

Our Ref : APPBCA-2017-11

15 Sep 2017

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See **Distribution**

Dear Sir/Madam

REQUIREMENTS ON BORED TUNNELLING WORKS

Objective

This circular is to inform the industry the control framework of safety requirements for bored tunnelling works. The framework aims to mitigate risks associated with bored tunnelling works in order to ensure structural stability of buildings and structures, and public safety. The requirements are applicable to projects involving tunnelling works carried out using Tunnel Boring Machines (TBM) under the category of Geotechnical Building Works (GBW).

Background

2 Over the past few months, BCA has met up with Institution of Engineers Singapore (IES), Association of Consulting Engineers Singapore (ACES), Geotechnical Society of Singapore (GeoSS) and BCA-Industry Joint Tunnelling Working Committee (JTWc) to gather feedback on the control framework in enhancing safety of bored tunnelling works. This circular, which has incorporated input from the professional institutions, is for compliance by Qualified Persons ("QP"), Accredited Checkers ("AC"), site supervisors, builders and developers with immediate effect.

Control framework for bored tunnelling works

3 Bored tunnelling works can cause unintended consequences of excessive settlements and depressions, if not managed properly. A rigorous control framework is required to ensure structural stability of buildings and infrastructures in close proximity to bored tunnelling works (see **Annex 1**) and to safeguard public safety during tunnelling.

The control framework consists of:

- | | | |
|------|--|--------------------------|
| i) | risk matrix for tunnelling works | (see Annex 2) |
| ii) | mitigation measures for various risk categories | (see Annex 3) |
| iii) | control measures for over-excavation | (see Annex 4) |
| iv) | specific conditions of permit for bored tunnelling works | (see Annex 5) |
| v) | form TUN_GBw_AnnexC-3 for records of excavation volume | (see Appendix A) |

4 The risk matrix categorises the risks of bored tunnelling works based on proximity to buildings and ground conditions. The risk categories are to be determined by QP(Design)s (“QP(D)”) and shown in the approved plans. For each risk category, suitable mitigation measures as listed in **Annex 3** shall be implemented during bored tunnelling works.

5 It is important to note that QP(Supervision) (“QP(S)”) must take all reasonable steps and exercise due diligence to ensure that there is no over-excavation during tunnelling works. Nevertheless, it is still essential to monitor the likelihood and any incidence of over-excavation during tunnelling. A flow chart summarising the actions to be taken when there is over-excavation is shown in **Annex 4**. QP(D)s are to develop the details based on this Annex, including the workflow, and indicate on the approved plans. QP(S)s are to implement the new TUN_GBW_AnnexC-3 form “Site Inspection & Approval Records for Tunnelling Works – Records of Excavation Volume” in **Appendix A** for tunnelling in close proximity to buildings and in mixed face condition.

6 The specific conditions of permit relating to bored tunnelling works are listed in **Annex 5**. They include requirements on supervision of bored tunnelling works, emergency preparedness plan and incident reporting.

Requirements on submission of structural plans

7 For projects involving GBW bored tunnelling works, the following details, reports and documents must be incorporated into the structural (ST) plan submission:

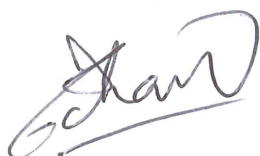
- a. Pursuant to regulations 10A(3) and 10A(6) of the Building Control Regulations, QP(D) and QP(Geo)(D) shall assess and specify on plans the risk category of each section of tunnel. The applicable items listed in **Annex 3** shall be incorporated in the plans.
- b. An impact assessment report pursuant to regulation 10A(2)(f) of the Building Control Regulations, must contain QP(D)’s and QP(Geo)(D)’s assessment on the building’s response to ground movement caused by tunnelling works and their recommendations on the measures to be taken to prevent any ground movement which may cause damage to or impair the stability of the buildings.
- c. Pursuant to regulation 10A(2)(h) of the Building Control Regulations, a report setting out a list of buildings and the risk categories for buildings located in close proximity to the tunnelling works, as well as their details including address of building, photograph, type of foundations, horizontal distance of building from tunnel, number of storeys and number of dwelling units for each building, emergency preparedness plan (including arrangement for decanting) and communication plan.
- d. Pursuant to regulation 10A(2)(h) of the Building Control Regulations, a flow chart with allowable over-excavation limits as determined by QP(D)s, developed based on **Annex 4**.

