SAFETY GUIDELINE FOR

Developments WITH Basement

FOREWORD

This Safety Guideline for Developments with Basement has been developed as a guide for proper planning and control of developments with regards to the construction of basement and deep excavation.

It is a requirement and shall be adhered to by all implementing agencies, developers, engineers, contractors, property owners and the public in general in planning, design, developing and maintaining throughout the development process.

Geotechnical reports pertaining to developments with basement shall be prepared according to this guideline and submitted to the local authority for reviewing, evaluation and approval of earthwork plans.

by

Technical Advisory Committee (TAC);
Geotechnical Consultation Unit (GCU);
Geotecnical Unit, Dept. of Engineering,
City Council of Penang Island.

www.mbpp.gov.my

MESSAGE FROM THE RT. HON. CHIEF MINISTER OF PENANG

Penang, especially on the island, is undergoing rapid development, many of which involve extensive excavation below ground. Strengthening safety standards and imposing specific guidelines for basement development is crucial, especially for areas with prevalent soft marine clay commonly seen in George Town.

There have been many issues of uneven ground settlement in the past, resulting from the lowering of the water table caused by deep excavation. Even adjacent ground of up to a distance of 30 times the depth of the excavation has also been affected, surrounding properties have suffered cracks and displacement, and temporary retaining walls and access roads had collapsed.

This specific Safety Guideline for Developments with Basement is the first for Penang Island and aims to prevent and reduce such mishaps, which may cause on-site hazards and damage to the surrounding areas and properties. The state-appointed Technical Advisory Committee has developed this Safety Guideline to improve security, stability and reliability of the environment around basement development.

The Technical Advisory Committee, with the City Council of Penang Island as the secretariat, developed this guideline after reviewing various proposals and models, studying the lessons learnt from experiences locally and elsewhere, and following good international practices. It is a necessary standard guideline to safeguard the public against the risks of catastrophe and damage due to unstable ground movements.

The guideline will serve as the main reference for planning approval, relating to basement development applications, and to be used by all the development agencies. The developers and their consultants, engineers and contractors are required to be fully responsible by abiding with this guideline in order to put safety first for all Penangites.

The City Council of Penang Island, assisted by an advisory panel of experts, continues to strengthen its technical unit, which will process and review applications for basement development. A monitoring team will also be set in place to ensure strict compliance.

We are confident that this guideline will be one of the main reference in the country. Putting safety first, giving priority to the security of the people and the structural stability of buildings will help Penang attain the standards required of an international and intelligent city that is clean, green, safe and healthy.

LIM GUAN ENG

OPENING NOTE BY THE HON. MAYOR, CITY COUNCIL OF PENANG ISLAND

The Safety Guideline for Developments with Basement emphasizes on the adherence to a comprehensive high safety standard of planning, construction, monitoring and maintenance specifically pertaining to deep excavation site with basement. It is a requirement throughout the development process.

Land scarcity especially on the island with development control such as height limitations and building line setbacks, nature and profile of terrain and the constraints due to naturally present soft marine clay ground conditions in areas within George Town are among the major challenges to developers. Thus, the need for basement structures for some developments is inevitable.

Recognising this, the local authority had to allow construction of basement for some developments. Therefore, it is imperative that more strict and thorough conditions are imposed before permission is granted for developments with basement. This guideline acts as a methodical and comprehensive mechanism to create a clear approach and direction to safeguard basement structures.

Consequently, this Safety Guideline for Developments with Basement serves as another initiative and step forward by City Council of Penang Island (MBPP) and the State Government of Penang to protect the interest and safety of purchasers and dwellers of properties including the public in general. It also constitutes a system much needed to upgrade the safety standards of developments in Penang. With the implementation of this guideline, Penang aims to reduce or even eliminate subsequent damages and fatalities due to basement construction failures.

Our appreciation goes to the Technical Advisory Committee for their provision of expertise, superior knowledge and technical support in developing this guideline.

DATO' PATAHIYAH BINTI ISMAIL

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1.0 OBJECTIVES

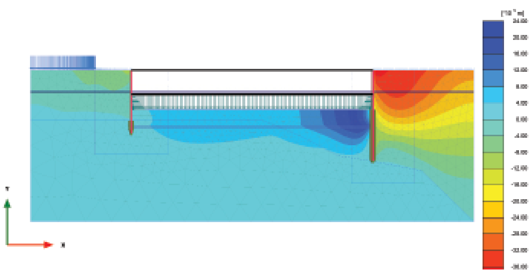
The Safety Guidelines for Developments with Basement is prepared for the purpose of implementing higher safety standards for basement development especially for deep excavation in soft marine clay in George Town.

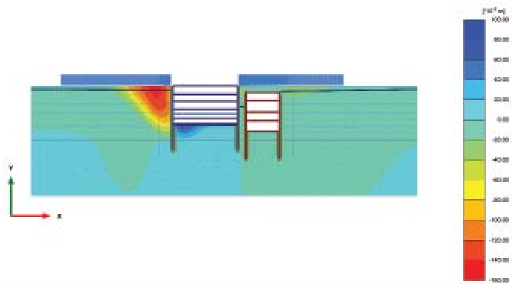
George Town has experienced some incidents of ground settlement issues induced by deep basement excavation works. For examples, the basement excavation works of Prangin Mall caused settlements of the adjacent ground up to a distance of 30 times of the depth of excavation due to temporary lowering of water table during basement excavation, and the collapse of temporary retaining wall and access road near Gurney Park.

As basement construction works can result in hazards in the construction site as well as the surrounding areas, it is prudent that a proper guideline be prepared to safeguard against the risk of catastrophes and damages due to ground movements.

The Technical Advisory Committee, appointed by Penang Government with the City Council of Penang Island as the secretariat, was commissioned to prepare the Safety Guideline for Developments with Basement.

The objective of this guideline is to safeguard the safety aspects of basement development which includes the safety of the excavation sites as well as the surrounding areas during the temporary construction stage, and the safety of basement structures in terms of their long term performance.





