Requirements on piling plan submission

Under BC (Amendment) Act 2007 & Regulations 2008

Er Dr Yet Nai Song

Building and Construction Authority

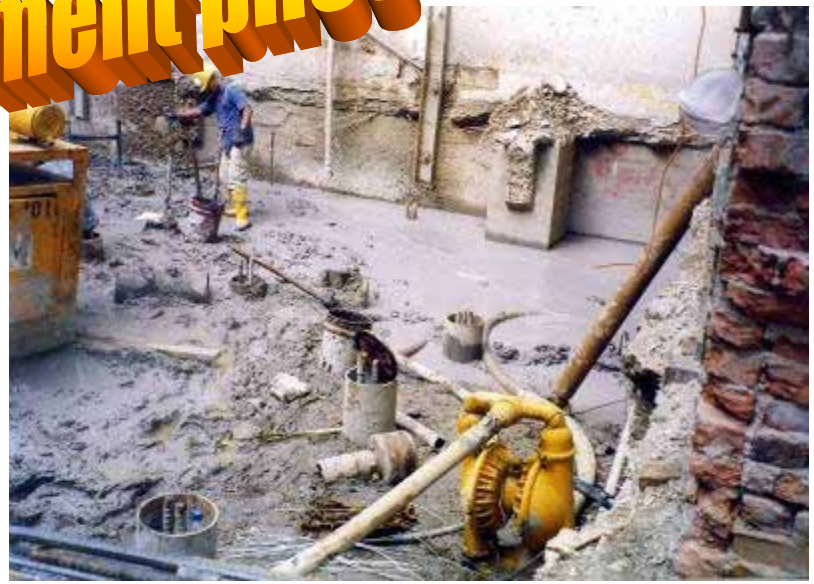
Types of piling submissions

Barrettes

Replacement piles

Bored cast-in place piles

Grouted micropiles



Types of piling submissions

Displacement piles

Driven piles

Jacked-in piles

Objective

- **To help Qualified Persons who prepare the piling plans to comply with requirements of BC (Amendment) Act 2007 & Regulations 2008**

Overview

1. Submission checklist
2. BC Regulations 10(2)
3. SS CP4 : 2003
4. BCA / IES / ACES Advisory Note on Site investigation & Load test
5. Piling Annexes B, C, D
6. Good practices in design & construction

(1) Submission checklist

Submission checklist

I. **Piling plans endorsed by QP and AC**

II. **Design reports by QP and AC**

III. **Declaration forms by QP and AC**

IV. **Site investigation report, endorsed & certified by a PE**

V. **A plan showing the layout and location of the site, boundary line and neighbouring buildings**

VI. **Impact assessment report, where applicable (eg. for foundations located within influence zone of sensitive structures, like MRT or CST tunnels)**

VII. **Clearance letters, where applicable, from the relevant authority**

Certifications by QP and AC on plans

STANDARD CERTIFICATION ON STRUCTURAL PLANS AND DESIGN CALCULATIONS BY THE QUALIFIED PERSON FOR STRUCTURAL WORKS

1) In accordance with Regulation 9 of the Building Control Regulations I, [redacted] the Qualified Person for structural works appointed under section 8(1)(a) or 11(1)(d)(i) of the Building Control Act, hereby submit the detailed structural plans and design calculations prepared by me and certify that they have been prepared in accordance with the provisions of the Building Control Regulations, the Building Control Act and any other written law pertaining to buildings and construction for the time being in force.

2) I further certify that these detailed structural plans and design calculations are in reference to Project reference No: [redacted]

3) Total number of structural plans submitted: 2
Total number of pages of design calculations in this book: 390

PROFESSIONAL ENGINEER
CIVIL
[redacted]
SINGAPORE

PE

(QUALIFIED PERSON FOR STRUCTURAL WORK STAMP & SIGNATURE)
Date: 04/08/2008

STANDARD CERTIFICATION ON STRUCTURAL PLANS AND DESIGN CALCULATIONS BY THE ACCREDITED CHECKER

1) I, [redacted] (ACCREDITED CHECKER) hereby certify that I have carried out an evaluation, analysis and review of the detailed structural plans and design calculations presented herein and am satisfied that there are no inadequacies in the key structural elements.

2) I further certify that these detailed structural plans and design calculations are in reference to Project Reference No : [redacted] and the key structural elements are consistent with the layout shown in the architectural plans.

3) Total number of structural plans checked : 2
Total number of pages of design calculations checked in this book : 390

4) I hereby declare that I have no professional or financial interest in the building works shown in the plans as defined in Section 18 of the Building Control Act (Cap 29)

ACCREDITED CHECKER
NO: [redacted]
[redacted]
in AC Organisation
Registration No: [redacted]
BUILDING CONTROL ACT
SINGAPORE

AC

(ACCREDITED CHECKER'S STAMP & SIGNATURE)
Date: 04/08/2008

Certifications by QP(geo) and AC(geo) on plans

STANDARD CERTIFICATION BY THE SPECIALIST ACCREDITED CHECKER

I, [redacted] being a registered specialist accredited checker, hereby certify that I have in accordance with the Building Control (Accredited Checkers and Accredited Checking Organisations) Regulations carried out an evaluation, analysis and review of the plans of the underground building works attached, and to the best of my knowledge and belief the plans do not show any inadequacy in the geotechnical aspects relating to the underground building works if carried out in accordance with those plans.

2 I append my Evaluation Report (comprising 286 pages) as well as the analyses and calculations I have performed in carrying out the evaluation, analyses and review of the geotechnical reports and design calculations are in reference to Project Ref. No.: A[redacted]

3 I hereby declare that I have no professional or financial interest in the underground building works shown in the plans as defined in Section 18 of the Building Control Act (Cap 29).

SPECIALIST ACCREDITED CHECKER
No: [redacted]
BUILDING CONTROL ACT SINGAPORE

AC(geo)

SPECIALIST ACCREDITED CHECKER'S SIGNATURE AND STAMP

Date: 2nd December 2008

STANDARD CERTIFICATION BY THE QUALIFIED PERSON FOR GEOTECHNICAL ASPECTS OF UNDERGROUND BUILDING WORKS

In accordance with Regulation 10A of The Building Control Regulations I, Er[redacted], the Qualified Person for the geotechnical aspects of the underground building works appointed under section 8(1)(d)(i) or 11(1)(d)(iii) of the Building Control Act, hereby submit the underground building works plans and the design calculations
prepared by me and certify that, to the best of my knowledge and belief, they have been prepared in accordance with the provisions of the Building Control Regulations, the Building Control Act and any other written law pertaining to buildings and construction for the time being in force.

2 I further certify that these underground building works plans and design calculations are in reference to Project Ref. No:
[redacted]

3 Total no. of underground building works plans submitted: 7
Total no. of pages of design calculations in this book: 201

PROFESSIONAL ENGINEER
GEOTECHNICAL
[redacted]
SINGAPORE

PE(geo)

QUALIFIED PERSON'S SIGNATURE AND STAMP
Date :

Info On Built Environment

- Safe
- High Quality
- Sustainable
- Friendly

Info For

- Home Dwellers/Building Owners
- Community
- Industry Professionals
  - Building Control & Management
  - Training Courses, Careers & Scholarship
  - Export Services
  - Procurement
  - Information On Construction Quality (IQUAS)
  - Technology Development

Structural Plan Approval And Permit To Commence Structural Works

Appendix H : Certification by Professional Engineer for Site Investigation Report

1. I, _____ the Professional Engineer, PE Registration No. _____ certify that the Site Investigation Report

   _____

   _____

   comprising all field and laboratory data, tests and results therein has been carried out by me or under my supervision or direction, and I have verified the accuracy of the information given in the site investigation report, and to the best of my knowledge and belief, all have been prepared in compliance in all respects with the provisions of the Building Control Act and Regulations, relevant Codes of Practice and Standards.

2. I further certify that I have the appropriate qualifications and experience, and I am familiar with the purpose of the investigation for which this Site Investigation Report is prepared in reference to Project Ref. No: _____

3. Total number of pages in the Site Investigation Report is _____

_____ _____

Professional Engineer for Site Investigation Signature and Stamp Date

Previous Page Back toTable of Content Next Page

Certification by PE for SI report

Certification by PE for SI Report

Certification by Professional Engineer For Site Investigation Report

1. I, [redacted] the Professional Engineer, PE Registration No. [redacted] certify that the Site Investigation Report

[redacted]

Comprising all field and laboratory data, tests and results therein has been carried out by me or under my supervision or direction, and I have verified the accuracy of the information given in the site investigation report, and to the best of my knowledge and belief, all have been prepared in compliance in all respects with the provisions of the Building Control Act and Regulations, relevant Codes of Practice and Standards.

2. I further certify that I have the appropriate qualifications and experience and I am familiar with the purpose of the investigation for which this Site Investigation Report is prepared in reference to Project Ref. No: [redacted]

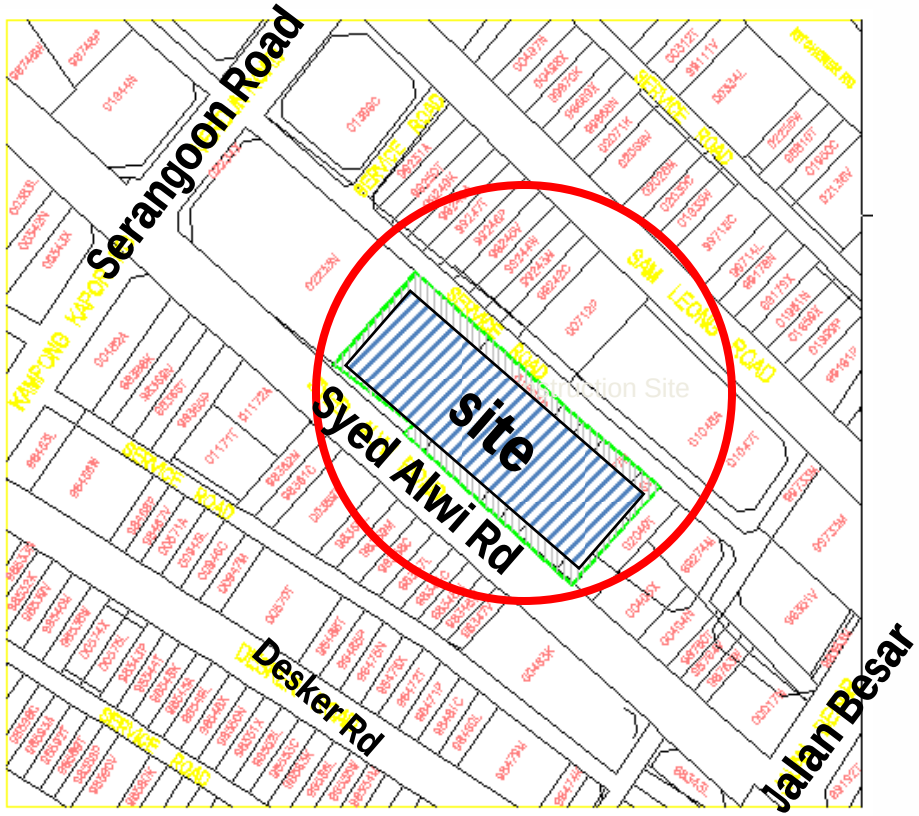
3. Total number of pages in the Site Investigation Report is 353

PROFESSIONAL ENGINEER [redacted] CIVIL [redacted] SINGAPORE

Professional Engineer for Site Investigation
Signature and Stamp

24/11/2008
Date

Plan to show Site Location

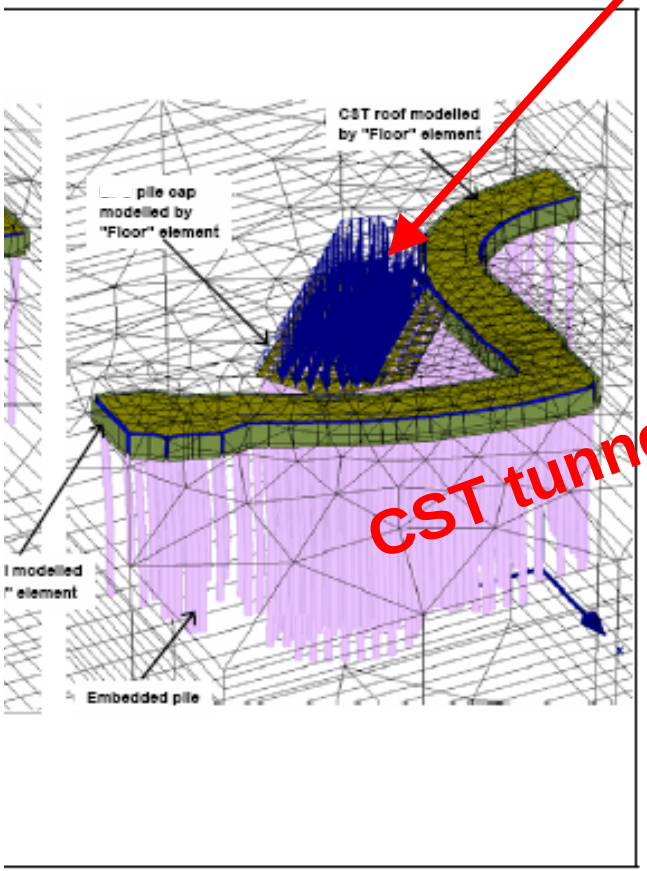


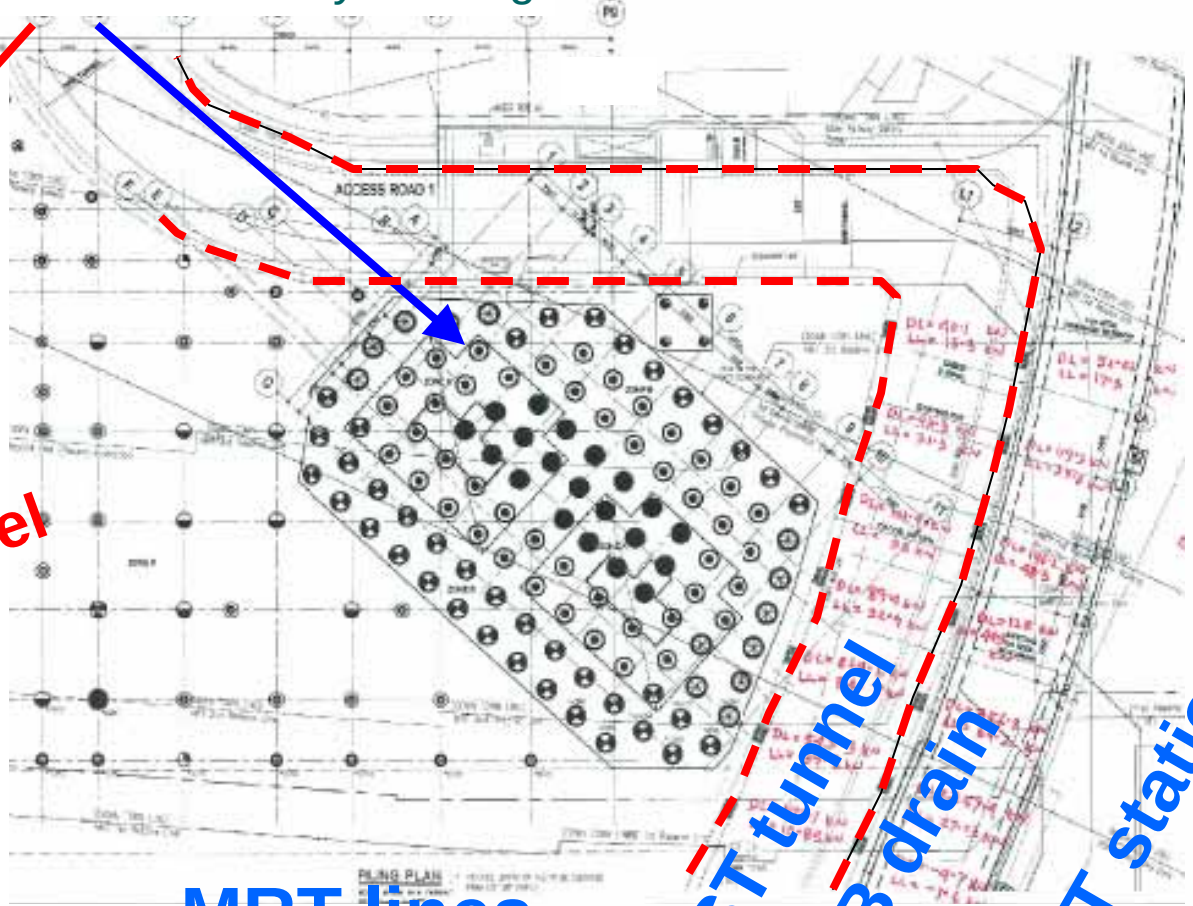
LOCATION PLAN

N. T. S.

An example of project close to sensitive structures

Pile Raft for a 66-storey building





CST tunnel

MRT lines

CST tunnel

PUB drain

MRT station

(2) Building Control Regulation 10(2)

Regulations 2003

Regulation 10(2)

(2) The pile layout plans shall show —

(a) the types of piles and the specification of materials to be used;

(b) the location of piles;

(c) the estimated pile penetration depth;

(d) the allowable pile bearing capacity before and after deduction of negative skin friction (if applicable) and details of pile joints; and

(e) the sectional details of piles and number and type of pile load tests.

