ENGINEERING SURVEY PRACTICE GUIDES FOR WORKS PROJECTS

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Land and Engineering Survey Board
The Government of the Hong Kong Special Administrative Region

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FOREWORD

This *Engineering Survey Practice Guides for Works Projects (ESPG)* presents a standard of good engineering survey practice for reference by the land and engineering surveyors of consultants, contractors and the government departments in carrying out survey works.

The *ESPG (2018)* was initially proposed by the Chief Land Surveyor of the Highways Department in 2015. The Land and Engineering Survey Board (LESB) Paper No. 2015/01 entitled *Documentation of the Engineering Survey Practice Guides for Works Projects* was endorsed by the LESB in its 102nd meeting held on 29 April 2015 to document the good practices of engineering survey. Preparation of *ESPG (2018)* was a collaborative effort of a task force team and an editorial board steered by the Land and Engineering Survey Board. The task force team was led by the Assistant Director/Survey and Mapping of the Lands Department, and its membership was made up of representatives, as listed on the next page, from various government departments. The *ESPG (2018)* was officially published in March 2018 for internal reference.

In April 2020, LESB proposed to revise the *ESPG (2018)* with a view to making it available for reference as a practical guide by practitioners in land and engineering surveying industry in addition to the government departments. Preparation of this revised *ESPG* was a collaborative effort of the experienced surveying professionals from Agricultural, Fisheries and Conservative Department, Civil Engineering and Development Department, Drainage Services Department, Highways Department, Housing Department, Lands Department, Marine Department and Water Supplies Department. A draft version was circulated to land and engineering survey practitioners in consultants in February 2021. They made very useful comments, which have been taken into account in finalizing this revised edition. Their contributions are gratefully acknowledged.

The *ESPG* gives guidance on good engineering survey practice and its recommendations are not intended to be mandatory. Survey practitioners are always welcome and encouraged to provide comments to the Secretary of the Land and Engineering Survey Board (Attn.: Senior Land Surveyor/Technical Information, Survey and Mapping Office, Lands Department) so that continual improvements can be made to future editions.

(Signed)
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Deputy Director/Survey and Mapping
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16 August 2021

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Editorial Board 2021

Revision History

Revision	Date	Amendment
0	March 2018	(Initial Release)
1	August 2021	Full revision for release to public
2	August 2023	Paragraphs 3.3.3.5, 3.5.1, 4.3.2.2, 4.5.2.1, 5.2.6.1, 5.5.2.2, 5.5.3.3, 7.1.1, 7.2, 13.2.1, 13.3, 13.5, 13.6, 15.3, 15.5.1.4, 16.3.3, 16.4, 16.5, 16.7, 16.9 and Chapter 14 amended. Chapter 17 added.

This ESPG is a continuously updated version incorporating amendments issued since the ESPG was last published.

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Chapter 1

Introduction

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Chapter 1 Introduction

1.1 Purpose and Scope

1.1.1 The purpose of this Engineering Survey Practice Guides for Works Projects (ESPG) is to document a standard of good engineering survey practice for reference by land surveying practitioners in carrying out survey for works projects.

1.1.2 This ESPG is for the use of Surveyors who are conversant with the relevant surveying principles and procedures. Apart from the technical aspects, it provides a reference guide to ensure sufficient survey inputs and proper surveying procedures for works projects, including management of survey data and proper records keeping for different kinds of engineering survey works.

1.2 Application

1.2.1 This ESPG gives guidance on good engineering survey practices, and its recommendations are not intended to be mandatory. It should be read in conjunction with the Engineering & Associated Consultants Selection Board (EACSB) Handbook (https://www.cedd.gov.hk/eng/publications/eacsb-handbook/index.html), the Project Administration Handbook (PAH) for Civil Engineering Works (https://www.cedd.gov.hk/eng/publications/standards-spec-handbooks-cost/stan-pah/index.html), the General Specification for Civil Engineering Works, Edition 2006 (https://www.cedd.gov.hk/eng/publications/standards-spec-handbooks-cost/stan-gs-2006/index.html), the general specification and particular specification of consultancy briefs and contracts for the works projects.

1.2.2 In the event that there is conflict, contradiction or ambiguity between any documents which form part of the contracts for the works projects, the order of precedence shall be applied as that the Particular Specification and/or General Specification, the provisions contained in the Brief of the consultancy agreement shall prevail over the provisions contained in this ESPG.

1.2.3 The Surveyors making references to this ESPG are reminded that they are fully responsible for making judgments and imposing suitable additional requirements to meet their surveying need. Reference to this ESPG does not release their responsibility in providing adequate surveying services to the standard as stipulated in the consultancy agreement and / or contract document.

1.3 Revision of ESPG

1.3.1 This ESPG is reviewed biennially or when required as suggested by the ESPG Editorial Board to keep the content up-to-date.

1.4 Interpretation

The following are the definitions of the terms used in this ESPG-

"Consultant" means the person, firm or company named in the Memorandum of Agreement and includes the Consultants' permitted assignees.

"Contractor" means the person, firm or company whose Tender has been accepted by the Employer and includes the Contractor's personal representatives, successors and permitted assigns.

"Engineer" means the person, company or firm appointed from time to time by the Employer and notified in writing to the Contractor to act as the Engineer for the purposes of the Contract. The person appointed may be described by name or as the holder for the time being of a public office.

"Surveyor" means a land and engineering survey practitioner working on behalf of the Government, the Consultant or the Contractor and performing land and engineering survey tasks in works projects.

Chapter 2

General Principles

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Chapter 2 General Principles

2.1 General Principles

2.1.1 The general principles applicable to the subsequent chapters are summarised in the following paragraphs. Supplementary guidelines may be given in some chapters as appropriate.

2.1.2 Instrumentation

2.1.2.1 With reference to the accuracy and standard required in the relevant works project, the Surveyor should use appropriate survey equipment and software for carrying out the surveying work. All equipment, hardware, firmware and application software should be agreed with Engineer.

2.1.2.2 The Surveyor is responsible for the calibration of equipment used for the survey work against appropriate standards upon commencement of works or immediately after the equipment is newly delivered, repaired or serviced. The calibration should be repeated at a specified interval and the records of calibration should be properly maintained.

2.1.2.3 The Surveyor should ensure that survey equipment is handled, stored and used in accordance with manufacturer's recommendations. The equipment should also be maintained by service agent. Copies of the manufacturer's recommendations, the user manuals or the similar documents should be kept properly.

2.1.3 Quality Assurance

2.1.3.1 Quality checking of the survey result should be arranged in accordance with the relevant quality standard and guidelines as appropriate.

2.1.3.2 Upon request of the Engineer, the Surveyor should facilitate the Engineer in surveillance checks on survey control networks, survey equipment and processing software, survey records and reports, and other necessary information as appropriate. The percentage of sampling checking for quality assurance of the deliverables is subject to the discretion of the Engineer.

2.1.3.3 Independent check by another Surveyor as instructed by the Engineer could be arranged for quality assurance.

2.1.4 Survey Records

2.1.4.1 Survey records should include but not limited to survey request form, hardcopies and digital copies of the survey observations, survey data reduction, CAD computer drawing files and other related reference drawings. All the survey records should be compiled and kept properly in computation folder for record. Digital survey data and computation should be appropriately archived. All the survey records may be submitted to the Engineer for inspection when required. Digital survey records which are part of digital check/inspection system should be adopted to support efficient flow of surveyed information and to enhance efficiency of works supervision and quality performance.

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Chapter 3

Survey Datum and Survey Control

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Chapter 3 Survey Datum and Survey Control

3.1 Introduction

3.1.1 This chapter is to cover the survey datum and control survey relating to engineering surveys in works projects in Hong Kong.

3.2 Scope

3.2.1 This chapter is to set out the horizontal and vertical datums to be used in engineering survey work and provide guidelines for establishing horizontal and vertical control stations in works project. Regarding horizontal survey control stations established by Global Navigation Satellite Systems (GNSS) survey equipment, the survey requirements and accuracy standards as stipulated in Chapter 4 “Global Navigation Satellite Systems (GNSS) Survey” should be referred.

3.3 Accuracy and Standards

3.3.1 Survey Datum

3.3.1.1 Unless otherwise specified in contract document or agreed with Engineer, all horizontal coordinates of the works shall be referenced to and expressed in the Hong Kong 1980 Grid System.

3.3.1.2 Unless otherwise specified in contract document or agreed with Engineer, all vertical levels of the works shall be referenced to and expressed in either:

(a) Hong Kong Principal Datum (HKPD) which is the height datum generally used in Hong Kong and referred through the bench marks of Lands Department; or

(b) Chart Datum (CD) which is 0.15m below HKPD.

3.3.2 Survey Monument

3.3.2.1 "***Geodetic survey station***" means a trigonometric station, a traverse station, a bench mark or a GNSS survey station emplaced and mathematically fixed under the Hong Kong Geodetic Survey System with coordinates published by the Geodetic Survey Section of Survey and Mapping Office of Lands Department.

3.3.2.2 The horizontal and vertical control stations provide an accurate positioning framework for the detailed design, construction and subsequent maintenance of the project. To ensure their stability and permanence, the establishment and preservation of control stations are of paramount importance. Position of control stations should be safe, permanent, stable and easily accessible.

3.3.2.3 The types of survey monuments used for the horizontal and vertical control stations depend on the scale and site condition of the project. Taking a large scale reclamation project as an example, the site usually has a large coverage with no stable ground for installation of bench mark. In order to ensure a stable and robust primary vertical control for the project, bedrock bench marks should be constructed in accordance with the requirements as stipulated in Appendix 3.1 (Drawing No.8) or as designed by the project Engineer for stable vertical control reference for the works project.

3.3.2.4 All control stations should be preserved properly and not be disturbed by any site activities as far as possible. For government works project, application for temporary land allocation from Lands Department may be considered to accommodate the primary control stations established outside the project area for providing better preservation and protection.

3.3.2.5 Specifications and drawings of sample survey monuments for horizontal and vertical control stations are provided at Appendix 3.1.

3.3.3 <u>Horizontal Survey Control</u>

3.3.3.1 All horizontal control stations for works shall be established by control network survey, traverse survey, GNSS survey in accordance with the accuracy and standard as stipulated in Paragraph 3.3.3.5 below.

3.3.3.2 For control network survey, the angle and distance measurements shall be computed and adjusted using Least Squares Adjustment.

3.3.3.3 For traverse survey, the measured data shall be computed and adjusted using Bowditch Rule or Least Squares Adjustment.

3.3.3.4 For GNSS survey, the requirements on data processing and accuracy standards should be referred to Chapter 4 “Global Navigation Satellite Systems (GNSS) Survey”.

3.3.3.5 The accuracy and standard of control network survey and traverse survey are summarised as follows-

		By Bowditch Rule		**By Least Squares Adjustment**		
		Allowable Angular Misclosure	**Allowable Linear Misclosure**	**Allowable Angle Residual**	**Allowable Distance Residual**	**Maximum Traverse Length**
Control Network Survey	Primary	N.A.		5”	1:30,000	N.A.
	Secondary			10”	1:15,000	
Traverse Survey	Primary	$10''\sqrt{n}$	(5+S/15) mm	10”	1:15,000 or 5mm (minimum)	2.5 km
	Secondary	$20''\sqrt{n}$	(10+2S/15) mm	20”	1:7500 or 10mm (minimum)	1 km

n : Number of survey stations in the traverse

S : Total length of the traverse in metres

3.3.4 Vertical Survey Control

3.3.4.1 All vertical control stations for works shall be surveyed by levelling or height traversing. The level misclosure shall be mathematically adjusted.