8 In accordance with section 10 of the Building Control Act, QP(S) is reminded and strongly advised to ensure all tunnelling works are supervised at all times by a resident engineer from the team of site supervisors as prescribed in Regulation 24 of the Building Control Regulations.

9 Nothing contained in this circular is meant to attempt to or to replace the QPs' exercise of professional judgment (a) in the preparation of plans for submission to BCA and/or (b) during the carrying out of building works. QPs are to exercise their independent professional judgment in preparing their plan submissions. Where applicable, QPs are expected to, given the circumstances at hand especially in adverse and highly variable ground conditions, incorporate more stringent and/or additional requirements when building works are being carried out.

10 I would appreciate it if you could disseminate the contents of this circular to your members. Please contact Er. Dr. Poh Teoh Yaw or Er. Kong Tze Foong at Tel 1800-3425222 or email bca_enquiry@bca.gov.sg should you need any clarification. Thank you.

Yours faithfully



Er. CHAN BEE BEE
DEPUTY GROUP DIRECTOR
BUILDING ENGINEERING GROUP
For COMMISSIONER OF BUILDING CONTROL

ATTACHMENTS

Annex 1	Definition of close proximity to existing buildings
Annex 2	Risk categories for various tunnelling conditions
Annex 3	Tunnelling risk categories and mitigation measures during design/construction stages
Annex 4	Flow chart summarising actions to be taken when there is over-excavation
Annex 5	Specific Conditions of Permit for Bored Tunnelling Works
Appendix A	TUN_GBW_AnnexC-3 form – Records of Excavation Volume

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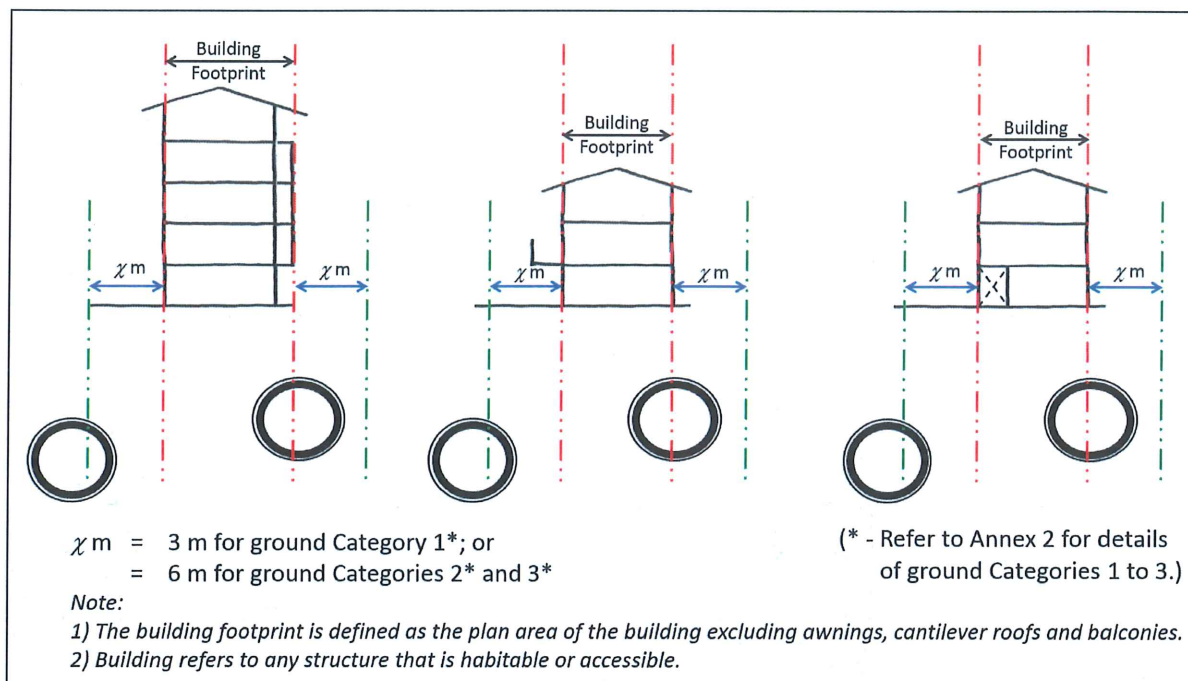
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Definition of close proximity to existing buildings