Regulations 2008

Regulation 10(2)

NOW...

(2) The pile layout plans shall show —

(a) the types of piles and the specification of materials to be used;

(b) the location of piles and site investigation boreholes ;

(c) the estimated pile penetration depth for each design zone ;

(d) the minimum embedded pile length into competent stratum, where applicable;

(e) the unit skin friction and unit end bearing resistance for pile designs;

(f) the allowable pile bearing capacity before and after deduction of negative skin friction (if applicable) and details of pile joints;

(g) the allowable total and differential foundation settlement;

(h) the allowable vibration limit during pile installation; and

(i) the sectional details of piles and number and type of pile load tests and the location of ultimate pile load tests.

Regulations 2008 – Reg 10A(5)

(Plans of foundation ≥ 30storeys)

NOW...

(5) The foundation plans for the design and construction of foundation for buildings of 30 or more storeys shall contain, where applicable —

(*a*) the layout, sections and details of all foundation works showing —

(i) types of piles or foundation and specification of material to be used;

(ii) location of piles or foundation and site investigation boreholes;

(iii) pile or foundation founding depth or pile minimum embedment into competent stratum for each pile or foundation;

(iv) unit shaft friction, pile base resistance or foundation bearing pressure;

(v) allowable foundation capacity before and after accounting for negative skin friction where applicable, allowable tension, and lateral load;

(vi) details of pile reinforcements, pile joints, connection with pilecap, pile shops;

(vii) allowable total and differential foundation movement; and

(viii) allowable vibration limit; and

(*b*) the number, type of pile or foundation tests, structural integrity tests and location of preliminary test pile or ultimate load tests and site investigation for the tests.

Building Control Regulations 2008

Regulation 10(2)

(2) The pile layout plans shall show —

(a) the types of piles and the specification of materials to be used;

(b) the location of piles and site investigation boreholes ;

(c) the estimated pile penetration depth for each design zone ;

(d) the minimum embedded pile length into competent stratum, where applicable;

(e) the unit skin friction and unit end bearing resistance for pile designs;

(f) the allowable pile bearing capacity before and after deduction of negative skin friction (if applicable) and details of pile joints;

(g) the allowable total and differential foundation settlement;

(h) the allowable vibration limit during pile installation; and

(i) the sectional details of piles and number and type of pile load tests and the location of ultimate pile load tests.

(a) Pile type & material specification, pile joints, sectional details

I. Do the plans show the pile types and material specification ?

II. Do the plans show pile size and pile details?

III. Do the plans show the pile capacity ?

(i) allowable foundation capacity, before and after accounting for negative skin friction,

(ii) allowable tension load, lateral load, where applicable.

Items to be shown on piling plan

Pile capacity & Pile reinforcement

Pile diameter

Working load

Pile reinforcement

PILING SCHEDULE 2 (OUTSIDE RAFT)

PILE TYPE	LEGEND	PILE SIZE (mm)	NO. OF PILES	DEPTH OF ENDTY BORE (m)	WORKING LOAD (tf)		ESTIMATED AVERAGE PILE PENETRATION FROM C.O.L.(m)	MINIMUM PENETRATION DEPTH INTO SPT N>100(m	MAIN REINFORCEMENT	LINKS
					COMPRESSION	TENSION				
A		φ1000	4	11.5	5850	–	51.0	6.5	17T25	T10–175
A(T)		φ1000	4	11.5	5850	1600	51.0	6.5	20T25	T10–175
B		φ1100	–	11.5	7100	–	52.0	7.5	20T25	T10–175
C		φ1200	4	11.5	8450	–	53.0	8.5	24T25	T10–175
C(T)		φ1200	8	11.5	8450	2500	54.0	8.5	24T25	T10–175
D		φ1300	4	11.5	9950	–	54.0	9.5	22T28	T10–175
D(T)		φ1300	3	11.5	9950	2500	55.0	9.5	22T28	T10–175
E		φ1400	6	11.5	11500	–	55.0	10.5	26T28	T10–175
F		φ1500	6	11.5	13250	–	56.5	11.5	29T28	T10–175
G		φ1800	5	11.5	15000	–	57.5	12.5	33T28	T10–175
H		φ1800	6	11.5	19000	–	60.0	14.5	32T32	T10–175

