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Building Engineering Division
Fax: 63257482
Tel: 63257585

See Distribution List

Dear Sirs

ADVISORY NOTE 1/05 ON DEEP EXCAVATION

All temporary earth-retaining structures (TERS) for deep excavation must be structurally safe and robust. This Advisory Note on Deep Excavation sets out the minimum requirements for the design and construction of TERS for deep excavation. It consolidates the requirements of the Building Authority that had been notified to the industry from time to time and incorporates some other key aspects of good current practices on the design, instrumentation, monitoring and construction of TERS.

2 The requirements of this Advisory Note (copy attached) are for compliance by PEs, QPs, and builders in the design and construction of TERS. I would appreciate it, if you could disseminate its contents to your members. The Advisory Note is also available on our website: www.bca.gov.sg.

3 Please contact me or Mr.Yang Kin Seng at Tel 63257571 if you need any clarification. Thank you.

Yours faithfully

CHEW KEAT CHUAN
SENIOR MANAGER
BUILDING ENGINEERING DIVISION
For COMMISSIONER OF BUILDING CONTROL

Distribution List

President
Institution of Engineers, Singapore
70, Bukit Tinggi Road
Singapore 289758
iesnet@singnet.com.sg

President
Association of Consulting Engineers, Singapore
70, Palmer Road #04-06
Palmer House
Singapore 079427
acesing@starhub.net.sg

President
Singapore Contractors Association Limited (SCAL)
Construction House
1 Bukit Merah Lane 2
Singapore 159760
enquiry@scal.com.sg

President
Professional Engineers Board, Singapore
1st Storey, Tower Block, MND Complex
5 Maxwell Road
Singapore 069110
registrar@peb.gov.sg

Controller
Building Control Unit
Jurong Town Corporation
The JTC Summit
8 Jurong Town Hall Road
Singapore 609434
josephl@jtc.gov.sg

Manager
Development & Building Control Department
Land Transport Authority
251, North Bridge Road
Singapore 179102
Kok_Hwa_GOH@lta.gov.sg

Senior Manager
Building Control Unit
Defence Science & Technology Agency
1 Depot Road #12-05
Singapore 109679
kkahhock@dsta.gov.sg

Head
Plan Approval (C&S) Unit
Building Quality Department
Housing & Development Board
HDB Hub
480 Lorong 6 Toa Payoh
Singapore 310480
ckc3@hdb.gov.sg

ADVISORY NOTE 1/05 ON DEEP EXCAVATION

1 All temporary earth-retaining structures (TERS) for excavation shall be structurally safe and robust. The requirements of this Advisory Note on deep excavation shall be complied with by Professional Engineers (PEs), Qualified Persons (QPs) and builders in the design and construction of TERS. The Advisory Note covering key aspects pertaining to the design and construction of TERS for excavation of four metres or deeper is as follows:

Section A: Site Investigation

- Codes and Standards
- Extent of Investigation
- Ground water conditions
- Existing building conditions

Section B: Design

- Design considerations
- Factor of Safety
- Soil Parameters
- Water pressures for design
- Robustness of design
- Numerical Modelling
- Sensitivity Analysis
- Jet Grouted Piles

Section C: Construction

- Multi-tier level monitoring
- Design review
- Independent checks
- Site inspection and approvals

Section D: Instrumentation and Monitoring

References

Section A: Site Investigation

2 Codes and Standards. Proper site investigation shall be carried out for the design and construction of TERS so as to give a thorough understanding and determination of the type and character of the ground conditions, and ground water conditions. It is guided by standards and codes of practices which include:

- *BS 5930:1999 Code of Practice for Site Investigations*
- *BS 1377:1990 Methods of Test for Soils for Civil Engineering Purposes*
- *BS 8002:1994 Code of Practice for Earth Retaining Structures*
- *BS 8081:1989 Code of Practice for Ground Anchorages*

3 Extent of investigation. The number of exploration or investigation points including boreholes shall provide the information required to establish adequately the ground conditions and its variability along the length of the proposed wall for purposes of TERS design and construction controls.

4 At critical areas and excavation in difficult grounds, spacing and location of exploration points shall be related more closely; and additional boreholes/cone penetration tests shall be conducted between boreholes to establish any ground variability and to delineate the penetration depth of the retaining walls.

5 For ground anchorages, the locations should also be sited along the line of the probable fixed anchor zone.

6 Ground water conditions. Water levels encountered during boring operations are known to be unreliable and they seldom represent equilibrium conditions. Standpipes and piezometers shall be installed to determine the ground water conditions and pore water pressures. Establishment of ground water conditions shall also include tidal and flood conditions.