1.1 DEFINITION OF BASEMENT

For the purpose of the use of this guideline, an excavation is deemed to be considered a basement when the following conditions are met:-

a) Excavation depth ≥ 3m and greater than 5m in length, and

b) Work is liable to affect any road, building, structure, slope steeper than 30º or water main 75mm in diameter or greater, within 25º from the horizontal plane measured from the base of the excavation, or

c) Excavation below water table where dewatering is likely to result from or is part of the method for excavation.

2.0 MAJOR CONSIDERATIONS

Considerations are given to:-

1) Safety of the basement excavation site proper,
2) Safety of the surrounding areas with respect to ground movements as a result of basement activities including possible temporary lowering of water table during construction, and
3) The long term performance of the permanent basement structures.

Major specific considerations are arranged into these three categories as described in subsequent sections.

2.1 SAFETY OF TEMPORARY BASEMENT EXCAVATION SITE

The safety of the temporary basement excavation site in this section refers to the safety of the excavation site proper during the whole duration of the construction period. This is the main section of geotechnical design which should include consideration of:-

a) Minimisation of ground movement and changes in groundwater table at surrounding areas, and
b) Construction of the permanent structure.

2.1.1 Design Concept

Construction methods shall be fully considered at the design stage. As such, the details of design concept of the basement development need to be explained and justified with respect to the following inter-related systems:-

a) Retaining wall system (gravity wall or embedded wall) or open cut slope,
b) Wall support system,
c) Foundation system,
d) Earthwork excavation (earth removal) system with dewatering/pumping system with or without recharging wells, and with or without temporary staging/platform,
e) Permanent struts and base (reinforced concrete structures-slabs and base),
f) Sequence of work or construction sequence and
g) Performance specification of the permanent basement structure.

The following **possible impacts** have to be considered as part of the design:-

a) Ground movement (lateral deflection and settlement),
b) Vibration and other form of ground disturbance during wall installation and ground improvement,
c) Changes in groundwater table due to dewatering/excavation works,
d) Piping or heaving, and
e) Long-term changes to groundwater table due to basement construction.

The method of minimising ground movement, changes in groundwater table and ground disturbance during construction would have to be clearly elaborated.

2.1.2 Method of Analysis

The global factor of safety method and limit state partial factor method are acceptable to be used for retaining wall analysis of basement excavation (PNAP APP-57). However, the two methods are not allowed to be used together.

A simplified design method like limit equilibrium method is adequate for a singly propped analysis. However, more sophisticated methods would be suitable for multi-propped analysis. Many 'deformation methods' type of numerical analysis software programs are available (CIRIA C517) such as:-

a) Beam on springs
b) Beams on elastic continuum
c) Finite difference methods
d) Boundary element methods
e) Finite element methods

Simplified calculation method and/or commercial/conventional software can be used for retaining wall analysis of the basement excavation. Unconventional software (e.g. self-written software) can only be used provided that detailed justifications (e.g. comparative rationalisation or case studies) are provided and accepted.

2.1.3 Excavation Stability

The stability of the excavation with a retaining wall (embedded or gravity) or slope shall have a global stability with a minimum Factor of Safety of 1.4 or equivalent partial factors used in accordance with Eurocode 7. All works shall be designed as permanent works for construction period of more than 6 months, and a minimum Factor of Safety of 1.4 shall be applied to the structural design. For temporary works with a construction period of 6 months or less, a minimum Factor of Safety of 1.2 can be applied to the structural design.

2.1.4 Piping and Heave

Piping or hydraulic failure can occur in non-cohesive soils. A minimum Factor of Safety of 1.5 against hydraulic failure shall apply (PNAP APP-57). For cohesive soils, basal failure or heave can occur. Hence, a minimum Factor of Safety of 1.5 against basal failure shall apply.

2.1.5 Progressive Failure Check

CIRIA C850 and CIRIA C517 advocate the implementation of a progressive-failure check which is also known as a one-strut-failure check. A progressive-failure check is to safeguard against the loss of human lives and injury by ensuring that catastrophic failure does not occur. For example in the case of a strutted wall, the design is to be checked for the removal of a single strut. The wall may incur excessive movement but should not cause suffer a total collapse.

The progressive failure check is only applicable to propped wall systems including ground anchored wall systems. Thus, it is not applicable for non-propped walls like cantilever embedded wall, gravity wall or slope. As all risks should be reduced if it is reasonably practical to do so, the robustness of the system should be improved, where necessary, to be able to withstand the loss of any prop without causing a catastrophic collapse. In the event that it is not reasonably practical to do so, a Risk Assessment and Management Strategy (RAMS) as described in Section 2.1.6 shall be required.

The use of RAMS should not be taken as an easier alternative in lieu of a design against progressive failure. It should only be implemented in lieu of a design against progressive failure if and only if reasonably practical solutions are not available. The onus is on the submitting Engineer to show that there is no reasonably practical solution available.

2.1.6 Risk Assessment and Management Strategy (RAMS)

The Risk Assessment and Management Strategy (RAMS) shall apply for all basement excavations, especially for non-propped walls like cantilever embedded wall and gravity wall, and slope. CIRIA C580 outlined the four stages of risk management to be strategized as:-

a) Hazard identification
b) Risk assessment
c) Risk reduction
d) Risk control

The Risk Assessment and Management Strategy shall include comprehensive instrumentation and monitoring during the construction period tying-in with specific critical stages of works.

2.2 SAFETY OF SURROUNDING AREAS

The safety of surrounding areas refers to public safety within a close vicinity of the basement excavation as well as the safety of the structures and infrastructures within a close vicinity of the basement excavation against damages due to ground movements and/or changes in groundwater table.

2.2.1 Zone of Influence of Excavation (ZIE)

The Zone of Influence of Excavation (ZIE) is the extent of the ground movements resulting from the basement excavation activities. It is normally specified as the distance away from the excavation face.

2.2.2 Settlement Assessments and Predictions

The probable settlements have to be assessed and expected settlements to be predicted. The intention of the assessments and predictions is to assess the probable effects of the excavation works on the surrounding structures.