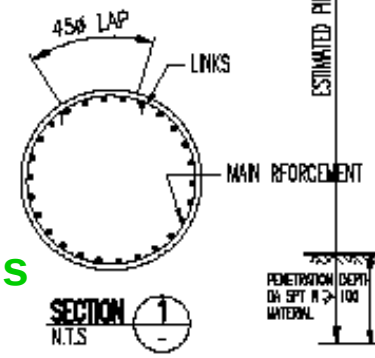
Details of Pile reinforcement

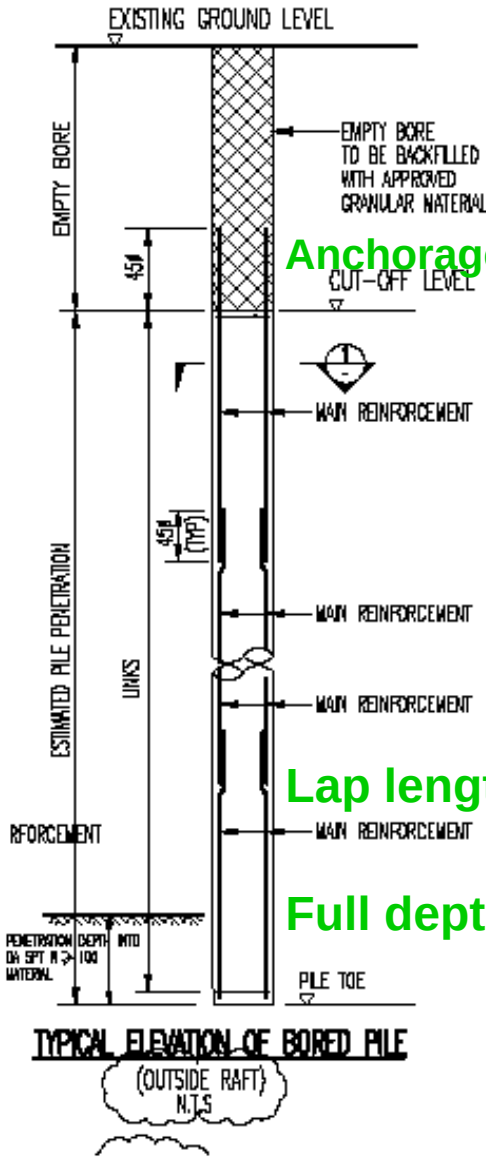
Anchorage length

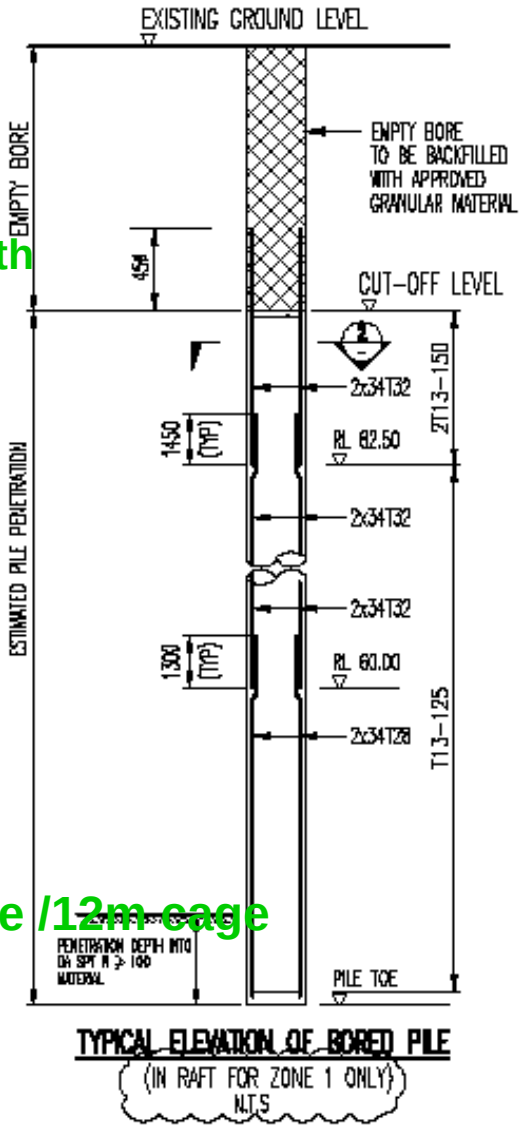
Lap length

Full depth cage /12m cage

Sectional details

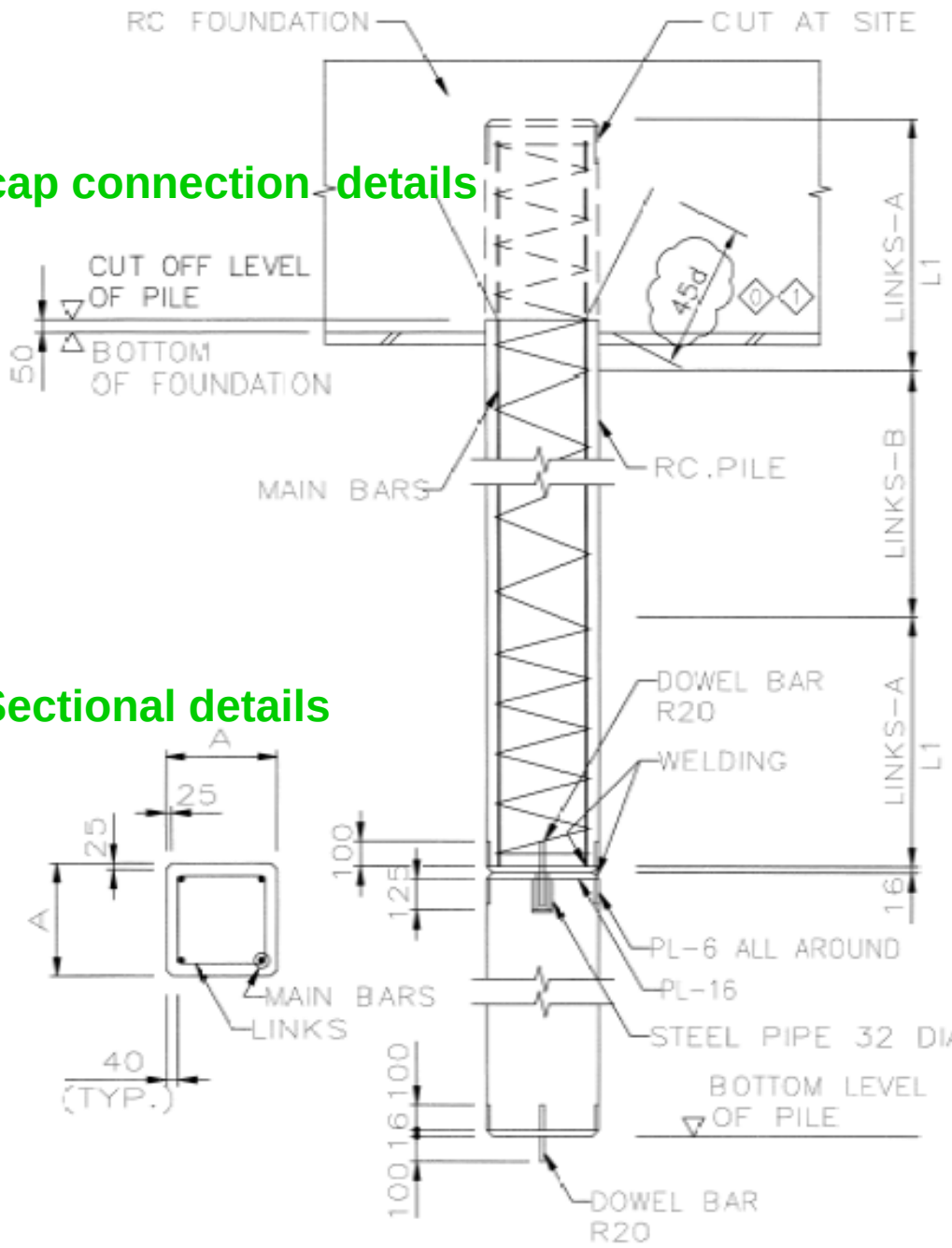




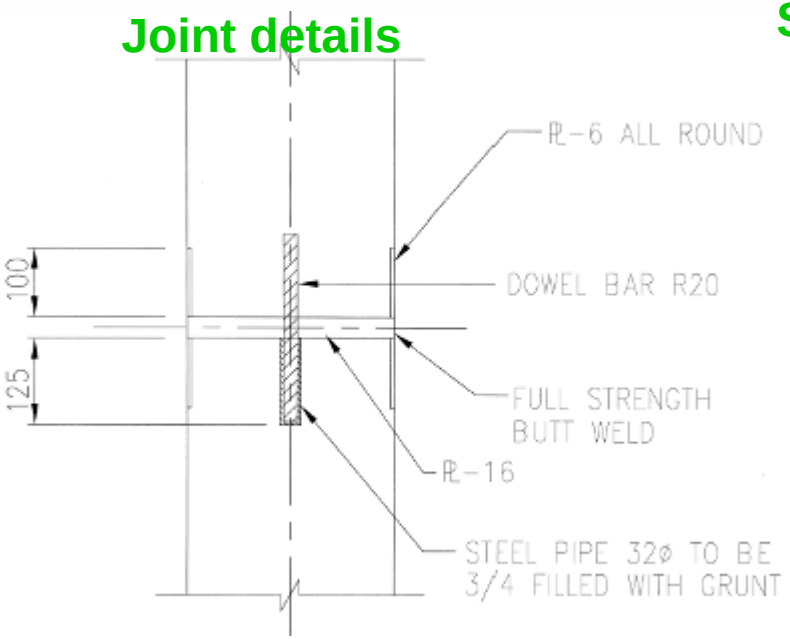


Details of RC pile

Pilecap connection details



Joint details



Sectional details

(b) Site investigation borehole

I. **Do the plans show location of site investigation boreholes?**

II. **Is there any borehole within the footprint of each block ?**

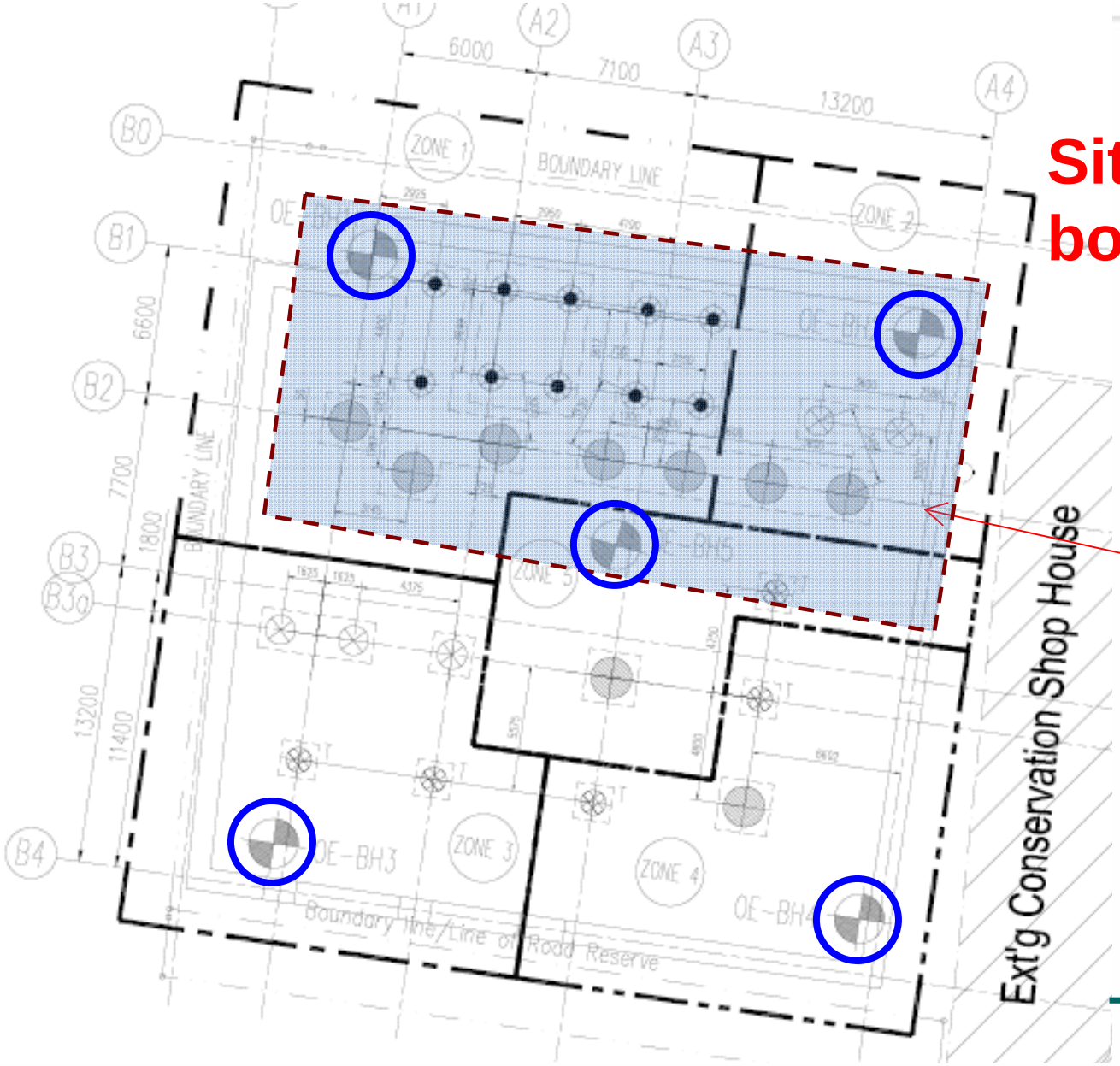
For buildings of 10-storeys or more

III. **Do number of boreholes exceed minimum ?**

IV. **Is depth of any borehole beyond proposed pile penetration depth ? (see BCA/IES/ACES advisory note 2003)**

Items to be shown on piling plan

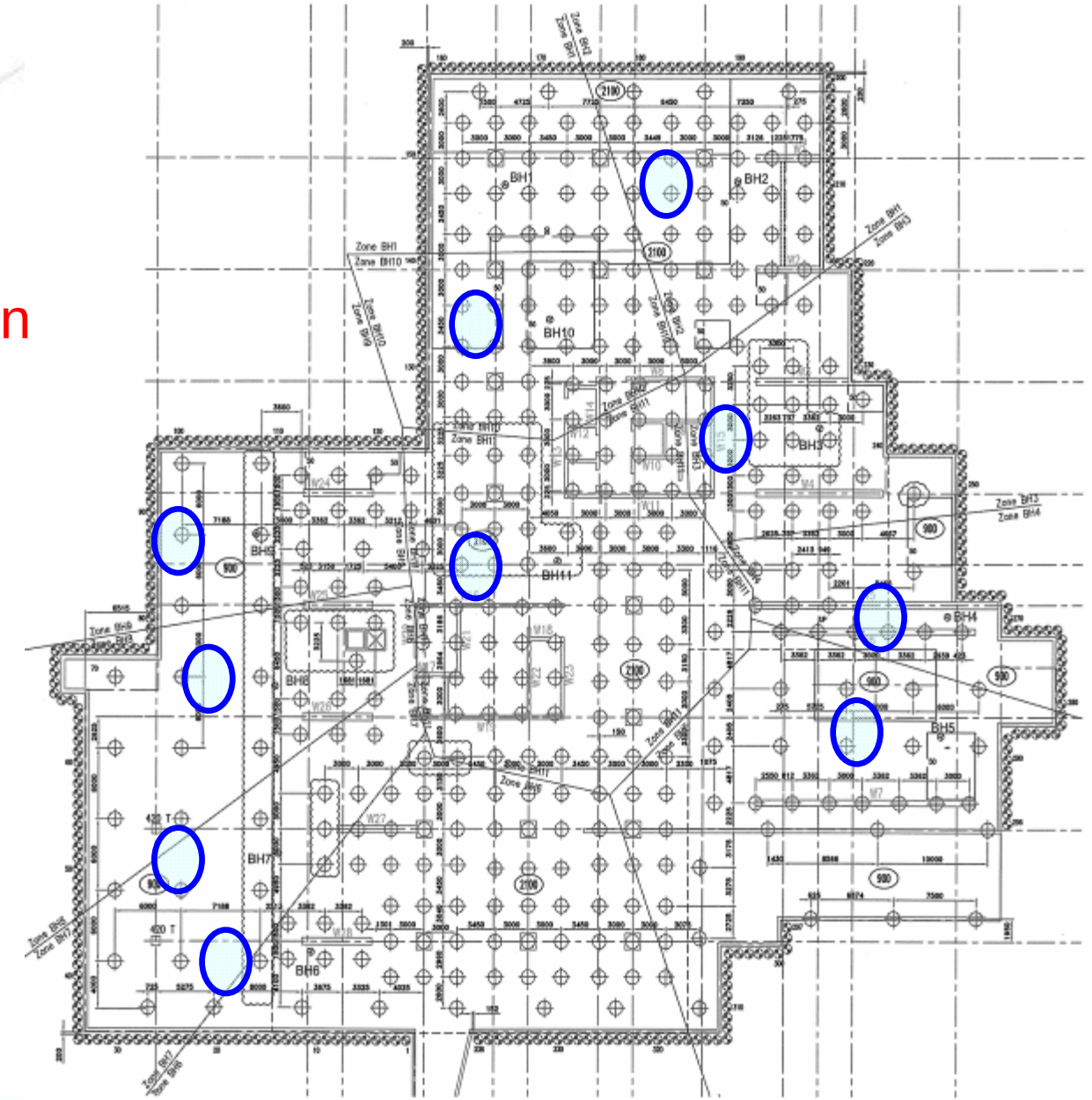
Site investigation boreholes (1)



Footprint of tower block

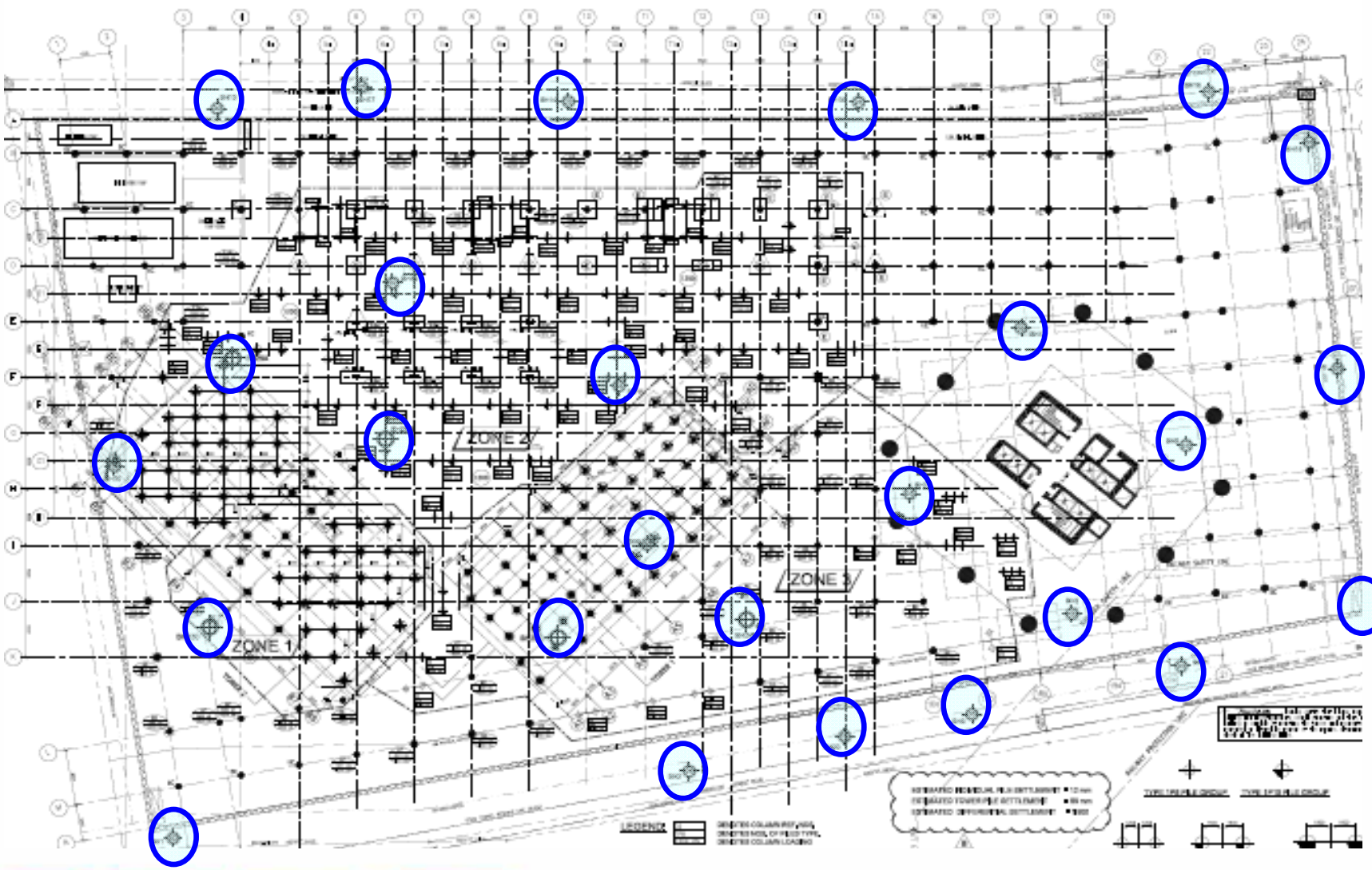
Total = 5 boreholes

Site investigation boreholes (2)



Total = 10 boreholes

Site investigation boreholes (3)



Total = 26 boreholes

(c) Pile depth & (d) Pile founding criteria

I. Do the plans show pile design zones (based on site investigation information) ?

II. Do the plans show the following information ?

(i) pile founding criteria (eg. pile founding depth / minimum embedment into competent stratum / pile set criteria / magnitude of jack in load)

(ii) a description of soil / rock for founding layer.

