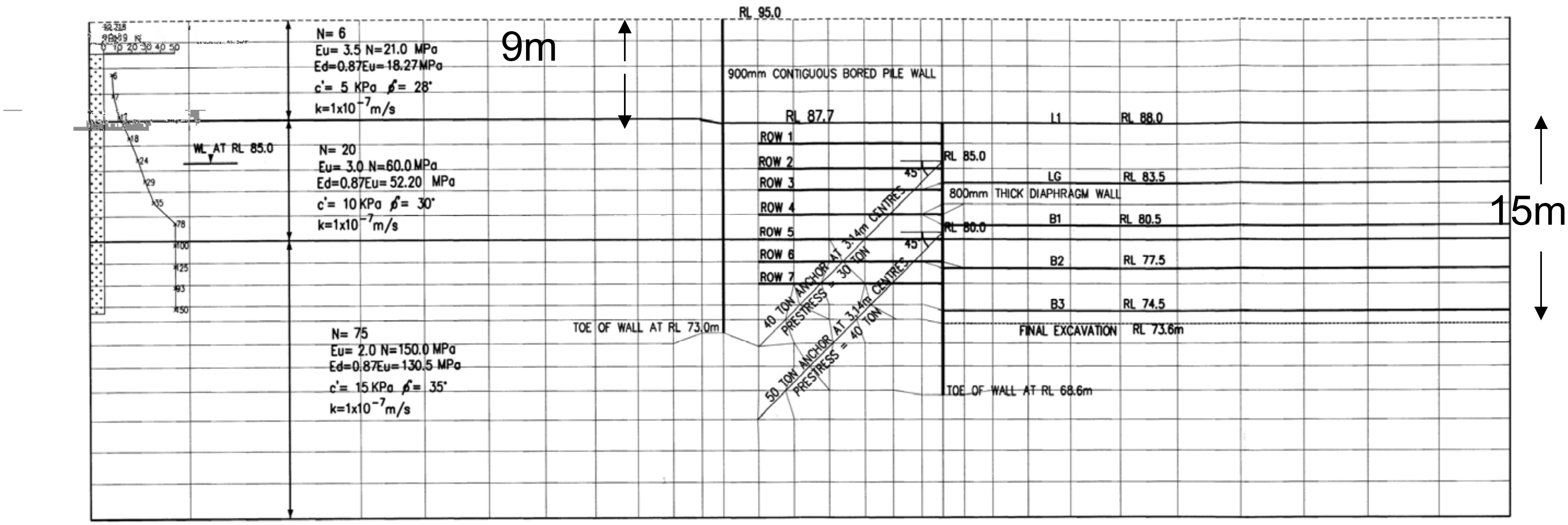
SOIL NAILS TO REDUCE LATERAL LOADS ON BUILDINGS


BUILDING
SWAY
BUILDING
GROUND LEVELS
LEVEL 3
PERMANENT SOIL
NAILS TO REDUCE
LATERAL PRESSURE
Original ground level
LEVEL 2
UNBALANCED
EARTH
PRESSURE
FINALGROUND LEVEL
LEVEL 1
TEMPORARY GRD ANCHORS
DIAPHRAGM WALL

MINISTRY OF FINANCE. PUTRAJAYA



ONE MENERUNG, BANDARAYA



SECTION A-A

FINITE ELEMENT MESH & PARAMETERS

SCALE :- 1 : 300

7 ROWS OF PERMANENT SOIL NAILS. 2 ROWS TEMPORARY GROUND ANCHORS

FIG. 4

ONE MENERUNG

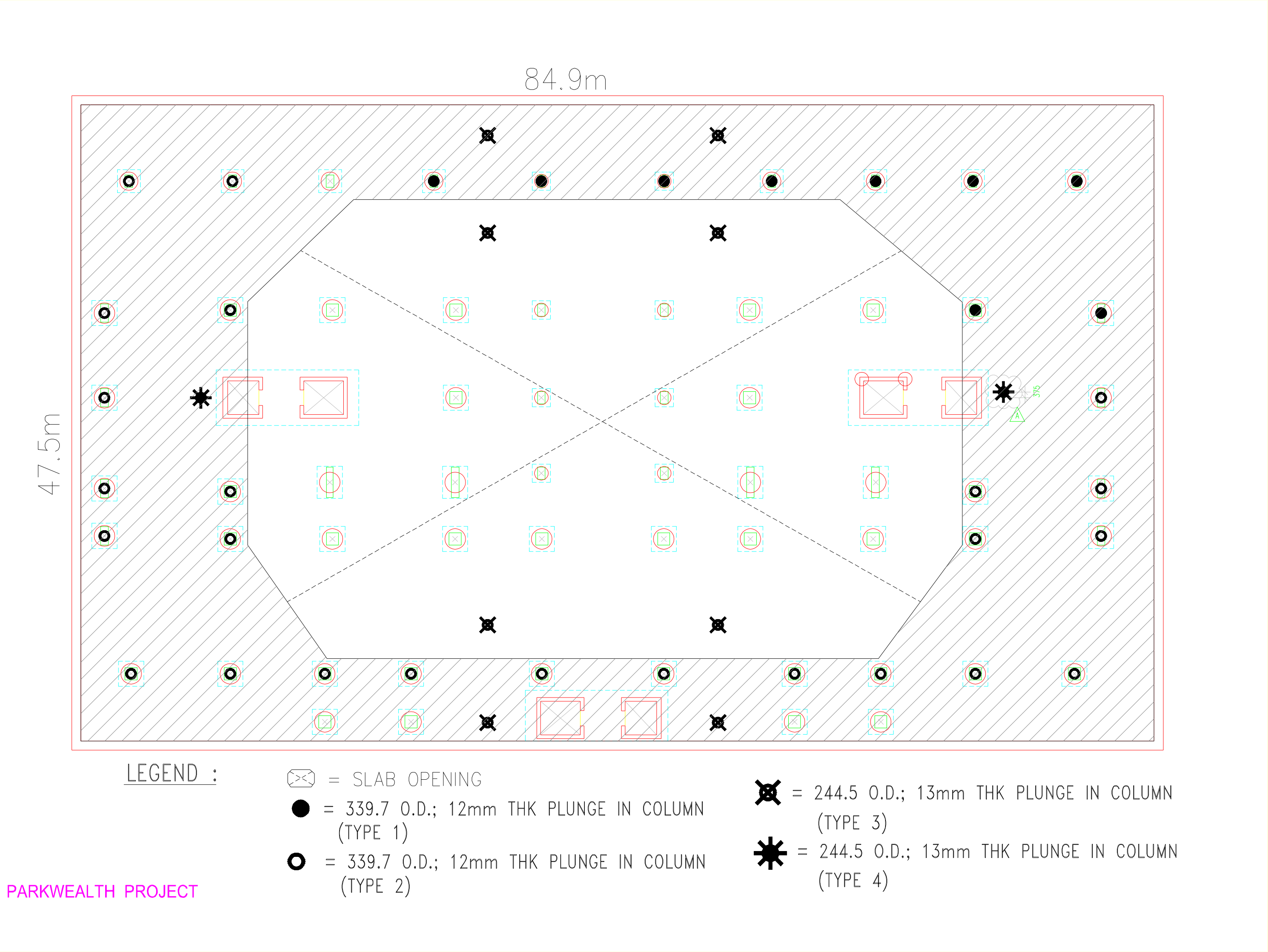
TOP – DOWN CONSTRUCTION

PARKWEALTH. JALAN TUN RAZAK

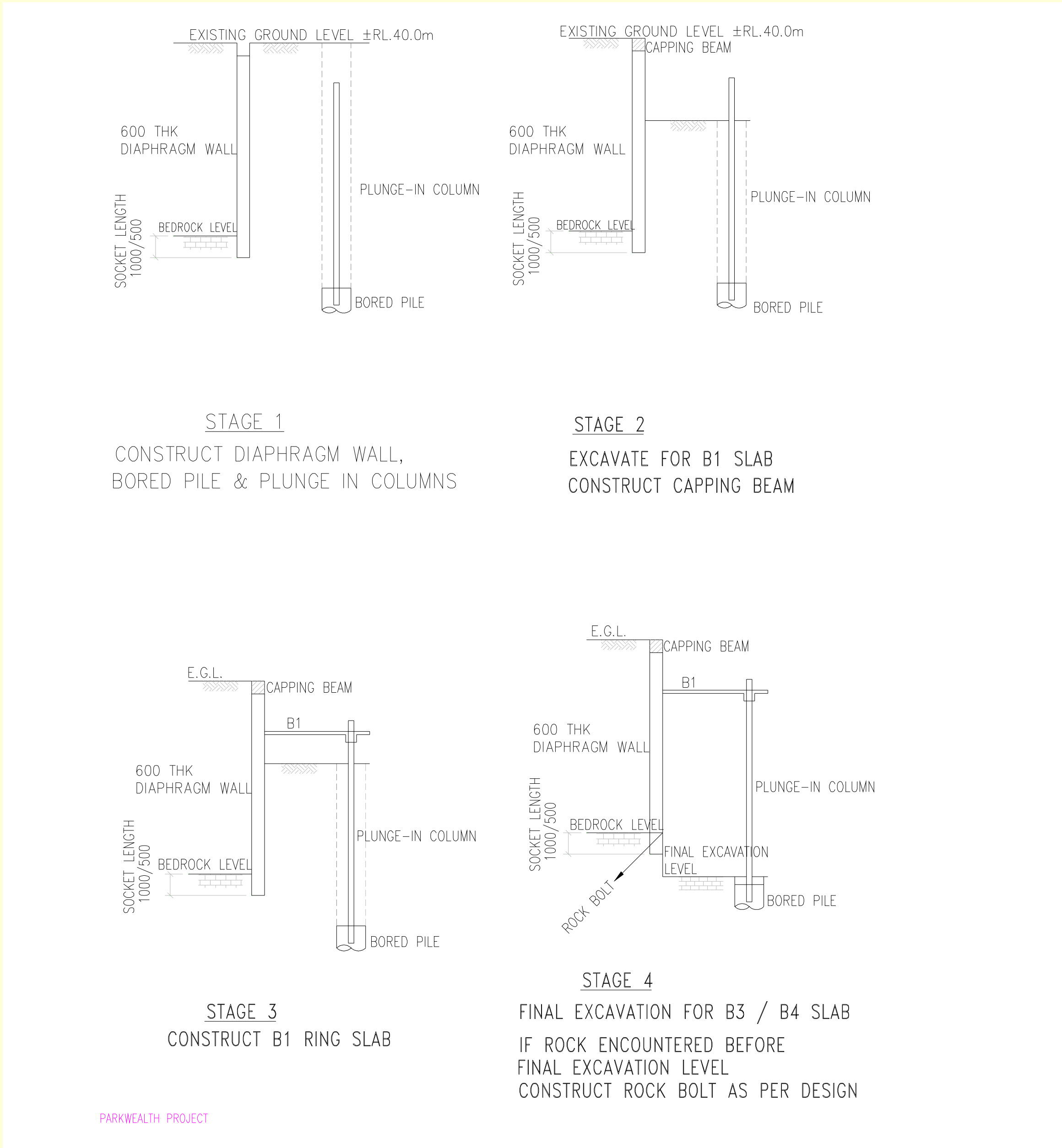
LOOSE SAND OVER LIMESTONE ABOVE EXCAVATION LEVEL.
DIAPHRAGM WALL TERMINATES ON BEDROCK ABOVE FINAL EXCAVATION LEVEL