Bored tunnelling works i) underneath the buildings; or ii) located within a horizontal distance of χ m from the external edge of the building footprint are defined as in close proximity to existing buildings.



Annex 2

Risk Categories for various tunnelling conditions			
	Category 1: Fresh to moderately weathered rock / Hard residual soil / Hard OA	Category 2: Ground other than Categories 1 and 3	Category 3: Mixed Face [^]
Case 1: Greenfield	Low	Low	Medium
Case 2: Building within tunnelling influence zone	Low	Medium	High
Case 3: Tunnelling directly or partially underneath buildings (Case 3a) or within a horizontal distance of χ m from the building (Case 3b)	Medium	High	High

[^]Mixed face refers to the presence of:-

- a) boulder/core-stone; or
- b) rock (grade III or less weathering) with rock content between 25% to 80%; or
- c) rock content < 25% in which the rate of advancement of TBM drops by more than 50% below normal average due to ground condition; or
- d) interface between soft soil and hard soil, for example between Marine Clay and OA.

Tunnelling risk categories and mitigation measures during design/construction stages			
Risk Category	ID	List of Required Mitigation Measures	Project Party(s) Responsible
Low	1	Assess suitability of the TBM for the ground condition and make modifications as necessary, such as adjusting the opening ratio of TBM cutterhead, changing the type of cutting tools, installing or removing grizzly bar prior to the launching of the TBM and during tunnelling operations.	Builder / QP(S)
	2	Weekly review of ring look-ahead drawings where KPIs and adjacent building or structure are identified for each ring and tunnelling KPIs are confirmed.	QP(S)
	3	Establish KPIs and the allowable limit for over-excavation, all to be shown on approved plans.	QP(D)*
	4	Continuous monitoring of KPIs such as excavated volume, thrust force, torque, rotation, penetration, speed, face pressure, grout pressure, flow rate/density etc.	Builder / QP(S)
	5	Assess type and volume of spoil removal per ring and adjust KPIs accordingly.	QP(S)
	6	Establish a procedure to holistically assess over-excavation, taking into consideration the key factors that will affect the reliability of each of the muck mass/volume measurement methods and other appropriate measurement systems. Assess the possible areas of over-excavation during tunnelling and validate with muck reconciliation.	QP(S)
	7	Submit a method statement for tunnelling works to QP(S) for acceptance.	Builder
	8	Adjust TBM PLC (programmable logic controller) to monitor KPIs, sound alarm and send SMS alert on breach of over-excavation limit and face pressure allowable limits to Tunnel Manager and QP(S)'s team, and apply cut-off when allowable over-excavation limit is breached.	Builder
	9	Plan in advance to identify adequate safe locations and target face pressures for CHI.	QP(D)*
	10	Provide recommendations for each CHI (planned and unplanned) to builder. Recommendations shall include, but not limited to, design analyses for each CHI and method statement, including procedure of adjusting compressed air pressure or reducing to free air during CHI, instrumentation etc.	QP(D)
	11	For each CHI (planned and unplanned), QP(S) to comply with Tunnel Annex C-2 and implement ground improvement if required. QP(S) shall monitor the work closely including instrumentation reading on ground response at least once every 6 hours, face log, water ingress observations and face stability. At all unplanned cutter head interventions when the tunnelling works encounter difficulties or unforeseen or unexpected problems, QP(S) and Builder shall carry out probes and grouting from surface of the area, where appropriate, before tunnelling work recommences.	QP(S) QP(S) / Builder
	12	Assess the instrumentation results and CHI records to determine whether the TBM is safe to proceed. QP(S) to comply with Tunnel Annex C-1.	QP(D) / QP(S)