Items to be shown on piling plan

Pile design zones based on boreholes

BORED PILE (GRADE 35) (FOR COMPRESSION PILES)

PILE TYPE	BORED PILE SIZE	PILE CAPACITY	REINFTS. PROVIDED	REINFTS. LENGTH	SPIRAL LINKS	TOTAL NO. OF PILES	ESTIMATED PENETRATION LENGTH (L) (from cut-off-level)									
							ZONE 1		ZONE 2		ZONE 3		ZONE 4		ZONE 5	
							BH1		BH2 & BH3		BH4		BH5		BH6	
							PL	SL (a)	PL	SL (a)	PL	SL (a)	PL	SL (a)	PL	SL (a)
A & B	ø600	212 T	9 T 16	12 m	T10-175		21.2	–	19.5	3.1	18.5	5.6	22.3	–	20.0	4.6
C	ø700	288 T	11 T 16	12 m	T10-175		23.2	–	21.0	4.6	20.0	7.1	22.5	0.2	21.0	5.6
D	ø800	377 T	13 T 16	12 m	T10-175		25.7	–	22.0	5.6	21.0	8.1	24.0	1.7	22.5	7.1
E	ø900	477 T	13 T 20	12 m	T10-200		26.2	–	23.0	6.6	22.0	9.1	25.0	2.7	23.5	8.1
F	ø1000	589 T	15 T 20	12 m	T10-200		26.5	0.3	24.5	8.1	23.5	10.6	26.0	3.7	24.5	9.1
G	ø1100	712 T	17 T 20	12 m	T10-200		27.7	1.5	25.5	9.1	24.5	11.6	27.5	5.2	26.0	10.6
H	ø1200	848 T	19 T 20	12 m	T10-200		28.7	2.5	26.5	10.1	25.5	12.6	28.5	6.2	27.0	11.6
J	ø1300	995 T	22 T 20	12 m	T10-200		30.2	4.0	27.5	11.1	27.0	14.1	29.5	7.2	28.0	12.6
					TOTAL											

PL= PILE LENGTH FROM cut-off-level
SL= SOCKET LENGTH INTO SPT > 100 SOIL

Example 1

Pile founding criteria (in hard soil)

Example 2
Pile founding criteria (in hard soil & rock)

BH No.	EST. LENGTH OF PILE (FROM COL)m	PILE FOUNDING CRITERION
1	19.1	14.5m OF HARD SILT (SPT>100) (RESIDUAL SOIL)
2	24.4	6.275m OF HARD SILTY SAND (SPT>100) (COMPLETELY WEATEHRED SANDSTONE)
3	20.7	1.8m OF HARD CLAYEY SILT (SPT>100) (RESIDUAL SOIL)
4	32.0	3.5m OF HARD CLAYEY SILT (SPT>100) (RESIDUAL SOIL)
5	17.1	2.3m OF HARD SILT (SPT>100) AND 0.2m OF MODERATELY WEATHERED SANDSTONE (SOCKETING)
6	15.8	2.35m OF VERY STIFF SILT WITH WEATHERED ROCK, SILTSTONE (SPT>100) AND 4.5m OF MODERATELY WEATHERED SILTSTONE (SOCKETING)
7	9.8	4m OF HARD HIGHLY WEATHERED SILT (SPT>100) AND 2m OF MODERATELY WEATHERED SILTSTONE (SOCKETING)
8	20.1	7m OF HARD SILT WITH CLAY (SPT>100)
9	15.8	4.85m OF HARD SILT WITH CLAY AND PIECES OF SILTSTONE (SPT>100) AND 3.5m OF MODERATELY TO HIGHLY WEATHERED, HIGHLY FRACTURED SILTSTONE (SOCKETING)
10	18.8	9.775m OF HARD CLAYEY SILT/SILTY CLAY (SPT>100)
11	20.1	8.275m OF HARD SILTY CLAY (SPT>100)

Example 3
Pile founding criteria (pile set)

THAT MEASURES THE PEAK PARTICLE VIBRATION VELOCITY.
SETTLEMENT MONITORING BY THE USAGE OF SETTLEMENT MARKERS.
CRACK MONITORING BY THE USAGE OF TELL-TALE GLASS.

20. ALL PRESTRESSED PRECAST SPUN PILES SHALL BE DRIVEN TO A FINAL SET OF 15M FOR THE LAST10 BLOWS.
THIS SET IS CALCULATED FROM THE HILEY'S FORMULA BASED ON THE PARAMETERS AS SPECIFICED BELOW.

$$Qu = \frac{ef\,WH\,[\,W + n^2 Wp\,]}{[\,S+0.5\,(C_1+C_2+C_3)\,]\,[\,W+Wp\,]}$$

WHERE
- Qu = ULTIMATE PILE CAPACITY
- ef = HAMMER EFFICIENCY = 100%
- W = HAMMER WEIGHT = 10 Ton
- H = HAMMER DROP HEIGHT = 750mm
- n = COEFFICIENT OF RESTITUTION = 0.4
- Wp = WEIGHT OF PILE
- S = SET = 2.0 mm / BLOW
- $C_1+C_2+C_3$ = TEMPORARY COMPRESSION = 14mm

SAFETY FACTOR = 3.0

WHERE THE METHOD OF PILE DRIVING & EQUIPMENT USED DIFFER FROM THOSE ASSUMED, CONTRACTOR SHALL PROPOSE SUBJECT TO SO'S APPROVAL THE SETS OF THE PILES SO THAT THE PILES CAN ACHIEVE THE DESIGNED WORKING LOAD CAPACITIES.

21. THE TYPE OF PILING FRAME USED ON SITE SHALL BE IN ACCORDANCE WITH ANY RELEVANT AUTHORITIES' REQUIREMENTS. DIESEL PILING HAMMERS ARE NOT PERMITTED IN URBAN AREAS.

(e) Geotechnical parameters

I. Do the plans contain unit shaft friction and unit pile base resistance used for pile design ?

II. Are soil strata / rock type given for the above ?

NOTES FOR BORED PILES:
ALL PARAMETERS TO BE CONFIRMED BY INSTRUMENTAL ULTIMATE PILE LOAD TEST
11) DESIGN PARAMETER :
UNIT SKIN FRICTION = 2.0 N (WHEN N<100 SOIL)
UNIT SKIN FRICTION = 250 KN/m^2 (WHEN N>100 SOIL)
UNIT END BEARING = 7000 KN/m^2 (WHEN N>100 SOIL)
12) SAFETY FACTOR :
1.5 (SKIN FRICTION) + 3.0 (END BEARING)
2.5 (SKIN FRICTION) + 2.5 (END BEARING)
1.5 (FOR SKIN FRICTION ONLY)
13) FOUNDATION SETTLEMENT:
TOTAL BUILDING SETTLEMENT LIMIT = 25mm
MAX. DIFFERENTIAL SETTLEMENT = 1/500
14) MINIMUM SPACING BETWEEN SPUN PILE TO BE 2.5 ϕ UNLESS OTHERWISE S
15) THE VIBRATION LIMIT FOR PILING IS 3 mm/sec

* SOIL DESIGN PARAMETERS

SOIL DESCRIPTION	ZONE 1 (BH4)		ZONE 2 (BH3)	
	SKIN FRICTION fs (kN/m^2)	END BEARING fb (kN/m^2)	SKIN FRICTION fs (kN/m^2)	END BEARING fb (kN/m^2)
FIRM TO STIFF SILTY CLAY	12		–	
VERY STIFF SILTY CLAY	80		93	
VERY STIFF SANDY CLAY	90		–	
VERY STIFF CLAYEY SILT	–		127	
HARD CLAYEY SILT STONE	200		200	9000
VERY HARD CLAYEY SILT STONE	200	9000	–	–

NOTE:
* VERIFIED BY INSTRUMENTED ULT LOAD TEST.

Items to be shown on piling plan

Unit shaft friction & base resistance used in pile design

5. ADOPTED DESIGN UNIT SKIN FRICTION FOR COMPRESSION PILE, Ks = 2.0N (LIMITED TO 150 KN/M2)

6. ADOPTED DESIGN MAX END BEARING FOR SOIL (OTHER THAN BH5, 6, 7 & 9) = 4500 KN/M2
   ADOPTED DESIGN MAX END BEARING FOR MODERATELY – HIGHLY WEATHERED SILTSTONE (JURONG FORMATION) AT BH5, 6 & 9 = 8000 KN/M2
   ADOPTED DESIGN MAX END BEARING FOR MODERATELY WEATHERED SILTSTONE (JURONG FORMATION) FOR BH7 = 10000 KN/M2

7. THE DESIGN PARAMETERS FOR SKIN FRICTION AND END BEARING WILL BE VERIFIED BY THE ULTIMATE LOAD TEST CARRIED OUT ON SITE PRIOR TO THE INSTALLATION OF THE WORKING PILES.

(f) Negative skin friction

I. Is there a design evaluation of the possibility of negative skin friction ?

(i.e. whether the soil is still undergoing consolidation at its final stress state ?)

II. Has negative skin friction been considered in the design ?

Items to be shown on piling plan

Building and Construction Authority

(g) Allowable settlements

I. Are allowable <u>total and differential foundation settlements</u> shown on plan ?

II. Are these allowable foundation settlements consistent with the design calculation ?

11) DESIGN PARAMETER :
UNIT SKIN FRICTION = 2.0 N (WHEN N<100 SOIL)
UNIT SKIN FRICTION = 250 KN/m^2 (WHEN N≥100 SOIL)
UNIT END BEARING = 7000 KN/m^2 (WHEN N≥100 SOIL)

12) SAFETY FACTOR :
1.5 (SKIN FRICTION) + 3.0 (END BEARING)
2.5 (SKIN FRICTION) + 2.5 (END BEARING)
1.5 (FOR SKIN FRICTION ONLY)

13) FOUNDATION SETTLEMENT:
TOTAL BUILDING SETTLEMENT LIMIT = 25mm
MAX. DIFFERENTIAL SETTLEMENT = 1/500

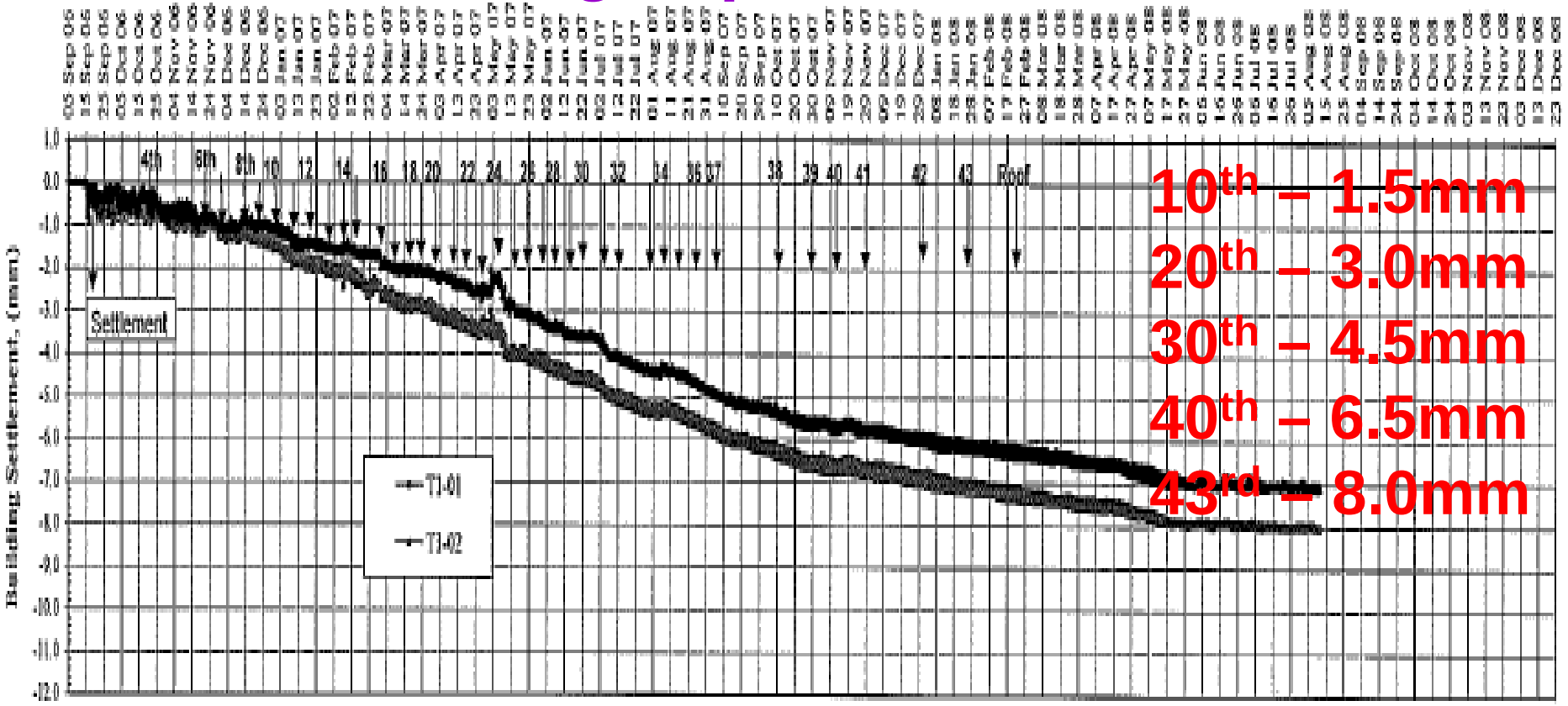
14) MINIMUM SPACING BETWEEN SPUN PILE TO BE 2.5 ϕ UNLESS OTHERWISE STATE

15) THE VIBRATION LIMIT FOR PILING IS 3 mm/sec

19. THE DIFFERENTIAL SETTLEMENT SHALL BE 1:1000 UNDER THE COMMERCIAL TOWER.

20. A 30mm ALLOWABLE TOTAL BUILDING SETTLEMENT HAS BEEN SET FOR THE PURPOSE OF MONITORING.

Sample variation of building settlement with time during superstructure erection



Settlement increases with building height.

(h) Vibration limits

I. Are allowable vibration limits specified on the plan ?

NOTES FOR BORED PILES:

ALL PARAMETERS TO BE CONFIRMED BY INSTRUMENTAL ULTIMATE PILE LOAD TEST.

11) DESIGN PARAMETER :

UNIT SKIN FRICTION = 2.0 N (WHEN N<100 SOIL)

UNIT SKIN FRICTION = 250 KN/m^2 (WHEN N≥100 SOIL)

UNIT END BEARING = 7000 KN/m^2 (WHEN N≥100 SOIL)

12) SAFETY FACTOR :

1.5 (SKIN FRICTION) + 3.0 (END BEARING)

2.5 (SKIN FRICTION) + 2.5 (END BEARING)

1.5 (FOR SKIN FRICTION ONLY)

13) FOUNDATION SETTLEMENT:

TOTAL BUILDING SETTLEMENT LIMIT = 25mm

MAX. DIFFERENTIAL SETTLEMENT = 1/500

14) MINIMUM SPACING BETWEEN SPUN PILE TO BE 2.5 ϕ UNLESS OTHERWISE STATED.

15) THE VIBRATION LIMIT FOR PILING IS 3 mm/sec

1

DIN 4150 : Part 3 "Structural vibration in buildings" Guideline on Limit of vibration

DIN 4150

Types of Structure.	Peak Particle Velocity (mm/sec)		
Frequency.	1 – 10 Hz	10 – 50 Hz	50 – 100 Hz
Commercial and Industrial Buildings. Type 1	20	20 - 40	40 - 50
Dwellings Type 2	5	5 - 15	15 - 20
Ancient and Historic Buildings. Type 3	3	3 - 8	8 – 10

(i) Verification tests

I. **Do the plans contain the following information ?**

(i) number of tests,

(ii) types of pile tests.

II. **Are types and number of tests provided complied with BCA/IES/ACES advisory note 2003 ?**

III. **Is location of ultimate pile load test shown on plan, and correlated with borelog ?**

IV. **Will the preliminary piles for the ultimate pile load test be instrumented, to verify the geotechnical parameters ?**
(Applicable to piles where strain gauges could be installed along the pile, eg. bored piles, hollow spun pile)

10. GEOTECHNICAL CAPACITY OF THE PILE SHALL BE TAKEN AS THE LESSER OF Qs/2 OR (Qs+Qb)/2.5, WHERE Qs IS THE ULTIMATE SHAFT RESISTANCE AND Qb IS THE ULTIMATE BASE RESISTANCE. NEGATIVE SKIN FRICTION SHALL BE CONSIDERED IN THE PILING DESIGN.