7 Existing Building Conditions. Pre-construction surveys shall be carried out to establish the condition of adjacent properties including obtaining the plans of existing buildings and structures. Special attention shall be paid to those buildings or structures that are sensitive to settlements.

Section B: Design

8 Design considerations. The design of TERS shall take into account the key design considerations tabulated in Table 1 at Annex A.

9 Factor of Safety. TERS shall be designed with an adequate safety factor that is not less than that of permanent works[1] and the calculations shall take full account of the tolerances adopted. Among other considerations, the factor of safety shall take into account abnormal risks or unusual or difficult ground or loading conditions,

[1] *This shall supercede such provisions as clauses 5.2.3 and 5.2.4 of CP4:2003 Code of Practice for Foundations which suggest that for temporary works, a lower factor of safety may be considered or material overstress is allowed.*

soil characteristics, extreme soil and groundwater conditions, need to restrict deformation, the consequence of failure and the impact of surrounding properties.

10 For structural steelwork of TERS, BS 5950 on Structural Use of Steelwork in Building shall be followed.

11 Soil Parameters. In assessing the shear strength, influence due to factors such as stress level imposed on the soil, strain rate effects, large strain situation, time effects, and sensitivity shall be considered. The values for the representative strength values shall make due allowance for the influence of sampling and the method of testing as well as for likely softening on excavation.

12 Water pressures for design. Water pressure regime used in the design shall be the most onerous that is considered to be reasonably possible for both active pressure and passive resistance. This includes the potentially high pore water pressure on the passive side.

13 Robustness of design. As a minimum, all types and conditions of loading on TERS shall be identified for design, which must be robust and incorporate sufficient redundancy to avoid catastrophic collapse of support system resulting from an isolated case of overloading or failure of any particular element.

14 In addition to the earth pressures under all identifiable conditions and surcharge/building loads, the design of TERS shall also consider

- accidental load
- one-strut failure
- material deficiencies and construction imperfections
- abnormal loads, particularly from construction surcharges, and higher groundwater levels caused by flooding or water-filled tension cracks;
- eccentric loads or out-of-balance forces and reactions from the support systems, both temporary and permanent e.g. due to inclined anchors or struts

15 Numerical Modelling. Experienced users with fundamental understanding of soil mechanics and clear understanding of numerical modelling shall supervise the use of advanced numerical analyses e.g. use of finite element method in geotechnical design. On the use of computer software, the users are advised to follow the guidelines in "*The use of computers for engineering calculations*" published by The Institution of Structural Engineers, UK (Mar 2002).

16 Sensitivity Analyses. For deep excavation and excavation in difficult sites, the designer shall not rely merely on ‘one-off’ analysis, in which a single set of geotechnical parameters is used, and the results of the analysis then taken as ‘the prediction’ of deformations, loads and stresses. The analyses shall include variations in the input parameters within a reasonable range corresponding to those actually determined from the site investigation and ground conditions, and to examine critically the effects of such variations on the computed deformations, loads and stresses.

17 Sensitivity analyses shall be performed as part of the design to demonstrate that the design and the models are not unduly sensitive to variations in any of the input parameters such as shear strength, soil stiffness and reduced wall stiffness due to cracking. It shall also cover the effect of time on the soil conditions and its impact on the performance of TERS.

18 Jet Grouted Piles (JGP). The use of JGP shall be restricted to ground strengthening or soil improvement works. It shall not be used as a compressive strutting system for TERS.

Section C: Construction

19 Multi-tier level Monitoring. In addition to the critical levels based on the final values, the pre-determined levels shall be set for each strutting level. The excavation will only proceed if the monitored performance for current level is within the pre-determined set for that strutting level. Otherwise, the design shall be reviewed with new analyses to be undertaken to estimate the final performance, and to re-assess and evaluate the design adequacy for all remaining stages. These results shall also be checked independently.

20 Design Review. The performance of TERS shall be monitored. A comprehensive design review shall be carried out when soil movement has exceeded work suspension level or any structural element of TERS has exceeded the design level or where there is structural distress. The works shall be stopped and made safe pending the outcome of the review. Construction shall not proceed until proper remedial actions have been put in place. As a minimum, the review shall include full analyses with justifications and validation for the design to be performed to assess and check on requirements for stability and to ensure that all minimum mobilisation factors, load factors and safety factors including robustness considerations are adequately met.