PERIMETER SLAB AS STRUTTING SYSTEM

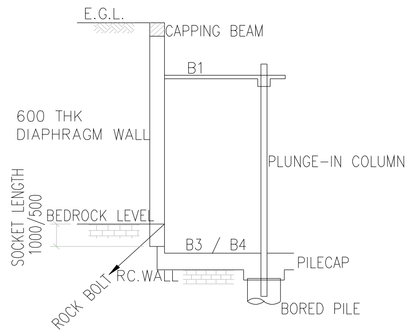
PARKWEALTH.JALAN TUN RAZAK



PARKWEALTH. JALAN TUN RAZAK



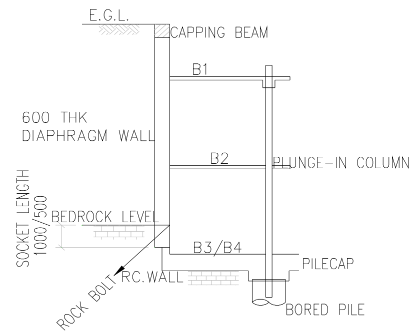
PARKWEALTH



STAGE 5

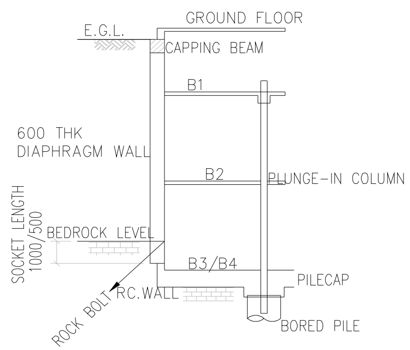
CONSTRUCT PILECAP & B3/B4 SLAB

CONSTRUCT RC WALL FROM TOE OF
DIAPHRAGM WALL TO B3/B4
IF ROCK ENCOUNTERED HIGHER THAN B3/B4



STAGE 6

CONTRUCT B2 SLAB
OR B2 & B3 FOR 4 BASEMENT EXC



STAGE 7

CONSTRUCT GF SLAB

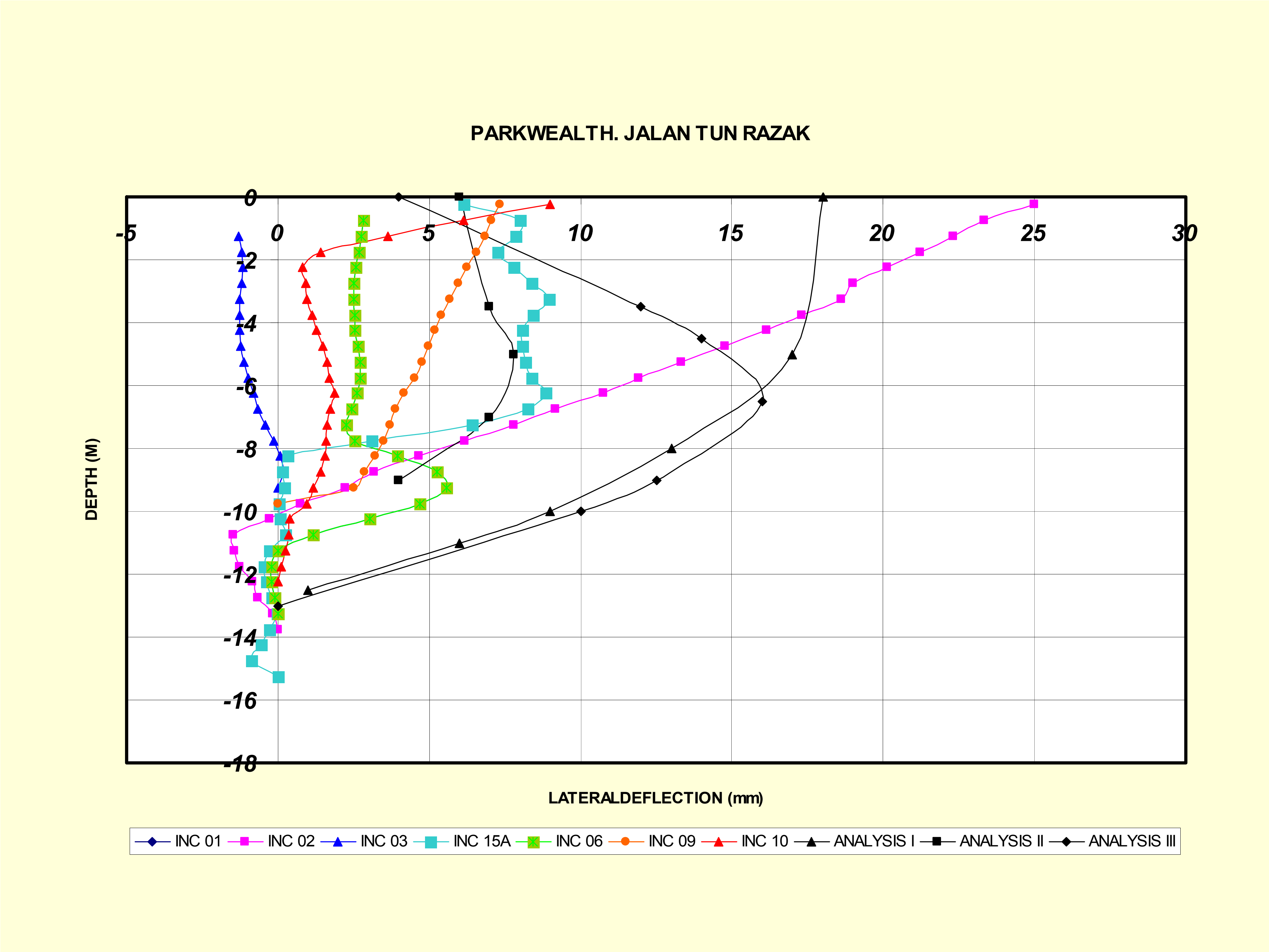
PARKWEALTH PROJECT

PARKWEALTH. JALAN TUN RAZAK

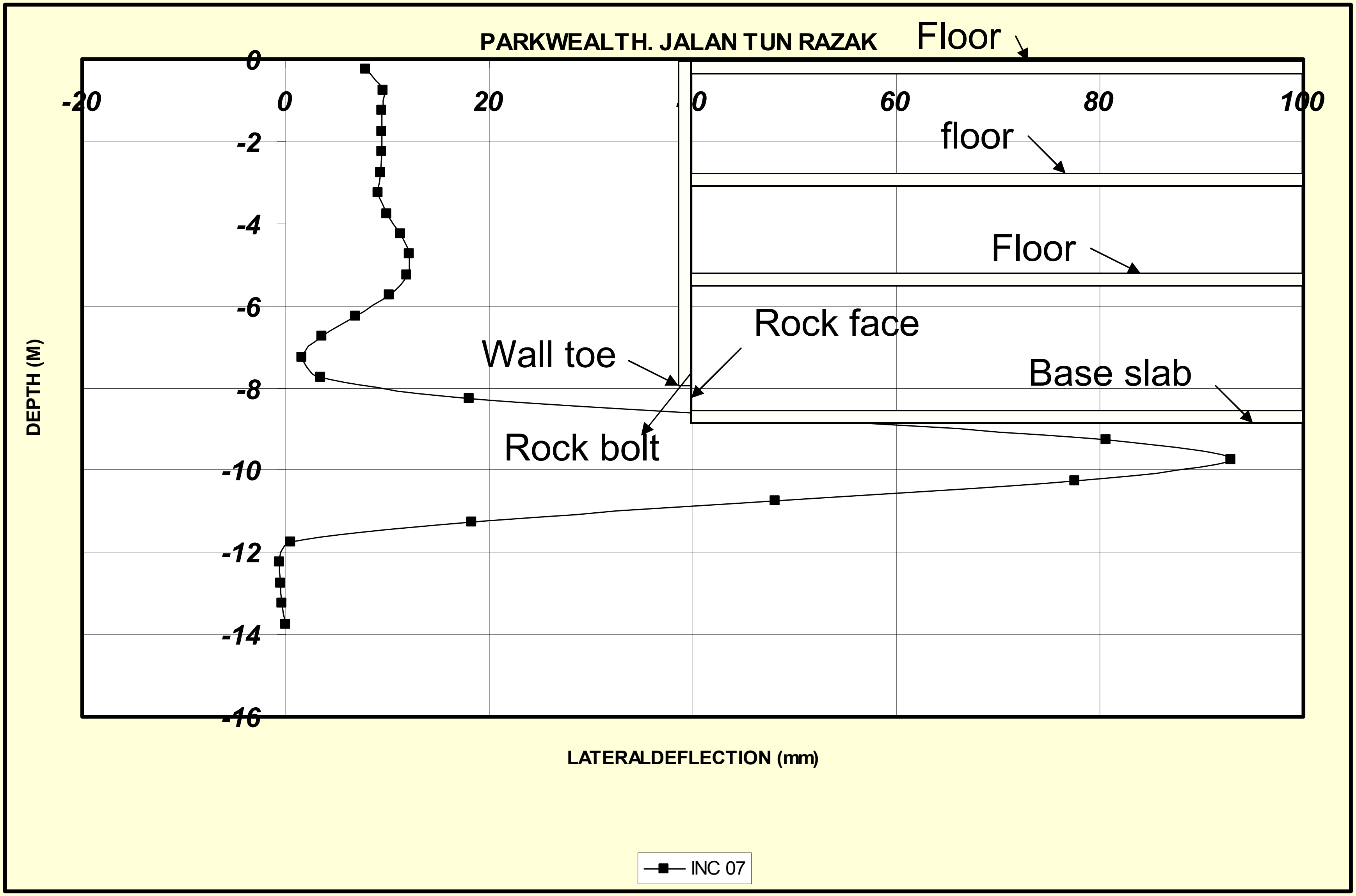
PARKWEALTH. JALAN TUN RAZAK

PARKWEALTH. JALAN TUN RAZAK

PARKWEALTH. JALAN TUN RAZAK



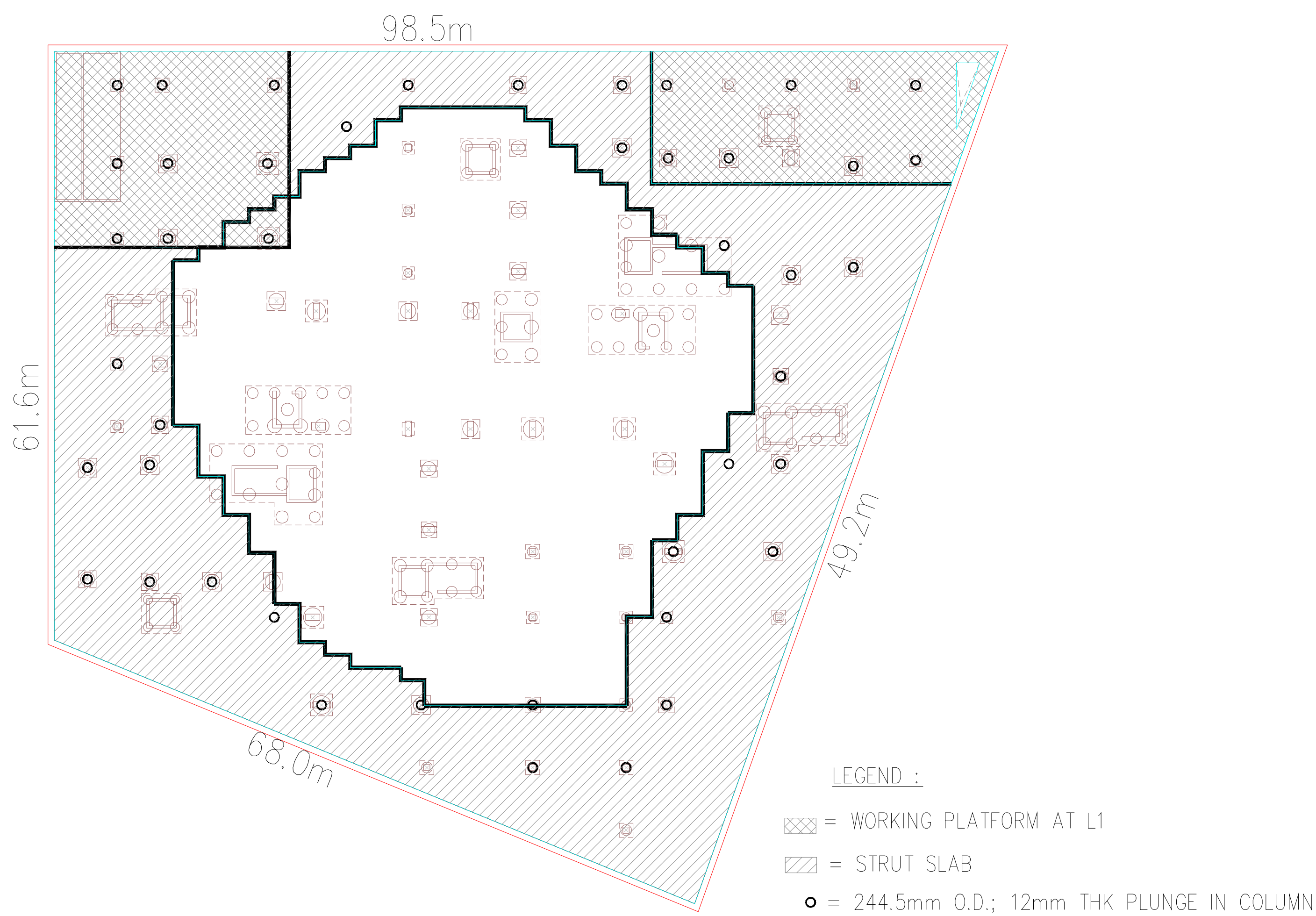
PARKWEALTH. JALAN TUN RAZAK
DEPTH (M)
LATERALDEFLECTION (mm)
-5
0
5
10
15
20
25
30
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
INC 01
INC 02
INC 03
INC 15A
INC 06
INC 09
INC 10
ANALYSIS I
ANALYSIS II
ANALYSIS III


PARKWEALTH. JALAN TUN RAZAK
Floor
floor
Floor
Rock face
Wall toe
Base slab
Rock bolt
-20
0
20
40
60
80
100
0
-2
-4
-6
-8
-10
-12
-14
-16
DEPTH (M)
LATERALDEFLECTION (mm)
INC 07