11. WORKING LOAD TEST REQUIREMENTS:

TEST DESCRIPTION	NUMBER OF PILES TO BE TESTED
ULTIMATE LOAD TEST	2 NO OF ϕ1500
WORKING LOAD TEST	3 NOS OF ϕ1800
	1 NO OF ϕ1200
	1 NO OF ϕ1000
HIGH STRAIN DYNAMIC TEST (PDA TEST)	5 NOS OF ϕ1800
	1 NOS OF ϕ1500
	1 NOS OF ϕ1400
	1 NOS OF ϕ1200
	1 NOS OF ϕ1000
PILE INTEGRITY TEST (PIT TEST)	10 NOS (ANY SIZE)

12. THE CONTRACTOR SHALL SUBMIT DETAILED METHOD STATEMENTS FOR

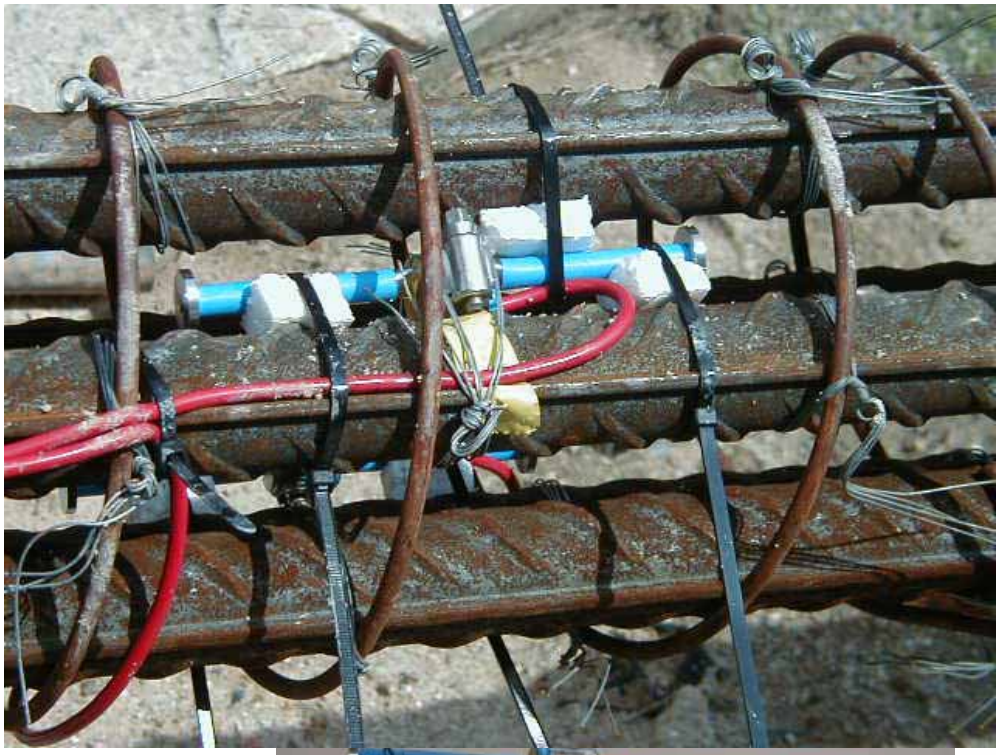
2ULT + 5WLT + 9PDA

Exceeded minimum !

Preliminary pile to be instrumented

	1 NOS OF ø1000
PILE INTEGRITY TEST (PIT TEST)	10 NOS (ANY SIZE)

12. THE CONTRACTOR SHALL SUBMIT DETAILED METHOD STATEMENTS FOR BORED PILE INSTALLATION AND THE CARRYING OUT OF PILE TESTING.
13. THE BASE OF THE PILE SHALL BE THOROUGHLY CLEAN, SOUND AND FREE FROM LOOSE SAND DEPOSIT, LAITANCE, SILT PRIOR TO CONCRETING. THE CONTRACTOR SHALL CLEAN THE BASE USING AIR LIFT AND/OR OTHER APPROVED METHOD.
14. MINIMUM REINFORCEMENT LAP SHALL BE 15 TIMES THE BAR DIAMETER.
15. ULTIMATE PILE LOAD TEST SHALL BE CONDUCTED ON FULLY-INSTRUMENTED PILES WITH AT LEAST ONE LEVEL OF FOUR VIBRATING WIRE STRAIN GAUGES NEAR THE PILE TOE AND AT EACH CHANGE OF SOIL STRATUM, BUT NOT MORE THAN 5 METRES BETWEEN ANY TWO LEVELS. THE VERTICAL SPACING OF THE STRAIN GAUGES SHALL NOT BE MORE THAN 3m IN THE SPT N > 100 SOIL LAYER. THE CONTRACTOR SHALL ALSO ALLOW FOR THE INSTALLATION OF THREE ROD EXTENSOMETERS IN EACH OF THE ULTIMATE TEST PILES.
16. THE CONTRACTOR SHALL CARRY OUT PRE-CONDITION SURVEYS ON ADJACENT BUILDING IN FULL COMPLIANCE WITH THE SPECIFICATIONS. THE COST OF CARRYING OUT PRE-CONDITION SURVEYS IS DEEMED TO BE INCLUDED IN THE TENDER.
17. THE BASE OF EACH PILE SHALL BE FULLY GROUTED.



A recap

Items to be shown on piling plan

a) Pile type & material specification, pile joints, sectional details

b) Site investigation boreholes

c) Estimated pile length for each design zone

d) Minimum embedded depth into competent stratum

e) Skin friction & End bearing for pile design

f) Pile capacity before & after negative skin friction

g) Allowable settlements

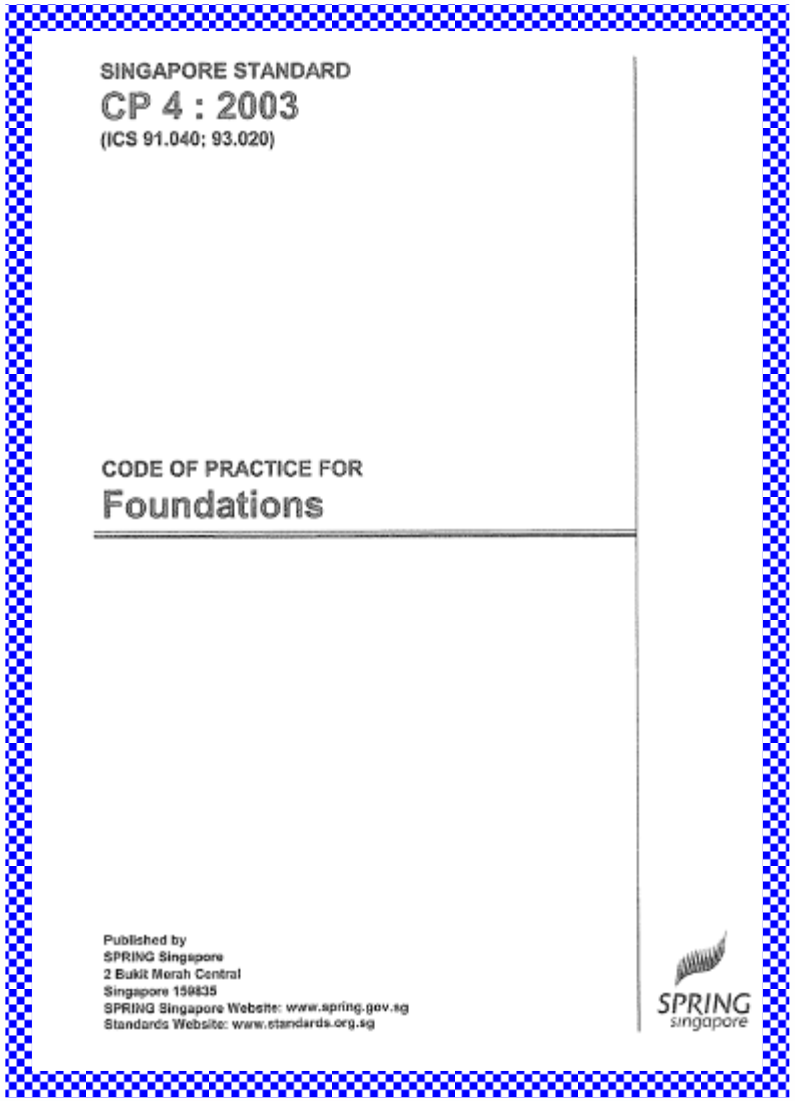
h) Allowable vibration limits

i) Pile load test & location

(3) SS CP4 : 2003

(Code of Practice for Foundations)

Code of Practice CP4 : 2003



Design for pile foundations [CP4 Clause 7.3.1]

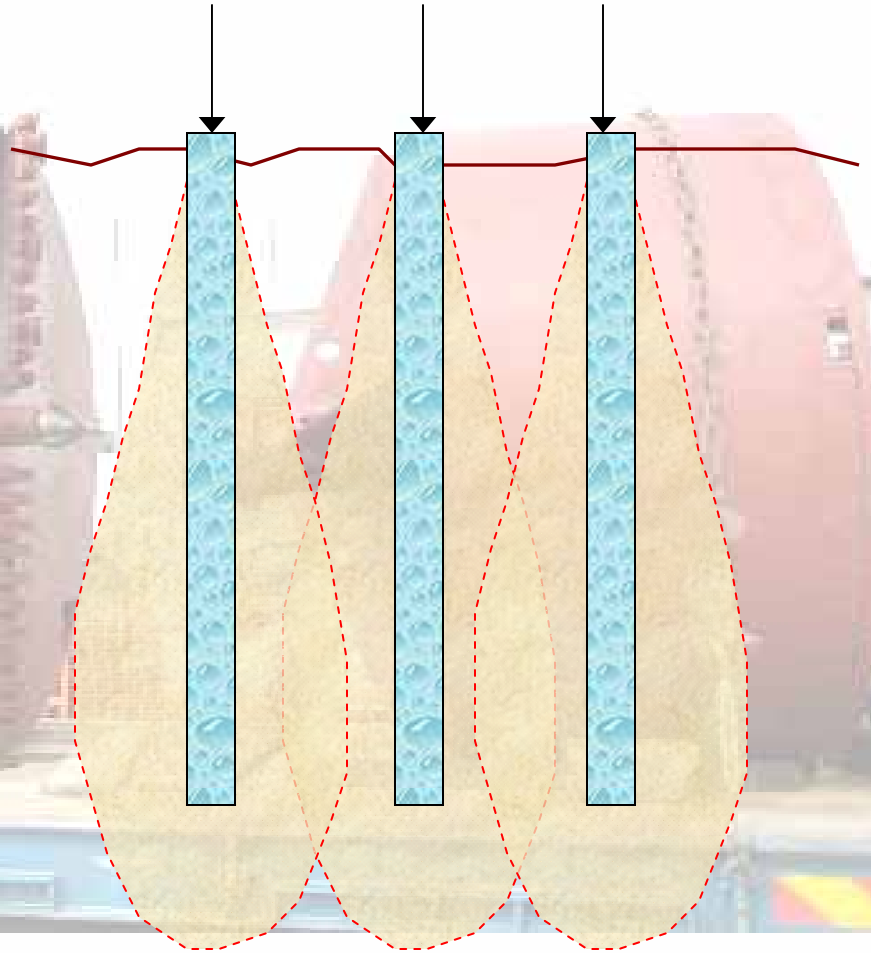
- **Every pile design has to satisfy 3 conditions:**

1. **Adequate safety factor against failure**
2. **Settlement of foundation under working load should not affect the serviceability of structure**
3. **Safety of nearby buildings should not be put at risk**

Pile Group Effect (CP4 Clause 7.3.4)

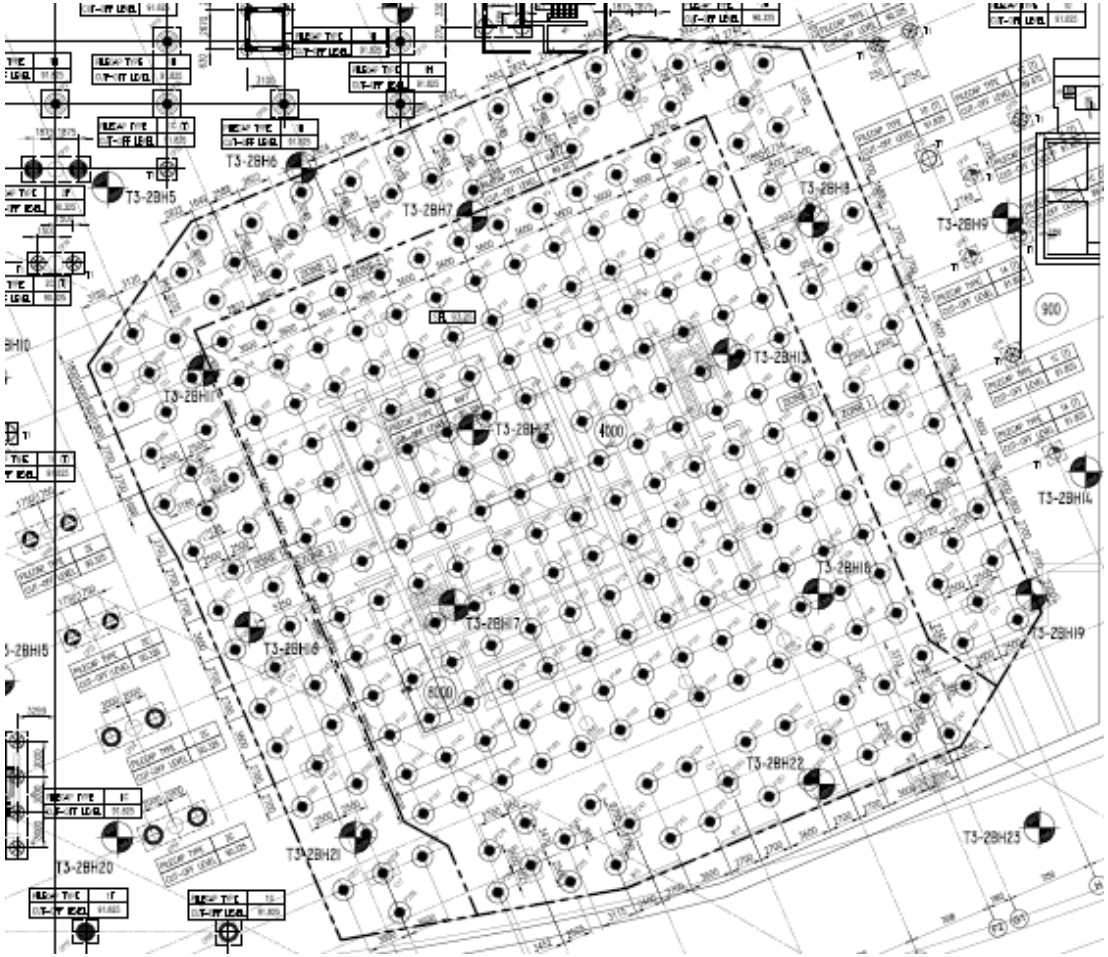
I. Group settlement is greater than settlement of individual pile