Low	13	QP(D) and QP(S) to assess adequacy of soil data and to request for more site investigation if required.	QP(D) / QP(S)
	14	Implement 24-hour ground surface watchman on TBM drive.	Builder
	15	Establish work suspension limit and action plans specific to tunnelling works.	QP(D)*
	16	Seek approval for flushing from QP(S).	Builder
Medium	17	[For Case 3 which involves tunnelling in close proximity to buildings] Site investigation boreholes are to be provided, as a minimum, one on each side of the building when tunnelling underneath the building, or along the side of the building when tunnelling in close proximity to the building. In addition, mapping out of a continuous profile of ground condition along the tunnel alignment using suitable investigative methods is to be carried out when there is a potential mixed face condition. <i>It is recommended that boreholes are to be located at least 1.5m away from the extrados of the TBM alignment.</i>	QP(D)*
	18	[For Case 3 which involves tunnelling in close proximity to buildings] Submit a schedule for tunnelling in close proximity to each building during Permit application and provide updates to BCA whenever there are any changes.	QP(S)
	19	Deploy full time Site Supervisors (SS) at the impacted buildings (to which tunnelling work is in close proximity) to observe signs of distress on the ground and/or structure when the TBM is progressing within the control zone. <i>Control zone is defined as a zone covering the impacted building plus (i) 20m before and after the impacted building; or (ii) a distance equivalent to the depth from the ground to the spring line of the tunnel, before and after the impacted building, whichever is less.</i> QP(S) or SS shall inspect the building on a daily basis and witness instrumentation monitoring.	QP(S)
	20	Ensure builder carry out secondary grouting via segment ports when over-cut sensor readings exceed the contract specification.	QP(S) / Builder
	21	When over-excavation is suspected, ensure builder carry out investigation to detect potential void and grouting of the identified void.	QP(S) / Builder
	22	Ensure builder implement, act on and report SMS alert on breach of tunnelling KPI and allowable over-excavation volume.	QP(S) / Builder
	23	Ensure builder implement a transverse ground instrumentation monitoring array to validate TBM KPIs just before going underneath/near a structure or building.	QP(S) / Builder
	24	Ensure builder carry out CHI to ensure TBM is in good condition before entering the control zone.	QP(S) / Builder
	25	Design and implement building protection measures, such as ground improvement, recharge well or building strengthening if required.	QP(D)* / Builder
	26	[For Case 3 which involves tunnelling in close proximity to buildings] Provide instrumentation monitoring on buildings, including: • 3D prisms, tiltmeters – real-time or 3 hourly • settlement markers, tape extensometers – daily • vibration meters – continuous monitoring The above instrumentation monitoring shall be applicable throughout the period when the face of the TBM is within 20m from the building.	QP(D)*