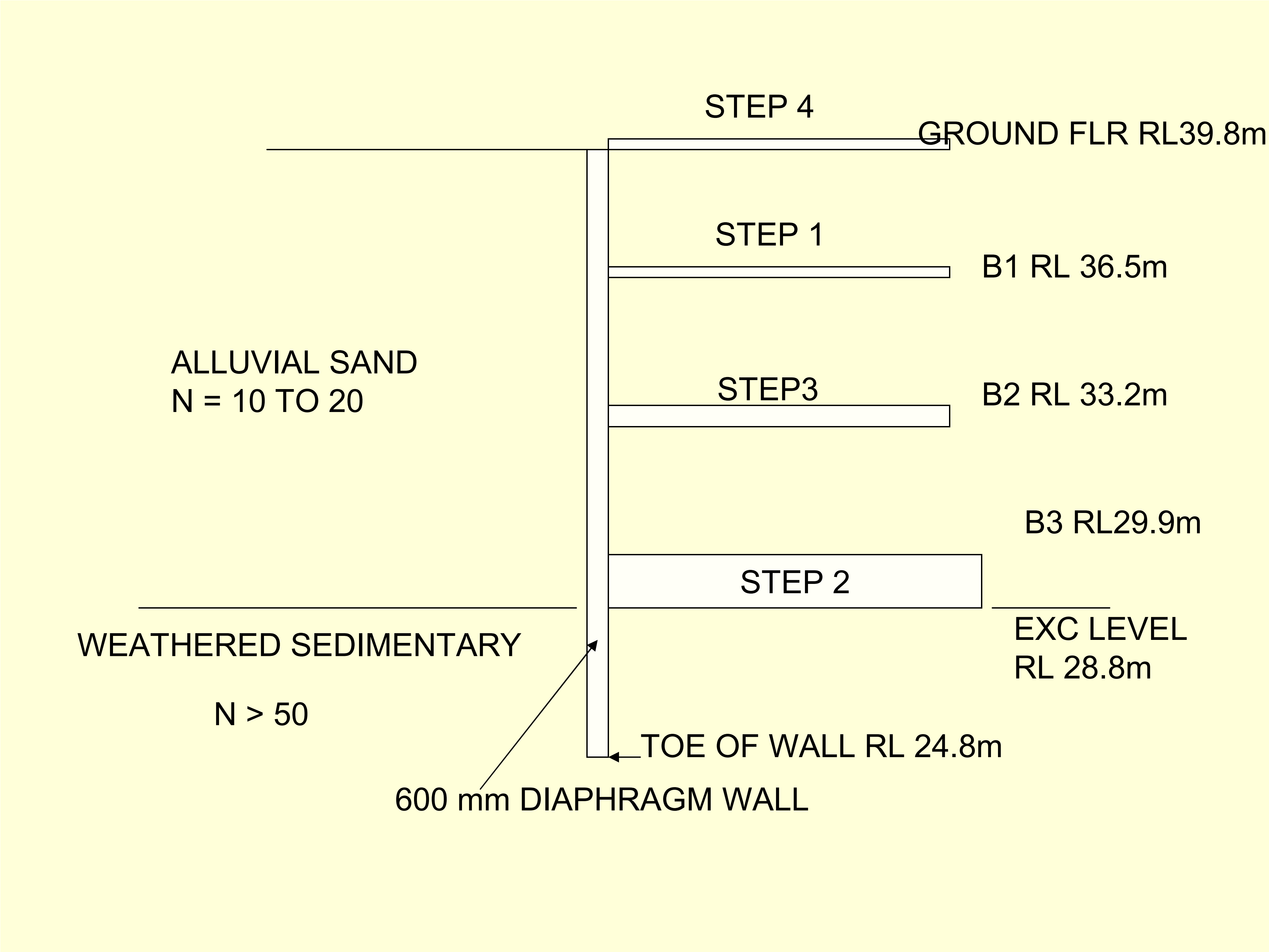
LOT 96.
SELANGOR DREDGING BERHAD
KLCC

PERIMETER RING SLAB
ALTERNATE FLOOR CONSTRUCTION SEQUENCE

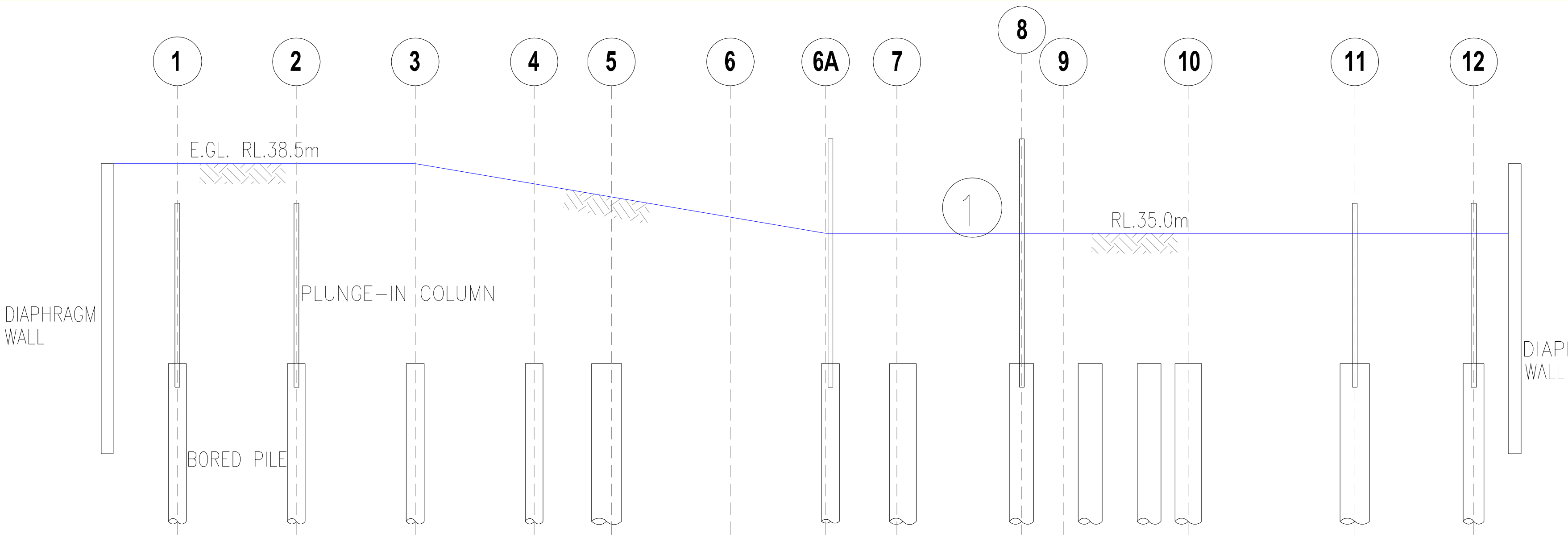
LOT 96. SDB. KLCC



SDB PROJECT


STEP 4
GROUND FLR RL39.8m
STEP 1
B1 RL 36.5m
ALLUVIAL SAND
N = 10 TO 20
STEP3
B2 RL 33.2m
B3 RL29.9m
STEP 2
EXC LEVEL
RL 28.8m
WEATHERED SEDIMENTARY
N > 50
TOE OF WALL RL 24.8m
600 mm DIAPHRAGM WALL