The generally acceptable limits for potential damages are ~ **1.6 < β (x10^{-3}) < ~ 3.3** for angular distortion and **0.75 < ε_h (x10^{-3}) < 1.5** for horizontal strain, based on Boscardin & Cording 1989. These limits should only be taken as a guide and would not absolve the engineers and the contractors of the excavation works from any liability as a result of the damages due to the ground settlement.

2.2.3 Instrumentation and Monitoring

CIRIA C517 stated that the main causes of damage to buildings in the surrounding areas are generally the ground movements or settlements as a result of wall installation and problems associated with groundwater lowering. Hence, the instrumentation and monitoring program for the whole ZIE has to commence monitoring (recording) before the wall installation, foundation installation and/or groundwater lowering works are carried out. Likewise, dilapidation surveys of all buildings within the vicinity of the ZIE have to be completed.

Instrumentation carried out shall include piezometers, settlement markers, building settlement markers, inclinometers and tiltmeter.

Alert, Alarm and Action limits shall be established together with the appropriate responses as part of design requirements.

2.3 PERFORMANCE OF PERMANENT BASEMENT STRUCTURES

2.3.1 Durability Requirements

The design lifespan of the basement structure shall be defined in view of the durability of the underground structure especially in an aggressive ground condition (BRE SD1 2005). The durability of the concrete should conform to Clause 4.4.2 of BS 8004:2015 Code of practice for foundations.

2.3.2 Wall Watertightness Requirements

BS8102:2009 specifies the wall water tightness requirement for basement structures. There are three types of categories:-

a) Type A – BARRIER – protection against water ingress by separation barrier system applied to the structure

b) Type B – STRUCTURAL INTEGRAL – protection against water ingress by structure

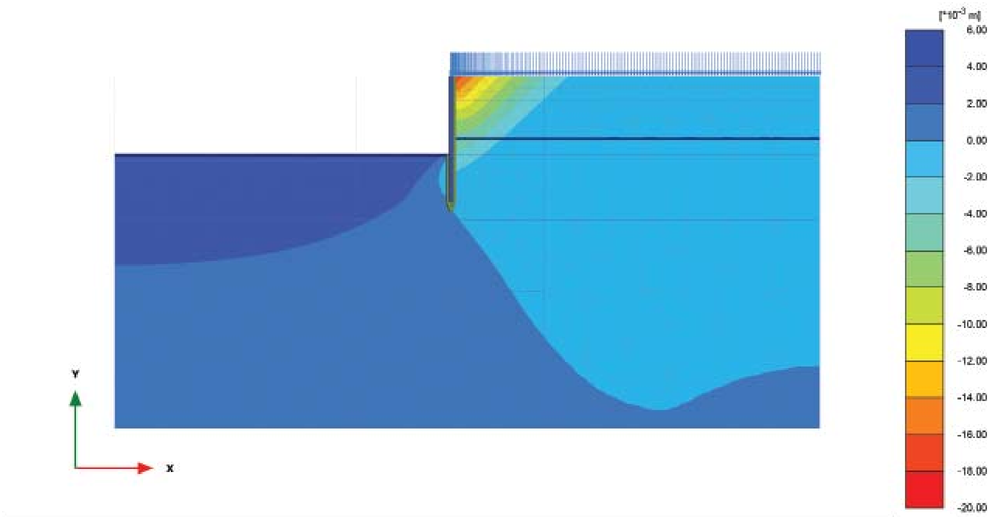
c) Type C – DRAINED – protection against water ingress by internal water management system

The lowering of groundwater table permanently is expected to be minimised and discouraged.

The type of wall water tightness system is required to be specified in the design submission report so that the developers, consultants and contractors are aware of the required type specified. This will dispel potential argument or misconception on the expected level of water tightness of the wall by all parties. Alternative design proposal could be reviewed with the appropriate level of watertightness of wall.

2.3.3 Permanent Lateral Support to Wall Requirements

For the permanent condition of basement structures, the floor slabs act as a permanent lateral support to the basement wall. Care is required when dealing with system slabs like prestress slabs.



Total displacements u_y

Maximum value = $4.030*10^{-3}$ m (Element 469 at Node 7971)

Minimum value = -0.01868 m (Element 109 at Node 603)

2.4 OTHER SPECIFIC CONSIDERATIONS

There are many other important considerations besides the major considerations mentioned in sections 2.1, 2.2 and 2.3. These are specific to the type of systems used and might only be applicable to some of the basement excavations under consideration. These specific considerations are elaborated in the subsequent subsections.

2.4.1 Alternative Design

It is common for specialist contractors to provide alternative designs to the consultant's comforming design. Hence, such alternative design for basement works have to be approved by the authority, but not necessarily required to go through the whole process of submission to the authority.

The responsibility of checking to ensure that the alternative design is proper still lies with the Geotechnical Engineer (GE) and Independent Geotechnical Checker (IGC).

2.4.2 Wall Design

Basement construction generally takes about 6 months to more than a year to construct. Hence, for the design of retaining wall, the wall shall be designed for a long term period. For the long term design, both the clays (cohesive soils) and the granular soils (non-cohesive soils) shall also be designed with their drained soil parameters (CIRIA SP95).

According to CIRIA C580 and BS8002:1994, the undrained conditions may be assumed for the short term design where the mass in situ permeability of the ground is low (i.e. a coefficient of permeability of the order of 10^{-8}m/s or less.

2.4.3 Props

For props, the following points shall be taken into considerations with respect to the safety of the strutting or props type of wall support system (CIRIA C517):-

a) For eccentric axial load on the waler made from a single section (UC, UB, RHS), the eccentricity should be taken as 10% of the overall dimension of the prop in the vertical plane. For twin beams waler, the eccentricity in the vertical plane shall be half the distance of the gap between the two beams.

b) For accidental load on struts or props, a load of 10kN to 50kN applied normal to the prop at any point in any direction shall be considered.

c) The walers shall be continuous over two or more strut supports and be designed for a maximum bending moment of $wl^2/10$, where w is the waler load per unit length and l is the horizontal strut spacing. If continuity is not possible, it should be designed for $wl^2/8$. Similarly, the end of a continuous waler should be designed for $wl^2/8$ as it acts as cantilever about the last strut support.

d) Prop removal is potentially dangerous as the forces are locked in the props at the stage of prop removal. Proper mechanism or procedure is necessary to remove props in a safe and controlled manner. The designer and site personnel shall discuss and agree on this method or procedure of prop removal.