21 The design and its assumptions shall be reviewed based on observed performance with recommendation on design modifications, preventive/contingency measures and working procedures to ensure safety of the excavation and to prevent unacceptable impacts on the surrounding buildings and other properties.

22 Independent Check. The design and construction of TERS shall be checked and reviewed independently by Qualified Person. The main tasks for such checks are listed in Table 2 at Annex B.

23 Site Inspection and Construction Control. The builder shall obtain the appropriate approvals from the PEs for the TERS and the QP using the form in Annex C, before proceeding with any excavation at critical stages and at every strut level. For ground movement monitoring control at every strut level, the form on Ground Movement Assessment Record at Annex D shall be used.

Section D: Instrumentation and Monitoring

24 As a minimum, monitoring of wall and ground movements/deformation, strut loads and piezometric pressures shall be carried out within and outside the excavation to provide data for design review on the performance. Control sections of TERS shall be identified and adequately instrumented with the validation or calibration between the design/predicted and actual values to be verified as early as possible during the construction stage.

25 The strain gauges for member forces shall be properly installed, calibrated and checked for meaningful interpretation and monitoring as the readings could be affected by many factors such as non-uniform stresses, temperature, joints, strut installation and pre-loading.

26 Caution shall be exercised when evaluating strut force by hydraulic jacking. In addition to the use of calibrated jacks, the loads shall be independently confirmed by calibrated load cell.

References

27 References include the following:

- BS 5930:1999 *Code of Practice for Site Investigations*
- BS 1377:1990 *Methods of Test for Soils for Civil Engineering Purposes*
- BS 8002:1994 *Code of Practice for Earth Retaining Structures*
- BS 5950-1:2000 *Structural Use of Steelwork in Building*
- BS 8081:1989 *Code of Practice for Ground Anchorages*
- BS EN 12716:2001 *Execution of Special Geotechnical Works - Jet Grouting*
- *Temporary Propping of Deep Excavations - Guidance on Design,* CIRIA C517, 1999
- *Design and Construction of Deep Basements including Cut-and-Cover Structures*, IstructE Publication, UK, 2004
- *Guidelines of Engineering Practice for Braced and Tied-back Excavations*, Geotechnical Special Publication No. 74, ASCE
- *Review of Design Methods for Excavation,* Geotechnical Engineering Office, Civil Engineering Department, GCO Publication, Hong Kong
- *The Use of Computers for Engineering Calculations* by The Institution of Structural Engineers (Mar 2002)

Annex A

Table 1: Design considerations on TERS

Key design considerations on TERS

- Adequate site investigation;
- Proper selection of the soil parameters for design;
- Effects due to onerous water pressures and seepage forces;
- Effects under both drained and undrained conditions of the soils, as well as the effect of time on soil drainage conditions;
- Effects of surcharge loads, including incidental loads, construction loads, adjacent slope, adjacent structures etc;
- Varying load conditions during stages of the construction
- Design robustness and redundancy considerations which shall include one-strut failure, accidental loads etc;
- Adequacy of wall embedment;
- Overall wall stability and basal heave;
- Structural adequacy of supporting system e.g walers, struts, anchors etc, including provision of adequate stiffeners;
- Provisions of restraints in structural members' connections, ties and bracings
- Sensitivity analyses and impact on the performance of TERS;
- Effects due to ground water lowering;
- Effects of ground deformation on neighbouring properties.

Specific Controls on Design

- Surcharge load of at least 10kN/sq m, construction loadings, and loads from adjacent existing structures and usage etc;
- No allowance for any material overstress*;
- One-strut failure and accidental loads;
- Full water table level or onerous water conditions and seepage pressures acting on both sides on the wall;
- Factor of safety for the design of TERS shall not be less than that for permanent works*;
- Mobilization factors of not less than 1.2 and 1.5 for effective stress and total stress parameters respectively for limit equilibrium calculations; and
- Unplanned excavation.

Note:
**This shall supercede such provisions as clauses 5.2.3 and 5.2.4 of CP4:2003 Code of Practice for Foundations which suggest that for temporary works, a lower factor of safety may be considered or material overstress is allowed.*

Annex B

Table 2: Main Tasks for Checks on TERS

Main tasks for checks on TERS include:

1. Independently review and check the design and construction of TERS to satisfy that the TERS is structurally safe and adequate, and is in accordance to the building codes and regulations. As a minimum, it shall take into account the following:
   - Appropriate standards and codes of practice for TERS;
   - Adequate site investigation and tests;
   - Appropriate soil parameters e.g. strength and stiffness; undrained and drained conditions of soils, effect of time on drainage conditions, effective stress parameters, and in-situ stresses;
   - Surcharge load and loads from the adjacent existing structures and usage;
   - Construction, incidental and abnormal loads etc;
   - Varying load conditions during stages of the construction;
   - Onerous water conditions and seepage pressures acting on both sides of the wall;
   - Robustness and redundancy considerations e.g. accidental strut removal and one-strut failure;
   - No allowance for any material overstress*;
   - Factor of safety for the design of TERS shall not be less than that for permanent works*;
   - Appropriate mobilisation factors for effective stress and total stress analyses for limit equilibrium calculations;
   - Impact on TERS due to soil drainage conditions with time;
   - Basal heave, overall wall stability and adequate wall embedment;
   - Structural adequacy of supporting system e.g walers, struts, anchors etc;
   - Adequacy in structural members' connections, ties and bracings;
   - Effects due to ground water lowering; and
   - Effects of ground deformation on neighbouring properties.

2. Before the commencement of TERS, review and check that the instrumentation and monitoring plan, measures to prevent damages to neighbouring structures, and the critical limits set for the works are acceptable and adequate;

3. At critical stages, inspect the site and review the actual site conditions and monitoring data to assess and evaluate the performance of the structural supporting system to ensure that the structural adequacy of TERS shall be maintained;

4. Carry out independent review and check on any amendment on TERS which have or would have structural or stability implications.

Note:
***This shall supercede such provisions as clauses 5.2.3 and 5.2.4 of CP4:2003 Code of Practice for Foundations which suggest that for temporary works, a lower factor of safety may be considered or material overstress is allowed*.**

Annex C

SITE INSPECTION & APPROVAL RECORDS

Project Ref:. _____ **Project Name:** _____

(This report is to be promptly updated by the PE for TERS and builder at every strut level and timely submitted to the QP. The QP must ensure that a copy of each of these completed reports is kept on site)

Location/Section: _____

Stage of TERS Erection	Depth of strut level* from ground surface	Dates of PE's site inspections of embedded walls/piling/ TERS**	Grid references of areas inspected	PE"s approval given to builder to proceed with excavation to next level. (Sign & Date)	Comments
Installation of embedded walls for TERS	N.A				
At Strut level no. 1					
At Strut level no. 2					
At Strut level no.( )					

Notes: * Strut level is measured from the ground surface downwards.

** TERS refers to the temporary earth retaining structures or system including embedded walls, earth berms, struts, walers, connections, kingposts, all structural components and measures which are integral in ensuring stability and structural integrity.

I confirm that the above information is accurate and correct and I am satisfied that TERS as constructed are fully in accordance with my design calculations and construction plans. I have given the approval to the builder to proceed excavation/construction to the next level/stage.

_____

Name, stamp & signature of PE for TERS **Date :** _____

I confirm that I have constructed the TERS according to the PE's plans and design calculations; and upon the completion of each and every strut level, I have obtained the PE's approval before further excavation to the next level.

_____

Name, stamp & signature of builder **Date :** _____

Comments by the Qualified Person :-
I have inspected the site and am satisfied with the performance of TERS. I agree with the PE's approval for the builder to proceed excavation/construction to the next level/stage. My other comments are : _____ **Name, stamp & signature of Qualified Person for Structural Works** **Date :** _____

Annex D

GROUND MOVEMENT ASSESSMENT RECORD

Project Ref:. _____ **Project Name:** _____

(This record is to be completed by the QP promptly upon the completion of every strut level and a copy must be kept on site)

Location/Section: _____

1 Assessment of ground movements:

a I have assessed the results taken from the monitoring instrumentation and site observations. The maximum measured movements are:
Wall lateral deflection : _____ mm

Ground settlement reading : _____ mm

b I have inspected the site and its neighbouring areas, and assessed the performance of TERS as constructed; and I am satisfied that TERS is structurally adequate and the works can safely proceed to the next excavation stage.

2 Actions taken

a * I am not satisfied with TERS as installed and its performance, and its shortcomings are as follows:

_____
_____
_____

b * I have taken the following immediate actions:

_____
_____
_____

_____
Name, stamp & signature of Qualified Person for Structural Works **Date:** _____

3 Taking of monitoring readings:

a I confirm that the TERS have been constructed according to the construction plans and design calculations endorsed by the PE.

b I have also witnessed the taking of readings from the monitoring instruments from _____ to _____ (dates). I have kept a record of the dates and times of these events including the construction/excavation activities.

Other comments:

_____
Name & signature of Site Supervisor **Date:** _____
Note: * delete if not applicable