Medium	26 Con't	Provide instrumentation including borehole extensometers, piezometers, water standpipe, settlement markers and inclinometers. <i>Note: all the instruments are to be provided, as a minimum, on both sides of the building. Borehole instruments directly above the tunnel should be terminated at least 2m above the tunnel crown.</i>	
	27	[For Case 3 which involves tunnelling in close proximity to buildings] Review 4 hourly I&M results and Tunnelling Key Performance Indicators (KPI) as defined in QP(D)'s drawings. Submit a summary of monitoring results and assessment report to BCA at least once daily when the TBM is located within the control zone.	QP(S)
	28	No Flushing in TBM.	Builder
	29	[For Case 3 which involves tunnelling in close proximity to buildings] Develop an emergency preparedness plan (including arrangement for decanting) and a communication plan as contingency.	Developer
	30	[For Case 3 which involves tunnelling in close proximity to buildings] Assess the need to carry out appropriate grouting at the front of TBM shield.	QP(S)
	31	[Required for the following buildings under Case 3: • Tunnelling underneath and within a horizontal distance of 3m from the buildings – Category 1 (Medium risk) • Tunnelling underneath and within a horizontal distance of 6m from the buildings – Categories 2 and 3 (High risk)] QP(D) to carry out detailed structural assessment, taking into consideration the existing condition of the building, to establish <u>ALL</u> of the following building capacity limits: a) Building Settlement (monitored using building settlement markers or equivalent). b) Differential Building Settlement between 2 immediate adjacent columns (monitored using building settlement markers or equivalent). c) Tilt (monitored using tiltmeters or prisms). The above building capacity limits and the "Specific actions for QP(S) upon the breach of Building limits" are to be included in the approved plans. <u>Specific actions for QP(S) upon the breach of Building limits</u> i) Upon breach of Work Suspension Limit of any of the above items, QP(S) shall carry out inspection on the building at least once daily to ascertain if there are any signs of building distress; and submit to CBC daily his certification of structural integrity of the building and assessment of any safety concern; and his recommendation on safety measures and the need for decanting. ii) QP(S) shall recommend to CBC the activation of decanting plan upon: 1) breach of building capacity limits of a) or b) or c), in combination with signs of structural distress on key structural elements; or 2) occurrence of structural cracks on key structural elements that lead to concerns on structural safety.	QP(D)* QP(D)* / QP(S)

High	32	(For High risk categories under Case 3) Assess and submit the assessment report to BCA on the need to: a) change the alignment; or b) temporarily decant the occupants; or c) provide ground improvement or strengthening/underpinning building foundation to ensure tunnelling works pass through safely.	QP(D)
	33	Provide full contingency measures on standby at critical locations. The measures shall include but not limited to, drilling and grouting capabilities.	Builder
Note: 1) The required mitigation measures for each tunnelling risk category is cumulative of the measures in all the lower risk category(s). For Low risk category, mitigation measure ID1 to ID16 shall be applicable; for Medium risk category, mitigation measures ID1 to ID31 shall be applicable; for High risk category, ID1 to ID33 shall be applicable. Should QP(D) and/or QP(S) assess that any of the required mitigation measures is not appropriate in any particular situation, he/they may propose a more appropriate alternative mitigation measure for BCA's acceptance. 2) * - Items to be shown on approved plans.			

Actions to be taken when there is over-excavation			
% over-excavation <u>detected</u> at the end of each ring excavated			
> 10%* rolling average of 5 rings	Over-excavation suspected; or > 15% *# for single ring		> 25%* for single ring
↓	↓		↓
	i) Immediately suspend TBM excavation and advancement. ii) For Case 3, carry out appropriate grouting at the front part of TBM shield. For Cases 1 and 2, QP to review the need for grouting at the front part of TBM shield. iii) Notify BCA.		
	↓		↓
	Verify over-excavation volume via 2a) or 2b) of the explanatory notes below		
	↓	↓	
	If <u>verified</u> over-excavation ≤ 15% *#	If <u>verified</u> over-excavation > 15% *#	
	↓	↓	
QP(S) shall review the need for probe drilling and grouting from ground surface	QP(S) shall review the need for probe drilling and grouting from ground surface	Carry out probe drilling and grouting etc. as per item 3) of the explanatory notes below	Carry out probe drilling and grouting etc. as per item 3) of the explanatory notes below
	↓	↓	↓
Notify BCA before re-start of TBM excavation and advancement			

* - QP(D) may propose limits not exceeding the values indicated.

- These values shall be identical.