2.4 OTHER SPECIFIC CONSIDERATIONS (con't)

2.4.4 Ground Anchors

Permanent ground anchors are discouraged as tedious long term maintenance programme will be required. In the event that permanent ground anchors are used, a detailed long term maintenance programme shall be included in the geotechnical report submission.

Temporary ground anchors are allowed if and only if all anchor strands can be removed and are properly scheduled to be removed. Consent from the adjacent lots is required if the ground anchors protrude beyond the site boundary.

2.4.5 Foundation

A common foundation system for deep basement is the non-displacement piles (bored piles, barrettes, caissons and micropiles). Displacement piles have to be considered with caution especially for reinforced concrete piles. The heaving of soil during basement excavation has the tendency to cause heaving of piles. This would be critical as pile heave reduces end bearing of piles drastically. This would also be critical for the joint capacity of driven or jack-in piles as well as short piles.

Stability of bored holes using measures such as bentonite, polymer, temporary casing shall be properly assessed to prevent collapse or heaving of bored holes.

Raft or pad footing would be suitable for shallow basement above the water table and/or good ground condition.

2.4.6 Dewatering and Recharging

Dewatering is a process of lowering the groundwater table which includes pumping of water from the basement excavation pit as well as multistage well point system.

Recharging, the reverse of dewatering, may be necessary to prevent lowering of water table, provided the ground condition is suitable for the intended purpose. Recharge wells would be placed at strategic locations where water is recharged back into the ground, hence, maintaining the water table at the original level.

No lowering of water table at the retained site with buildings or structures is allowed for the design of temporary or permanent works.

2.4.7 Observational Method

Observational method of basement excavation is permitted in BS EN 1997-1:2004 and CIRIA C517. Comprehensive detail of the observational method is presented in CIRIA Report 185 which states that "The Observational Method in ground engineering is a continuous, managed, integrated, process of design, construction control, monitoring and review that enables previously defined modifications to be incorporated during or after construction as appropriate. All these aspects have to be demonstrably robust. The objective is to achieve greater overall economy without compromising safety".

The Observational Method has a technical and procedural auditing activity that assesses a wide range of the project as follows:-

a) National & Corporate Policies,
b) Corporate & Project Organisations,
c) Design & Planning,
d) Construction Control,
e) Monitoring,
f) Review, and
g) Implement Planned Modification (including Contingency Plans) or Emergency Plans.

In essence, the Observation Method requires intellectual and organisational preparedness in executing the excavation works.

CIRIA Report 185 also cited that Observational Method must not be used in the following situations:-

a) Where there is insufficient time to fully implement and complete the contingency and emergency plans, and
b) Where observations would be difficult to obtain or are unreliable.

BS8002:1994 states that the design should be based on representative or conservative values and BS EN 1997-1:2004 recommends design values to be cautious estimates. Hence, the design approach or concept should be conservative in nature and stringent requirement shall be applied as laid out below as per BS EN 1997-1:2004:-

a) Acceptable limits of behaviour shall be established;

b) The range of possible behaviour shall be assessed and it shall be shown that there is an acceptable probability that the actual behaviour will be within the acceptable limits;

c) A plan of monitoring shall be devised, which will reveal whether the actual behaviour lies within the acceptable limits. The monitoring shall make this clear at a sufficiently early stage, and with sufficiently short intervals to allow contingency actions to be taken successfully;

d) The response time of the instruments and the procedures for analysing the results shall be sufficiently rapid in relation to the possible evolution of the system;

e) A plan of contingency actions shall be devised, which may be adopted if the monitoring reveals behaviour outside acceptable limits.

Note: For more details of the Observational Method, refers to CIRIA Report 185.

3.0 SUBMISSION REQUIREMENTS

3.1 Report Submission

3.1.1 Comprehensive geotechnical reports shall be submitted for the application of Earthwork Plans. Reports submitted shall be comprehensive enough to demonstrate the feasibility of the entire scheme in a safe and orderly manner taking into account of the major considerations mentioned in Section 2.0.

3.1.2 The report shall include layout plan of wall support system with propping layout (if applicable) and the sequence of construction. The calculation should include realistic ground movement estimates for the entire works, preliminary sizing of props (struts and waler, if applicable). This would exclude the design details which are to be submitted before the commencement of works.

In essence, the geotechnical report shall include but not limited to (PNAP APP-25):-

a) An outline of the topography, geology and groundwater condition of the site and the surrounding area;

b) A description of the proposed works and discussion of how the existing geotechnical features (such as slopes and retaining walls) and adjacent foundations will affect or be affected by such works;

c) A discussion to demonstrate the feasibility of the proposed development, including descriptions of construction methods and sequence of works;

d) Schematic plans and sections of the proposed site formation works and foundation works, taking the above discussion into account;

e) Descriptions of intended investigations of the stability of existing structures within the zone of influence of excavation (ZIE), and any preventive or remedial works that may be needed.

3.1.3 The excavation involving dewatering, the following information shall be provided but not limited to (PNAP APP-22):-

a) The foundation details of adjoining buildings and details of nearby underground utilities (e.g. water main, gas main, sewer and the like);

b) Details of the dewatering proposals including ground treatment, if any (e.g. grouting and recharging);

c) The method and sequence of construction; and

d) The location and details of instrumentation for monitoring the effects of the works on adjoining buildings, streets and land (including the change in groundwater conditions in the adjoining ground) during construction, together with information on:-

   i) Criteria for limiting movements and groundwater pressures and action to be taken if these limiting values are reached;

   ii) Intervals between readings; and

   iii) Availability of monitoring records.