LOT 96. SDB. KLCC

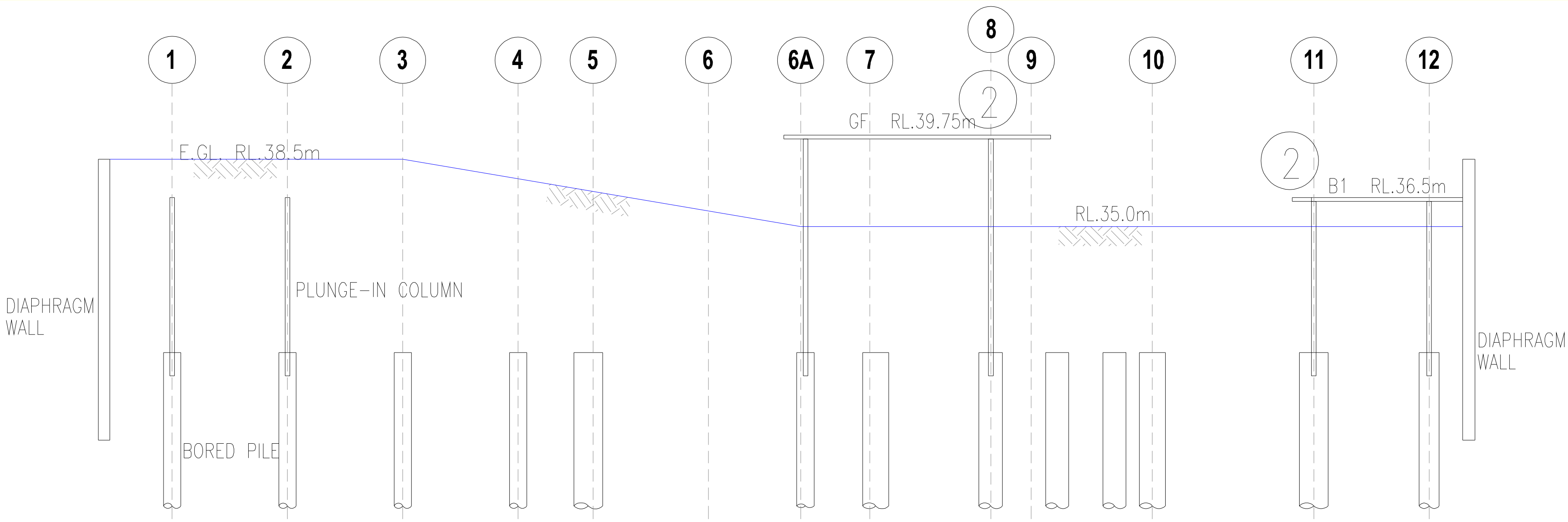


STAGE 1

EXCAVATE FOR B1 SLAB FROM 6A TO 12

SDB PROJECT

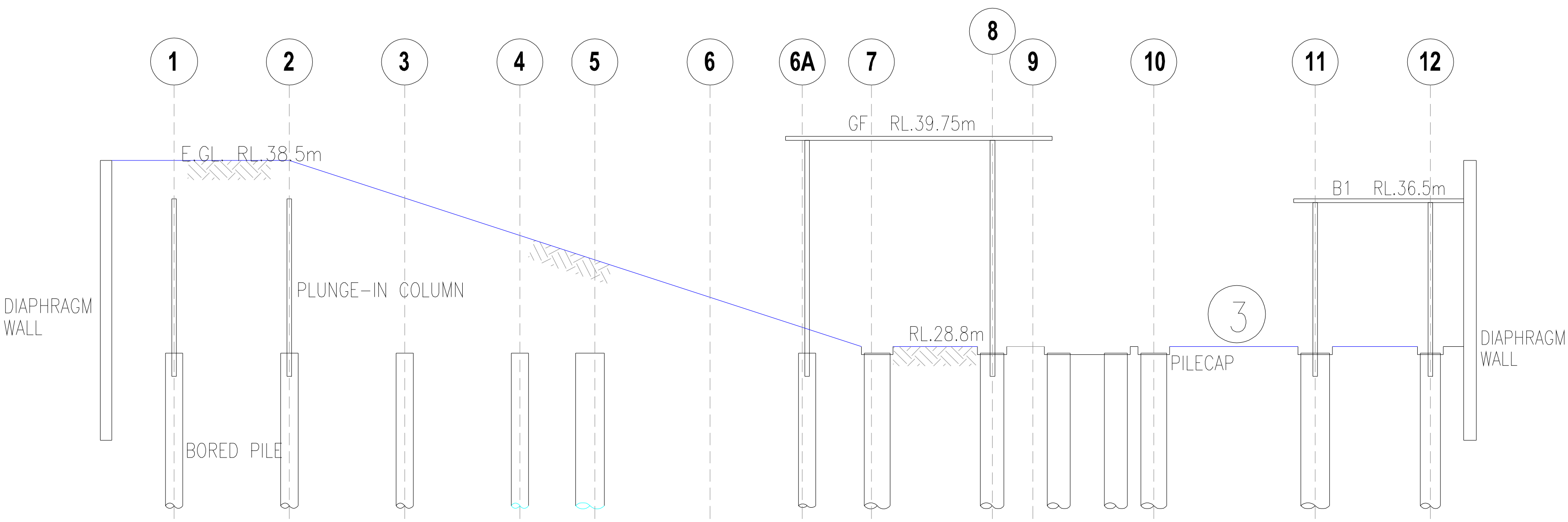
LOT 96. SDB KLCC



STAGE 2

CONSTRUCT B1 SLTRUT SLAB AND GF WORKING PLATFORM

LOT 96. SDB KLCC

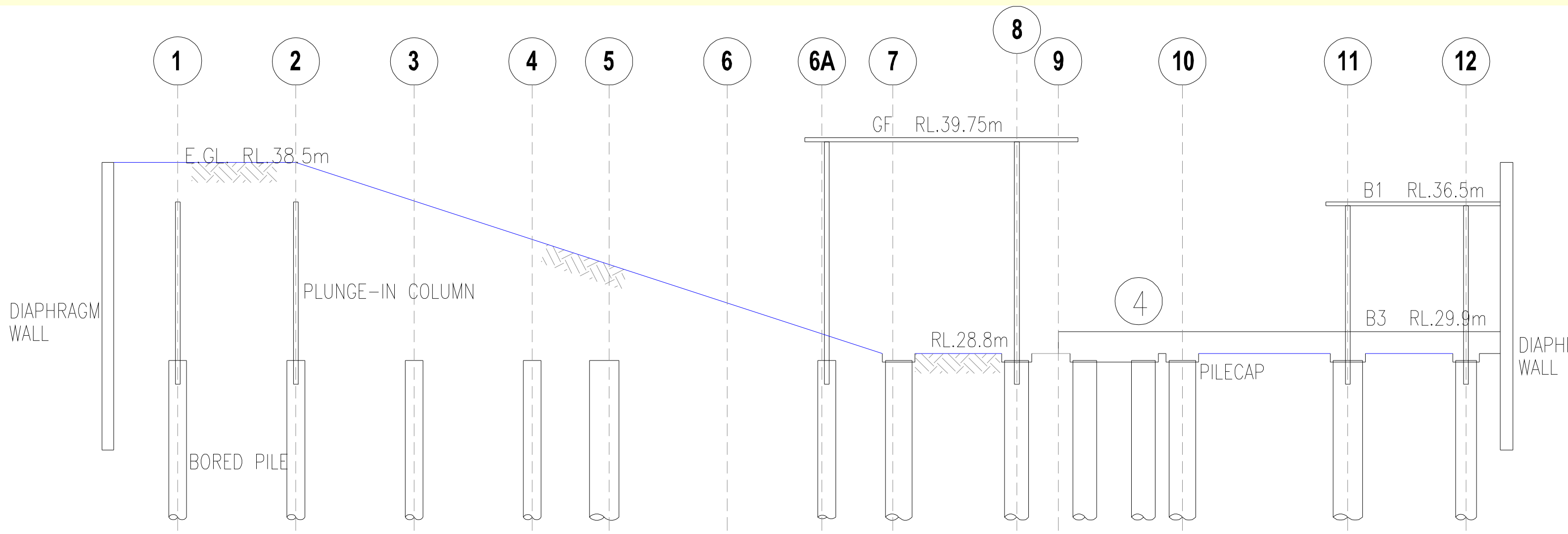


STAGE 3

FINAL EXCAVATION FOR B3 SLAB FROM GRID 7 TO 12

SDB PROJECT

LOT 96. SDB KLCC

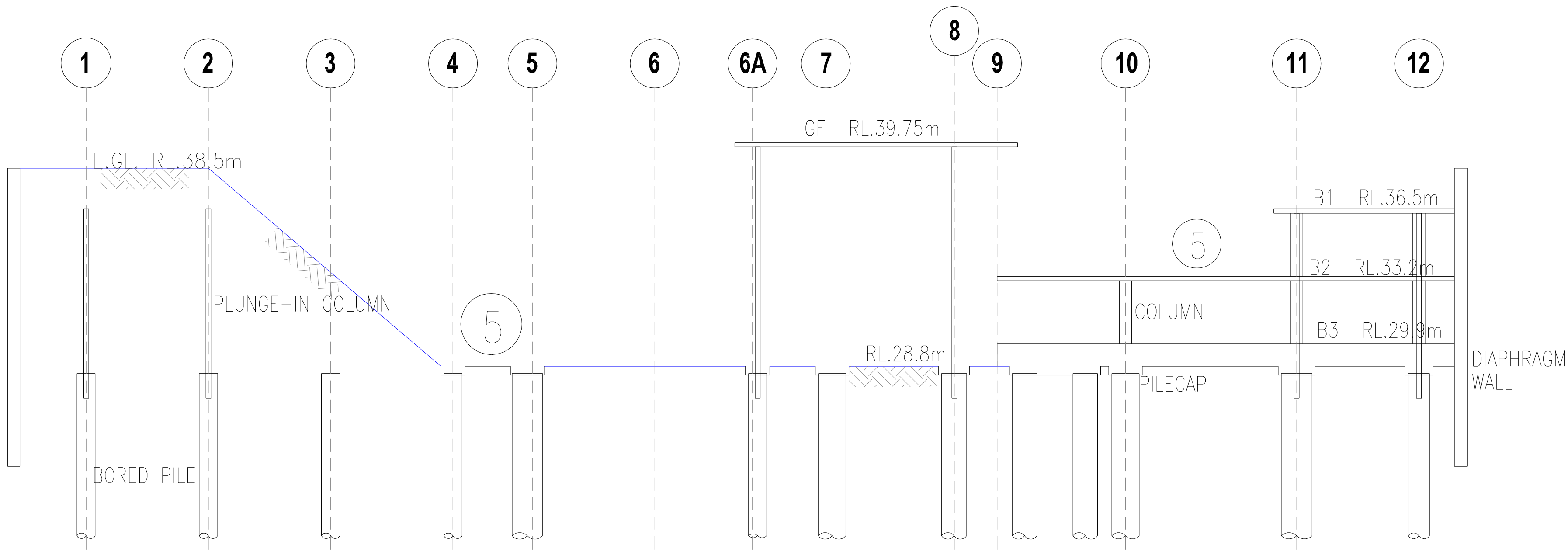


STAGE 4

CONSTRUCT B3 SLAB FROM GRID 9 TO 12

SDB PROJECT

LOT 96. SDB KLCC

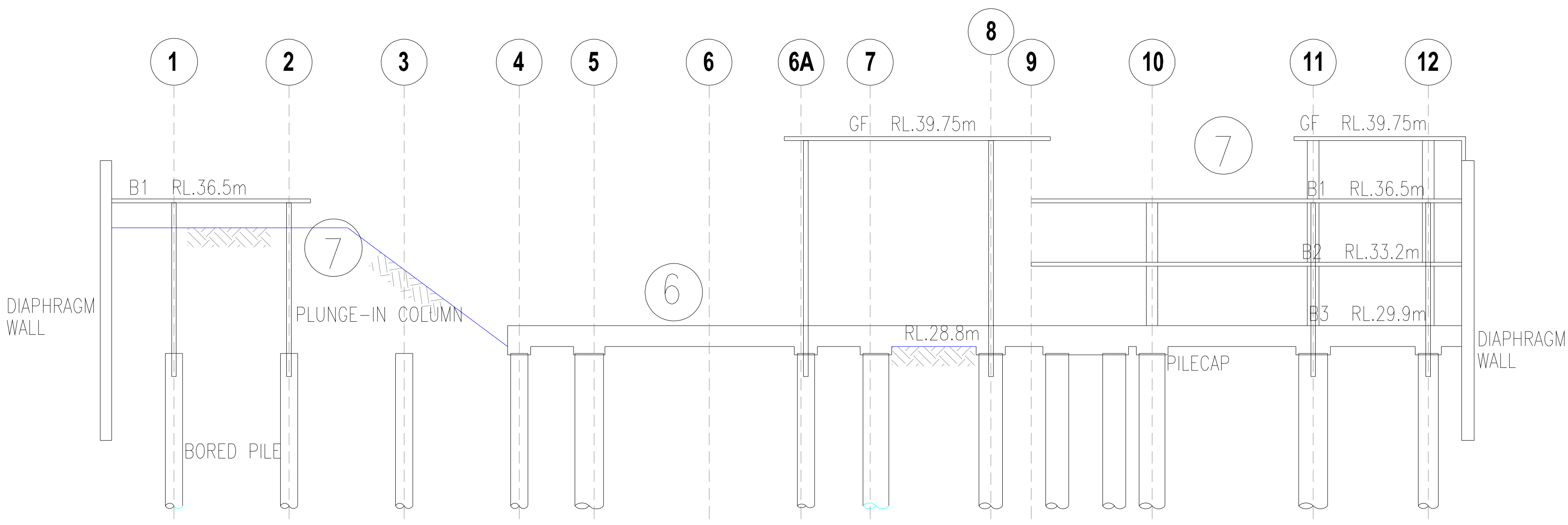


STAGE 5

CONSTRUCT B2 SLAB FROM GRID 9 TO 12 AND

EXTEND FINAL EXCAVATION TO GRID 4

LOT 96. SDB KLCC



STAGE 6

COMPLETE B4 SLAB TO GRID 4

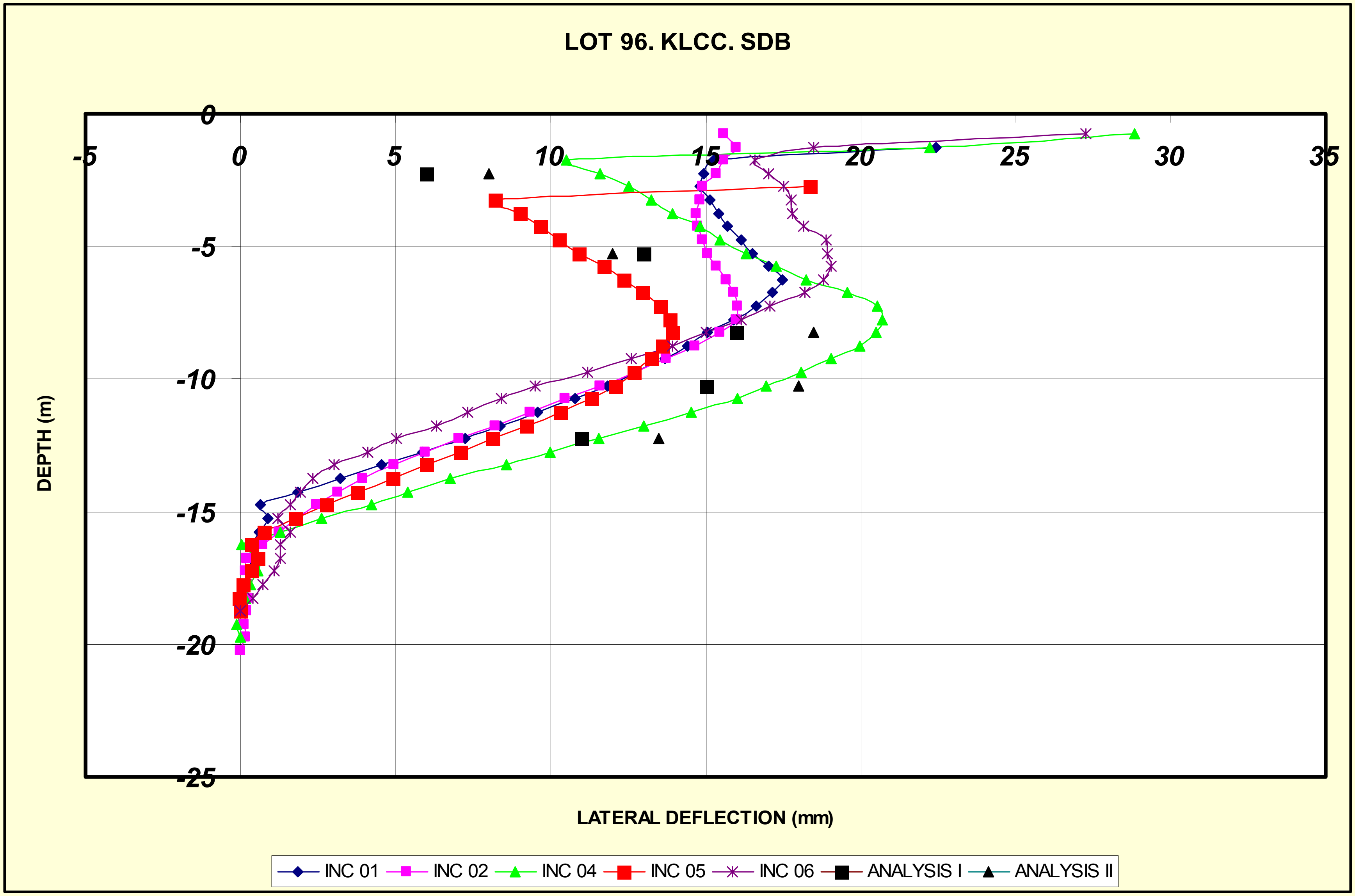
STAGE 7

REPEAT TOP DOWN CONSTRUCTION FOR GRID LINE 1 TO 6
COMPLETE REST OF FLOOR SLABS FROM GRID 6A TO 12

SDB PROJECT

Lot 96. S.D.B. KLCC

Lot 96. S.D.B. KLCC



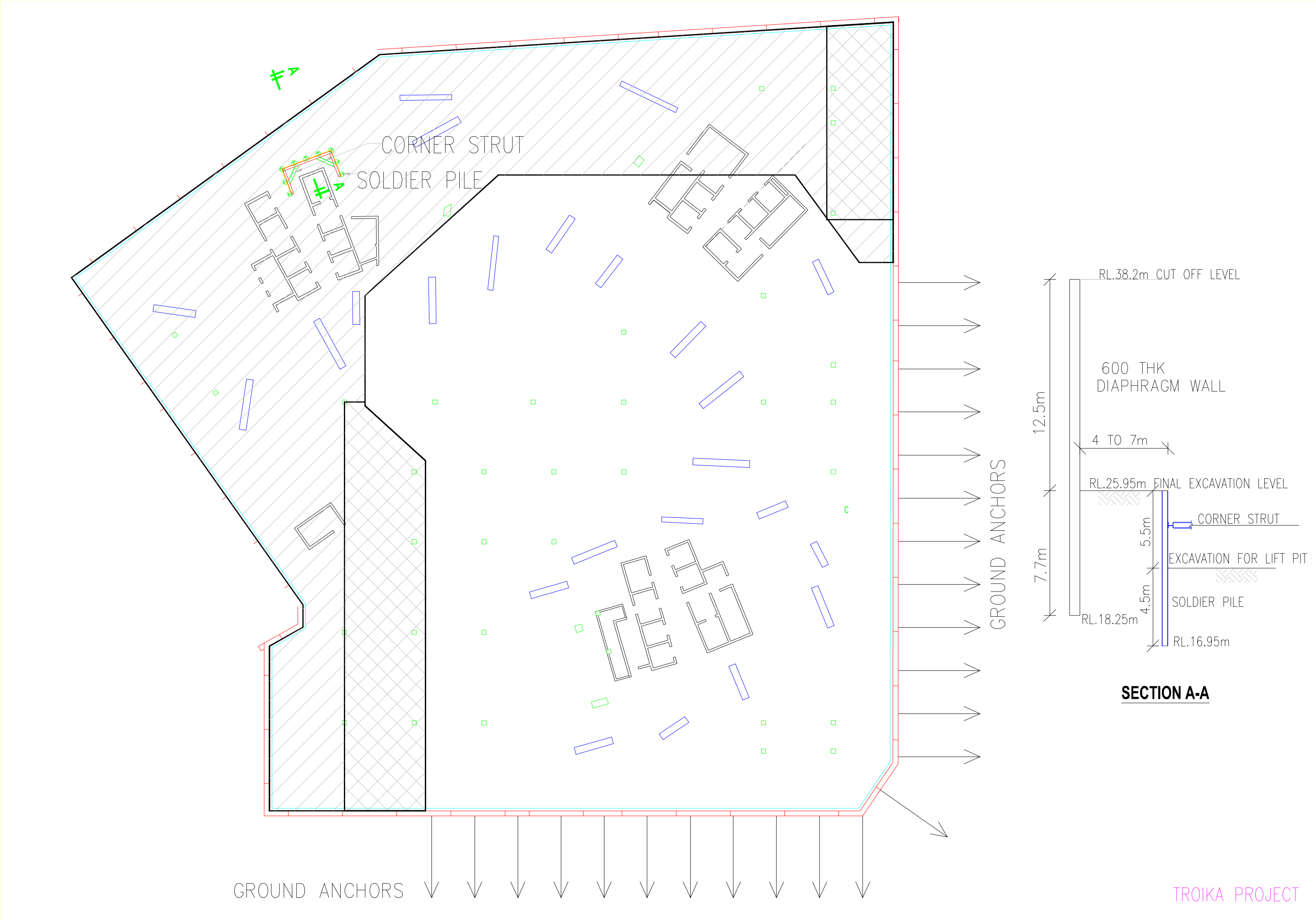
LOT 96. KLCC. SDB
0
-5
-10
-15
-20
-25
-5
0
5
10
15
20
25
30
35
DEPTH (m)
LATERAL DEFLECTION (mm)
INC 01
INC 02
INC 04
INC 05
INC 06
ANALYSIS I
ANALYSIS II

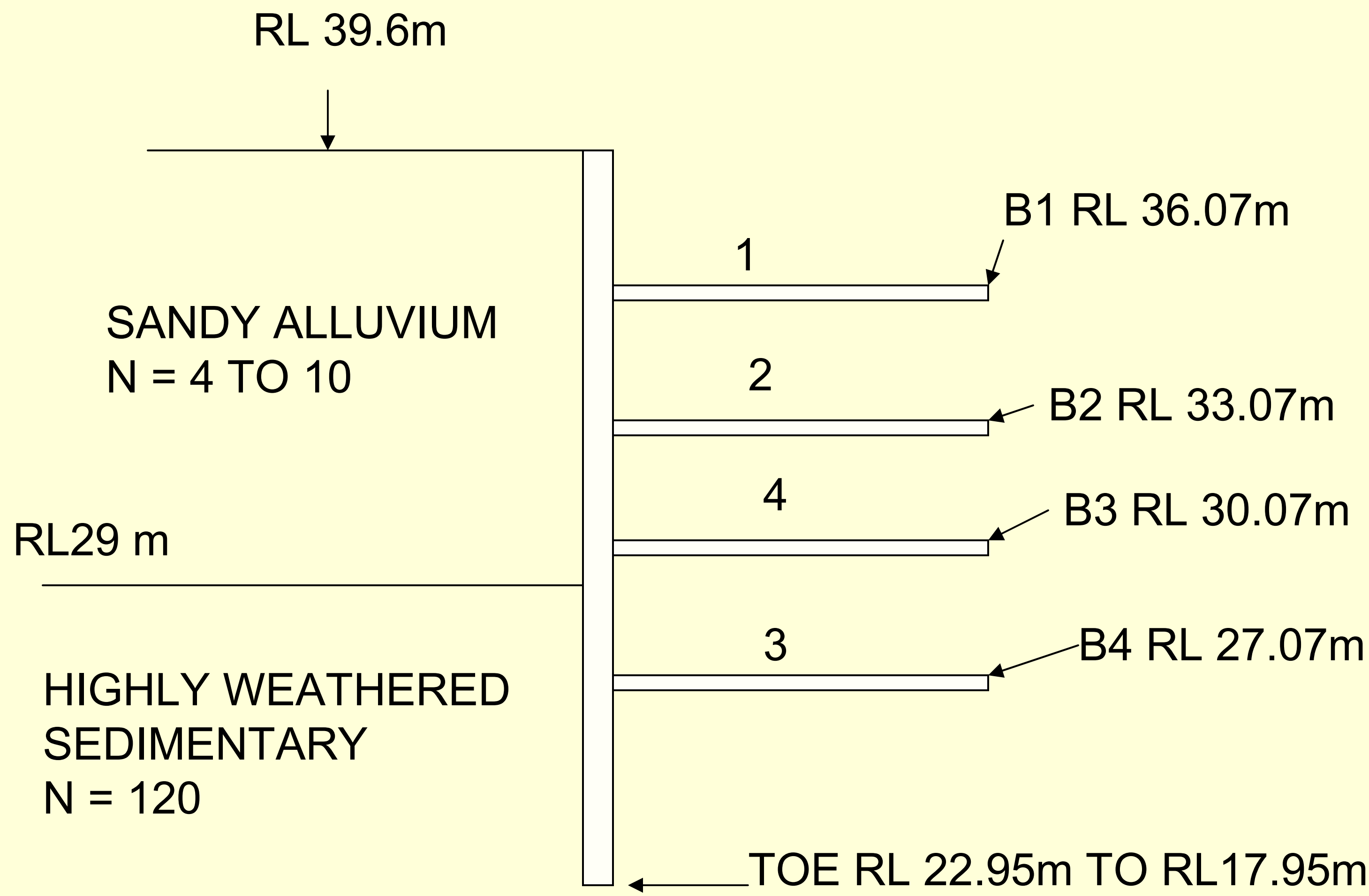
TROIKA
JALAN BINJAI
KLCC

STRUT SLABS ON 2 RECTANGULAR SIDES.
GROUND ANCHORS OTHER 2 SIDES.