3.3.4.2 The accuracy and standards of levelling and height traversing are listed as follows-

	Precise Levelling	Ordinary Levelling	Height Traversing
Allowable Misclosure	$4\sqrt{k}$ mm	$12\sqrt{k}$ mm	$(10 + 10\sqrt{n})$ mm

n : Total number of traverse legs

k : Total distance of levelling route in kilometres

3.4 Instrumentation

3.4.1 The General Principles in Chapter 2 should apply.

3.4.2 The minimum equipment requirements for different horizontal and vertical control surveys are listed as follows-

(a) Minimum Requirement of Equipment for Horizontal Control Surveys

	Control Network Survey		Traverse Survey	
	Primary	Secondary	Primary	Secondary
Angular Accuracy	1”	3”	3”	20”
Distance Accuracy	3mm + 1ppm		3mm + 2ppm	

(b) Minimum Requirement of Equipment for Vertical Control Surveys

	Precise Levelling	Ordinary Levelling	Height Traversing
Equipment	Precise Level Standard deviation of height measurement: 0.4mm (1 km double-run)	Ordinary Level Standard deviation of height measurement: 1.5mm (1 km double-run)	Total Station Angular accuracy: 5” Distance accuracy: 5mm + 2ppm
Levelling Staff	Invar staff	Ordinary staff	N.A.

3.5 Survey Procedures

3.5.1 Horizontal Survey Control

3.5.1.1 The survey planning and design shall be conducted in accordance with the following requirements and criteria-

<table>
<tr><th rowspan="2"></th><th colspan="2">Control Network Survey</th><th colspan="2">Traverse Survey</th></tr>
<tr><th>Primary</th><th>Secondary</th><th>Primary</th><th>Secondary</th></tr>
<tr><td>Survey Planning and Design</td><td colspan="2">➢ The survey control network shall be designed from whole to part and be controlled by at least 2 known horizontal control stations.
➢ Unless otherwise specified in contract document or agreed with Engineer, the known horizontal control stations shall be Trigonometric Stations or Main Traverse Stations of the Survey and Mapping Office, Lands Department or other control stations with higher order of accuracy.
➢ Position check of origin shall be required by observing included horizontal angles and at least one distance to two known stations.
➢ To ensure a geometrically strong survey network, the angles between the horizontal control stations should be within the range of 30° to 150°. If it is a control traverse network, the traverse legs should be kept nearly equal in length as far as possible.</td><td colspan="2">➢ The traverse shall be designed from whole to part, and shall start from and close onto different known horizontal control stations. No unclosed traverses are allowed.
➢ Unless otherwise specified in contract document or agreed with Engineer, the known horizontal control stations shall originate from the geodetic survey control stations of the Survey and Mapping Office, Lands Department.
➢ Position check of the origin shall be required by observing included horizontal angles and at least one distance to two known stations.</td></tr>
<tr><td rowspan="2">Control Bearings</td><td colspan="2" rowspan="2">N.A.</td><td colspan="2">➢ Control bearings shall be observed reciprocally between traverse survey stations and some other geodetic survey control stations, at such station intervals as will adequately control the orientation of the traverse lines. The number of traverse survey stations between control bearings shall not be more than:-</td></tr>
<tr><td>8</td><td>15</td></tr>
<tr><td>Maximum Traverse Length</td><td colspan="2">N.A.</td><td>2.5 km</td><td>1 km</td></tr>
</table>

3.5.1.2 The origin check for the known horizontal control stations shall be conducted in accordance with the following acceptable criteria-

Origin Check				
Allowable Discrepancy	**Control Network Survey**		**Traverse Survey**	
	Primary	**Secondary**	**Primary**	**Secondary**
Angular measurement	5”	5”	5”	60” when < 100m 30” when > 100m
Distance measurement	16ppm	33ppm	10mm+33ppm	15mm+100ppm

3.5.1.3 The field observations shall be conducted in accordance with the following requirements and criteria-

(a) Angular Measurements

	Control Network Survey		**Traverse Survey**	
	Primary	**Secondary**	**Primary**	**Secondary**
No. of arcs	4	2	2	1
Spread of angles	≤ 6”	≤ 10”	≤ 10”	N.A.
Difference between FL & FR	≤ 20”	≤ 20”	N.A.	N.A.

FL: Face Left
FR: Face Right

(b) Distance Measurements

	Control Network Survey		**Traverse Survey**	
	Primary	**Secondary**	**Primary**	**Secondary**
No. of measurements	➢ Reciprocal measurements. ➢ At least 2 independent pointing with 3 measurements each for each network line. ➢ For measurement over 300m, temperature and pressure readings should be recorded at both ends of the line during the distance measurement for atmospheric correction.		➢ Reciprocal measurements. ➢ At least 3 measurements for each traverse leg. ➢ For measurement over 300m, temperature and pressure readings should be recorded at both ends of the line during the distance measurement for atmospheric correction.	
Spread of measurements	5mm+1ppm		5mm	
Difference of reciprocal measurements	10mm+2ppm		10mm	

3.5.2 Vertical Survey Control

3.5.2.1 Unless otherwise specified in contract document or agreed with Engineer, all vertical control stations for the works shall be originated from the bench marks of the Survey and Mapping Office, Lands Department.

3.5.2.2 Temporary Bench Marks (TBM) shall be established from the vertical control stations for the works by levelling or height traversing which starts and closes at different vertical control stations or bench marks of the Survey and Mapping Office, Lands Department.

3.5.2.3 Before each levelling survey, two-peg test shall be carried out and collimation error shall not exceed the allowable value as specified below-

	Precise Levelling	**Ordinary Levelling**
Allowable collimation error	1mm / 30m	3mm / 30m

3.5.2.4 The field survey for vertical control shall be conducted in accordance with the requirements and criteria as specified below-

	Precise Levelling	**Ordinary Levelling**	**Height Traversing**
Origin check	At least 2 consecutive known bench marks or vertical control stations for the works at both ends of the levelling route shall be selected for origin check. Levelling / height traversing between them shall be run at least in one direction for checking. Discrepancy between the height differences of the measured value and the computed value shall not exceed the allowable misclosure value as specified in paragraph 3.3.4.2.		
Line of sight	➢ Maximum sight distance < 30m ➢ Distance difference per set-up (BS-FS) < 0.5m ➢ Cumulative distance (∑BS - ∑FS) < 1m	BS and FS distances shall be kept equal as far as practicable.	Both BS and FS vertical angle measurements on both faces (FL and FR) are required.
Elimination of systematic error	➢ Different invar staff shall be used for starting of forward run and backward run ➢ 0.3m on both ends of invar staff shall not be used to avoid uncertainty resulting from refraction and/or bar-code reading.	---	➢ Reciprocal distance measurements shall be conducted to eliminate the effects of atmospheric refraction and curvature of the earth. ➢ For distance measurement over 300m, temperature and pressure readings should be recorded at both ends of the line for atmospheric

			correction.
Elimination of zero error	Even setup and the same invar staff shall be used on starting and closing bench marks of each levelling section.	---	---

BS : Backsight
FS : Foresight
FL : Face Left
FR : Face Right

3.6 Deliverables

3.6.1 Coordinates list, location diagram, tie measurement records and photographs of the newly established control stations should be prepared for record and reference.

3.7 Quality Assurance

3.7.1 The General Principles in Chapter 2 should apply.

3.8 Survey Records

3.8.1 The General Principles in Chapter 2 should apply.

Appendix 3.1
Specifications of Survey Monuments for Horizontal and Vertical Control Stations

Horizontal Control Stations

1. Type A Triangulation Monument

   Type A Triangulation Monument is a concrete structure which is composed of a 1250mm height cylindrical pillar and a 1500mm x 1500mm horizontal platform. A stainless steel plate is installed on the top of the pillar for forced-centering of survey instrument. The detail specification is described in Drawing No. 1A and 1B in Appendix 3.1 respectively.

2. Type B Triangulation Monument

   Type B Triangulation Monument is a concrete structure which is composed of a 380mm height cylindrical pillar and a 1500mm x 1500mm horizontal platform. The detail specification is described in Drawing No. 2A and 2B in Appendix 3.1 respectively.

3. Picket Box (fixed in open ground)

   A 400mm stainless steel rod is fixed vertically in the open ground by concrete block. A metallic picket box is installed for protection of the protruded part of the stainless steel rod. The detail specification is described in Drawing No. 4 in Appendix 3.1.

4. Picket Box with Concrete Platform

   A 400mm stainless steel rod is fixed vertically in the ground by concrete block. A metallic picket box installed on a 1500mm x 1500mm concrete platform is constructed for protection of the protruded part of the stainless steel rod. The detail specification is described in Drawing No. 5 in Appendix 3.1.

5. Picket Box (fixed on rock surface)

   A 210mm stainless steel rod is fixed vertically in the rock by epoxy. A metallic picket box is firmly installed on the rock surface by concrete for protection of the protruded part of the stainless steel rod. The detail specification is described in Drawing No. 6 in Appendix 3.1.

6. Survey Nail

   The detail specification of survey nail is described in Drawing No. 7 in Appendix 3.1.