3.1.4 Two sets of reports are required for the submission of basement development:-

a) Geotechnical Design Report, to be prepared and endorsed by a Geotechnical Engineer (GE) which shall include appendices of

i) a Soil Investigation report of the site and surrounding area,

ii) a Dilapidation Survey report of the structures and infrastructures within the Zone of Influence of Excavation (ZIE), and

iii) Damage Prediction report of structures within the Zone of Influence of Excavation (ZIE).

b) An Independent Geotechnical Checker report, to be prepared and endorsed by an Independent Geotechnical Checker (IGC), which shall include:-

i) An independent review of the basement development,

ii) An independent review of the Dilapidation Survey report of the structures and infrastructures within the Zone of Influence of Excavation (ZIE), and

iii) An independent review of the Damage Prediction report of structures within the Zone of Influence of Excavation (ZIE).

3.2 Qualifications of GE and IGC

3.2.1 The Geotechnical Engineer (GE) shall be a Professional Engineer with a Practicing Certificate in Civil Engineering or Geotechnical Engineering registered with the Board of Engineers Malaysia (BEM), having at least three (3) years of relevant experiences in basement design and construction with one (1) year gained in Malaysia.

3.2.2 The Independent Geotechnical Checker (IGC) shall be a Professional Engineer with a Practicing Certificate in Civil Engineering or Geotechnical Engineering registered with the Board of Engineers Malaysia (BEM), having at least ten (10) years of relevant experiences in basement design and construction with one (1) year gained in Malaysia.

3.0 SUBMISSION REQUIREMENTS (con't)

3.3 Supervision of Works

3.3.1 Geotechnical Engineer (GE) shall be responsible for full time supervision of the basement and foundation works. He can be represented on site by an Engineer registered with BEM, assisted by a Clerk of Work (CW).

Performance review (PNAP APP-115) shall be carried out by the GE for the construction works of piles and walls, prior to the physical earthwork excavation for the basement. The assumptions used for the design proposal have to be verified to ensure the validity of the design. The assumptions to be verified shall include the geological condition and the groundwater regime. Unconventional designs or new technologies have to be verified too.

3.3.2 Independent Geotechnical Checker (IGC) shall inspect the site at a minimum frequency of once a month. The Independent Geotechnical Checker (IGC) shall visit the site personally and cannot assign a representative to act on his or her behalf.

3.3.3 Geotechnical Engineer (GE) shall prepare, endorse and submit Site Progress report to the Council directly at least once a month. Independent Geotechnical Checker (IGC) shall prepare, endorse and submit a Checker Review report on the adequacy of the GE report to the Council for every site visit.

4.0 REFERENCES

The references used in this guideline are listed below.

1) **PNAP APP-22**, Dewatering in Foundation and Basement Excavation Works, Practice Note for Authorised Persons and Registered Structural Engineers, Buildings Department, HKSARG, August 2009.

2) **PNAP APP-25** Requirement for a Geotechnical Assessment at General Building Plan Submission Stage Regulation 8(1)(ba) of Building (Administration) Regulations, Practice Note for Authorised Persons and Registered Structural Engineers, Building Department, HKSARG, April 2015.

3) **PNAP APP-57** Requirements for an Excavation and Lateral Support Plan Building (Administration) Regulation 8(1) (bc), Practice Note for Authorised Persons and Registered Structural Engineers, Building Department, HKSARG, February 2012.

4) **PNAP APP-115** Performance review - Item 6(g)(ii) in Column B, Section 17(1) of the Building Ordinance, Practice Note for Authorised Persons and Registered Structural Engineers, Building Department, HKSARG, August 2009.

5) **CIRIA C580** Twine D. and Roscoe H., Temporary Propping of Deep Excavations – Guidance on Design, 1999.

6) **CIRIA C517** Gaba A.R., Simpson B., Powrie W. and Beadman D.R., Embedded Retaining Walls – Guidance for Economic Design, 2003.

7) **CIRIA SP95** William B.P. and Waite D., The Design and Construction of Sheet-Piled Cofferdams, Special Publication 95, 1993.

8) **BS8002:1994** Code of Practice for Earth Retaining Structures.

9) **BS EN 1997-1:2004** Eurocode 7: Geotechnical Design – Part 1: General Rules.

10) **BRE SD1 2005**, Concrete in aggressive ground, Special Digest 1:2005 Third Edition, BRE Construction Division.

11) **Boscardin, M.B. & Cording, E.J. (1989)** "Building Response to Excavation-Induced Settlement", Journal of Geotechnical Engineering, ASCE, Volume 115 No. 1 Janunary 1989, pp1-21. *Note: This article is available at IEM Penang.*

12) **CIRIA Report 185** Nicholson D., Tse C.M., and Penny E.I.C, The Observational Method in ground engineering: principles and applications, CIRIA Report No 185, 214p, 1999.

13) **BS 8004:2015** Code of practice for foundations, BSI Standards Publication, p27.

14) **BS 8102:2009** Code of practice for protection of below ground structures against water from the ground, BSI Standards Publication.

5.0 APPENDICES

APPENDIX A

RECOMMENDED FORMAT OF GEOTECHNICAL REPORT FOR THE SUBMISSION REQUIREMENT

APPENDIX B

RECOMMENDED FORMAT OF INDEPENDENT GEOTECHNICAL CHECKER (IGC) REPORT FOR THE SUBMISSION REQUIREMENT

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CURRICULUM VITAE OF INDEPENDENT GEOTECHNICAL CHECKER (IGC)

EXECUTIVE SUMMARY

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NOTES:

a) IGC shall carry out independent assessment on the basement development which shall include numerical analysis, hand calculations, and or spreadsheet.

b) Any non-compliance shall be highlighted in the conclusion.

c) The independent assessment on the Dilapidation Survey report shall highlight any structures, buildings and/or infrastructures that are left out, and comment on the adequacy of the report.

d) The independent assessment on the Damage Prediction report shall highlight any structures, buildings and/or infrastructures that are left out, and comment on the adequacy of the report.