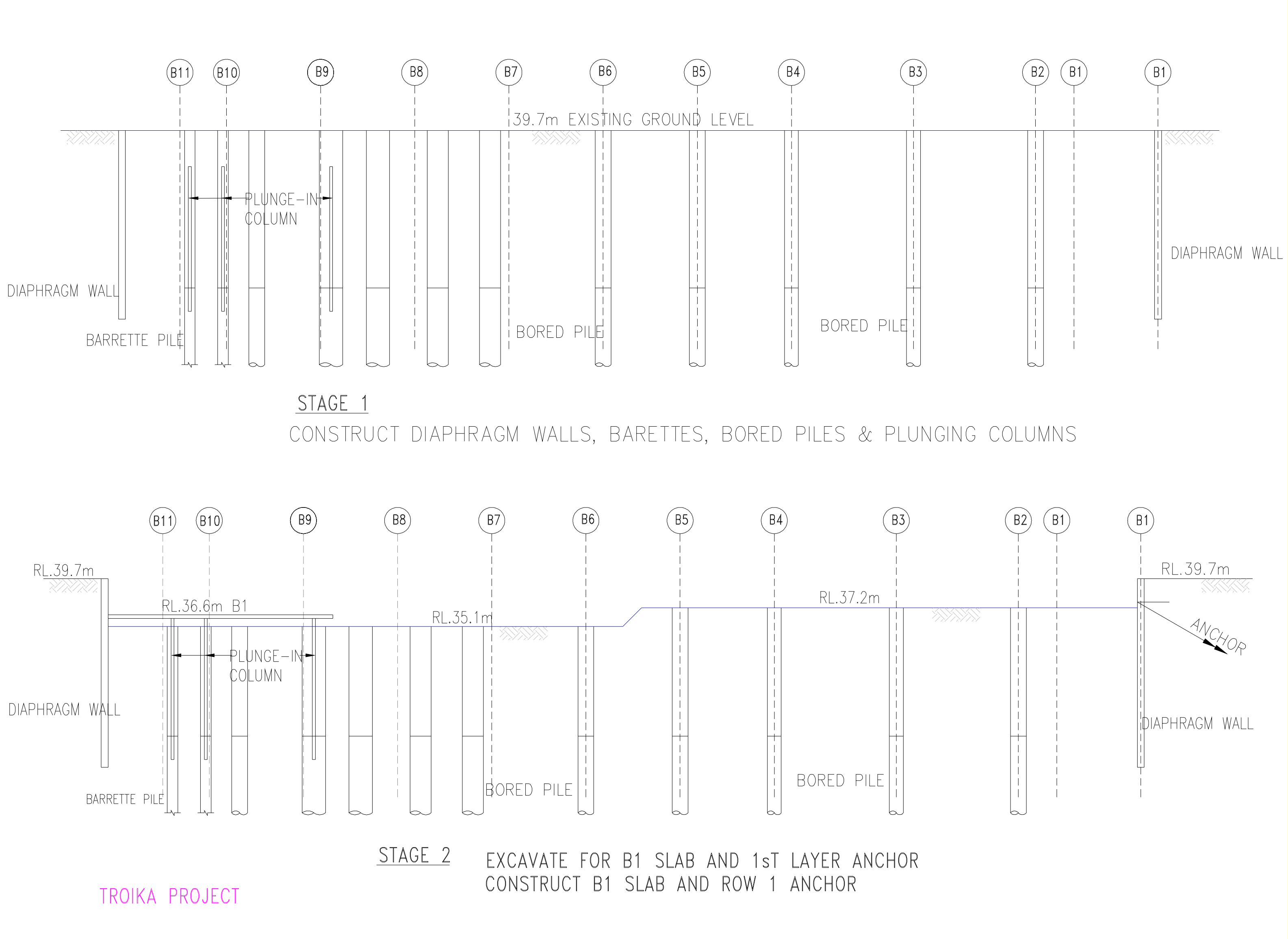
ALTERNATE FLOOR SLAB CONSTRUCTION

TROIKA, JALAN BINJAI, KLCC

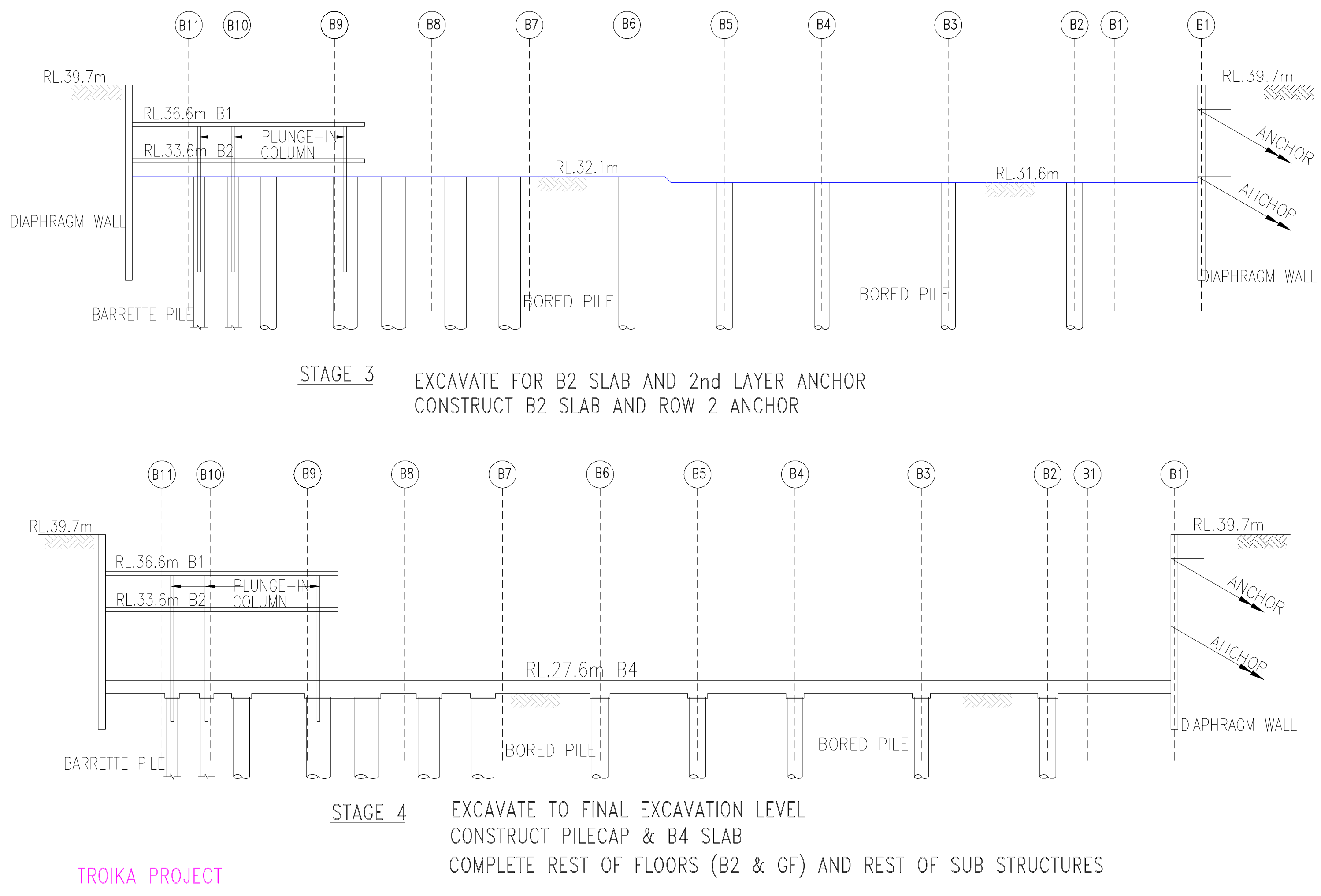



RL 39.6m
B1 RL 36.07m
1
SANDY ALLUVIUM
N = 4 TO 10
2
B2 RL 33.07m
4
B3 RL 30.07m
RL29 m
3
B4 RL 27.07m
HIGHLY WEATHERED
SEDIMENTARY
N = 120
TOE RL 22.95m TO RL17.95m

TROIKA, JALAN BINJAI, KLCC



TROIKA, JALAN BINJAI, KLCC



TROIKA, JALAN BINJAI, KLCC

TROIKA, JALAN BINJAI, KLCC

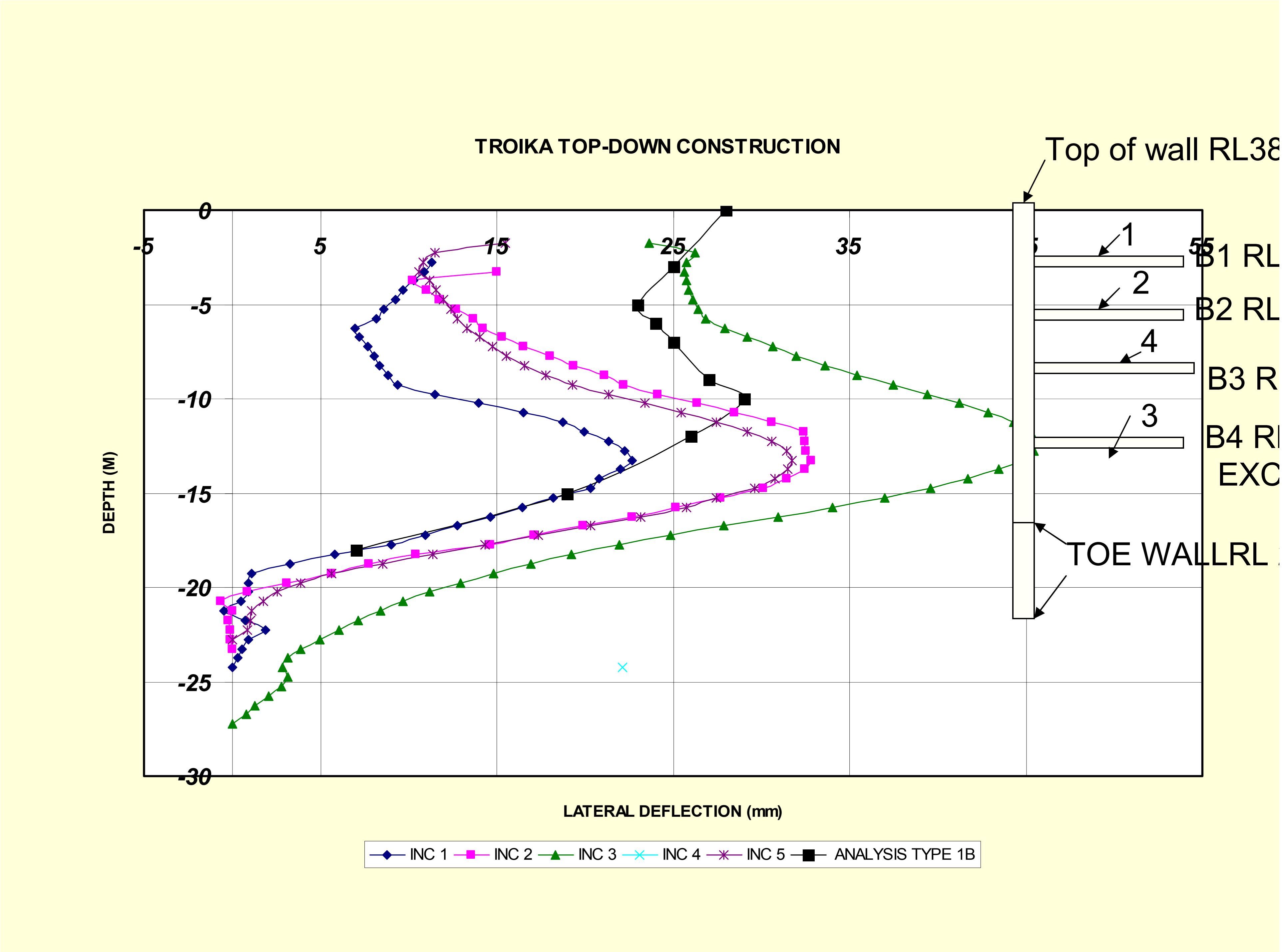
TROIKA, JALAN BINJAI, KLCC

TROIKA, JALAN BINJAI, KLCC

TROIKA, JALAN BINJAI, KLCC

TROIKA, JALAN BINJAI, KLCC

TROIKA. JALN BINJAI, KLCC



TROIKA TOP-DOWN CONSTRUCTION
Top of wall RL38
0
-5
-10
-15
-20
-25
-30
-5
5
15
25
35
55
1
2
4
3
B1 RL
B2 RL
B3 R
B4 RI
EXC
TOE WALLRL
DEPTH (M)
LATERAL DEFLECTION (mm)
INC 1
INC 2
INC 3
INC 4
INC 5
ANALYSIS TYPE 1B