Vertical Control Stations

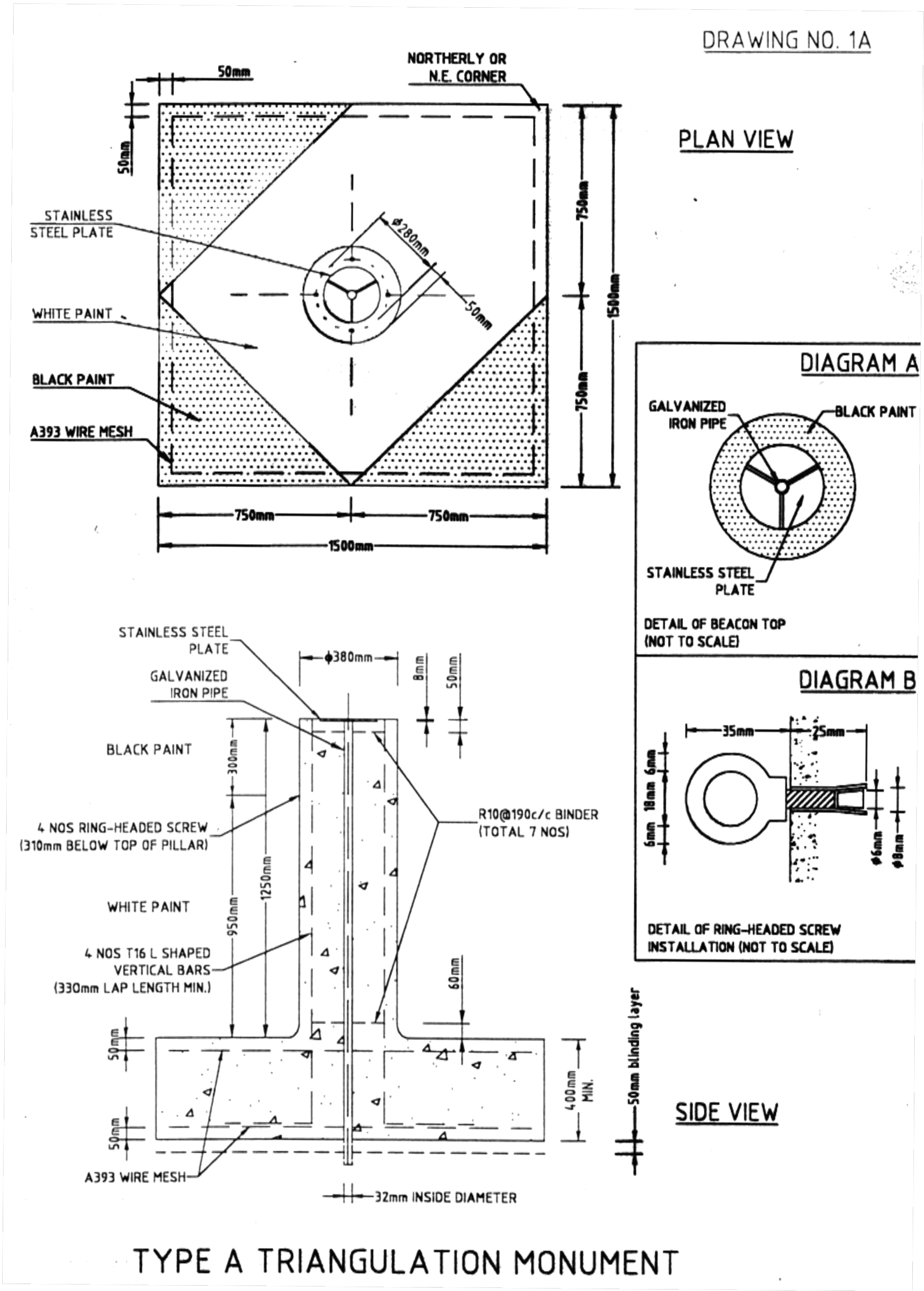
1. Bedrock Bench Mark

   A bedrock bench mark is a very stable vertical control monument which is composed of a picket box with concrete platform and a reinforced mini-pile embedded at least 5m in bedrock underground. The detail specification is described in Drawing No. 8 in Appendix 3.1.

2. Survey Pin

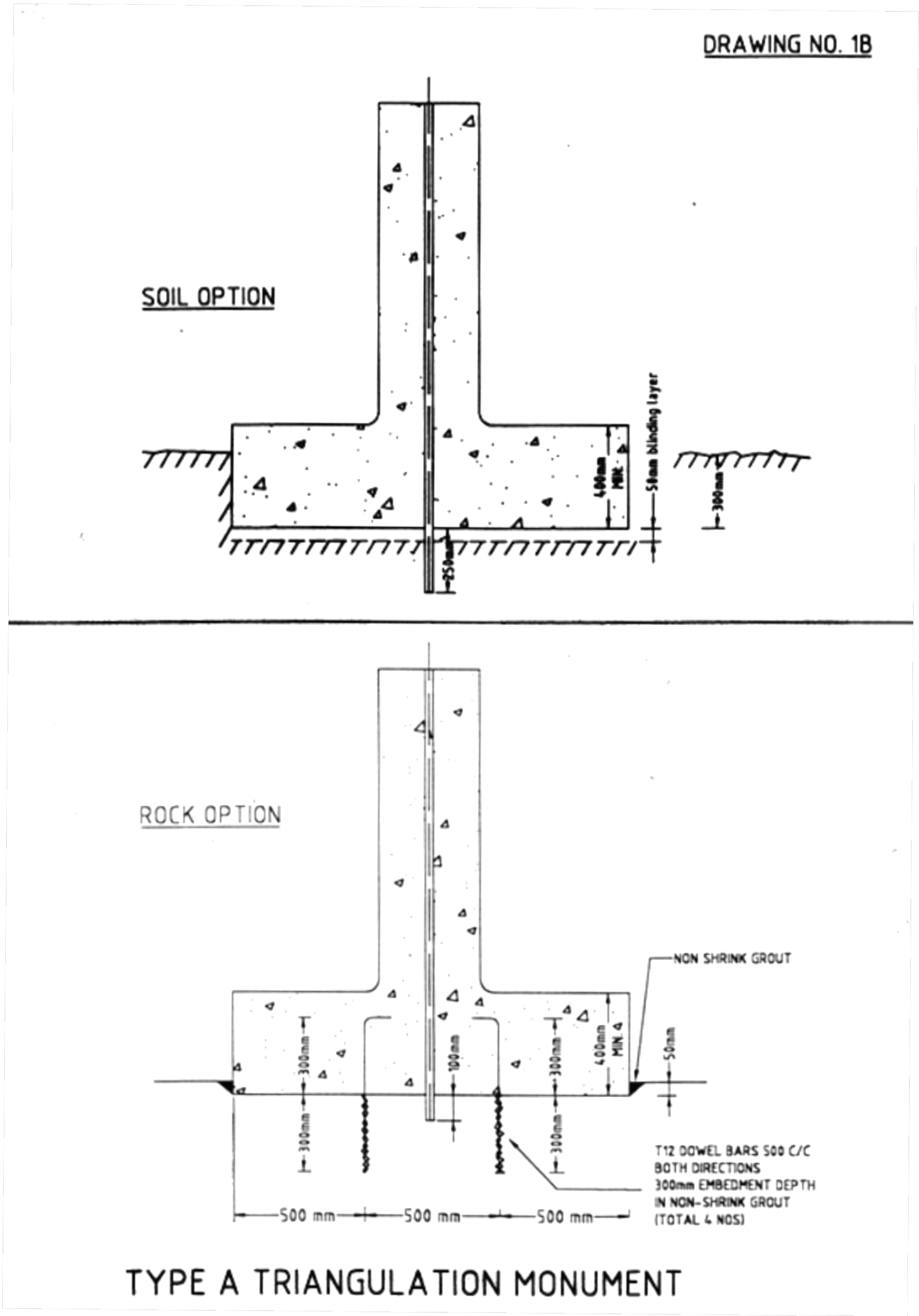
   The detail specification of Survey Pin is described in Drawing No. 7 in Appendix 3.1.