APPENDIX C1

EXPLANATORY NOTES/SUGGESTED CONTENTS FOR THE GEOTECHNICAL REPORT

Suggested contents with explanatory notes for the Geotechnical Report of basement excavation are as follows:-

1.0 INTRODUCTION

1.1 Name of the project and the developer

1.2 Names of submitting persons and consultants

1.2.1 C&S consultant

1.2.2 Geotechnical Design Consultant

1.3 Project description:
Locations, layout plan of proposed development, terrain description, adjacent properties, any major infrastructure (e.g. bridges, roads, river, channels, tunnels, pylons).

2.0 BUILDING STRUCTURES, RETAINING WALL, SUPPORT SYSTEM & FOUNDATION SYSTEMS

2.1 Number of storeys for proposed superstructures

2.2 Number of basements and excavation depths *[in text description and drawings]*.

2.3 Type of retaining systems selected for basement excavation:-

2.3.1 Type of retaining wall (temporary/permanent) for the basement excavation (e.g. diaphragm wall, secant pile wall, contiguous bored pile wall, sheet pile wall and gravity wall) *[in text description and engineering drawings]*.

2.3.2 Cross Sections of the proposed basement together with the retaining wall and support system *[to scale drawings]*.

2.3.3 Details of the wall including type of wall, height, depth, thickness, section, materials *[in text description and engineering drawings]*.

2.3.4 Type of support system for the wall (temporary/permanent) (e.g. ground anchors, strutting and top-down).

NOTES:

The design and selection of construction method, of cut-and-cover structures shall take into account at least the following:

a) Geology.

b) Hydrogeology and strata permeabilities in the vicinity of the excavation.

c) Lateral movements and settlements which would be expected in relation to existing structures shall be considered.

d) Depth of construction and its sequence of works.

e) Any particular difficulties that special plant might face with respect to access, clearance and working space.

f) Control over heave and instability of the base during excavation, and long-term settlement and heave.

g) The methods by which the completed structure shall be secured against floatation.

2.4 TYPES OF FOUNDATION *[in text description and engineering drawings]*

2.4.1 Foundation systems (shallow or deep foundation) (e.g. rafts, bored piles, driven piles, jack-in piles, micropiles and barettes).

2.4.2 Details of foundation including depth, dimensions, materials, etc.

2.5 Proposed construction method and sequence of construction for each stage of excavation and installation of support system *[in text description and engineering drawings].*

2.6 The description should include the influence of the basement excavation and foundation system adopted on the surrounding buildings, structure, like settlements and lateral displacement of surrounding buildings, potential cracks & noise level, etc.

3.0 Geology of the Site and Site Conditions

3.1 General geology of the site (substantiate with Geological Map, Geological memoirs).

3.2 Describe the site conditions and surroundings (e.g. terrain of the site, surrounding conditions and any river or water course).

4.0 Subsurface Investigations and Geotechnical Parameters

4.1 Describe the field tests and laboratory tests carried out for the subsurface investigation.
Note*: The Geotechnical Engineer shall have his own personnel to full time supervise the S.I. as required by the Board of Engineers Malaysia in circular 4/2005 "Engineer's Responsibility for Subsurface Investigation".*

4.2 Presentation of the subsoil/rock profile in cross-sections together with the borehole logs shown clearly in the cross-sections.

4.3 Subsurface investigation summary descriptions of the subsoil, rock, groundwater condition.

4.4 Groundwater conditions (levels) of the site (standpipes shall be installed to monitor the groundwater).

4.5 Subsurface investigation (S.I.)

4.5.1 Locations of boreholes or other field tests to be superimposed on the building plan layout plan.

4.5.2 Indicate the types of field tests carried out (e.g. Boreholes, Standard Penetration Test, Piezocones, Pressuremeters, Dilatometers, Trial Pits, Mackintosh probes, Plate Load Test, Permeability Test and Seismic Test).

4.5.3 Subsurface cross-sections with borelogs clearly show the Reduced Levels of ground, type of soils, results of in-situ tests (SPT "N", S_u etc.), rock (RQD, recovery), groundwater level and profile.

4.5.4 Description of the soil/rock profiles.

4.5.5 Describe any irregularities encountered during S.I. (if any) like sudden rise of water level, water gushing out, slump zone, sudden drop of water level, boulder, etc.

4.5.6 Plot results obtained from in-situ/field and laboratory tests (whenever available):

4.5.6.1 SPT "N" values vs. depth/reduced levels.

4.5.6.2 Undrained shear strength (c_u) (for clay) vs. depth/reduced levels.

4.5.6.3 Drained parameters, Φ' vs. depth/reduced levels (from CIU Tests and Shear Box Tests).

4.5.6.4 Uniaxial compressive strength of rock.

4.5.6.5 Coefficient of consolidation, c_v, c_h (if applicable e.g. in alluvium for clay layer) vs. depth/reduced levels.

4.5.6.6 Compressibility of soil e.g. CR, RR (if applicable e.g. in alluvium clay layer) vs. depth/reduced levels.

4.5.6.7 Yield stress of soil (P_c') (if applicable e.g. in alluvium clay layer) vs. depth/reduced levels.

4.5.6.8 Permeability of soils (m/sec) vs. depth/reduced levels (needed for retaining wall water cut-off design and hydraulic check).

4.5.6.9 Stiffness, (G,E) vs. depth/reduced levels (for prediction of wall and ground movements in numerical analyses).

***Note**: Factual report of the S.I. can be submitted as appendix in separate volume.*

4.5.7 If correlation are used to obtain the relevant soil parameters for all analyses, the following information should be supplied and described in the report:

4.5.7.1 Equations used and their relevancy.

4.5.7.2 Standards or literature referred to, and the details of the source should be reported.

4.5.7.3 Present graphs or plots used to correlate available basic soil parameters.

4.5.8 Full listing (tables) of all the soil/rock parameters and groundwater conditions used in the numerical analysis and hand calculations.

5.0 Geotechnical Design

5.1 Foundation Design

5.1.1 The adopted soil parameters for the design of the foundation:-

5.1.1.1 The adopted soil parameters should be related to the soil parameters described in Section 4.0 above and tabulated for easy reference.