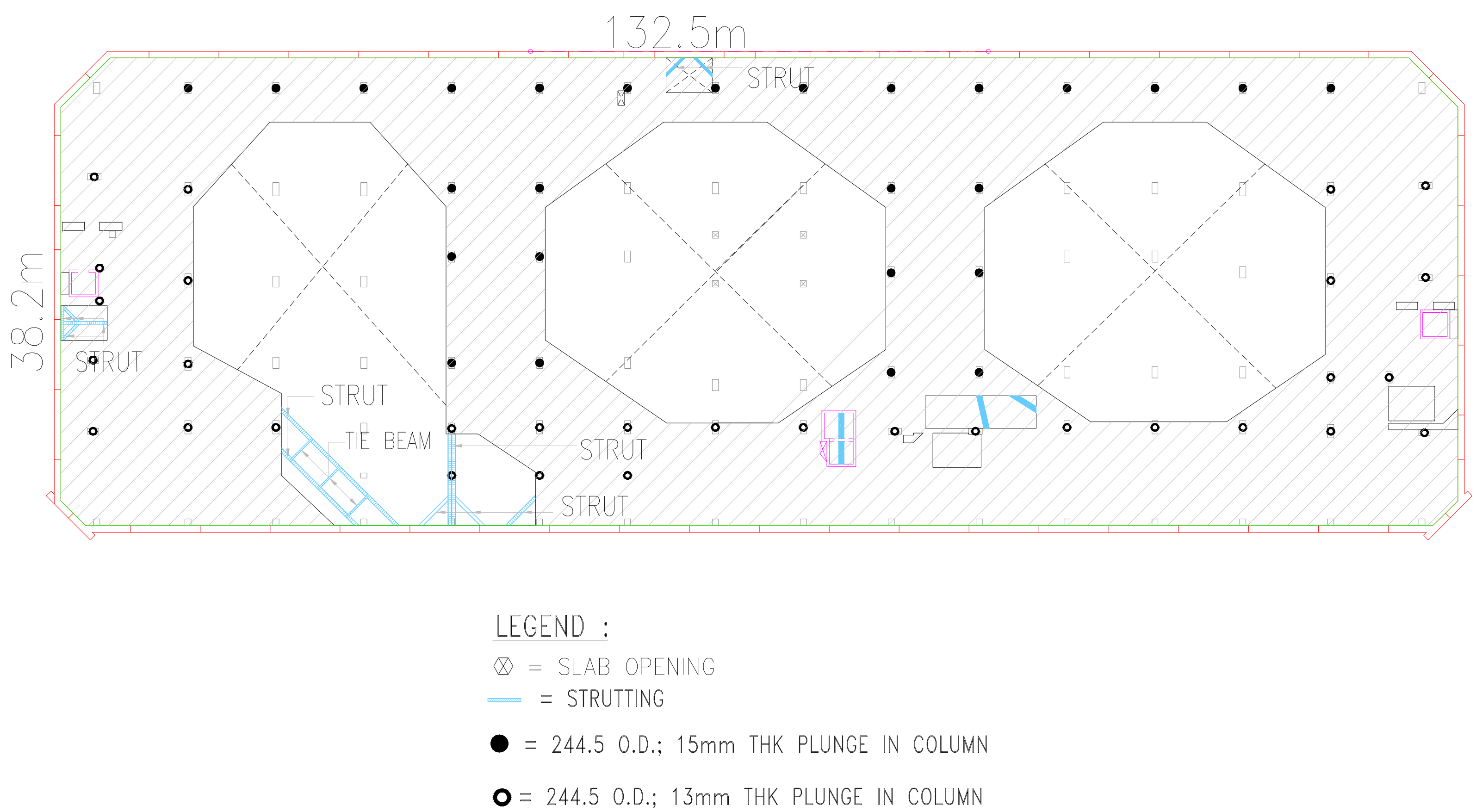
BANGSAR VILLAGE 2

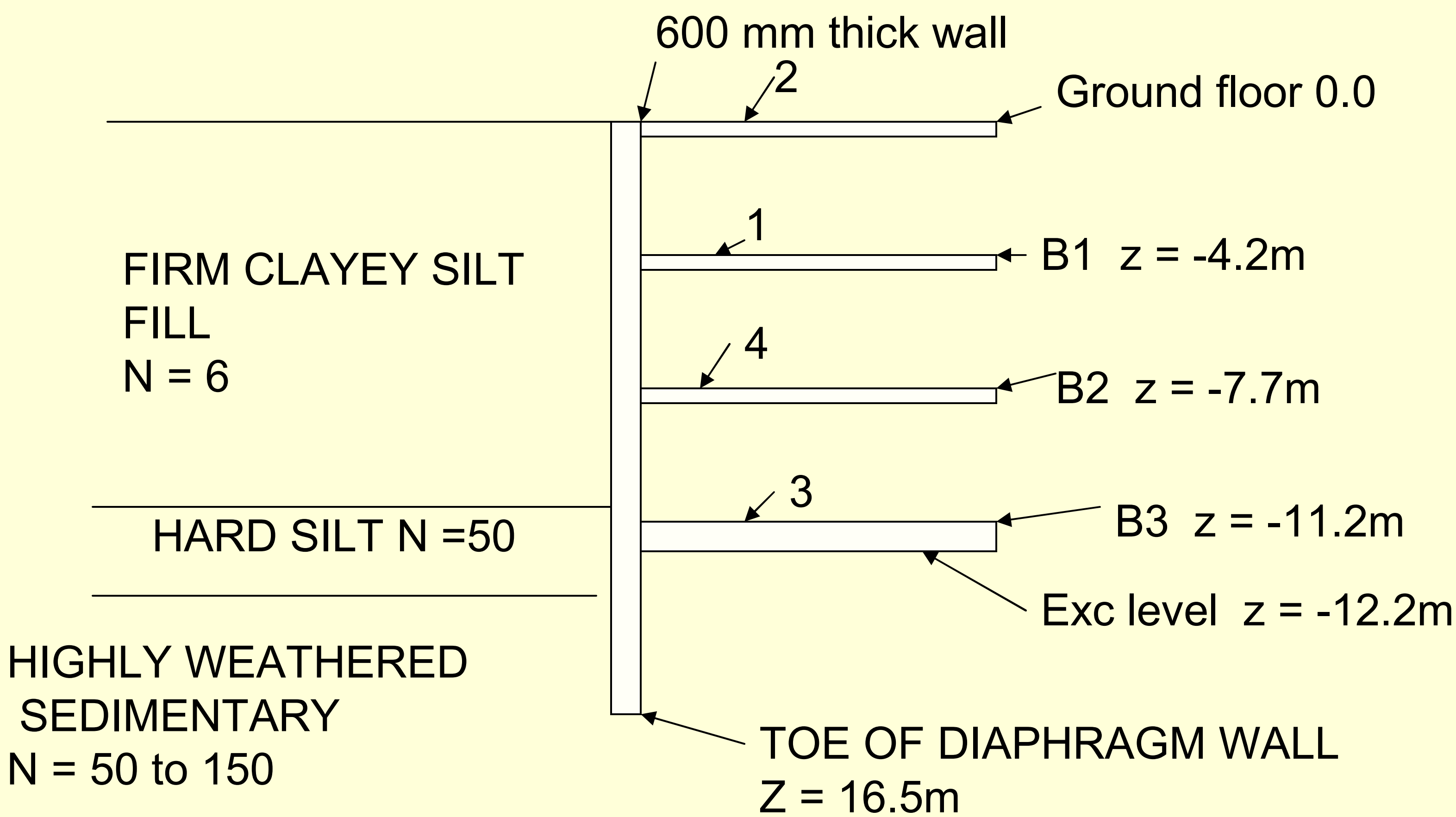
ENG LIAN

RING SLAB AND STRUT SLABS

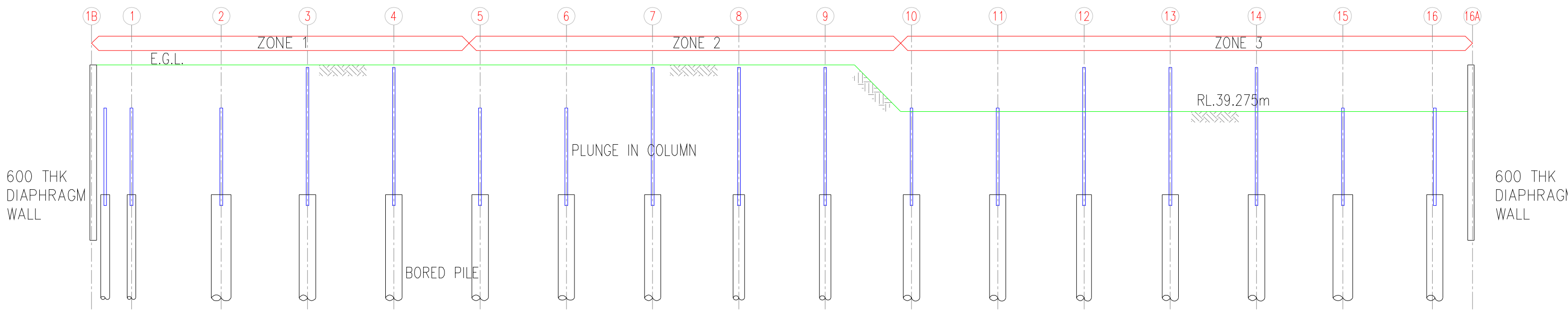
ALTERNATE FLLOR CONSTRUCTION

BANGSAR VILLAGE 2



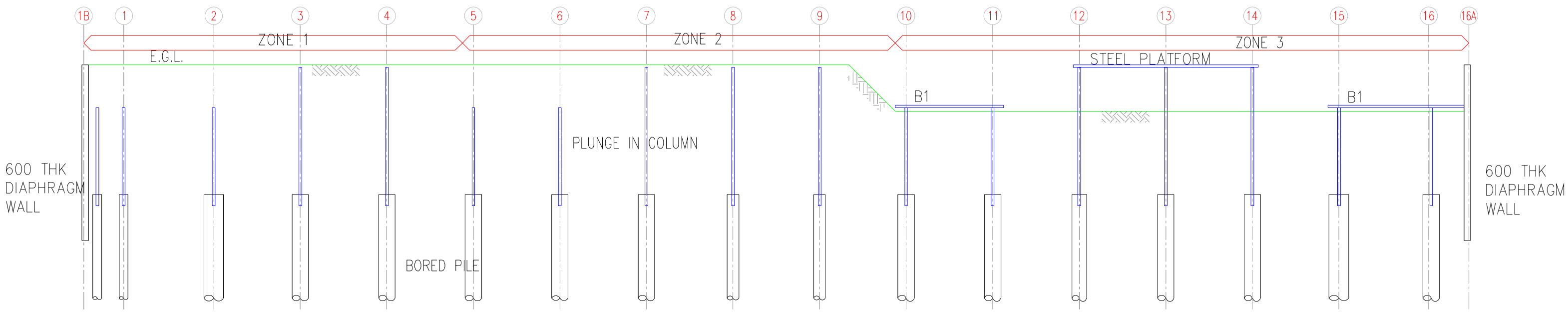

600 mm thick wall
2
Ground floor 0.0
1
B1 z = -4.2m
FIRM CLAYEY SILT
FILL
N = 6
4
B2 z = -7.7m
3
B3 z = -11.2m
HARD SILT N =50
Exc level z = -12.2m
HIGHLY WEATHERED
SEDIMENTARY
N = 50 to 150
TOE OF DIAPHRAGM WALL
Z = 16.5m

BANGSAR VILLAGE 2, ENG LIAN



STAGE 1

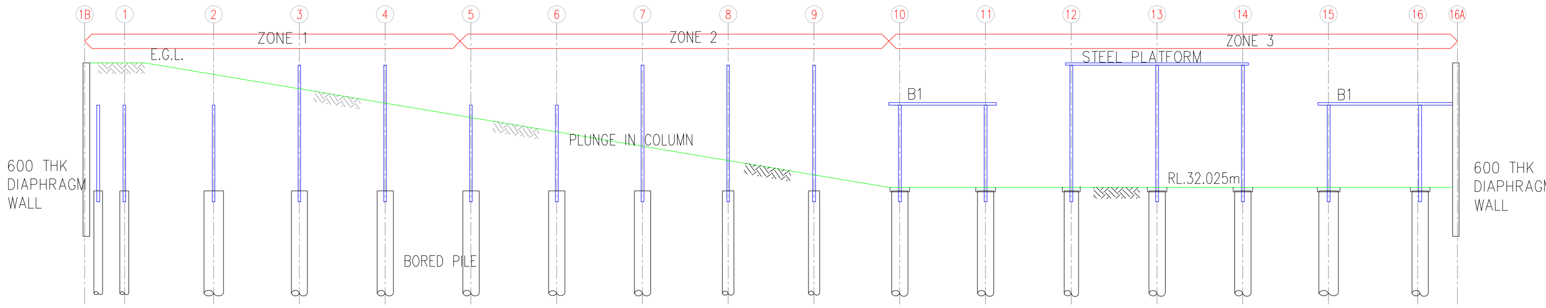
1. EXCAVATE TO SOFFIT OF B1 RL.39.275 (ZONE 3)



STAGE 2

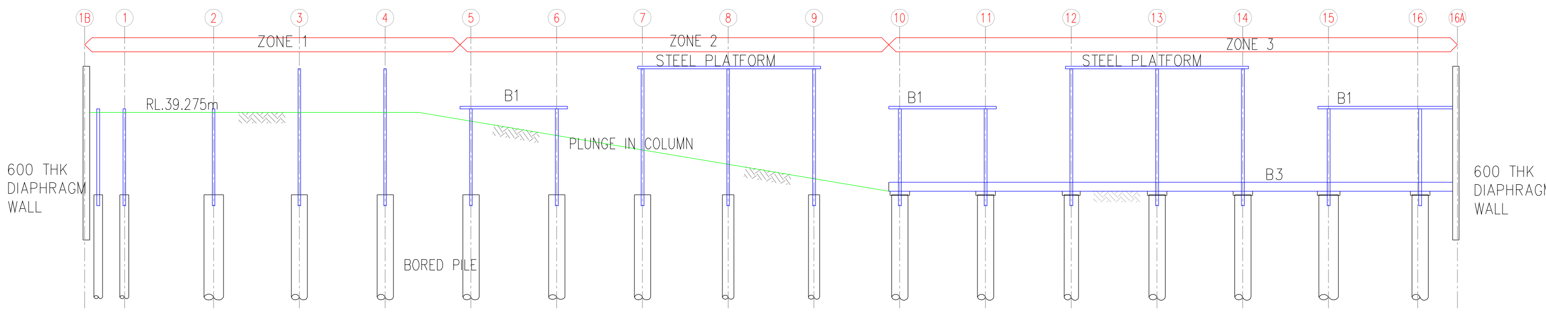
1. CONSTRUCT B1 RING SLAB AT RL.39.825 (ZONE 3)
2. ERECT THE STEEL PLATFORM AT ZONE 3

BANGSAR VILLAGE 2. ENG LIAN



STAGE 3

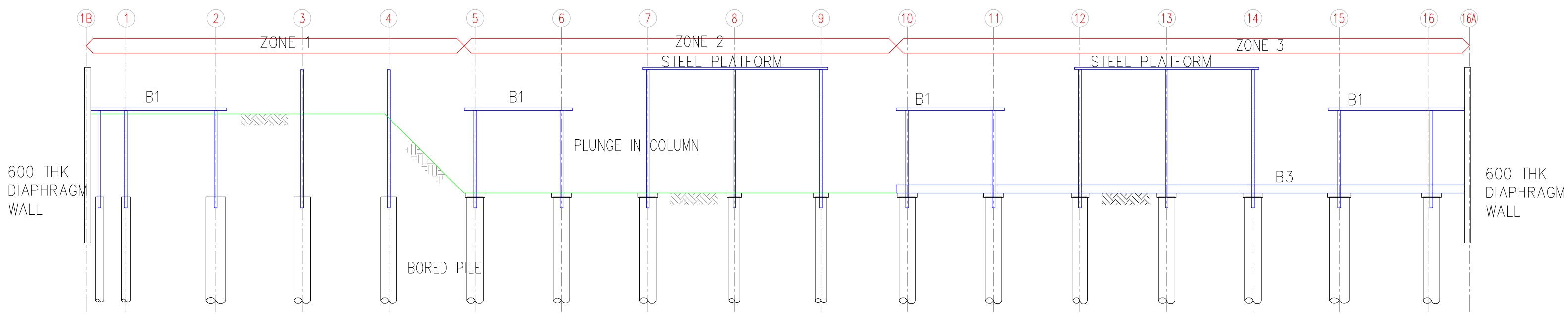
1. EXCAVATE TO FINAL EXCAVATION LEVEL RL.32.025, AND COMMENCEMENT OF PILECAP CONSTRUCTION AT ZONE 1