Appendix 3.1
Drawing No. 1A – Type A Triangulation Monument

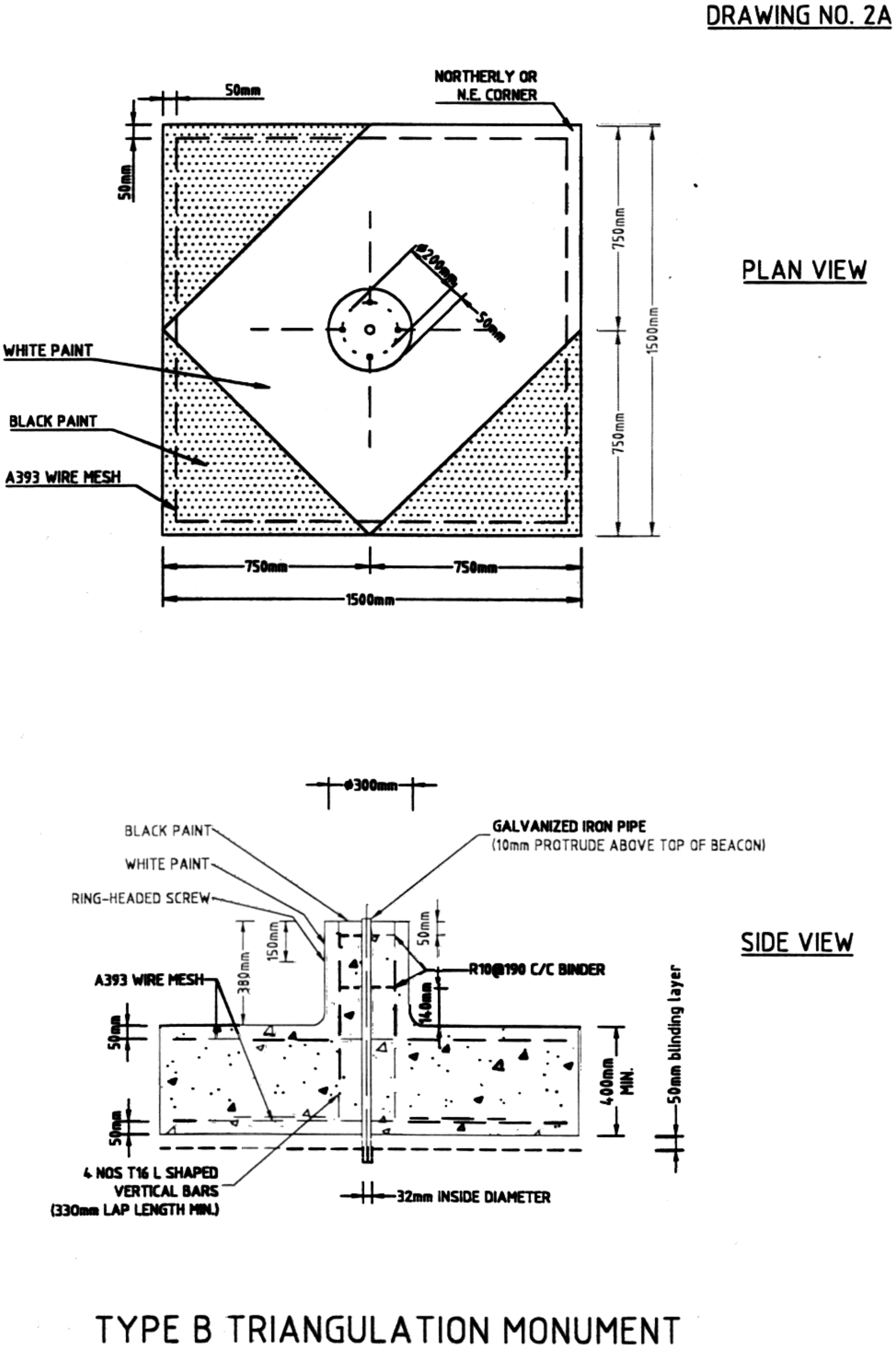


Appendix 3.1

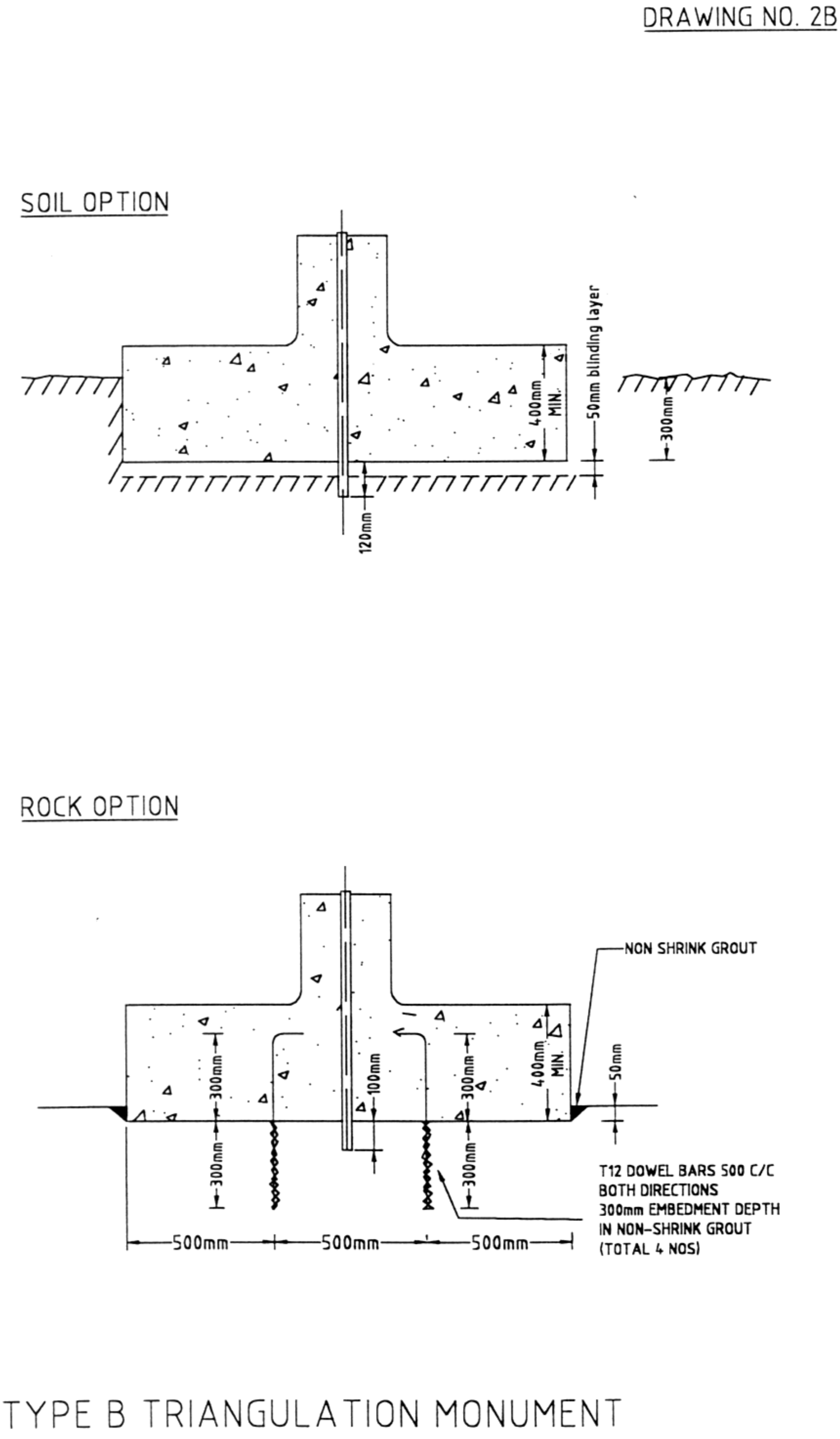
Drawing No. 1B – Type A Triangulation Monument



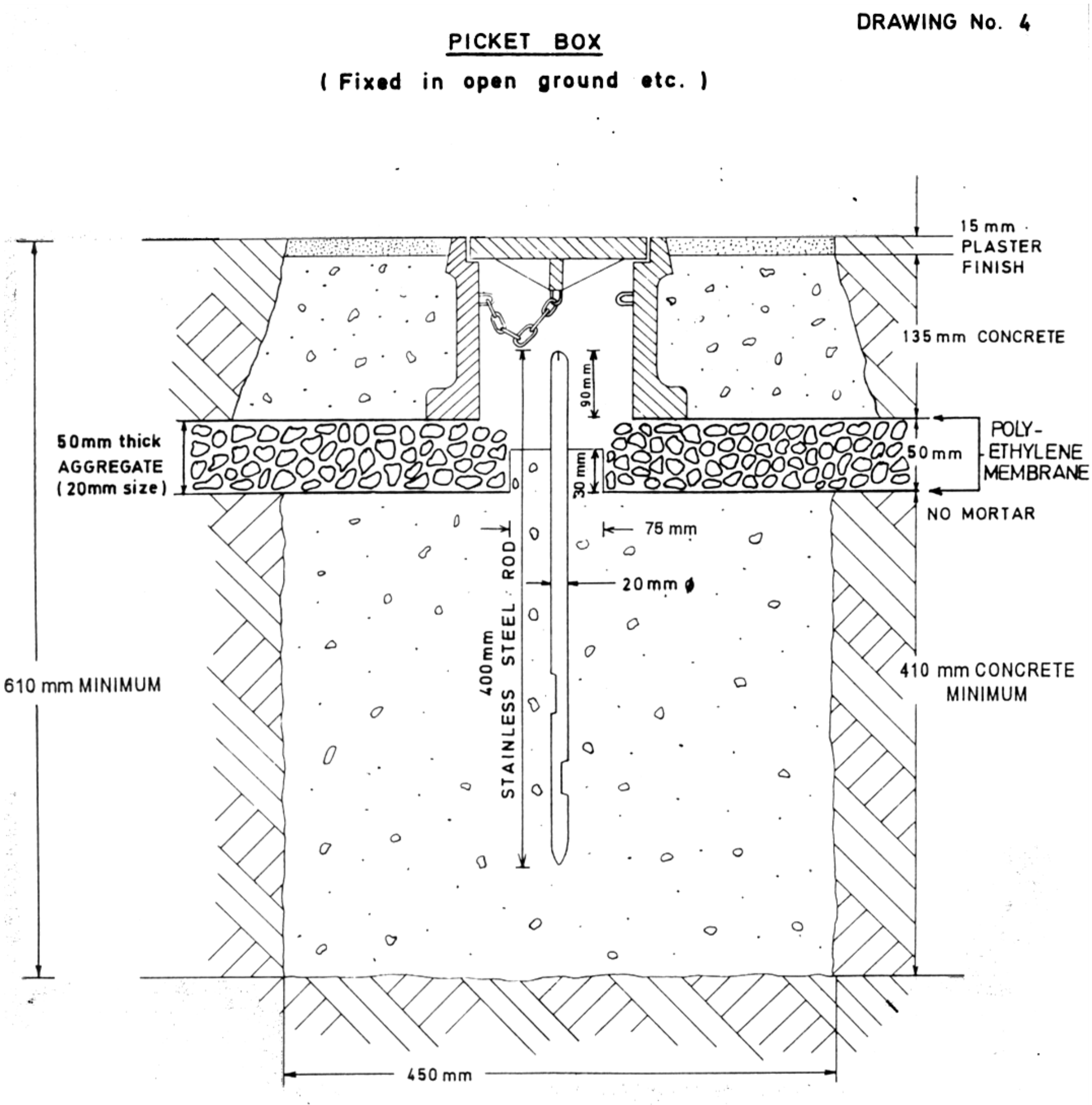
Appendix 3.1
Drawing No. 2A – Type B Triangulation Monument