II. Differential settlement between two pile groups < 1:500

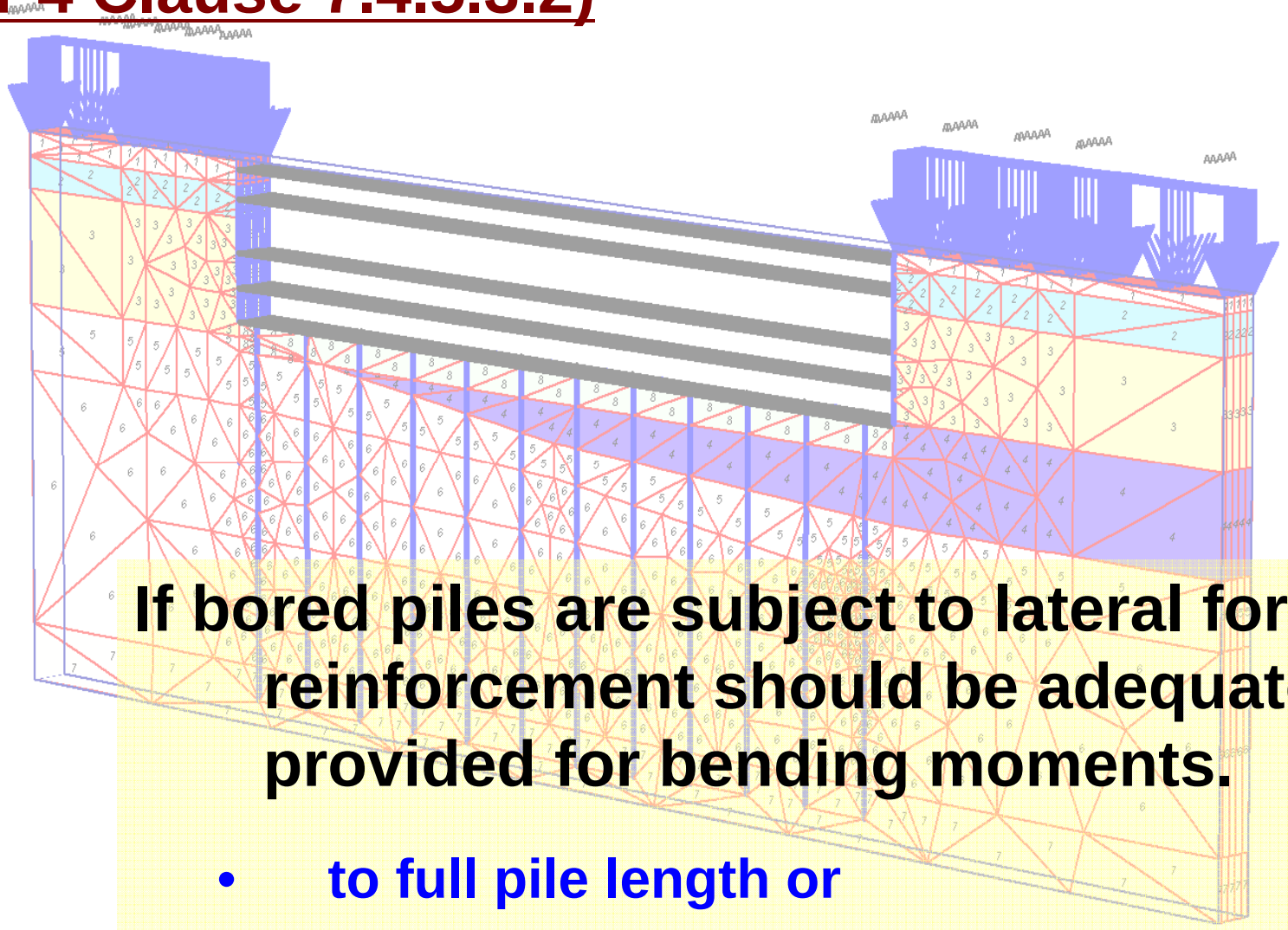


An example where pile group effect is dominant with overlapping of stress bulbs of individual piles

300 nos 1.8m piles within 60mx60m footprint



Effect of lateral forces during basement excavation (CP4 Clause 7.4.5.3.2)

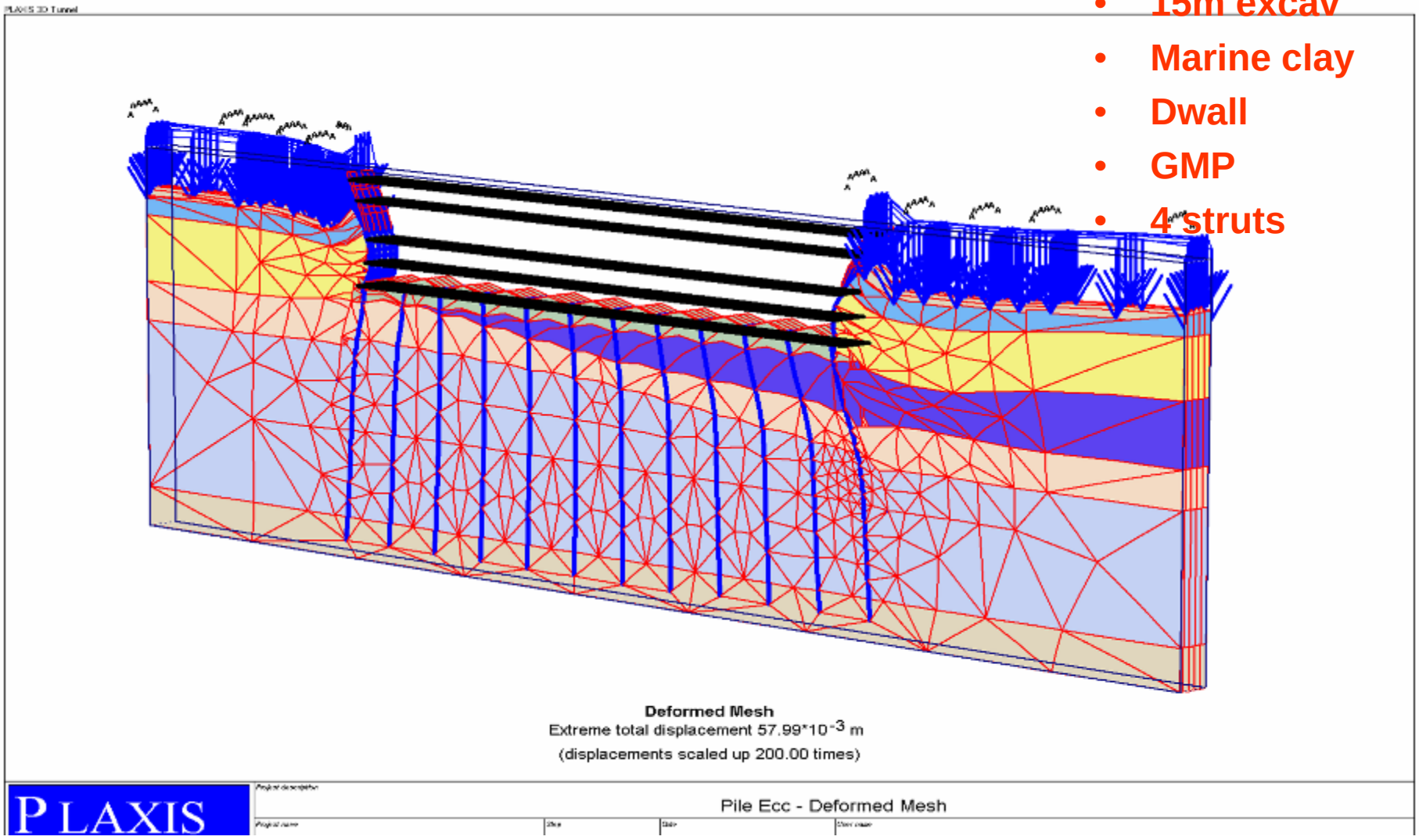


If bored piles are subject to lateral forces, reinforcement should be adequately provided for bending moments.

- **to full pile length or**
- **to where bending moment is negligible.**

An example of effect of basement excavation on foundation piles

- 15m excav
- Marine clay
- Dwall
- GMP
- 4 struts



- **Foundation piles should be designed for the effect of basement excavation.**

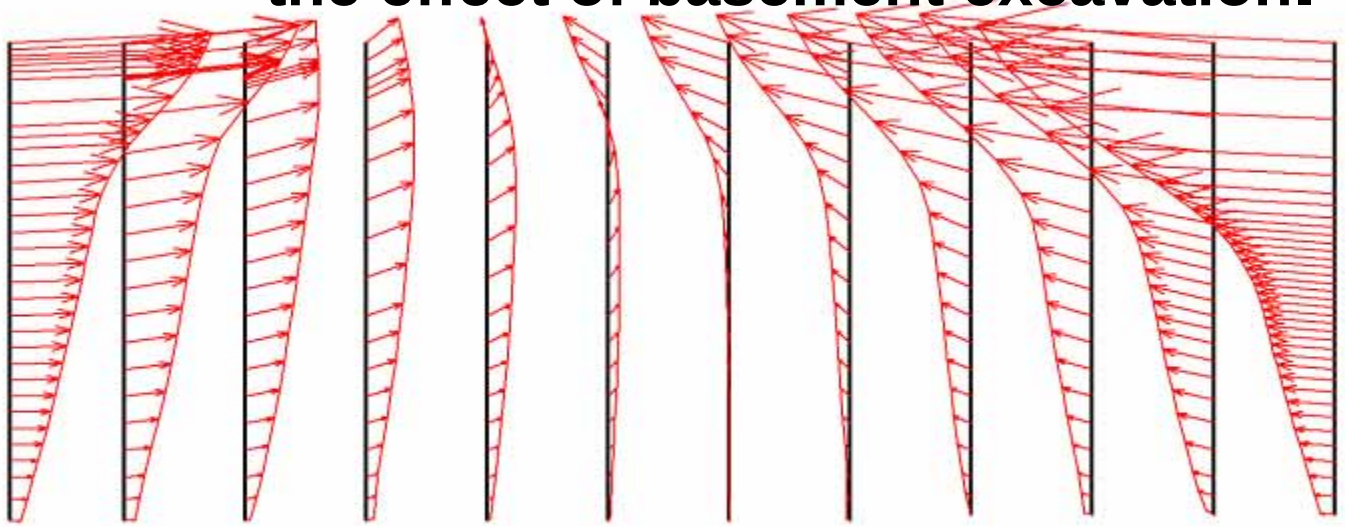


Table 1 Pile Ecc and Maximum Forces at Final Stage of Excavation

Pile	Position from Dwall [m]	Max ecc [mm]	Max N [kN]	Max BM [kNm]	Max SF [kN]	Remarks
L1	4	20	2029	615	-595	in GMP
L2	12	18	1782	488	-346	in GMP
L3	20	7	1753	229	-372	in GMP
R1	4	36	2340	820	1030	in GMP
R2	12	30	3592	-740	357	in GMP
R3	20	24	3255	-645	236	in GMP

Foundation piles move by 36mm, and experience bending moment of 820 kNm !

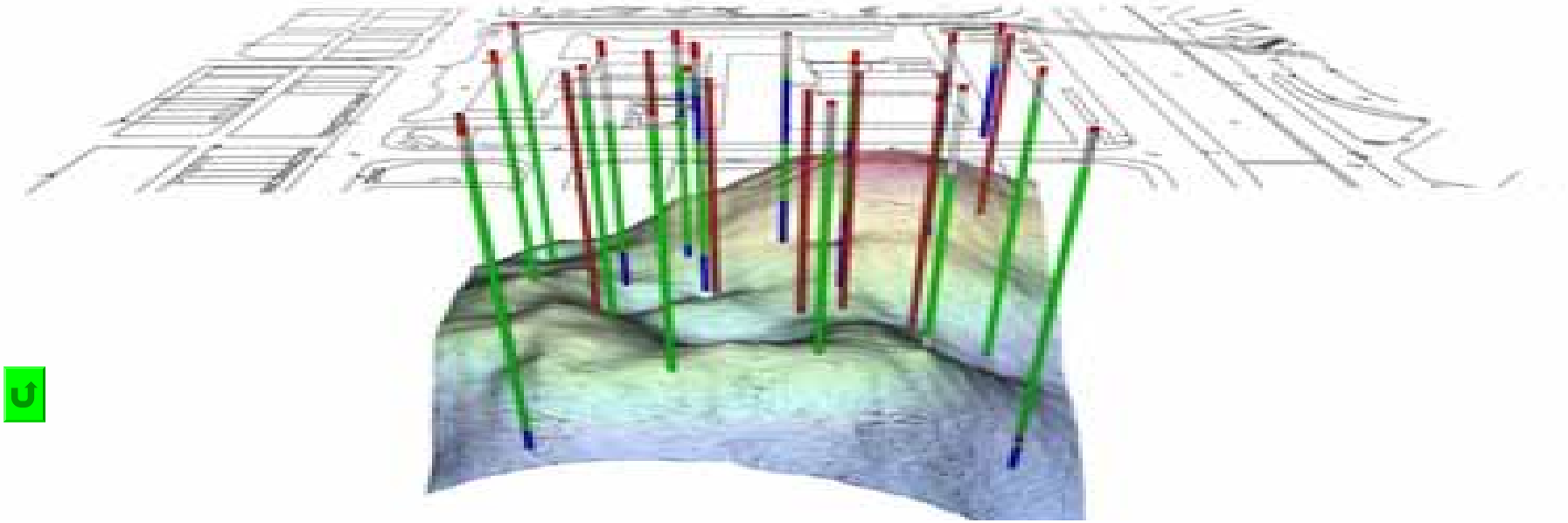
(4) BCA / IES / ACES Advisory note

(for buildings of 10-storeys or more)