STAGE 4

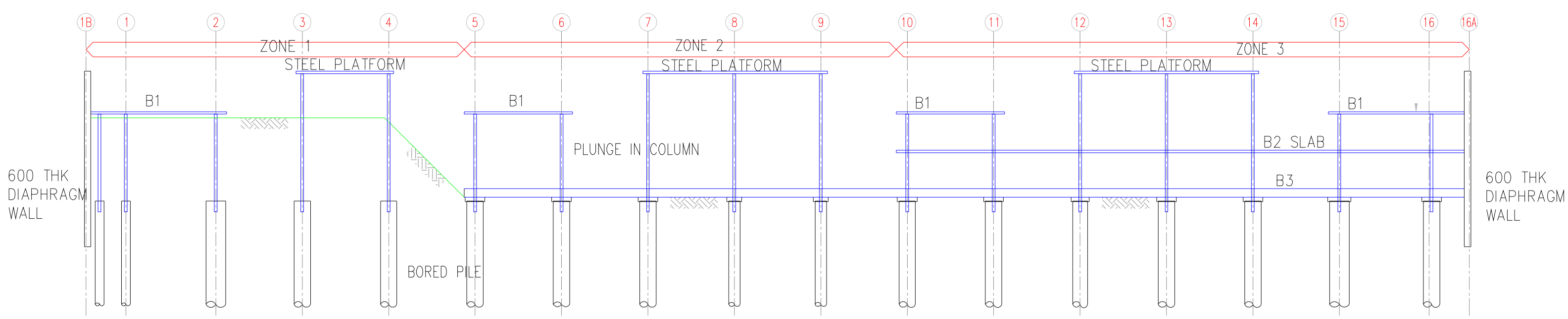
1. CONSTRUCT B3 RAFT SLAB AT RL.32.825 (ZONE 3)
2. EXCAVATE TO SOFFIT OF B1 RL.39.275 (ZONE 1)
3. CONSTRUCT B1 RING SLAB AT RL.39.825 (ZONE 2)
4. ERECT THE STEEL PLATFORM AT ZONE 2

BANGSAR VILLAGE 2, ENG LIAN



STAGE 5

1. EXCAVATE TO FINAL EXCAVATION LEVEL RL.32.025, AND COMMENCEMENT OF PILEUP CONSTRUCTION AT ZONE 2
2. CONSTRUCT B1 RING SLAB AT RL.39.825 (ZONE 1)



STAGE 6

1. CONSTRUCT B2 SLAB AT RL.36.325 (ZONE 3)
2. CONSTRUCT B3 RAFT SLAB AT RL.32.825 (ZONE 2)
3. ERECT THE STEEL PLATFORM AT ZONE 1
4. REPEAT TOP DOWN CONSTRUCTION PROCEDURE FOR ZONE 1

BANGSAR VILLAGE 2, ENG LIAN

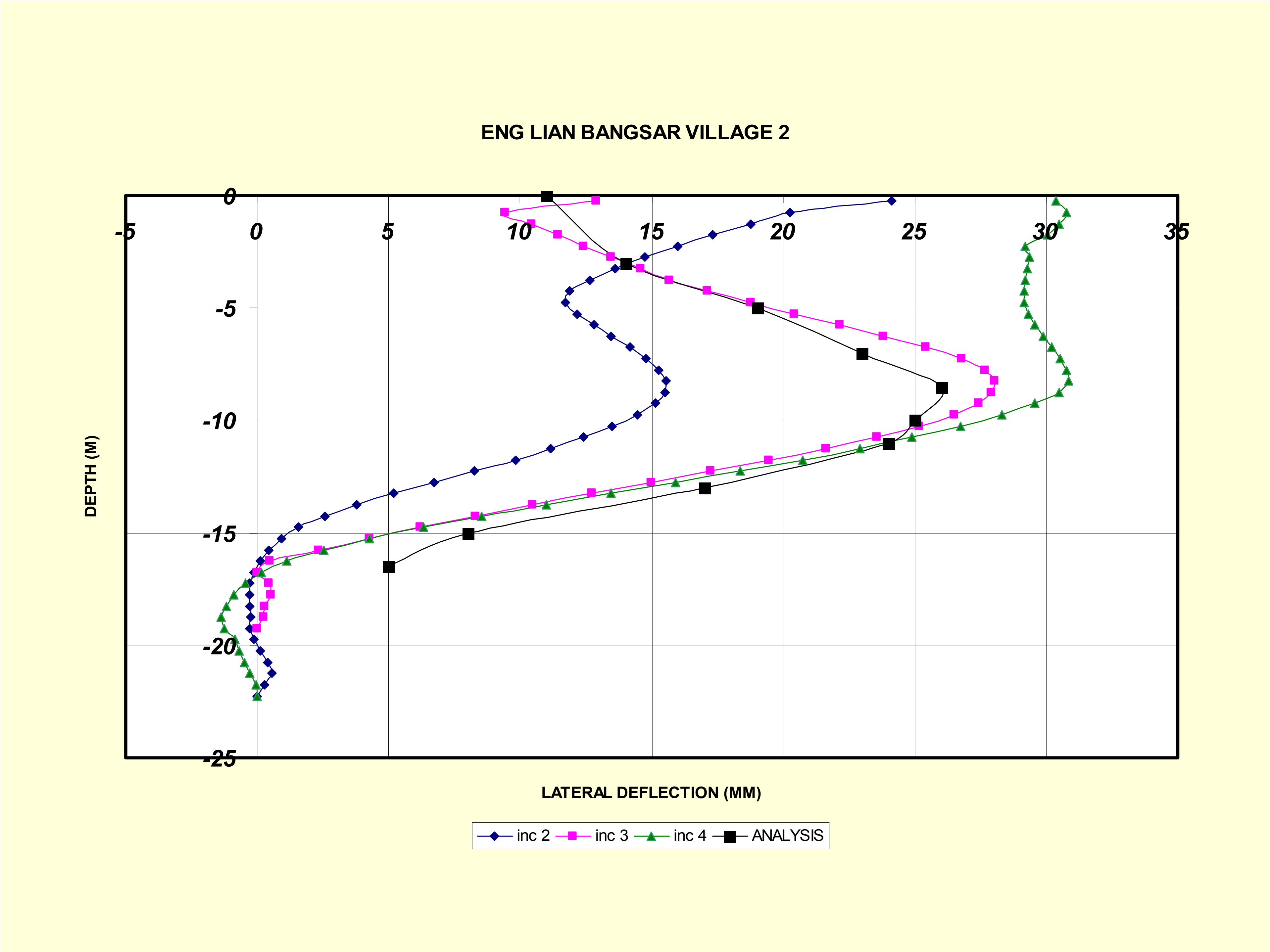
BANGSAR VILLAGE 2, ENG LIAN

BANGSAR VILLAGE 2, ENG LIAN

BANGSAR VILLAGE 2, ENG LIAN

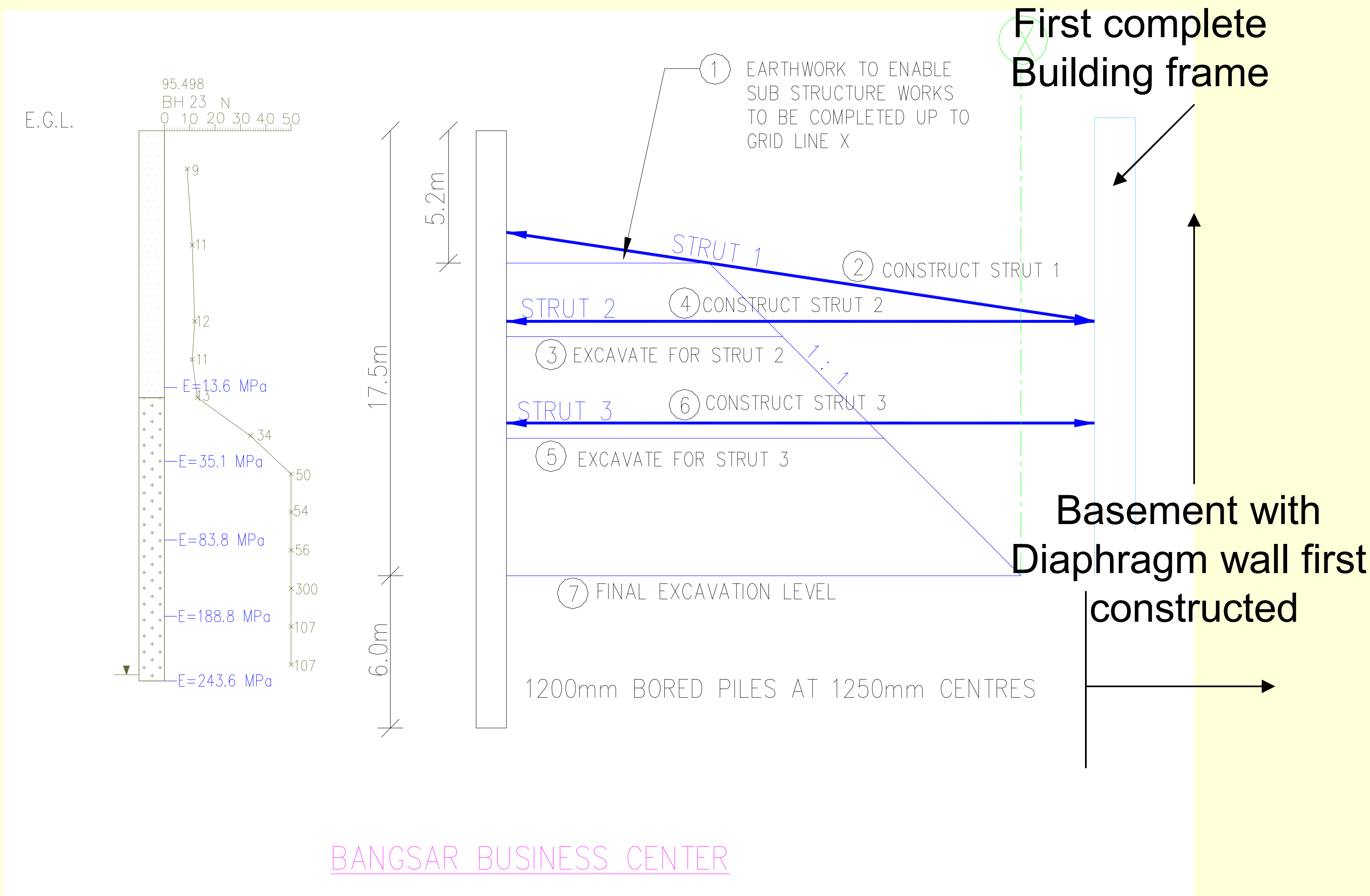
BANGSAR VILLAGE 2, ENG LIAN

BANGSAR VILLAGE 2, ENG LIAN


ENG LIAN BANGSAR VILLAGE 2
-5
0
5
10
15
20
25
30
35
0
-5
-10
-15
-20
-25
DEPTH (M)
LATERAL DEFLECTION (MM)
inc 2
inc 3
inc 4
ANALYSIS

BANGSAR SHOPPING CENTRE EXTENSION.
BANDARAYA DEVELOPMENT
NEXT TO MULTI-STOREY BUILDING AND 4 STOREY CAR PARK STRUCTURE ON TIMBER PILES