Appendix 3.1
Drawing No. 2B – Type B Triangulation Monument

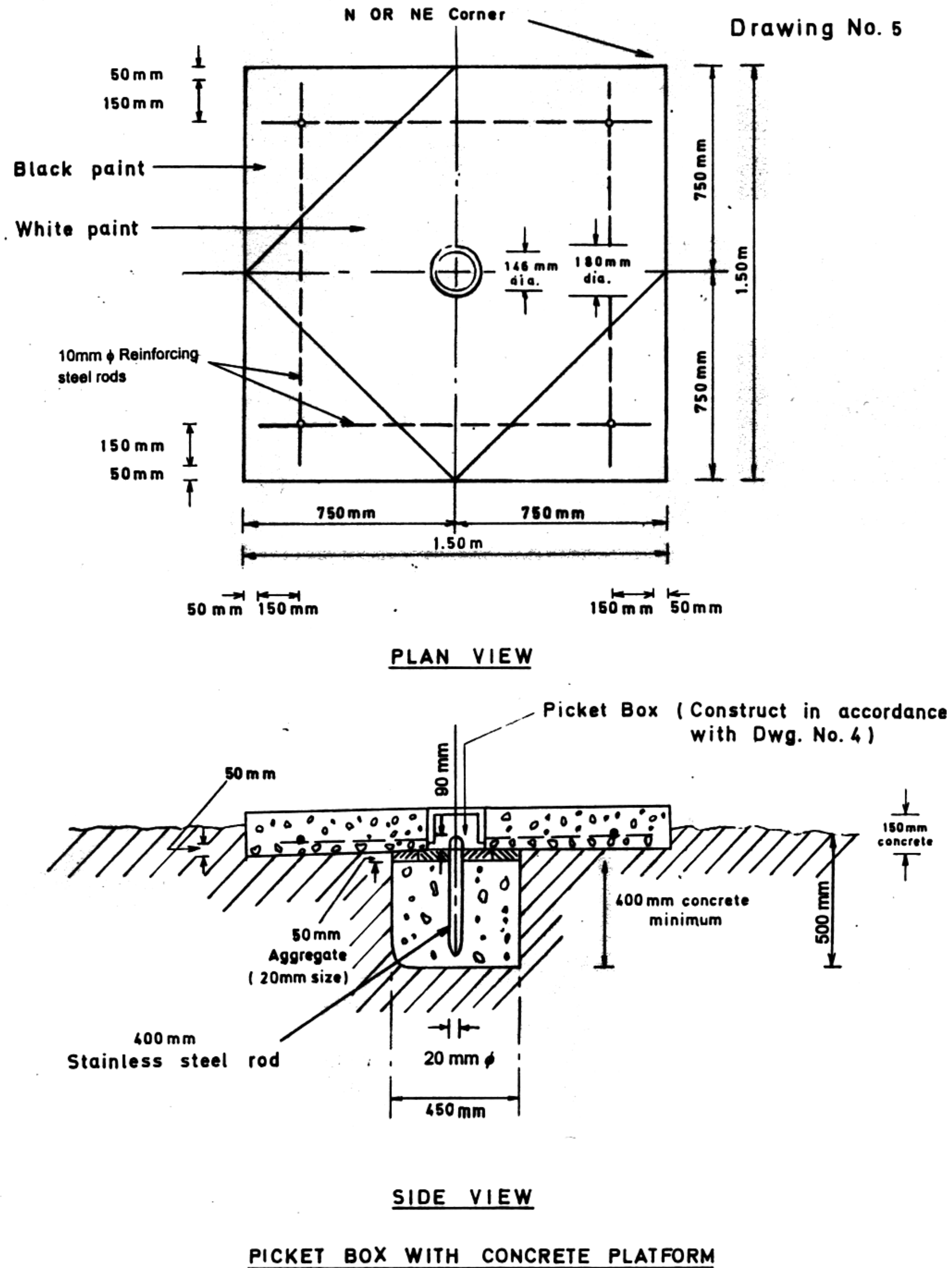


Appendix 3.1
Drawing No. 4 – Picket Box Fixed in Open Ground

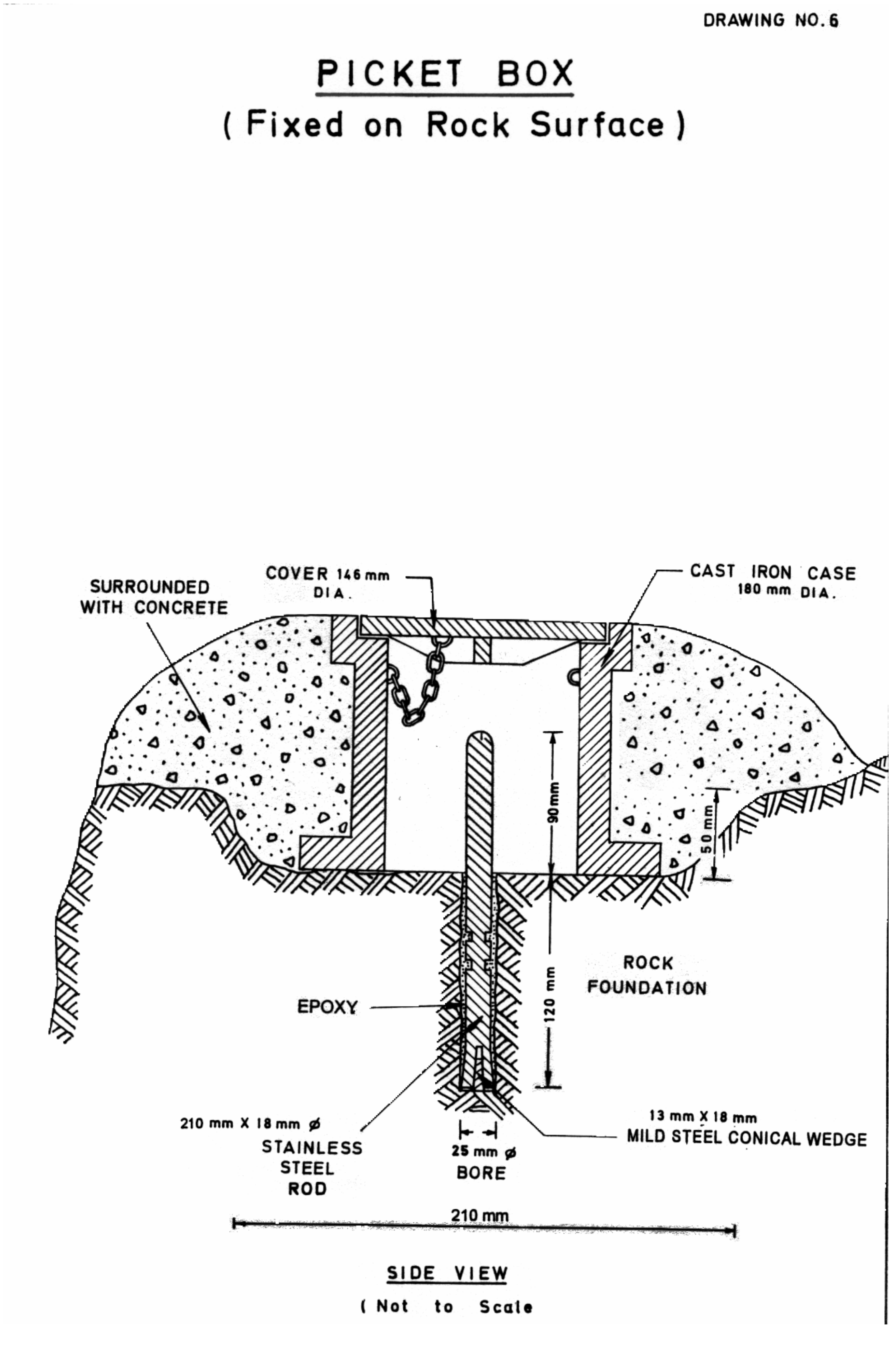


SIDE VIEW
NOT TO SCALE

Appendix 3.1
Drawing No. 5 – Picket Box with Concrete Platform



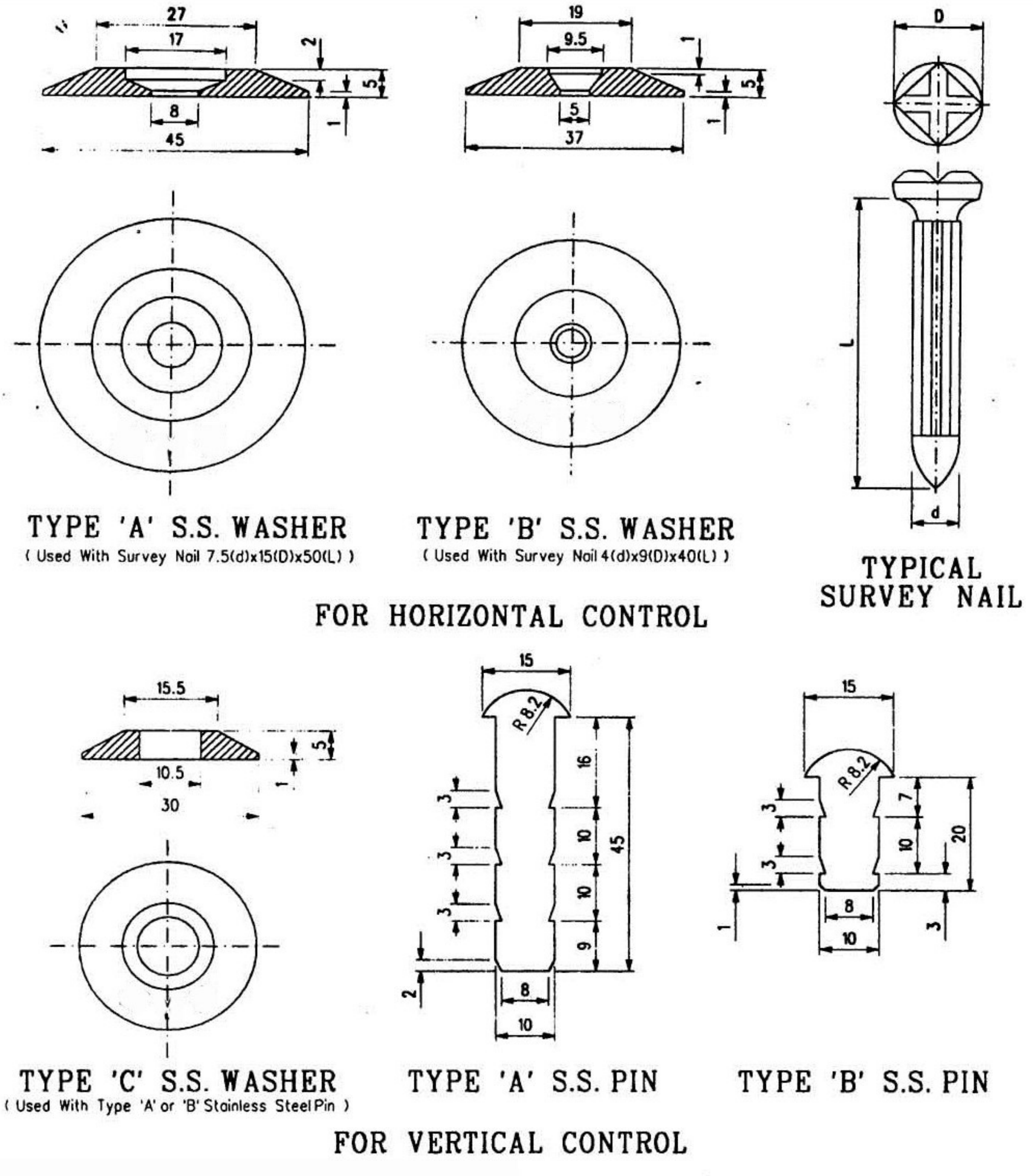
Appendix 3.1
Drawing No. 6 – Picket Box Fixed on Rock Surface



Appendix 3.1

Drawing No. 7 – Survey Marks for Horizontal and Vertical Control

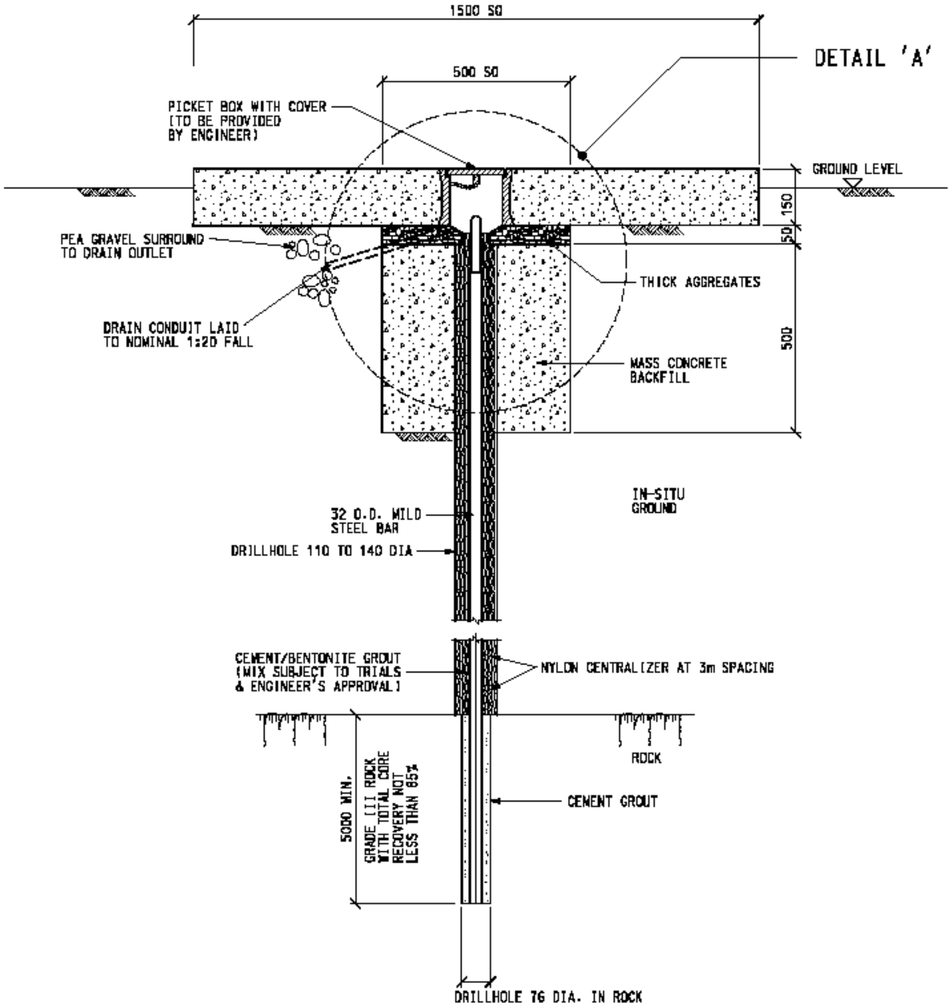
SURVEY MARKERS FOR HORIZONTAL AND VERTICAL CONTROL



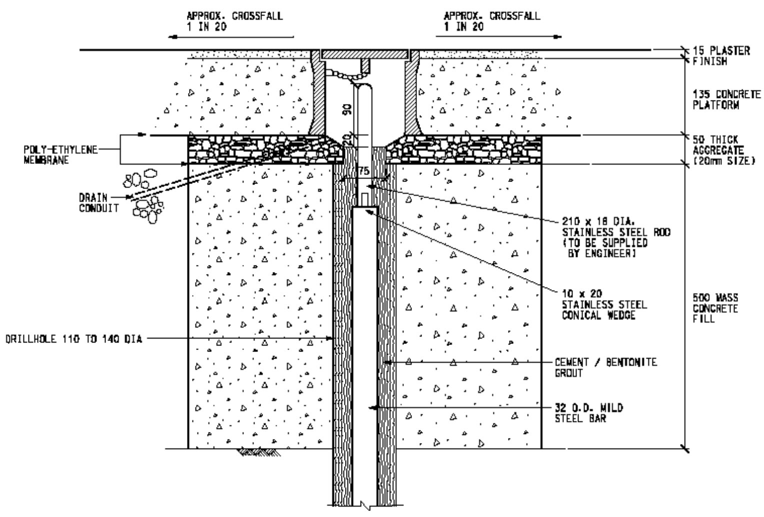
Notes :

1. These survey markers are only for uses, with guidelines, by engineering survey staff.
2. All dimensions are in mm.
3. All stainless steel material denoted by 'S.S.' to be grade 304.
4. All English lettering to be acid etched on stainless steel with red color paint back-filling.
5. Type 'A' stainless steel pin should normally be used with type 'C' stainless steel washer. Type 'B' stainless steel pin could be used when ground conditions prohibit the use of type 'A' pin.

