



TUNNEL CONSTRUCTION GUIDELINES 02 – UNDERGROUND ROCK BLASTING

INTRODUCTION

This guideline is intended to:

- Provide an introduction to aspects of rock blasting for tunnels (and shafts) of relevance to the general practitioner in Hong Kong (geotechnical engineers and engineering geologists). Emphasis is given on blasting in urban areas;
- Outline Hong Kong regulations / procedures; and
- Briefly mention alternative excavation techniques.

A general description of types of explosives and detonators used for construction, surface blasting, underwater blasting and blast design are outside the scope of this guideline.

This guideline should be read in conjunction with GIG 04.4 Hard Rock Tunnelling, GIG 5.1 Tunnel Instrumentation and TCG 01 TBM Selection.

BACKGROUND

Drill and blast (D&B) is a common tunnel construction method, particularly in Hong Kong due to the prevalence of hard rock which may require blasting for underground excavation. In addition, rock blasting may be the sole feasible rock excavation method for construction of caverns in hard rock masses.

DRILL AND BLAST OR OTHER METHOD?

Although this is not the primary subject of this TCG, it may be of benefit to outline the general criteria for D&B use over other methods such as Tunnel Boring Machines (TBM), roadheader, hand excavation (assisted by mechanical or chemical means), or raise boring for shaft construction.

Generally, D&B is used where the tunnels are too short to warrant the use of a TBM, where there are variations in cross section and profile, where it is important to maximise access to the tunnel face, where the rock is too hard for excavation by roadheader, or where shaft diameter is beyond the capabilities of raise boring equipment.

OVERVIEW OF HONG KONG REGULATIONS

General

Since blasting requires the storage, transport and use of commercial explosives, it is subject to various regulations to ensure its safe implementation. This section provides an introduction to the Hong Kong regulations. Guidelines on procedure for application of blasting permit in Hong Kong are given in a subsequent section.

Hong Kong Blasting References

- Dangerous Goods Ordinance, Chapter 295 - Commissioner of Mines, Mines Division (MD), Civil Engineering and Development Department (CEDD)
- CEDD MD - Practice and Guidance Notes
- CEDD Project Administration Handbook for Civil Engineering Works (2008) - Project management approach for projects in the Public Works Programme
- Geotechnical Engineering Office (GEO) Circular No. 27 & PNAP APP-72 (previous reference PNAP 178) - a blasting assessment is required
- PNAP APP-24 and APP-137 (previous reference PNAP 77 and 289 respectively) - Railway protection, and Ground-borne Vibrations Arising from Pile Driving and Similar Operations
- Geoguide 4 (1992) - Provides general blasting advice
- GEO Report No. 15 (1997) - Assessment of Stability of Slopes Subject to Blast Vibrations
- GEO Report No. 94 (1999) - Rock Slope Failure along Sau Mau Ping
- GEO Report No. 100 (2000) - Methods of Assessment and Monitoring of the Effects of Gas Pressures on Stability of Rock Cuts due to Blasting in the Near-Field
- GEO Report No. 102 (2000) - A Study of the Effects of Blasting Vibration on Green Concrete
- GEO Report No. 232 (2008) - Prediction and Control of Air Overpressure from Blasting in Hong Kong
- WSD Departmental Instruction (DI) No. 1038 (Revised Jan 2009)
- Mass Transit Railway Corporation (MTRC) - Generally no blasting allowed within 3m of MTR tunnels / facilities

- Environmental Protection Department (EPD) - Environmental Impact Assessment (EIA), Hazard to Life Assessment and Environmental Permit (EP) Conditions
- Eurocode 8: Design of structures for earthquake resistance - Part 5: Foundations, retaining structures and geotechnical aspects Technical Requirement

Technical Requirement for Hazard to Life Assessment

An assessment shall be carried out if the Contractor's storage, transport and use of explosives could adversely impact on populated areas or on any Potential Hazardous Installations nearby. The assessment must follow the criteria for evaluating hazard to life as stated in the Technical Memorandum to the EIA Ordinance. The hazard assessment needs to include the execution of a Quantitative Risk Assessment (QRA) expressing population risks in both individual and societal terms, and the identification and assessment of practicable and cost-effective risk mitigation measures.

In practice, a QRA is required for:

- Explosives storage (on-site magazine)
- Delivery from the on-site magazine to the works site for Contractors using their own licensed explosives delivery vehicle
- Sometimes for use of explosives.

KEY ISSUES AND CONSTRAINTS FOR BLASTING WORKS IN HONG KONG

General

Environmental effects of rock blasting include ground vibrations, air overpressure / noise, fumes and dust, and flyrock. Rock blasting must be controlled to prevent any potential for damage. Some environmental or political factors may severely constrain the use of D&B.

The practical implementation of the D&B method may require an on-site magazine (Licensed Mode A Store, as defined by MD). This guideline outlines the key aspects of site selection studies and design for such magazines.