5.1.2 Design and analysis methodology:

5.1.2.1 Standards, special reports or literature referred to, should be quoted and the relevant section attached in Appendix.

5.1.2.2 Method of analysis and design should be substantiated, with either computer or hand calculations. The details of analyses and designs should be elaborated in the report and this includes:

a) Design method.

b) Capacity of the foundation.

c) Factors of safety (FOS) used.

d) Depth/length/size of piles, and grades of concrete used.

e) Sizes of shallow foundation/deep foundation.

f) Serviceability tolerances (movements expected at working load).

g) Assessment of construction or installation method on the adjacent properties.

5.1.2.3 Show table of the proposed foundation (e.g. type of foundation, sizes, depth, rock socket (if any), working load and testing).

5.1.2.4 Design and analysis of various type of foundation proposed (calculations shall be include in the appendix).

5.1.3 Verifying Tests of Foundation

5.1.3.1 Number of preliminary piles to be tested and what type of tests.

5.1.3.2 Schedule of testing.

5.1.3.3 Number of working piles to be tested and what type of tests.

5.2 Retaining Wall and Support System Design

5.2.1 Overall Stability Check

5.2.1.1 Check for overall stability via limit equilibrium stability analysis.

5.2.1.2 Check for vertical stability of the wall under self weight and imposed load (e.g. from columns on the wall, inclined anchors, etc). Analysis method and FOS shall be similar to foundation.

5.2.1.3 All key information of input and output shall be clearly stated and attached in the appendix.

5.2.2 Basal Failure Check

5.2.2.1 Carry out analysis on basal heave failure check.

5.2.2.2 All key information of input and output shall be clearly stated and attached in the appendix.

5.2.3 Hydraulic Failure Check

5.2.3.1 Carry out analysis on hydraulic failure check such as using Terzaghi method. This check is to ensure the penetration depth of the wall is deep enough to have proper cut-off and prevention of hydraulic failure.

5.2.3.2 To prevent heaving due to artesian pressure (usually applicable for clay layer needs to be evaluated. Where necessary and appropriate, relief wells shall be used inside the excavation.

5.2.4 Numerical Analysis

As prediction of wall movements, and ground deformations of retained ground and groundwater changes are necessary for basement excavation, only full numerical analysis program is allowed.

5.2.4.1 Introduction of the Numerical Analysis Software used

a) Describe the numerical analysis program used (e.g. PLAXIS, CRISP and FLAC).

5.2.4.2 Numerical Analysis Input Parameters and Materials

a) The constitutive soil/rock model used in the numerical analysis.

b) Interface element used in the numerical analysis and its properties.

c) Model used in numerical analysis to model wall and support system (e.g. anchors or struts or top down).

d) Full listing of parameters adopted in table form. For each cross section analysed, a full set of parameters shall be presented to represent that particular section.

5.2.4.3 Numerical Analysis

a) Geometry of Model and Material model clearly shown on the numerical analysis mesh *[in printout of FEM Program with clear demarcation]*.

b) Calculation phases in numerical analysis (refer to stages of construction). All stages of modelling shall be tabulated in the table.

***Note**: Flowchart for the analysis is required to be carried out.*

5.2.4.4 Numerical Analysis Results and Findings

a) Present the bending moment and shear force envelopes of the wall element for each stage of excavation and final stage *[in printout of numerical analysis program output figure in colour and listed in table form].*

b) Present structural design of the wall element and support system (e.g. struttings, walers and inclined struts) *[Present clearly the design assumptions, results and analyses attached in appendix).*

c) Present deformation of the wall element for each stage of excavation and final stage *[in printout of numerical analysis program output figure in colour and listed in table form].*

d) Present deformation of the retained ground behind the wall for each stage of excavation and final stage *[in printout of numerical analysis program output figure in colour and listed in table form].*

e) Present deformation of the wall element for each stage of excavation and final stage *[in printout of numerical analysis program output figure in colour and listed in table form].*

f) Present total deviatoric strain (γ_s) of the subsoil model in the numerical analysis for each stage of excavation and final stage *[in printout of numerical analysis program output figure in colour].*

g) Present mobilised strength (τ_{mob}) of the subsoil model in numerical analysis for each stage of excavation and final stage *[in printout of numerical analysis program output figure in colour].*

5.2.5 Instrumentation and Monitoring Scheme

5.2.5.1 Proposed Instrumentation scheme

a) Type and number of instruments used.

b) Location of the instruments (to attach instrumentation layout).

c) Monitoring programme (frequency of monitoring) prior to, during and after construction of foundation works.

5.2.5.2 To prepare necessary monitoring trigger value (e.g. Alert, Action and Alarm) based on the design carried out for the basement excavation works. This is important to be clearly stated to ensure timely actions are taken to prevent uncontrolled movement in the wall and surrounding ground during excavation.

5.2.5.3 To list down the action plan for each trigger value of Alert, Action and Alarm.

6.0 Conclusions

7.0 References

7.1 Standards, special reports of literature referred to, should be quoted.

FLOWCHART for Design of Retaining Wall and Support System for Basement (REFERENCE)

1. Project information study
- ✓ Determine depth/area/ sequence of excavation.
- ✓ Understand project requirements/ specifications.

↓

2. Site location study
- ✓ Study the topography, hydrography, historical usage of site location.
- ✓ Study site condition surrounding excavation site and identify critical buildings/structures/ utilities.
- ✓ Determine the limit of work boundary.

↓

3. Subsurface information study
- ✓ Geological study.
- ✓ Determine subsoil profiles.
- ✓ Determine groundwater level.
- ✓ Determine soil/rock design parameters.

Insufficient SI → Propose additional subsurface investigation (SI).

Additional SI information ← (back to 3)

Sufficient SI ↓

4. Selection of suitable earth retaining system and construction sequence
- ✓ Select wall type and support system.
- ✓ Service period (temporary or part of permanent structure).
- ✓ Economic, workability and availability.
- ✓ Determine effective construction sequence (clearly specify in drawing).
- ✓ Risk assessment for the proposed options.