Annex 4 explanatory notes - applicable to GBW tunnelling work only

- 1) When the rolling average of 5 rings indicates an over-excavation volume exceeding 10%, QPs shall review the need for probe drilling and grouting from ground surface and proceed to implement necessary measures to mitigate risk of ground movements.
- 2) When over-excavation is suspected or when the readings indicate an over-excavation volume exceeding 15% at the end of any ring excavated, the Builder and QPs shall immediately suspend TBM excavation and advancement. Builder and QPs shall proceed to carry out, for tunnelling in close proximity to building, appropriate grouting at the front part of TBM shield; or for other cases, QPs shall review the need for grouting at the front part of TBM shield. QPs and Builder shall notify BCA immediately.

The Builder and QPs shall subsequently verify the magnitude of over-excavation volume by adopting a holistic assessment, comprising but not limited to:

- a) muck reconciliation for slurry TBMs using i) dry mass computation, ii) total volume measurements, iii) belt weigher, and iv) volume calculations of STP separated muck including gravel, sand and fines for each tunnel ring; or

- b) muck reconciliation for EPB TBMs using i) muck skip counts and ii) gantry crane weigher.

In addition, QPs shall also review tunnelling operational parameters (of TBM KPIs, slurry, conditioners), assess the observations made on the ground surface and readings of deep monitoring instruments in close proximity to the location where the over-excavation is suspected/indicated through readings.

If the over-excavation volume is verified to be less than or equal to 15%, QPs shall review the need for probe drilling and grouting from ground surface and proceed to implement necessary measures to mitigate risk of ground movements. QPs shall notify BCA before allowing the tunnelling works to continue when QPs are satisfied that all the voids formed from the over-excavation have been filled up.

- 3) When the readings indicate an over-excavation volume exceeding 25% or if the over-excavation volume has been verified to be more than 15%, Builder and QPs shall continue to suspend TBM excavation and advancement. QPs shall investigate the reasons for the over-excavation together with the Builder, and ensure that the Builder implement mitigation measures to make safe the situation, including carrying out probe drilling and grouting from the ground surface as well as implementing necessary measures to mitigate risk of ground movements. QPs shall conduct a visual inspection on the buildings in close proximity to the tunnelling works and review the instrumentation readings to assess whether the buildings are safe or if they require any strengthening and/or rectification. After the repairs are completed, the QPs shall re-assess and modify if necessary, the method statement and operational parameters for the TBM and the KPIs, depending on the cause of the over-excavation. QPs shall also review the mitigation proposals on the tunnelling works. Upon completion of all mitigation measures, QPs shall notify BCA before allowing the tunnelling works to resume when QPs are satisfied that all the voids formed from the over-excavation have been filled up. Where applicable, QPs shall implement and submit TUN_GBW_AnnexC-3 form to BCA.

Specific Conditions of Permit for Bored Tunnelling Works

For Projects Involving Bored Tunnelling Works (for both GBW and non-GBW):

The parties to this Permit shall comply with the specific conditions below:

Supervision of KPI

- (a) QP(S) and Builder shall continuously monitor and review the key tunnelling operational parameters including face pressure and excavation volume so as to maintain a safe and stable tunnelling face at all times.

Tunnelling within control zone

- (b) When tunnelling within control zone, QP(S) shall submit to CBC (Commissioner of Building Control) daily his certification of structural integrity of the building and assessment of any safety concern in the course of the tunnelling works.

Over-excavation control measures

- (c) When over-excavation is suspected or when the readings indicate an over-excavation volume exceeding 15% at the completion of each ring excavated, the Builder and QPs shall immediately suspend TBM excavation and advancement and notify BCA immediately.

QPs shall notify BCA before allowing the tunnelling works to resume when QPs are satisfied that all the voids formed from the over-excavation have been filled up. Where applicable, QPs shall implement and submit TUN_GBW_AnnexC-3 form to BCA.