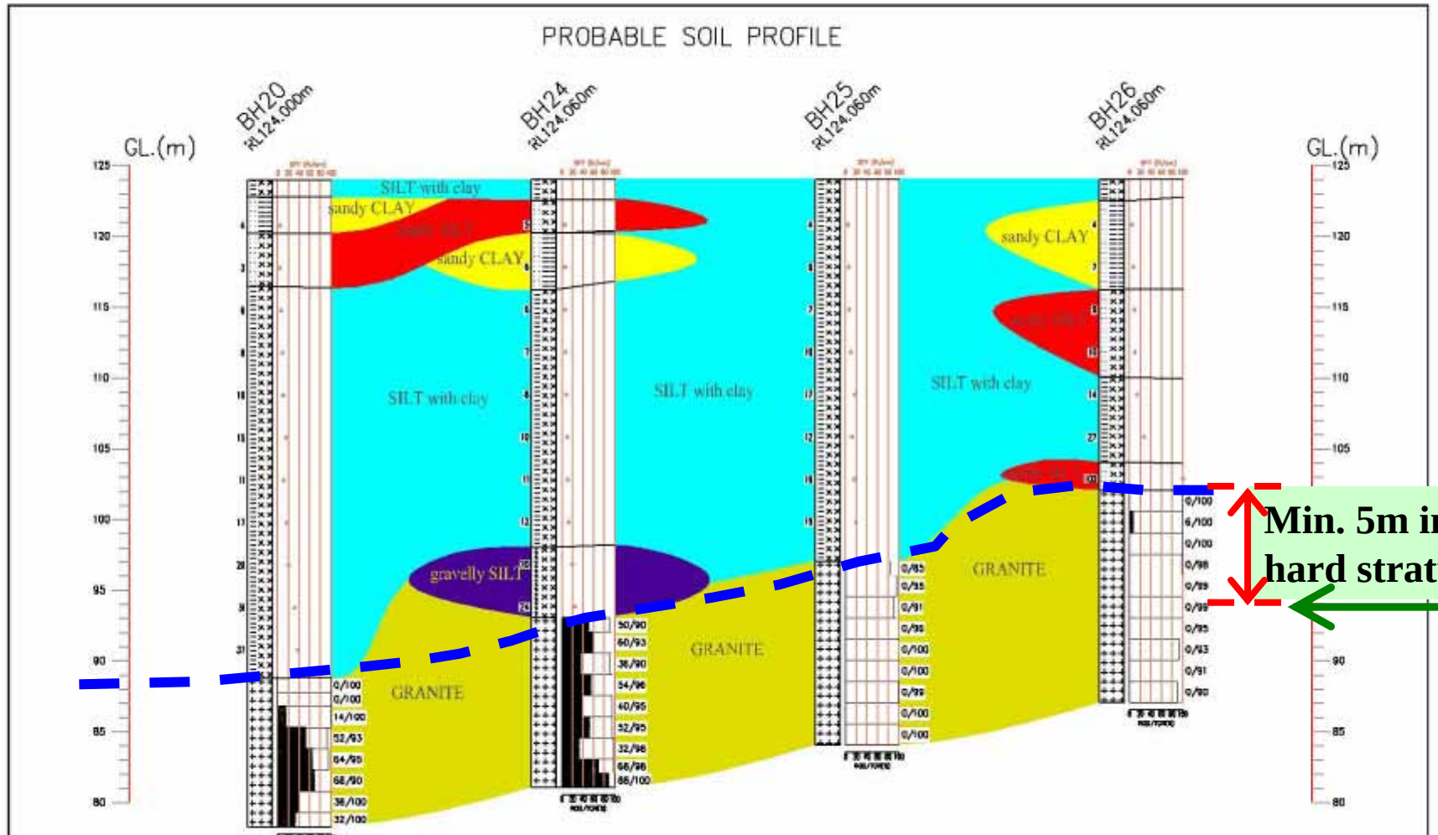
Requirements for Site Investigation

- **to establish the soil strata and ground variation**

	Minimum requirement
(a) **Number of boreholes**	- 1 borehole per 300 m^2 - 1 borehole at 10 to 30m spacing - Minimum 3 boreholes
(b) **Depth of boreholes**	- 5 metre into hard stratum with N>100 - 3 times pile diameters beyond pile founding level.

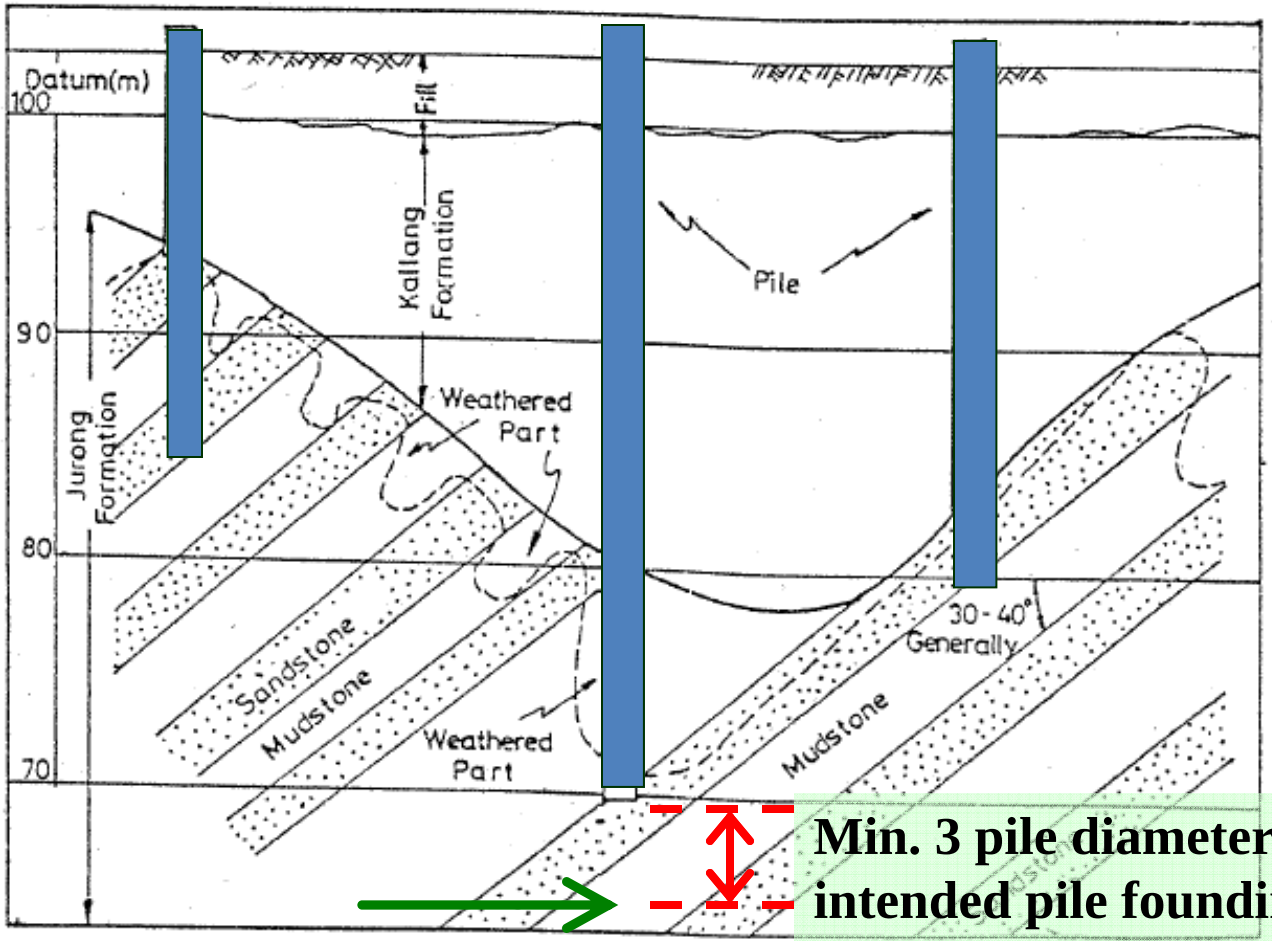


(1) Rockhead varies from RL 102m to RL88m
(2) The quality of bedrock varies greatly.



Example of soil profile for Bukit Timah Formatio

Example of soil profile for Jurong Formation



Requirements for pile load tests

Type of Load Test	Pile Test Schedule
(a) **Ultimate load test** on preliminary pile (preferably instrumented)	1 number or **0.5%** of the total piles whichever is greater.
(b) **Working load test**	2 numbers or **1%** of working piles installed or 1 for every 50 metres length of proposed building, whichever is greater.
(c) Non-destructive **integrity test**. (Note: This is for the purpose of quality control, and high-strain type should be used for bored piles)	2 numbers or **2%** of working piles installed, whichever is greater.

Load measurement for pile load tests (CP4 Clause 7.5.5.2.1)

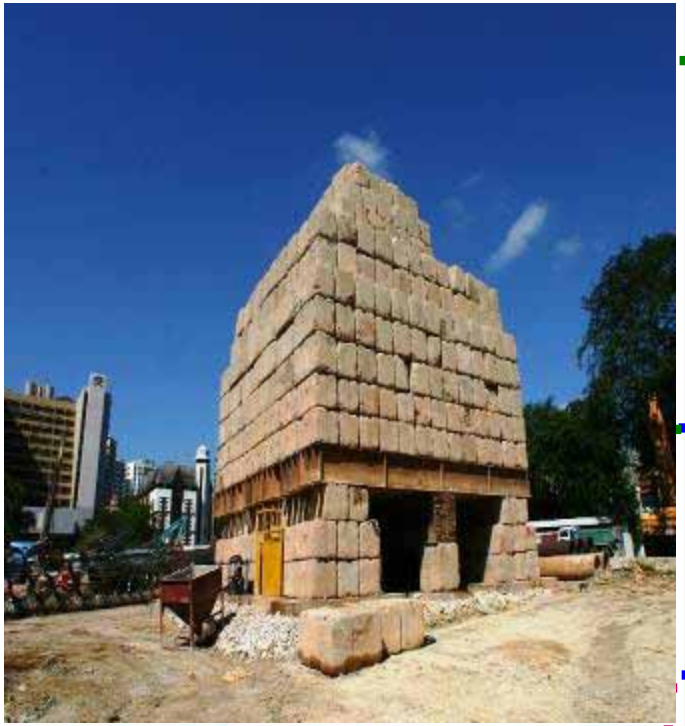
- **Load should be measured by a calibrated load gauge & a calibrated pressure gauge**

(5) Piling Annexes

(for buildings of 10-storeys or more)

Building and Construction Authority

Piling Annex B
Certificate of supervision of pile load test



Annex B

THE BUILDING CONTROL ACT (Cap 29)

CERTIFICATION OF SUPERVISION ON PILE LOAD TEST
[Regulation 27 of The Building Control Regulations]

Commissioner of Building Control Building and Construction Authority 5 Maxwell Road #05-00 Tower Block, MND Complex Singapore 069110	INSTRUCTIONS 1 * Delete accordingly 2 Please use BLACK INK to complete the form

Particulars of Structural Works to which this Certificate relates

Project ref. no.: _____ ST _____

*Lot / Plot : _____ *TS / MK : _____

Address/Road : _____

Building Name (if any) : _____

Project Title : _____

_____

Pile load test ref. no. : _____ Method of testing : _____ Date of test : _____

Part A: To be completed by the Qualified Person for Structural Works / # Qualified Person for Geotechnical Aspects

I confirm that:
*(a) I have reviewed the *static pile load test procedure and it is in accordance to CP4:2003,*
(b) I have inspected the test equipment, e.g. load cell, pressure and dial gauges, and they are properly calibrated by SPRING and not faulty,
(c) I have implemented the measure to prevent manipulation of load test result,
(d) All recordings of load and settlement readings are witnessed by me or the site supervisor,
*(e) I have examined the test records for the *static pile load test and I am satisfied that the load test result is valid and accurate,*
*(f) The test pile is loaded to a maximum of ___ times working load and it has *passed/failed the load-test criterion specified, and*
(g) I am satisfied with the pile load test results, the load test together with the site records confirmed the design assumptions and parameters made in the pile design.

Signature & Name of Qualified Person for Structural Works Date :	# Signature & Name of Qualified Person for Geotechnical Aspects Date :

QP

QP(geo)

Part B: To be completed by the Builder

I confirm that:
*(a) I have carried out the *static pile load test in accordance to CP4:2003,*
(b) There is no preloading of test pile or tampering of test equipment, e.g. load cell, pressure and dial gauges before and during the load test, and
(c) All recordings of load and settlement readings are witnessed by the qualified person or the site supervisor.

Signature & Name of Builder Date :	Name & Address of Builder Firm

Builder

Part C: To be completed by the Site Supervisor (s)

I confirm that I have witnessed the recording of load and settlement readings for the load test.

Signature & Name of Site Supervisor (s)

Date :

Site supervisor

Only applicable for underground building works

Building and Construction Authority

Piling Annex C

Interim certificate of supervision of piling works

Annex C

THE BUILDING CONTROL ACT (Cap 29)

INTERIM CERTIFICATE OF SUPERVISION ON PILING WORKS
[Regulation 23(1) of The Building Control Regulations]

Commissioner of Building Control Building and Construction Authority 5 Maxwell Road #05-00 Tower Block, MND Complex Singapore 069110	INSTRUCTIONS 1 * Delete accordingly 2 Please use BLACK INK to complete the form

Particulars of Structural Works to which this Certificate relates

Project ref. no.: _____ ST _____

*Lot / Plot : _____ *TS / MK : _____

Address/Road : _____

Building Name (if any) : _____

Project Title : _____

_____

Part A: To be completed by the Qualified Person for Structural Works / # Qualified Person for Geotechnical Aspects

*I, the Qualified Person appointed under * Section 8(1)(b) / Section 8(1)(d)(ii) / Section 11(1)(d)(ii) / Section 11(1)(d)(iii) of the building Control Act for structural works certify that *(50%/100%) piling works have been completed on _____ _____ (date) and that the same has been carried out and completed under my supervision in accordance with the set of piling plans/calculations approved under the Building Control Act. I further confirm that all the piles had been installed to founding depths which had been determined by me.*

Signature & Name of Qualified Person for Structural Works
QP
Date :
	# Signature & Name of Qualified Person for Geotechnical Aspects
	QP(geo)
	Date :

Part B: To be completed by the Builder

I confirm that I have sought the qualified person(s)'s approval for the founding depths of all the piles installed and they are constructed in accordance with the approved set of plan provided by the qualified person(s).

Signature & Name of Builder Builder Date :	Name & Address of Builder Firm

Part C: To be completed by the Site Supervisor (s)

I confirm that I have sought the qualified person(s) 's confirmation on the founding depths of all the piles installed.

Signature & Name of Site Supervisor (s)
Site supervisor
Date :

Only applicable for underground building works

Building and Construction Authority

Piling Annex D

Certificate for monitoring building settlement

THE BUILDING CONTROL ACT (Cap 29)

CERTIFICATE OF MONITORING BUILDING SETTLEMENT
[Regulation 37 of The Building Control Regulations]

Commissioner of Building Control
Building and Construction Authority
5 Maxwell Road #05-00
Tower Block, MND Complex
Singapore 069110

INSTRUCTIONS
1 * Delete accordingly
2 Please use BLACK INK to complete the form

Particulars of Structural Works and building to which this Certificate relates

Project ref. no.: _____ ST _____

*Lot / Plot : _____ *TS / MK : _____

Address / Road : _____

Name / block number of building : _____

Project Title : _____

_____

To be completed by the Qualified Person for Structural Works / # Qualified Person for Geotechnical Aspects

I confirm that the above building has reached _____ storeys on _____ (date) under my supervision.

I further confirm that I have personally determined and I am satisfied that building settlement monitoring results so far for the above building do not exceed the design limits in accordance with the approved set of structural plans/calculations, together with the conditions under which they were approved and all the relevant provisions stipulated under the Building Control Act and its Regulations.