Key Tunnel Blast Design Parameters - These include the following:

- Tunnel geometry : face area, 'diameter' and tunnel profile (shape)
- Rock type and quality
- Blasthole diameter, burden and spacing
- Cut configuration
- Allowable Maximum Instantaneous Charge

- Available delay range of non-electric detonators
- Delay initiation sequence

For details, reference should be made to the proceedings of the Joint Technical Seminar held on 13th June 2009 (<http://www.ags-hk.org/>) and to specialised technical literature.

Geological Effects on Tunnel Blast Design - Varying geological conditions may require (refer to <http://www.ags-hk.org/>):

- Relocating the 'cut' into more competent ground
- Adding or deleting individual blastholes or a 'ring' of blastholes from the face (thus reducing or expanding the hole spacing)
- Adjusting the bulk emulsion explosive density
- Adjusting the blast 'pull' lengths

Some ground conditions are more prone to overbreak or underbreak. Fragmentation is also related to rock mass conditions.

Key Safety and Environmental Effects of Tunnel Blasting -

The principal constraints limiting the practicality and safe use of rock blasting in tunnel construction relate to risks to the workforce, the general public, and sensitive receivers such as existing buildings and structures, utilities, geotechnical features (slopes & retaining walls), or natural terrain. The key environmental effects, and associated main mitigation measures, are as follows:

- Ground vibrations - Related to instantaneous charge weight and the distance between the ground and the blast source
- Air overpressure - Refer to MD references and GEO Report No. 232
- Fumes and dust generated by the blast - Good tunnel ventilation required; water sprays to prevent or control dust
- Flyrock.

Blasting also has the following near-field effects:

- Blasting induces new discontinuities and may damage the rock mass. Blasting generally increases near-field rock mass permeability;
- Excavations by mechanical means generally need less support, due to the lesser disturbance on rock mass quality compared to rock blasting.

Controlled blasting to limit damage to the surrounding rock mass is therefore also essential to limit the impacts of the construction method in terms of support and groundwater control requirements.

Sequencing of the excavation by blasting is also a consideration, especially for large span tunnels or rock caverns.

Observations on Selected Blasting References –

- GEO Report No. 15 – Soil slopes and retaining walls currently often control the majority of blast charge weights. Recorded instability for soil slopes or retaining walls during blasting is rare. The Hong Kong Institution of Engineers is carrying out some research on blasting vibration and its effect on stability of slopes (refer to the activities of the Working Group on Cavern and Tunnel Engineering, as reported in <http://www.hkieged.org/geodiv/workgroup.htm>).
- Geoguide 4 – This provides blasting related information, which does not reflect the latest developments in blasting technology.

TYPICAL INVOLVEMENT FOR GEOTECHNICAL ENGINEERS OR ENGINEERING GEOLOGISTS IN HONG KONG

General – Such involvement may include the following:

- Assistance to preparation of Blasting Assessment Report (BAR) - An indicative submission flowchart for BAR and Method Statement for Blasting is given on the last page
- Visual inspection of sensitive receivers (such as existing slopes, retaining walls and buildings)
- Analysis of slopes and retaining walls
- Analysis of blast charge weights and controlling sensitive receivers
- Determination of blasting control measures and blasting protection measures
- Assessment for explosives storage and delivery
- Blast monitoring

Project Planning Phase – Feasibility study: identify key hazards & constraints; estimates of explosives consumption; programme / production rates; assess the need for a site magazine.

Project Design Phase – When planning ground investigation works, the following may be considered: rock mass jointing; specialist testing of rock strength or abrasivity (e.g. Drilling Rate Index (DRI) & quartz content); and the review of applicability of rock blasting in closely fractured or decomposed rocks.

The pre-contract BAR shall be prepared by the designer and subsequently provided to the appointed contractor. It shall include the following:

- Condition of sensitive receivers that may be affected;

- Safe blasting limits (Peak Particle Velocity (PPV), etc.);
- Indicative protective measures, and monitoring requirements;
- Indicative blast design, method of carrying out the blasting and safety procedures; and
- Proposals for explosive supply, and if required any site explosives magazine.

Typical selection criteria for explosives magazine include explosives storage capacity based on allowable separation distances, distance from MD delivery pier to magazine site, average distance from magazine site to works area, environmental and heritage impacts, land availability, site constraints, and access for MD mines explosives delivery vehicles.

Project Construction Phase – The Contractor shall prepare the final BAR and Method Statement (see flow chart on last page).

Monitoring shall be carried out to verify that the PPV and AOP limits for the sensitive receivers are not exceeded during blasting.

Geological mapping may help to confirm the effectiveness of overbreak control measures.

It should be borne in mind that contractual claims may relate to overbreak and its implications for the works.

CONCLUDING REMARKS

For major tunnelling infrastructure projects, blasting needs to be considered as an economical method of rock excavation. Blasting in urban areas needs good control to ensure safety for the workers and general public.

Challenges related to BAR approval process in Hong Kong include the vibration and air overpressure limits, and the Hazard to Life Assessment. The awareness of blasting issues and responses from stakeholders may be difficult to manage or anticipate.

The time to gain approval and the size of the submissions appear to be increasing.

Input from blasting specialist staff is required to support the BAR process.