Flushing of TBM

- (d) Flushing refers to an operational technique in slurry TBMs to remove obstructions in cutter head chamber in order to move the TBM. For tunnelling in medium and high risk categories, no flushing is allowed. For tunnelling in low risk category, builder shall seek written consent from QP(S) before flushing can be carried out.

Cutterhead intervention

- (e) QP(S) shall implement tunnel control measures (TUN_GBW_Annex C-1 and TUN_GBW_Annex C-2) at all planned and unplanned CHI locations.
- (f) In accordance with regulation 10A(3)(a)(iv) of the Building Control Regulations, the Builder shall carry out cutter head interventions (CHI) under compressed air as specified by QP(D) for all planned stoppages. CHI shall not be carried out under free air conditions unless assessed and approved by QP(S) under the following conditions:

- i) in full face rock with face pressure stepped down gradually; or
- ii) within ground improvement block with face pressure stepped down gradually.

QP(S) and Builder shall notify BCA immediately of any cutter head intervention carried out under free air.

- (g) Where there is an unplanned stoppage for a cutterhead intervention, QP(S) and Builder shall notify BCA immediately. Further to this, QP(S) and Builder must comply with the requirements set out in paragraphs (e) and (f) above.

Emergency preparedness plan

- (h) For tunnelling in close proximity to existing buildings, the developer, Builder and QP(S) must take all reasonable steps and exercise due diligence to put in place an emergency preparedness plan on decanting occupants of buildings undermined by tunnelling works.

Incident reporting

- (i) QP(S) and Builder shall suspend TBM excavation and advancement and notify BCA immediately whenever there is excessive movements (immediate settlement exceeding 150 mm for incident reporting purposes), sinkhole or blowout.

SITE INSPECTION & APPROVAL RECORDS FOR TUNNELLING WORKS – RECORDS OF EXCAVATION VOLUME

Project Ref: _____ Project Name: _____

This form is to be prepared (by Builder) and certified (by the QP(S) and QP(Geo)(S)) for tunnelling in close proximity^A to building or in mixed face condition. The QP(S) and the QP(Geo)(S) are required to **submit** a copy of the completed form(s) to the Commissioner of Building Control (CBC) via **CORENET weekly**. When over-excavation is suspected or the over-excavation reading at the end of each ring excavated has exceeded the allowable limit^B for over-excavation, QP(S) and QP(Geo)(S) are to inform CBC **immediately** and to submit the completed form by **12 noon** the next working day.

Section A: To be completed by Builder and QP(S)'s Site Supervisor**Tunnelling Activity**

(Please tick at least one of the following boxes)

- ☐ For cutter head position located in close proximity^A to building (^A - tunnelling directly or partially underneath buildings or within a horizontal distance of x m from the building as defined in Annex 1 of Circular "Requirements on Bored Tunnelling Works")
- ☐ For cutter head position in mixed face condition

Mixed face:- Presence of a) boulder/core-stone; or
 b) rock (grade III or less weathering) with rock content between 25% to 80%; or
 c) rock content < 25% in which the rate of advancement of TBM drops by more than 50% below normal average due to ground condition; or
 d) interface between soft soil and hard soil, for example between Marine Clay and CA.

Allowable limit^B for over-excavation: _____ % of theoretical volume at the end of each ring excavated.

		Builder's Tunnelling Manager or Site Supervisor				QP(S)'s Site Supervisor				
Tunnel Ring No.	Change in excavated volume (%) from theoretical volume (±)	Name	Date	Time	Signature	Within allowable limit? (Y/N)	Name	Date	Time	Signature

Section B: To be completed and declared by Builder

I have reviewed the data and declare that:

(Please tick the applicable box)