BSC EXTENSION, BANDARAYA DEVELOPMENTS



BSC EXTENSION

TOWER
ON
BORED
PILES

CAR PARK
ON
TIMBER PILES

1500MM
DIAMETER
CBP

BSC EXTENSION

DIAPHRAGM WALLS

THIS PART BASEMENT AND PART STRUCTURE CONSTRUCTED FIRST

EARTH BERM

BSC EXTENSION

BSC EXTENSION

BSC EXTENSION

Progressively excavating the berm

BSC EXTENSION

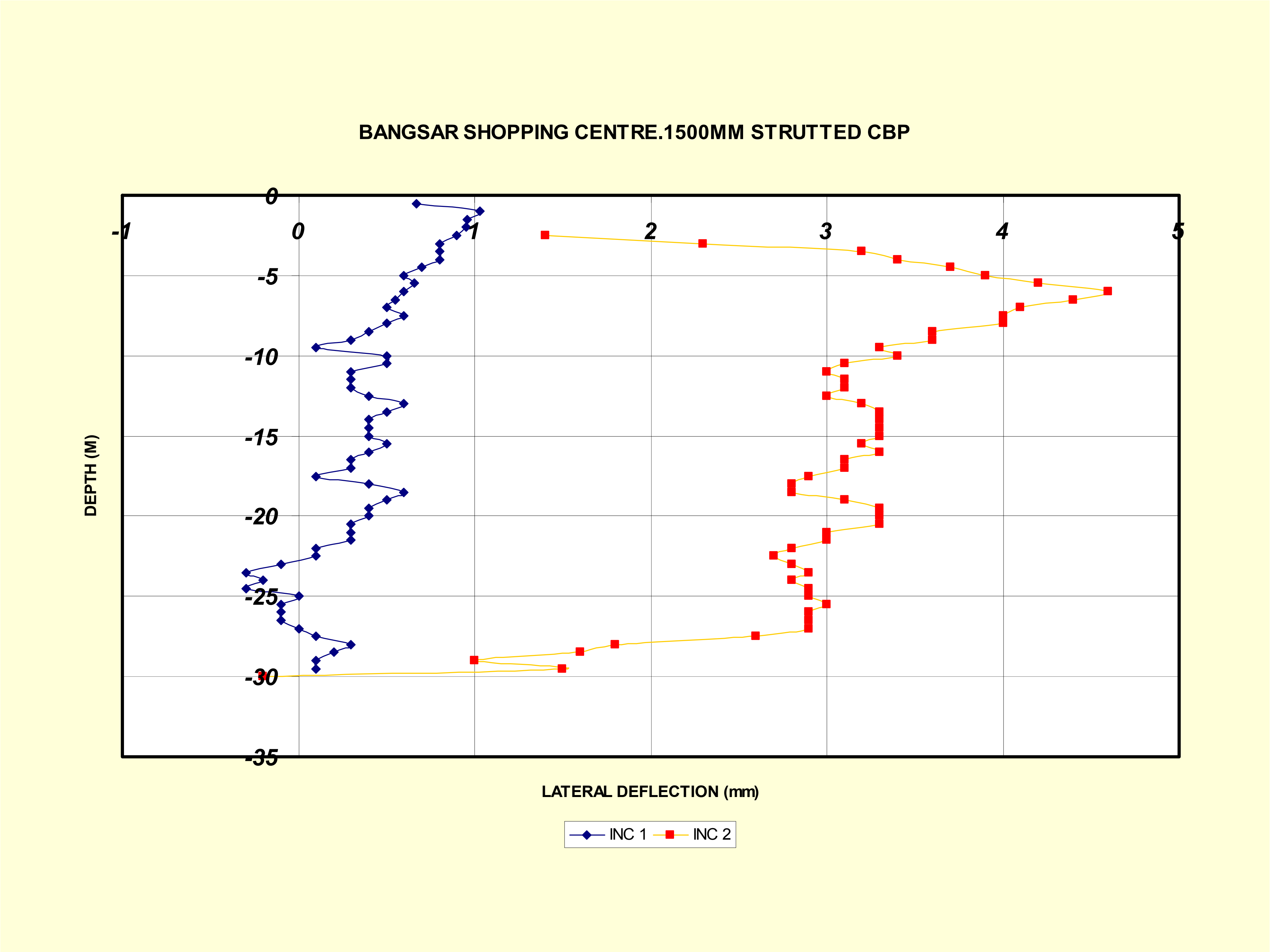
BASEMENT SLAB CAST

BSC EXTENSION

BSC EXTENSION

BSC EXTENSION

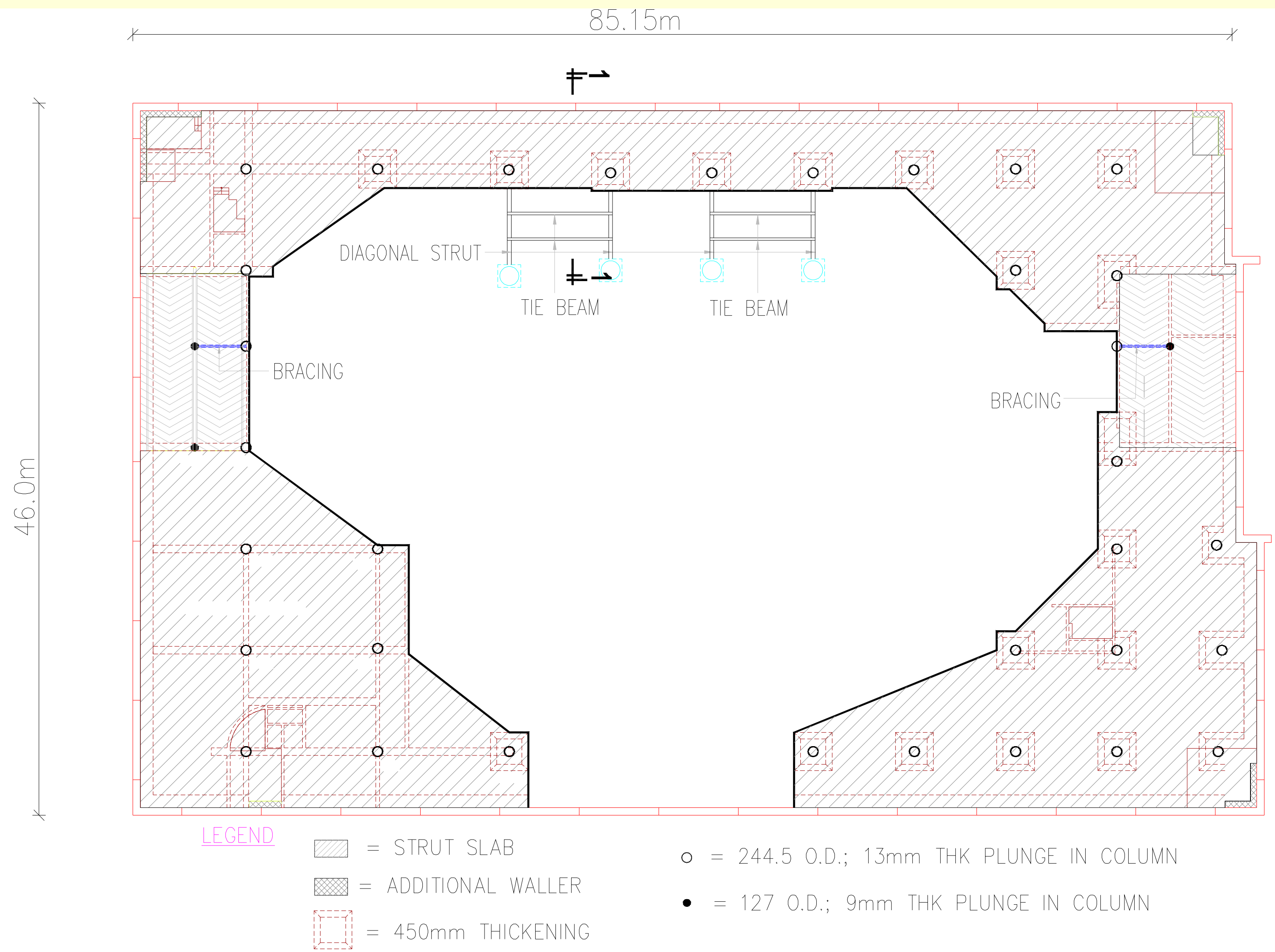
BSC EXTENSION


BANGSAR SHOPPING CENTRE.1500MM STRUTTED CBP
-1
0
1
2
3
4
5
0
-5
-10
-15
-20
-25
-30
-35
DEPTH (M)
LATERAL DEFLECTION (mm)
INC 1
INC 2

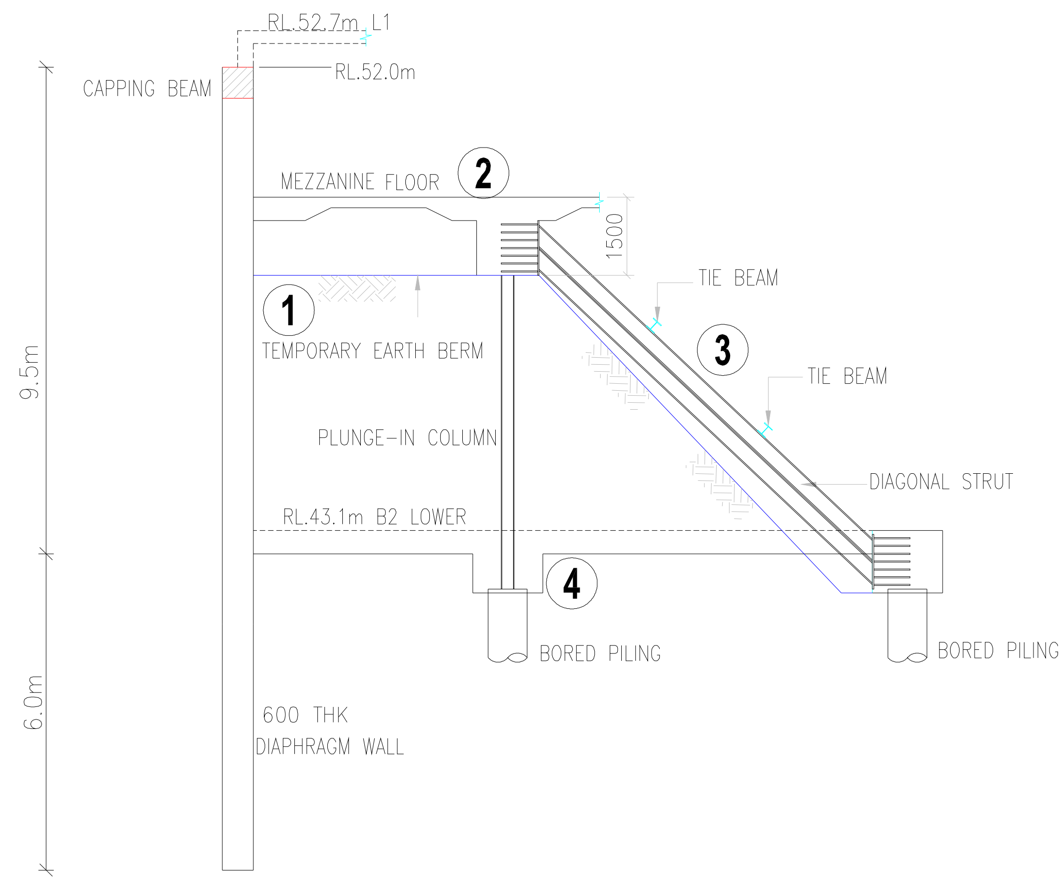
UAC MUTIARA DAMANSARA

TOP – DOWN RESTRAINT SLAB WITH INCLINED STRUTS

UAC MUTIARA DAMANSARA



UAC



SECTION 1–1

UAC PROJECT

UAC MUTIARA DAMANSARA

UAC MUTIARA DAMANSARA

UAC MUTIARA DAMANSARA

UAC MUTIARA DAMANSARA

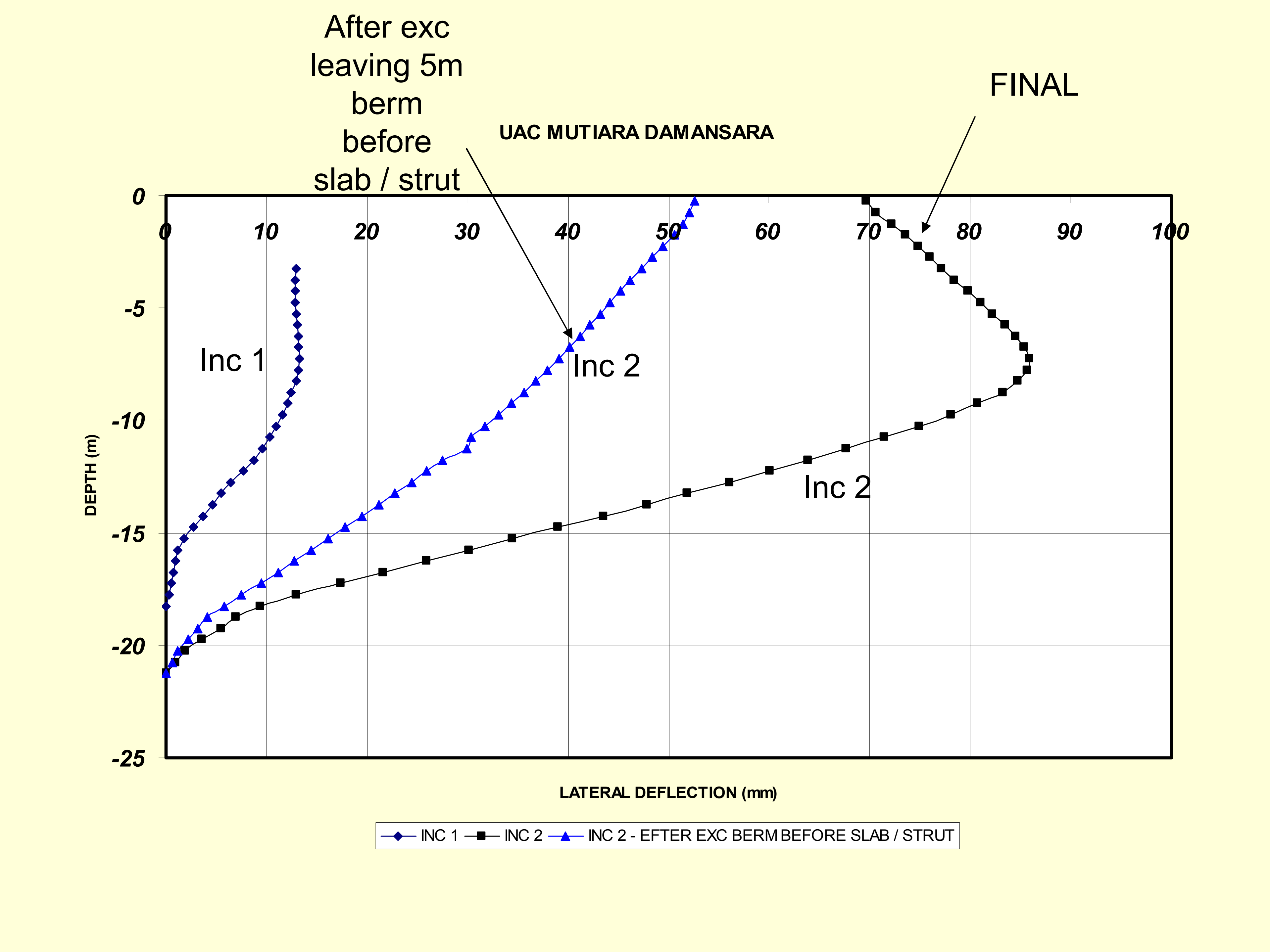
UAC MUTIARA DAMANSARA

UAC MUTIARA DAMANSARA

GF

B1

B2



After exc leaving 5m berm before slab / strut
FINAL
UAC MUTIARA DAMANSARA
0
10
20
30
40
50
60
70
80
90
100
0
-5
-10
-15
-20
-25
Inc 1
Inc 2
Inc 2
DEPTH (m)
LATERAL DEFLECTION (mm)
INC 1
INC 2
INC 2 - EFTER EXC BERM BEFORE SLAB / STRUT

UP AND DOWN AT THE SAME TIME

One Mont Kiara

GOING UP TO 11 FLOORS BEFORE B4 COMPLETE

G F

B1

B2

EXC.
TO B4

B3 LAST

One Mont Kiara

One Mont Kiara

GF

B1

B2

EXC FOR B4

B3 LAST

SOIL IMPROVEMENT FOR DEEP EXCAVATION

TWO CASES:

- SOIL – CEMENT MIX IN MALACCA – see paper this afternoon by YEE. Analysis support by Dr.C.T.Toh Consultant

- JET GROUT WITH CBP – on going project

SOIL – CEMENT MIX, MALACCA

SOIL CMENT MIX - MALACCA

JET GROUT COLUMNS AND CBP , HOLY ROSARY CHURCH, BRICKFIELDS

CBP AND EXCAVATION NEXT TO HOLY ROSARY CHURCH

CBP WALL NEXT TO HOLY ROSARY CHURCH

CBP WALL NEXT TO HOLY ROSARY CHURCH

CBP WALL NEXT TO HOLY ROSARY CHURCH

CBP WALL NEXT TO HOLY ROSARY CHURCH

CONCLUDING REMARKS

LECTURE PRESENTED MECHANICS OF EXCAVATION AND CASE HISTORIES AND BASEMENT CONSTRUCTION METHODS :

- ***CIRCULAR CANTILEVER D/W***
- ***CANTILEVER CBP, SECANT AND DIAPHRAGM WALLS***
- ***TOP – DOWN CONSTRUCTION***
- ***PRE-STRESSED STRUTS***
- ***WALL WITH PERMANENT SOIL NAILS***
- ***UP – DOWN CONSTRUCTION***
- ***SOIL IMPROVEMENT TECHNIQUES***

CONCLUDING REMARKS

- ***CANTILEVER Δh/ H = 0.2 to 0.6% . BUT up to 1% for soft ground and severe recharge***
- *CLOUGH AND O'ROUKE RANGE OF WALLS WITH LOW SUPPORT STIFFNESS 0.3 TO 0.8%*
- ***TOP – DOWN Δh/ H = 0.12 to 0.36%. But up to 1% for narrow berms and poor soil. 0.02% if pre-stress struts used.***
- *CLOUGH & O'ROURKE RANGE FOR WALLS WITH HIGH SUPPORT STIFFNESS – UP TO 0.3%*

CONCLUDING REMARKS

- ***ALL THE DESIGNS ARE SUPPORTED BY F.E. ANALYSIS USING SAGE CRISP. ACCUMULATED EXPERIENCE HAS ENABLED GOOD UNDERSTANDING OF MECHANICS OF EXCAVATION, KNOWLEDGE OF PARAMETERS FOR ANALYSIS, KNOWLEDGE OF LIMITATIONS OF METHODS OF ANALYSIS AND WAYS OF OVERCOMING LIMITATIONS***

- ***STRUCTURAL ANALYSIS OF TOP-DOWN SLABS/FRAMES BY 3 – D ANALYSIS METHODS***

CONCLUDING REMARKS

- ***ESTIMATES OF WALL PERFORMANCE ARE REASONABLY GOOD***

- ***COMPREHENSION OF SOIL BEHAVIOUR, MECHANICS OF EXCAVATION AND SOIL-STRUCTURE INTERACTION COUPLED WITH PRACTICAL KNOWLEDGE OF CONSTRUCTION METHODS AND EXCAVATION LOGISTICS HAS ENABLED ECONOMICAL AND SAFE DESIGNS***

END OF LECTURE

THANK YOU