SELECTED ADDITIONAL REFERENCES AND SOURCES OF INFORMATION

CEDD Mines Division and publications:
www.cedd.gov.hk/eng/services/mines_quarries/

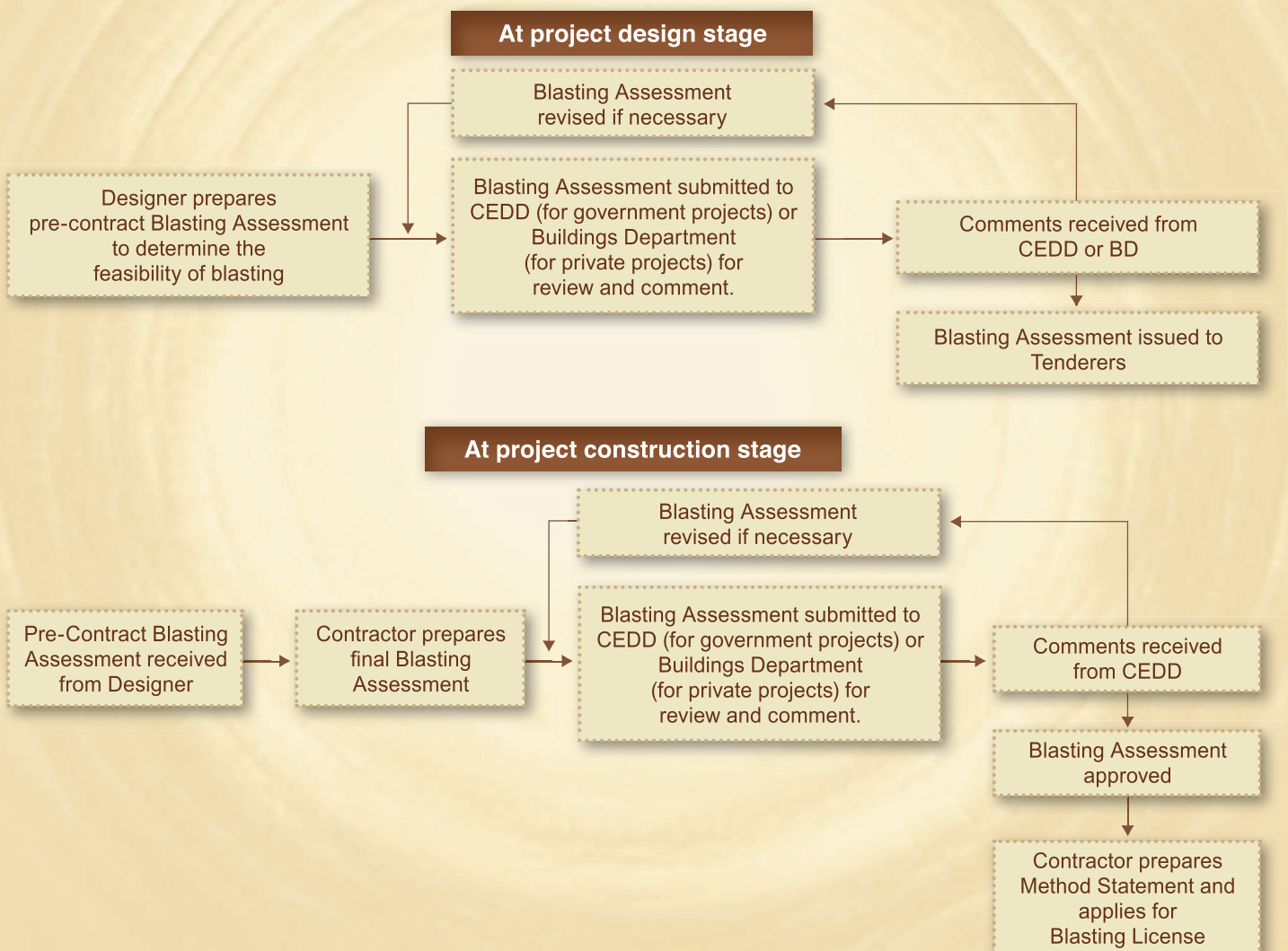
www.cedd.gov.hk/eng/publications/

EPD, Environmental Impact Assessment Ordinance -
<http://sc.epd.gov.hk/gb/www.epd.gov.hk/eia/legis/index1.htm>

Joint Technical Seminar by AGS(HK), HKIE (Geotechnical Working Group on Cavern and Tunnel Engineering) and HKTS, "Tunneling – Selected Topics", 13th June 2009. 'Tunnel Blast Design' by

T. Magub and 'Blasting Assessments' by M. Wallace. Website link to download the presentation files: <http://www.ags-hk.org/>

Hong Kong Institution of Engineers - Technical talks - Geotechnical Division - 'Blasting is a powerful tool', 2007; 'Blasting related failures', Mar 2007; and 'Technical Talk on Blasting Regulations', Jan 2008 - www.hkieged.org/HKIE/download; Blasting in Hong Kong, A Review of Current Blasting Assessment Requirements, Jun 2008 (by G. Bridges, jointly organised by the Civil Division and Materials Division).



Outline of Blasting Assessment (After G. Bridges, 2008)