- ☐ The excavated volume was within the allowable limit^B for over-excavation.
- ☐ The over-excavated volume reading has exceeded the allowable limit^B for over-excavation. I have suspended the TBM excavation and advancement immediately and shall proceed to carry out, for tunnelling in close proximity to building, appropriate grouting at the front part of TBM shield; or for other cases, actions as determined by QP(S). I have then verified that the allowable limit^B for over-excavation **has not been exceeded**. I shall carry out probe drilling and grouting from the ground surface and implement necessary measures to mitigate risk of ground movements as determined by QP(S).
- ☐ The over-excavated volume reading has exceeded the allowable limit^B for over-excavation. I have suspended the TBM excavation and advancement immediately and shall proceed to carry out, for tunnelling in close proximity to building, appropriate grouting at the front part of TBM shield; or for other cases, actions as determined by QP(S). I have then verified that the allowable limit^B for over-excavation **has been exceeded**. I shall carry out probe drilling and grouting etc. as per item 3) in Annex 4 explanatory notes of the Circular "Requirements on Bored Tunnelling Works".
- ☐ The over-excavated volume reading **has exceeded 25%**. I have suspended the TBM excavation and advancement immediately and shall proceed to carry out, for tunnelling in close proximity to building, appropriate grouting at the front part of TBM shield; or for other cases, actions as determined by QP(S). I shall carry out probe drilling and grouting etc. as per item 3) in Annex 4 explanatory notes of the Circular "Requirements on Bored Tunnelling Works".

Name & Signature of Technical Controller
for & on behalf of the BuilderName, UEN, stamp of Builder
Date: _____

Section C: To be completed and certified by QP(S) and QP(Geo)(S)

We have reviewed the data and declare that:
(Please tick the applicable box)

- ☐ The excavated volume was within the allowable limit* for over-excavation.
- ☐ The over-excavated volume reading has exceeded the allowable limit* for over-excavation and we have notified BCA. *The builder has suspended / We have instructed the builder to suspend* the TBM excavation and advancement immediately. We have instructed the builder to proceed to carry out, for tunnelling in close proximity to building, appropriate grouting at the front part of TBM shield; or for other cases, actions as determined by us. We have then verified that the over-excavation limit **has not been exceeded**. We have assessed that probe drilling and grouting from ground surface *and other mitigation measures as attached* to be implemented by the builder to mitigate risk of ground movements *is / is not* required. We will notify BCA before allowing the tunnelling works to continue when we are satisfied that all the voids formed from the over-excavation have been filled up.
- ☐ The over-excavated volume reading has exceeded the allowable limit* for over-excavation and we have notified BCA. *The builder has suspended / We have instructed the builder to suspend* the TBM excavation and advancement immediately. We have instructed the builder to proceed to carry out, for tunnelling in close proximity to building, appropriate grouting at the front part of TBM shield; or for other cases, actions as determined by us. We have then verified that the over-excavation limit **has been exceeded**. *The builder has proceeded to / We have instructed the builder to* carry out probe drilling and grouting etc. as per item 3) in Annex 4 explanatory notes of the Circular "Requirements on Bored Tunnelling Works". We will notify BCA before allowing the tunnelling works to continue when we are satisfied that all the voids formed from the over-excavation have been filled up.
- ☐ The over-excavated volume reading has **exceeded 25%** and we have notified BCA. *The builder has suspended / We have instructed the builder to suspend* the TBM excavation and advancement immediately. We have instructed the builder to proceed to carry out, for tunnelling in close proximity to building, appropriate grouting at the front part of TBM shield; or for other cases, actions as determined by us. *The builder has proceeded to / We have instructed the builder to* carry out probe drilling and grouting etc. as per item 3) in Annex 4 explanatory notes of the Circular "Requirements on Bored Tunnelling Works". We will notify BCA before allowing the tunnelling works to continue when we are satisfied that all the voids formed from the over-excavation have been filled up.

Name, stamp & signature of QP(S)
Date: _____

Name, stamp & signature of QP(Geo)(S)
Date: _____

- * Allowable over-excavation limit as shown in approved plan or in contract specifications or in QP(D)s' specifications.
(not exceeding 15% for one ring)
- * To delete as appropriate.