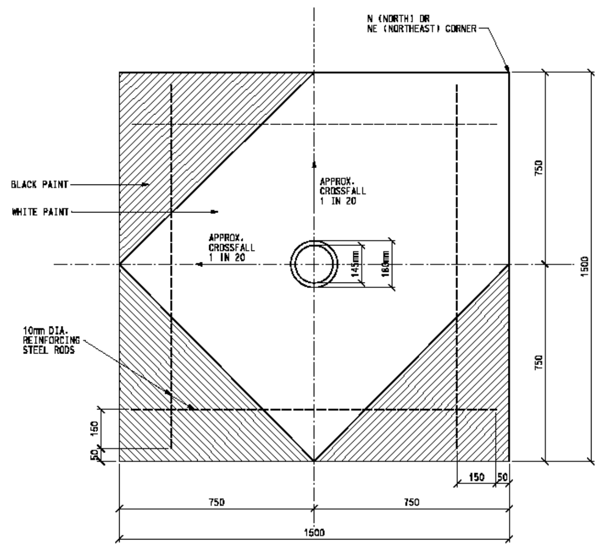
Appendix 3.1
Drawing No. 8 – Details of Bedrock Bench Mark



BEDROCK BENCHMARK



DETAIL 'A'



BEDROCK BENCHMARK PLAN VIEW

Chapter 4

Global Navigation Satellite Systems (GNSS) Survey

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Chapter 4 Global Navigation Satellite Systems (GNSS) Survey

4.1 Introduction

4.1.1 The use of Global Navigation Satellite Systems (GNSS) for works projects is generally classified into GNSS static survey for establishing survey control (GNSS Control Survey) and Real Time Kinematic survey (RTK Survey) for setting-out/ check setting-out and detail survey.

4.2 Scope

4.2.1 This chapter is to set out the accuracy requirements and procedures for the GNSS survey conducted for engineering purposes and it is applicable to all engineering survey works involving the use of GNSS.

4.3 Accuracy and Standards

4.3.1 <u>GNSS Control Survey</u>

4.3.1.1 A GNSS Survey Control Scheme consists of a set of GNSS survey control stations determined by simple baselines or a network of baselines. It is classified into Class I and Class II. The classes are defined to cater for general engineering surveying purpose. Class I Control Scheme shall be observed by Static Survey Method and Class II Control Scheme shall be observed by Static or Fast Static Survey Method-

Survey Method	Class of Control [See Note below]	Base error (a) (mm)	Length dependent error (b) (ppm)
Static	I	5	1
Static or Fast Static	II	10	3

The accuracy of the GNSS baseline is represented by the following formula:

$$\sigma = \pm\sqrt{a^2 + (bL)^2} \text{ mm}$$

where a is base error in mm
b is length dependent error
L is the length of the GNSS baseline in kilometers

4.3.2 <u>RTK Survey</u>

4.3.2.1 A RTK system check shall be done before the commencement and at the end of RTK survey task for checking the overall equipment settings, positioning quality, and transformation settings. It shall also be made at any appropriate time during the course of each RTK observation session or at any time the base receiver(s) and rover receiver(s) are setup and initialised to detect for blunders and the initialization quality of the survey. The observation criteria and acceptance criteria for the RTK system check shall be set and approved by the Surveyor prior to the survey. In addition, the following requirements for RTK system check shall be followed:

(a) By setting up own base station(s) for RTK survey:
If only one base station is set up, at least two known control stations shall be measured. If two base stations are set up, at least one known control station shall be measured from the two different base stations. Two base stations are recommended.

(b) By application of RTK correction data of the Satellite Positioning Reference Network (SatRef) of LandsD:
If a single rover is used, at least one known control station shall be measured.

4.3.2.2 Under normal circumstances, the discrepancy of the surveyed coordinates of the same point obtained from two RTK observation sessions either in Easting/Northing and the HKPD height shall not exceed 2 cm and 5 cm respectively. A larger discrepancy may also be accepted by the Surveyor depending on the purpose and positioning accuracy requirement of the survey.

4.4 Instrumentation

4.4.1 The General Principles in Chapter 2 should apply.

4.4.2 Dual-frequency GNSS receiver which is capable of making carrier phase observations shall be used in GNSS survey for various kinds of engineering survey works.

4.5 Survey Procedures

4.5.1 GNSS Control Survey

4.5.1.1 Origin of Survey

(a) Class I GNSS Control Survey

The origin shall be the Satellite Positioning Reference Stations or GNSS control stations of Geodetic Survey Section of Lands Department.

(b) Class II GNSS Control Survey

The origin shall be the GNSS control stations originated from the Satellite Positioning Reference Stations of Lands Department or higher order.

4.5.1.2 Selection of Control Stations

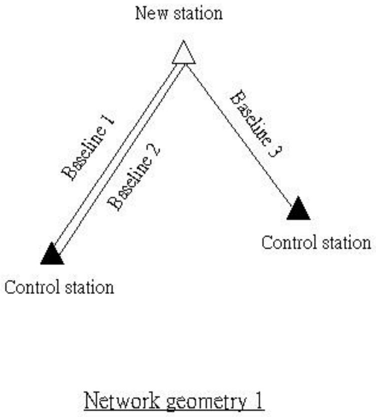
(a) Check clearance to sky. Avoid obstruction above 15° cut-off angle. Unless otherwise approved by the Surveyor, obstruction diagram should be prepared for checking the availability of satellites. A sample obstruction diagram is at Appendix 4.1;

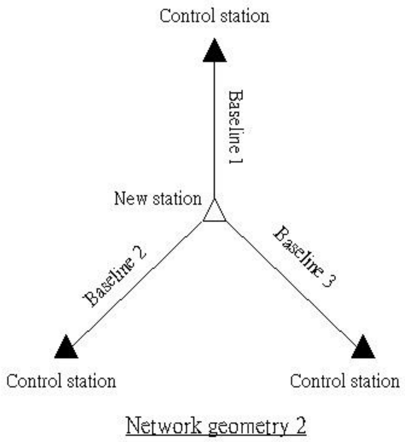
(b) Check for possibility of multipath. Avoid locations in close proximity to the significantly reflective surfaces and radio transmission sources;

(c) Check for inter-visibility of control station if terrestrial measurement is to be taken; and

(d) The intersection angle of the baselines at the new GNSS control station should be geometrically strong (preferably within the range of 30° to 150°).

Examples of network geometry are shown below.



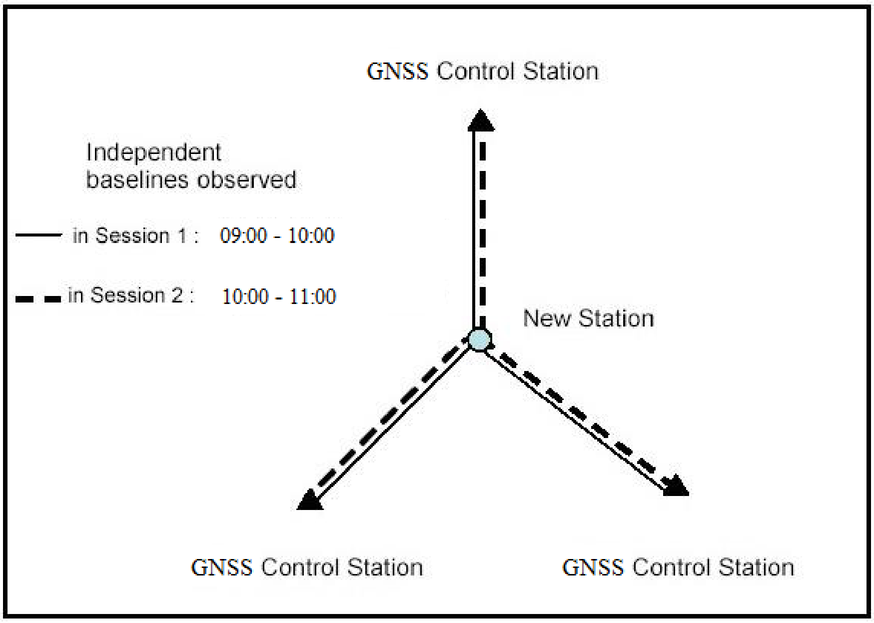


4.5.1.3 Control Scheme Configuration

(a) Every new GNSS control station shall be fixed by at least 3 GNSS baselines and be connected to, at least, two GNSS control stations;

(b) All GNSS baselines of the control scheme shall be independent baseline; and

(c) At least two observation sessions shall be carried out for every baseline of Class I GNSS control survey. Example of different observation sessions for GNSS baselines is shown in below diagram.



4.5.1.4 Recommended Observation Criteria

(a) Static Survey.

- No. of Satellite $\geqq$ 5
- GDOP $\leqq$ 5
- Observation session $\geqq$ 60 minutes
- Epoch rate = 5 seconds
- Elevation mask $\geqq$ 15°

(b) Fast Static Survey
- No. of Satellite ≧ 5
- GDOP ≦ 5
- Observation session ≧ 15 minutes
- Epoch rate = 5 seconds
- Elevation mask ≧ 15°
- Interval between observation sessions ≧ 30 minutes

4.5.1.5 Field Observation

(a) Check the instrument against the checklist as approved by the Surveyor;

(b) Record field information in GNSS observation field sheet at Appendix 4.2 or other form as approved by the Surveyor;

(c) For Class I GNSS Control Survey, GDOP shall be recorded in regular time interval. If the GDOP varies from the specification substantially, the observation time shall be extended if necessary;

(d) Set up all the GNSS antennae again for a new observation session; and

(e) New station fixed by GNSS should be checked by means of angular and linear measurements whenever practicable.

Note1 : To avoid discrepancy due to difference in survey origin, linking GNSS control station to existing control station surveyed by traditional means (such as traversing) should be carried out with caution.

Note2 : For prolonged GNSS observation session, data linkage between the GNSS antenna and receiver should be checked regularly to avoid loss of connection.