↓

5. Ultimate limit stage (ULS) analysis
- ✓ Moderately conservative soil/rock design parameters.
- ✓ Highest possible groundwater level during service period.
- ✓ Consider unplanned excavation (0.5m or 10% of excavation depth whichever deeper).
- ✓ Surcharge load (construction/operational load or minimum 10kPa whichever greater).
- ✓ Determine wall depth and support levels for following checks:
  - ➢ Wall stability check
  - ➢ Vertical stability check
  - ➢ Basal heave stability check
  - ➢ Hydraulic failures check
- ✓ Calculate wall bending moment, shear force and support load (ULS)

↓

6. Serviceability limit stage (SLS) analysis
- ✓ Moderately conservative soil/rock design parameters.
- ✓ Highest possible groundwater level during service period.
- ✓ Not consider unplanned excavation.
- ✓ Surcharge load (construction/operational).
- ✓ Follow wall depth and support levels in ULS analysis.
- ✓ Evaluate deformation of retaining wall and retained ground.
- ✓ Carry out damage assessment of surrounding buildings, structures and ultilities.
- ✓ Calculate wall deflection, bending moment, shear force and support load (SLS).

→

7. Worst case scenario (WCS) analysis
- ✓ One strut failure.
- ✓ Accidental impact load on strut.
- ✓ Flooded condition.
- ✓ Calculate wall bending moment, shear force and support load (WCS).

↓

8. Structural design
- ✓ Determine design value (ULS x 1.0 or SLS x 1.4 or WCS x 1.05 whichever is critical) for wall and supports.
- ✓ Crack width check (to design criteria).

APPENDIX C2

EXPLANATORY NOTES/SUGGESTED CONTENTS FOR THE DILAPIDATION ASSESSMENT REPORT

Dilapidation Survey Report

Dilapidation Survey report of Buildings and Structures within the Zone of Influence of Excavation (ZIE) shall be carried out before the construction stage of the development, and should contain the followings:-

1. The minimum limit of works (area) shall be extended from the edge of the excavation to the limit of 5 mm settlement contour obtained from numerical analysis (due to excavation of the basement and potential changes in groundwater OR at least 2 times the maximum depth of excavation (including pilecap and liftpit depth whichever is deeper) whichever is LARGER. This area of interest shall be defined as Zone of Influence of Excavation (ZIE).
2. Carry out visual inspection of the buildings and structures that are within the Zone of Influence of Excavation (ZIE) and also some selected area beyond that but could be of interest in the assessment. The works include :
   - 2.1 To identify the presence and types of structural defects
   - 2.2 To identify any sign of structural distress and deformation
   - 2.3 To identify any sign of material deterioration.
   - 2.4 To identify any sign of water seepage
   - 2.5 To identify any change of use of buildings, renovation and misused.
3. Each structure/building inspected shall have a clear reference number, location and address. Distances of these structures from the proposed site should be indicated.
4. Describe with the aid of figures, sketches and photographs visible signs of structural distress such as visible cracks due to shear movement, building settlement, tilt of building, settlement of ground, leakages, and others.
5. All reports shall include Visual Inspection Form for each structure/building inspected (inspection form shall state whether inspection is carried out internally and/or externally and whether permission to enter premise was denied or not).
6. The Visual Inspection Form shall cover all the aspects listed above and shall be attached with photos (in colour).
7. Both Hardcopy and Softcopy (in PDF) shall be submitted.
8. The Dilapidation Survey report shall be endorsed by a Professional Engineers or a Professional Engineer with Practicing Certificated registered with the Board of Engineers Malaysia (BEM).

APPENDIX C3

EXPLANATORY NOTES/SUGGESTED CONTENTS FOR THE DAMAGE PREDICTION REPORT

Damage Prediction Reports of Buildings and Structures within the Zone of Influence of Excavation (ZIE)

1. To prepare and submit a Damage Prediction report showing the contours of predicted settlement surrounding the excavation. The assessment will be based on the available survey information provided by the Surveyor employed by the Client.
2. The Damage Prediction report on the affected buildings/structures shall refer to same reference number and address used in the Dilapidation Survey report.
3. Analysis of tolerance and damage potential of buildings/structures with respect with the predicted settlements or lateral strains.
4. The Damage Prediction report for the buildings/structures within the Zone of Influence of Excavation (ZIE) will have the following details:
   - 4.1 Description and assessment of the building foundation.
   - 4.2 Site measurements, site photos and test results where appropriate (if applicable).
   - 4.3 Analyses and calculations to establish the building/structure response to the ground movements calculated due to the excavation works (check against lateral strain and differential settlement or angular distortion).
   - 4.4 Conclusion for each building/structure within the Zone of Influence of Excavation (ZIE) whether it is acceptable or not based on Boscardin & Cording (1989) damage criteria (Acceptable limits are : Negligible, Very Slight and Slight).

   Note*: The acceptable damage criteria based on Boscardin & Cording, 1989 is* ***"Slight"*** *Category.*

CATEGORY	ANGULAR DISTORTION β (x 10^{-3})	HORIZONTAL STRAIN ε_h (x 10^{-3})
Negligible	< ~ 1.1	> 0.5
Very Slight	~ 1.1 < β < ~ 1.6	0.5 < ε_h < 0.75
Slight	~ 1.6 < β < ~ 3.3	0.75 < ε_h < 1.5
Moderate	~ 3.3 < β <	1.5 < ε_h < 3.0
Severe	>~ 6.7	> 3.0

5. If the buildings/structures FAILED to achieve the acceptable damage criteria, then two options for the Geotechnical Engineer to consider :-

   Option 1 The basement excavation retaining wall and support system to be redesigned to ensure that all buildings/structures PASS the acceptable damage criteria.

   Option 2 The necessary strengthening and underpinning of the affected structures/ buildings to be proposed and obtain approval from the owners of the affected structures/buildings. Drawings and calculations are to be submitted to show the proposed strengthening and protective measures.

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