Signature & Name of Qualified Person for Structural Works	# Signature & Name of Qualified Person for Geotechnical Aspects
_____	_____
Date :	Date :

Signed by QP

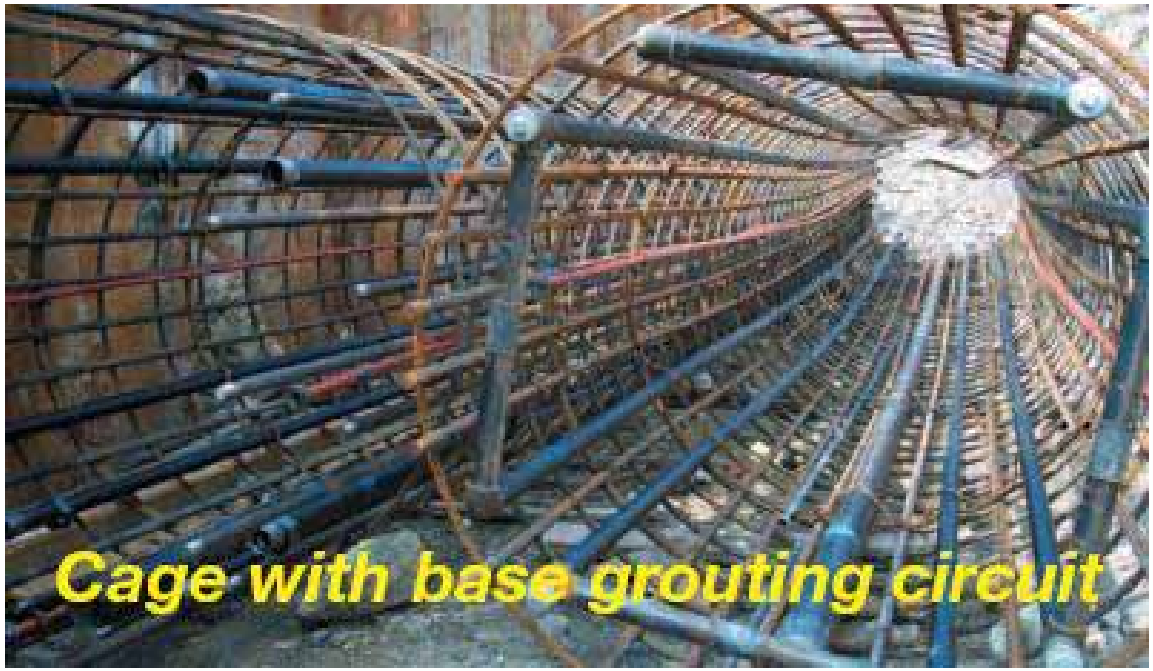
Signed by QP(geo)

Only applicable for underground building works

(6) Some good practices in pile design & construction

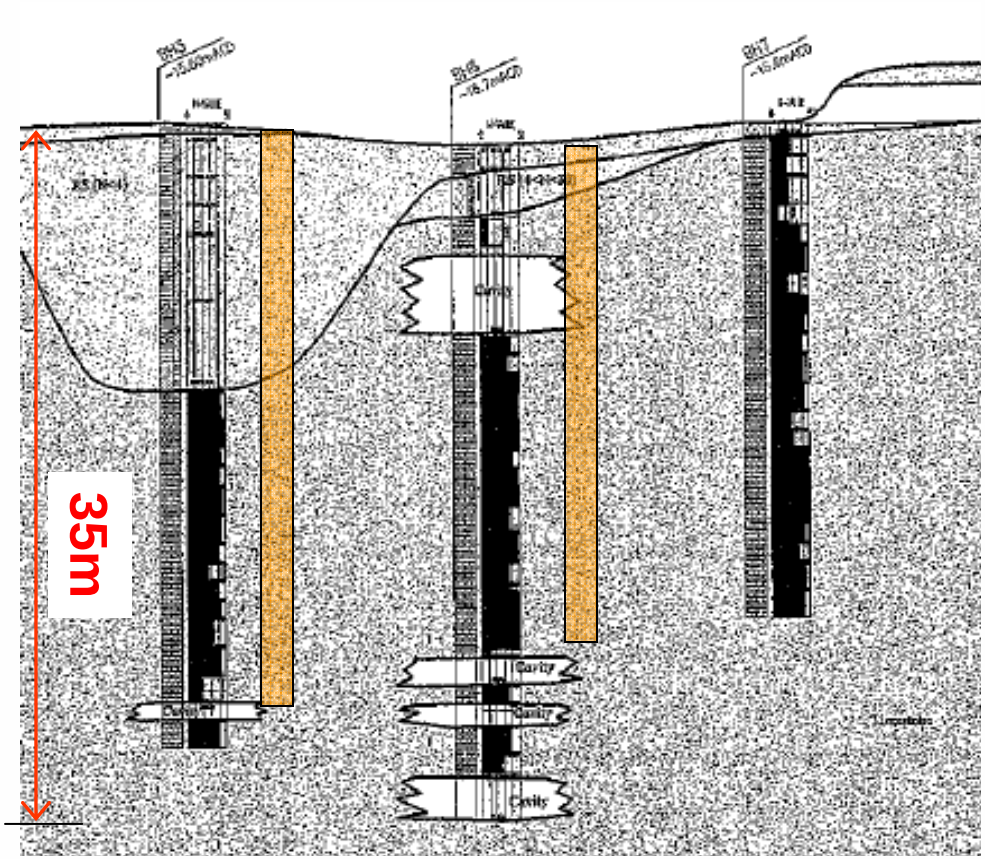
a) Reduce over-reliance on pile base resistance

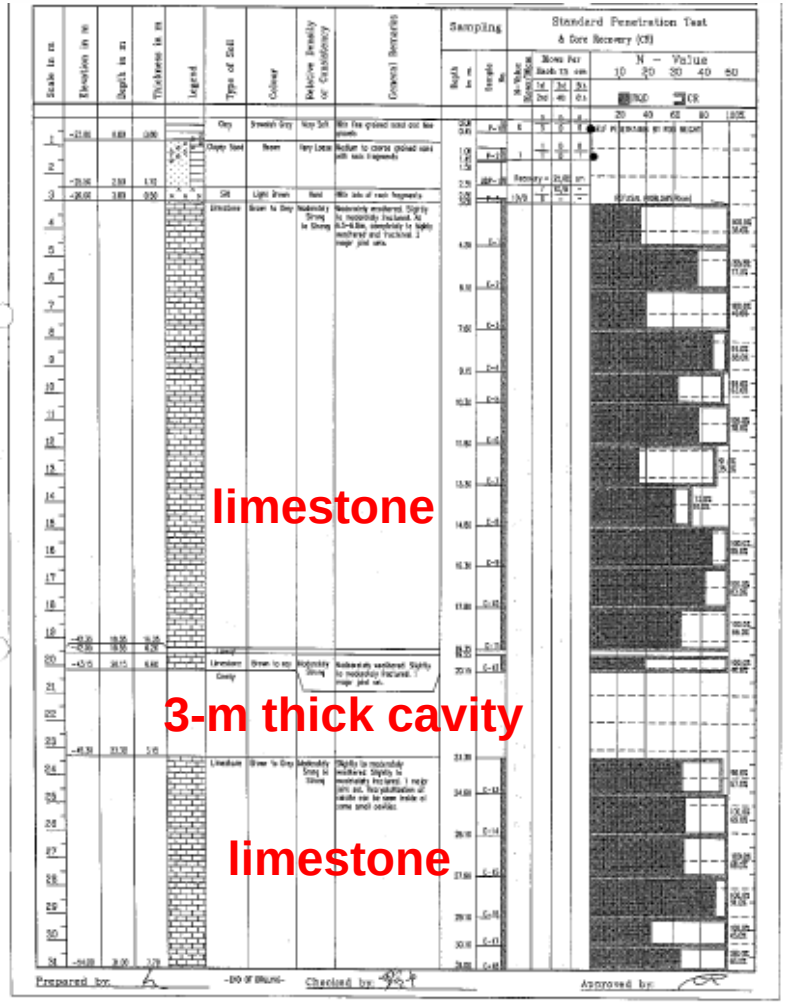
1) Applying a minimum safety factor to skin friction, for bored piles, where soft toe may occur



a) Reduce over-reliance on pile base resistance

2) In erractic soil condition, eg limestone area





(b) Preliminary pile at borehole location

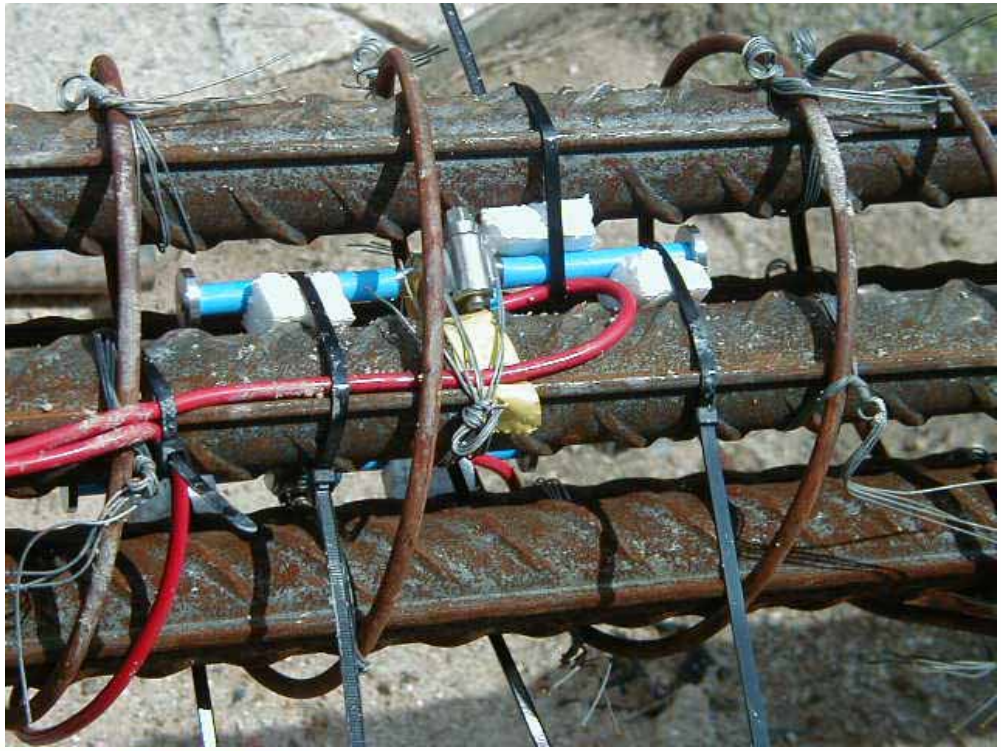
Borehole

Ultimate test pile

(c) Judicious location of strain gauges

- **Taking into account :**
  - **change of soil layers**
  - **thickness**
  - **variability**

- **To aid interpretation**
  eg. measurement of skin friction at various soil /rock layers



(d) Innovative Investigative preliminary pile

CP4 Clause 7.5.4.1

- **Preliminary piles may be formed with voids at base or soft toes to determine ultimate shaft resistance**

(e) Investigative preliminary piles installed using similar construction method as working production piles

CP4 Clause 7.5.4.1

Wet hole method

Dry hole method

(f) Proper transfer of load to Kentledge frame

Use stiffener for effective transfer

g) Minimum distance between test pile & Kentledge leg

- **Distance between Kentledge leg to surface of test pile ≥ 1.3 m (CP4 Clause 7.5.5.2.1)**

(h) No preloading on piles before test

(i) Conduct working load test at location where it matters

Pile Size (mm)	Working Load (kN)	Nos	No. of Load Test
ASM	-	135	0
1000	5800	147	0
1200	8400	99	1
1500	13200	115	2
1800	19000	159	3
2000	23500	96	1
2200	28500	88	1
2500	36800	62	1
2800	41600	22	1
3000	53000	16	
	Total :	939	

Examples :

(1) Piles within the tower footprint

(2) Piles carrying larger load

(j) No preselection of pile for working load test

(k) Keep rock/soil sample at site for verification

Building and Construction Authority

(I) Impose quality control measure at site

1) Pile bore stability

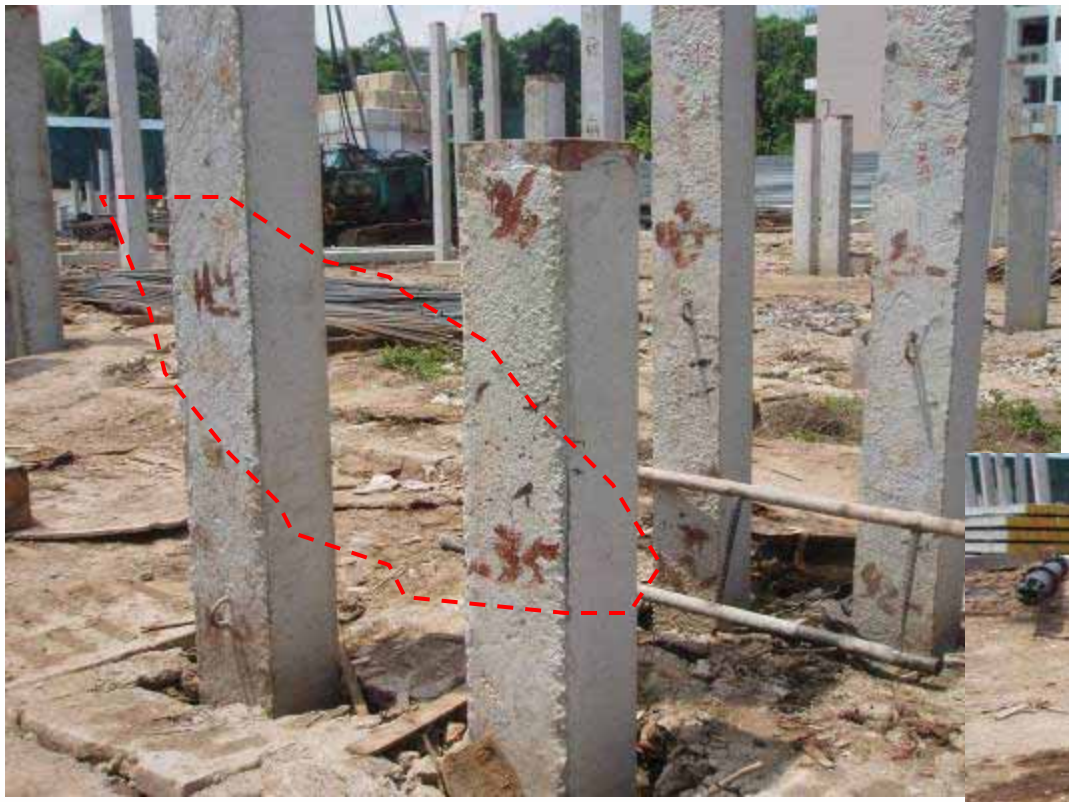
2) Pile base cleanliness

3) Tests on stabilizing fluids

(l) Impose quality control measures at site

4) **Sufficient cooling time for weld to gain strength**

(m) Check & verify obvious change in pile depth



Eg:

(1) Site investigation

(2) Load tests

Recap of Some Good Practices

a) Reduce over-reliance on pile base resistance

b) Preliminary pile at borehole location

c) Judicious location of strain gauges

d) Innovative preliminary pile

e) Preliminary pile installed using same method as working piles

f) Proper load transfer to Kentledge frame

g) Minimum distance between test pile & Kentledge leg

h) No preloading on piles before test

i) Conduct working load test at location where it matters

j) No preselection of pile for working load test

k) Check & verify obvious change in pile depth

l) Keep soil/rock samples at site for verification

m) Impose quality control at site

Summary

1. Requirements of piling plan submission under recent BC amendment Act and Regulations

2. Requirements for foundations of buildings more than 10-storeys

3. Good practices in design, load tests & construction

Concluding remark

Standard Certification by QP on plans and calculations

"I .... certify that they have been prepared in accordance with the provisions of the Building Control Regulations, the Building Control Act and any other written law pertaining to buildings and construction for the time being in force."

- **QP who prepare plans and calculations for piling plans have to comply with the requirements of BC Act and regulations**

THE END

Thank you !