4.5.1.6 Baseline Processing

(a) Use the GNSS baseline program recommended by the GNSS receiver manufacturer;

(b) Apply suitable antenna calibration models for antennae of different manufacturers used in an observation session;

(c) Check the processing parameters including antenna types, cut-off angles, a priori root mean square settings, tropospheric and ionospheric models used, etc.;

(d) Check the GNSS data against observation criteria and remove less desirable data whenever necessary, e.g. large GDOP, many cycle slips or from poor satellites;

(e) Check and only accept baselines with fixed integer ambiguity solution; and

(f) The discrepancy of horizontal baseline components of repeated baselines shall be less than $2\sqrt{2}\sigma$ where σ is the standard error of the measured baseline specified in paragraph 4.3.1 above.

4.5.1.7 GNSS Adjustment Computation

(a) The known GNSS control stations shall be checked before being adopted as origins. The measured horizontal baseline components of the GNSS control stations shall not differ from the computed horizontal baseline components derived from published values by more than 2σ. (i.e. dLat (observed) - dLat (computed) < 2σ and dLong (observed) - dLong (computed) < 2σ);

(b) Record the checked GNSS Control Stations in GNSS Survey Origin Checking Form. A sample GNSS Survey Origin Checking Form is at Appendix 4.3;

(c) The datum transformation and map projection parameters published by the Geodetic Survey Section of Lands Department shall be used for converting the geodetic coordinates in ITRF96 into Hong Kong 1980 Grid coordinates;

(d) Check the adjustment parameters so that proper observation standard deviations and test parameters are used;

(e) All GNSS baselines used for computing the solution shall be independent baselines;

(f) Every new GNSS control station shall be fixed by at least 3 independent GNSS baselines and be connected to, at least, two GNSS control stations;

(g) All Control Schemes shall be adjusted by the method of least squares; and

(h) The residual of horizontal baseline components shall be less than 2σ.

4.5.2 RTK Survey for Detail Survey

4.5.2.1 Planning and Reconnaissance

(a) Check the suitability of GNSS for the survey on the following at planning or reconnaissance stage:

i) Check that the achievable accuracy is up to the job requirements;

ii) Check clearance to sky. Avoid obstruction above 15° cut-off angle. Use the obstruction diagram, if necessary. A sample obstruction diagram is at Appendix 4.1;

iii) Identify suitable time slot. Ensure that sufficient number of satellites is available throughout the whole observation periods (no. of satellite ≧ 5, GDOP ≦ 5);

iv) Check for possibility of multipath. Avoid locations in close proximity to the significantly reflective surfaces and radio transmission sources; and

v) For using SatRef RTK correction data, check internet availability of the area to be surveyed.

(b) Use up-to-date Datum Transformation Parameters from Survey and Mapping Office of Lands Department or localised transformation parameters as appropriate;

(c) Set observation criteria and acceptance criteria for RTK system check according to accuracy requirement or as approved by the Surveyor. The observation time depends on the accuracy requirement. Reference to the manufacturer's recommendations shall be made in observation time for the highest level of accuracy measurements.

(d) Set observation criteria and acceptance criteria for RTK measurements according to accuracy requirement or as approved by the Surveyor;

(e) For setting up own base station, at least two known stations shall be use for checking if only one base station is setup. Two base stations are recommended;

(f) For using SatRef RTK correction data, make sure a SatRef reference station is available within 10 km of the area to be surveyed.

(g) Obtain surveyed World Geodetic System (WGS84(ITRF96)) coordinates, Hong Kong 1980 Grid coordinates and HKPD of known stations whenever possible; and

(h) The recommended practical limit for high accuracy GNSS-RTK shall not exceed 2 km.

4.5.2.2 Field Measurement

(a) Perform RTK system check and check the transformation settings before commencement of survey. Observe the observation criteria for system check and the observation criteria for measurements during survey.

(b) After taking about 50 number of points or two hours, one of the following checking procedures, where appropriate, shall be carried out. If the discrepancy between two RTK observation sessions exceeds the allowable discrepancy in paragraph 4.3.2.2 or the allowable discrepancy as accepted by the Surveyor, all the surveyed points observed prior to the checking shall be discarded and the surveyed details shall be re-observed.

(c) Measure a known station and compared against its known coordinates;

(d) Measure an unknown point for two or more times. When taking these measurements, the rover receiver shall be reinitialised between these measurements;

(e) Measure an unknown point from two different base stations; and

(f) Compare distance between two RTK surveyed points by tie measurement.

4.5.2.3 All measurement records and relevant information shall be compiled in the computation folder

4.5.2.4 Office Work

(a) Compute the control stations, if necessary. Reduce the field measurements recorded and plot the detail survey plan by using CAD and GNSS processing software approved by the Surveyor. The detail survey plan should be prepared in compliance with the procedures in Chapter 5 Record (Detail) Survey.

4.5.3 <u>RTK Survey for Setting-out/ Checking setting-out</u>

4.5.3.1 Planning and Reconnaissance

(a) Repeat the procedures at paragraph 4.5.2.1.

4.5.3.2 Field Measurement

(a) Perform RTK system check and check the transformation settings before commencement of survey. Observe the observation criteria for system check and the observation criteria for measurements during survey.

4.5.3.3 Recommended workflow

(a) Navigate to the setting-out location using the calculated coordinates and take a measurement (e.g. YYYYM1). Compare the surveyed coordinates with the calculated coordinates. Trace the direction and displaced distance, move to the exact location.
    i) Take a measurement at the exact location then store (YYYYM1) and overwrite previously stored surveyed coordinates;
    ii) For using SatRef RTK correction data or setup of one base station, force stop and reinitialising the rover receiver. Then, take another measurement and store the surveyed coordinates (e.g. YYYYM2). For setup of two base stations, change the rover receiver channel to another base receiver, take another measurement and store the surveyed coordinates (e.g. YYYYM2);
    iii) Compare the two surveyed coordinates (i.e. YYYYM1 and YYYYM2). If the two surveyed coordinates are consistent with each other, the setting-out location is correctly located;
    iv) Establish the setting-out mark at the setting-out location; and
    v) Take a measurement on the setting-out mark and store the surveyed coordinates with a different name for record. Compare the surveyed coordinates with the calculated coordinates for checking.

(b) All measurement records and relevant information shall be compiled in the computation folder.

4.5.3.4 Office Work

(a) Reduce the field measurements recorded using GNSS processing software approved by the Surveyor. Compile all relevant information in the computation folder.

4.6 **Deliverables**

4.6.1 Coordinates list, location diagram and photographs of the newly established control stations should be submitted.

4.6.2 Regarding RTK for detail survey, guidelines about deliverables in Chapter 5 "Record (Detail) Survey" should also be referred.

4.6.3 Regarding RTK for setting out and checking setting out survey, guidelines about deliverables in Chapter 6 "Setting Out and Check Survey" should also be referred.

4.7 **Quality Assurance**

4.7.1 The General Principles in Chapter 2 should apply.

4.8 **Survey Records**

4.8.1 The General Principles in Chapter 2 should apply.

4.8.2 GNSS Control Survey

4.8.2.1 Survey records should include the following items:

(a) GNSS control diagrams;

(b) Obstruction diagrams;

(c) Field notes;

(d) Softcopy of full set of raw data in RINEX (Receiver Independent Exchange) Format;

(e) GNSS control station summary;

(f) New survey station summary;

(g) Baseline processing parameters;

(h) Baseline processing results;

(i) Checking of control origin;

(j) Comparison of repeated baselines;

(k) Least square network adjustment results (including residuals of all observations);

(l) Final coordinates of new GNSS stations; and
  i) WGS84(ITRF96) Geodetic coordinates
  ii) HK 1980 Grid coordinates;

(m) Backup of the GNSS computation work project in digital form.

4.8.3 RTK survey

4.8.3.1 Survey records should include the following items:

(a) Field notes including the following information:
   i) Date of survey;
   ii) Start/ stop time;
   iii) Equipment ID;
   iv) Antenna height;
   v) Elevation mask;
   vi) System check records;
   vii) Any special event which may affect the quality of the observation (such as bad weather condition); and
   viii) Terrestrial measurements for independent checks

(b) Coordinate list of RTK surveyed points together with the corresponding position and height quality values and GDOP; and

(c) Shots diagram showing the RTK surveyed points

Appendix 4.1

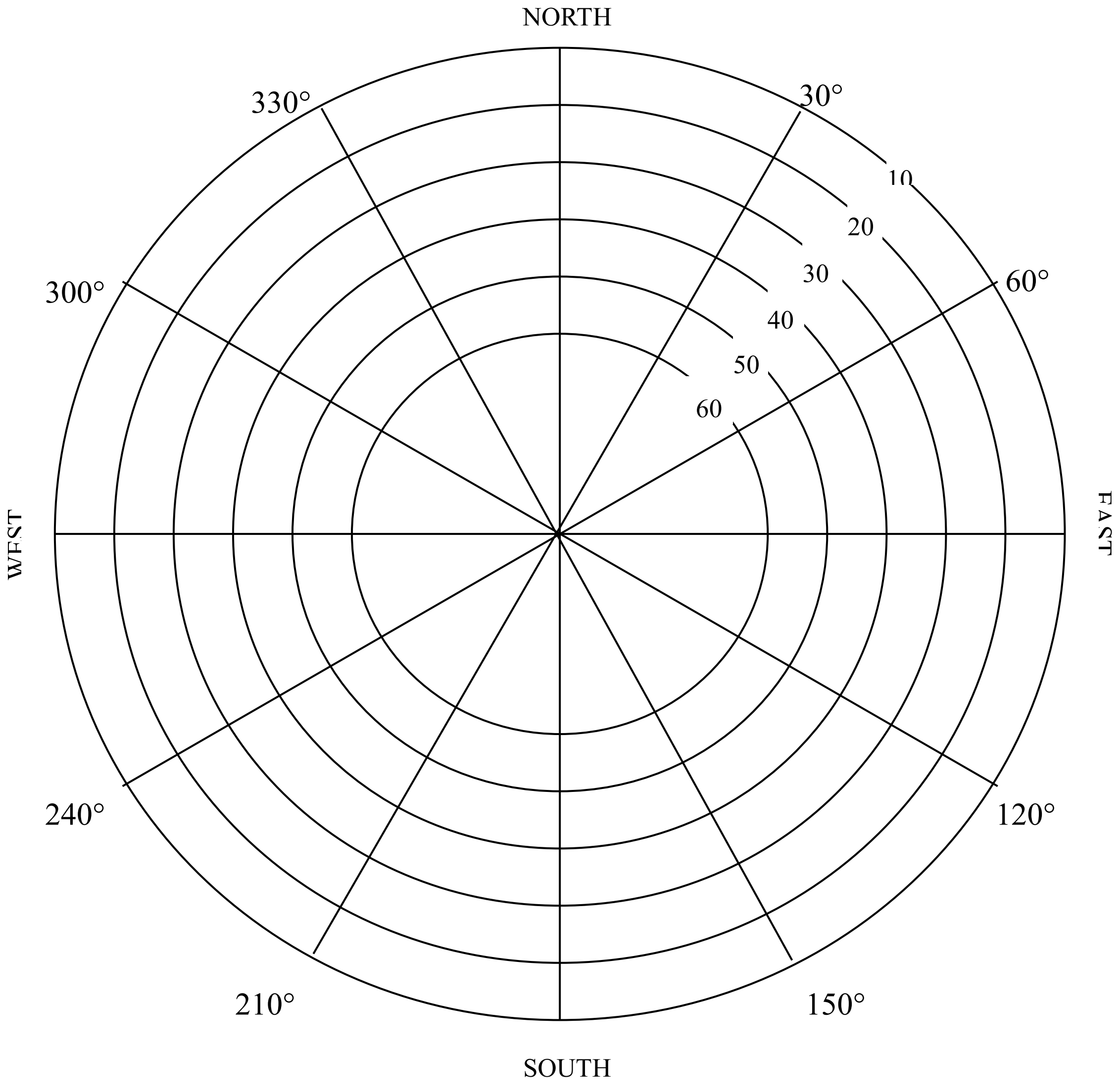
GNSS Station Horizon Obstruction Diagram (Sample)

Equipment I/D: ____________________________

(for measuring elevation angle)

Station No.: ________________

Approximate Position:	Latitude: ________ ° ________	Longitude: ________ ° ________	Height: __________ m



Note : Identify obstructions and shade in the relevant area on the chart above.

Do not record for elevations below 10 degrees. If there is no obscurity then indicate so.

Prepared by : __________________________ Post: _________________ Date : ______________

Checked by : __________________________ Post : _________________ Date : ______________

Appendix 4.2
GNSS Observation Field Sheet (Sample)

Survey project / Job No. ____________________________

Station Information

Station Name :_______________

Locality :_______________________________________

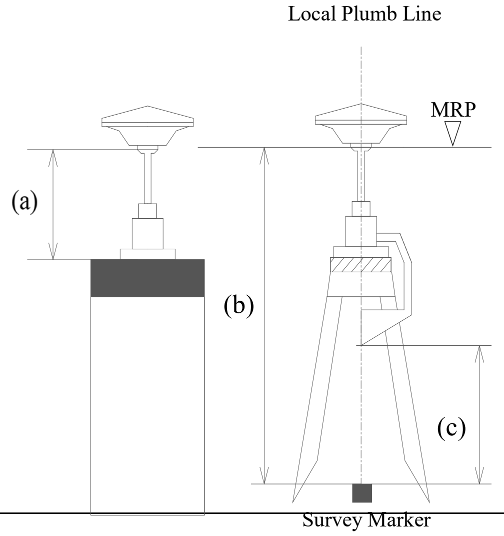
Date and Time	**Receiver Position**
Collection Rate : _________________	Latitude/Northing : ______________
Session No. : _________________	Longitude/Easting : ______________
Start Day/Time (Local Time) : __________	Ellipsoidal/
End Day/Time (Local Time) : __________	Orthometric Height : __________________

Instrument and Antenna Information

Receiver Model and No. : __________

Antenna Model and No. : __________

Antenna Height Measurement (Make measurements before and after observing session)



Measurement Position (Refer to diagrams and tick)

☐(a) ☐(b) ☐(c)

*Pocket tape/ Height Hook/ Height rod ID no._____________

	BEFORE	AFTER
	________ m	________ m
	________ m	________ m
Mean (Before and After)		________ m
Other offset (please indicate on sketch)		________ m
TOTAL ANTENNA HEIGHT		________ m

*delete if not applicable MRP – Mechanical Reference Plane

Obstruction or possible interference ______________________________________

____

General weather conditions ______________________________________

____

Operated by: ____________________ Checked by: ____________________

Post: ____________________ Post: ____________________

Date: ____________________ Date: ____________________

Appendix 4.3
GNSS Survey Origin Checking Form (Sample)

		Latitude			Longitude			Remark
		Deg	Min	Sec	Deg	Min	Sec	
Station Name								(1) known value
								(2) known value
Baselines component computed from known value								(3) = (1) - (2)
Measured baseline component								(4)
Diff. (mm)	(0.0001" =3mm)	mm			mm			(5) = (3) - (4)
*Allowable difference (mm)		mm			mm			

		Latitude			Longitude			Remark
		Deg	Min	Sec	Deg	Min	Sec	
Station Name								(1) known value
								(2) known value
Baselines component computed from known value								(3) = (1) - (2)
Measured baseline component								(4)
Diff. (mm)	(0.0001" =3mm)	mm			mm			(5) = (3) - (4)
*Allowable difference (mm)		mm			mm			

		Latitude			Longitude			Remark
		Deg	Min	Sec	Deg	Min	Sec	
Station Name								(1) known value
								(2) known value
Baselines component computed from known value								(3) = (1) - (2)
Measured baseline component								(4)
Diff. (mm)	(0.0001" =3mm)	mm			mm			(5) = (3) - (4)
*Allowable difference (mm)		mm			mm			

		Latitude			Longitude			Remark
		Deg	Min	Sec	Deg	Min	Sec	
Station Name								(1) known value
								(2) known value
Baselines component computed from known value								(3) = (1) - (2)
Measured baseline component								(4)
Diff. (mm)	(0.0001" =3mm)	mm			mm			(5) = (3) - (4)
*Allowable difference (mm)		mm			mm			

*Allowable Difference = 2σ where

For Class I Control Scheme, $\sigma = \pm\sqrt{(5^2+L^2)}$ mm, where L is the length of the baseline in kilometres

For Class II Control Scheme, $\sigma = \pm\sqrt{(10^2+(3L)^2)}$ mm, where L is the length of the baseline in kilometres

Prepared by : __________________ Checked by : __________________

Date : __________________ Date : __________________

Chapter 5

Record (Detail) Survey

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Chapter 5 Record (Detail) Survey

5.1 Introduction

5.1.1 Record survey is to record the existing topography and positions of natural or man-made features within the extent of site. In works project, record survey serves for various purposes in different project stages such as construction design, earthwork computation and payment, as a proof of works done, etc.

5.1.2 References can be made to the Clause 1.47 "Survey of the Site" in the General Specification for Civil Engineering Works, Volume 1, 2006 Edition (https://www.cedd.gov.hk/eng/publications/standards-spec-handbooks-cost/stan-gs-2006/index.html) and Particular Specification, that joint survey should be carried out, and the result should be agreed with the Engineer as soon as practicable before commencing the works in the area surveyed.

5.1.3 For other types of record survey such as "Drainage Record Survey", "Water Mains Record Survey" and "Tree Survey", please refer to Chapters 11, 12 and 13 respectively.

5.2 Scope

5.2.1 This chapter describes various types of record detail survey and sets out the standards and procedures of work.

5.2.2 Record survey could be summarised as initial survey, interim survey and as-built survey as listed below:

(a) Initial survey is that required to record all original land forms, features, existing seabed and embankment forms, levels and the like before commencement of the works.

(b) Interim survey is that required to record the site at any time during the project period as requested by the Engineer.

(c) As-built survey is that final survey to be executed on all completed phases of the works.

5.2.3 Initial Survey

5.2.3.1 Before commencement of the works, the Surveyor should carry out a detail survey within the subject site to record all initial levels and positions of existing features and the surveyed topography on initial survey record plans. In works project, the Surveyors from different parties should carry out the initial survey jointly after completion of site clearance as agreed. The initial survey results should be submitted to the Engineer for agreement before commencing other works in the area surveyed.

5.2.4 Interim Survey

5.2.4.1 The Surveyor should carry out, to the Engineer's satisfaction, any extra surveys required to resolve any doubts which may arise as to the correctness of any survey or record at any time specified by the Engineer. Interim survey would be carried out throughout the construction period at timely intervals as stipulated in Particular Specification or agreed with Engineer for the purposes of recording the works progress, earthwork computation and as basis for interim payment.

5.2.5 As-built Survey

5.2.5.1 As-built survey serves to record the as-constructed positions of all features whether are newly constructed or original features have been modified during the construction period. It provides the proof of the works done in the project. The Surveyors from different parties should carry out as-built survey jointly at any time specified by the Engineer or in accordance with the timeframe (i.e. phase completion) set in Particular Specification or agreed with the Engineer.

5.2.6 As-built Survey for Road Work

5.2.6.1 To assure the provision of the required road inventory records for the asset management of the Highways Department, as-built surveys of those completed road works to be handled over to Highways Department should fulfill the requirements of Geographical Information System (GIS) Specifications for Engineering Surveys of Highways Department available on Highways Department's website (https://www.hyd.gov.hk/en/technical_references/technical_document/GIS_Specifications/index.html).

5.3 Accuracy and Standards

5.3.1 The types of features shall be surveyed including lines, positions and levels for the surface features and survey details within the site unless otherwise specified by the Engineer.

5.3.2 Accuracy for Planimetric Information

5.3.2.1 The acceptable tolerance for each type of feature shall comply with the tolerance acceptable to the Engineer and capable of coping with the tolerance as required by the project requirement.

5.3.3 Accuracy for Vertical Information

5.3.3.1 The acceptable tolerance for each type of feature shall comply with the tolerance acceptable to the Engineer and capable of coping with the tolerance as required by the project requirement.

5.3.4 Spot Levels

5.3.4.1 With reference to drawing scales, sufficient spot levels shall be surveyed such that the true ground topography is accurately represented on drawings.

5.4 Instrumentation

5.4.1 The General Principles in Chapter 2 should apply.

5.4.2 The following equipment is normally used for record survey subject to project requirements and site conditions.

(a) GNSS Multi-Satellite Equipment for Static & RTK Survey;

(b) Total Station;

(c) Levelling Equipment;

(d) Laser Scanning Equipment;

(e) Unmanned Aerial Vehicle (UAV);

(f) Data Logging System & Data Processing Software;

(g) General Equipment; and

(h) Survey Consumables

5.5 Survey Procedures

5.5.1 The survey shall be carried out in accordance with the requirements as stipulated in the instructions, guidelines, notes and relevant documents which are currently in use and acceptable by the Engineer.

5.5.2 Planning & Reconnaissance

5.5.2.1 General

(a) Identify the project location, area and the extent of the survey;

(b) Search and collect the data of survey origins for the project;

(c) Obtain appropriate mapping for the area and identify the route of access;

(d) Verify and familiarise with the project area and the extent of the survey;

(e) Select essential details, which are for further reference and layout computation, if any;

(f) Locate existing control stations;

(g) Determine the positions & consider the monumentation of new control stations in accordance with Chapter 3 "Survey Datum and Survey Control";

(h) Plan and select suitable survey equipment to be used; and

(i) Liaise with local people if necessary.

5.5.2.2 Additional requirement with GNSS/UAV/laser scanning Application

(a) The guidelines in Chapter 4 "Global Navigation Satellite Systems (GNSS) Survey", Chapter 14 "Unmanned Aerial Vehicle Survey" and Chapter 15 "Laser Scanning Survey" shall apply.

5.5.3 Field Survey

5.5.3.1 Establishment of Control Stations

(a) The guidelines in Chapter 3 "Survey Datum and Survey Control" shall apply.

5.5.3.2 Detail Survey by Radiation

(a) Check the equipment set-up carefully before survey, including the centering and levelling of the survey instrument;

(b) Record the type or model and identity number of survey equipment used and other administrative data on the field measurement books at the start of daily field operation;

(c) Check and record on the field measurement book the horizontal collimation error and the vertical index error at the start of daily field operation. (FL and FR readings shall not differ by more than 1 minute. Request for calibration if necessary);

(d) Observe bearing orientation to at least 2 known control stations and measure a distance to at least 1 known control station for verification;

(e) Check the bearing orientation by sighting to one of the reference points after taking about 50 shots and at the end of the observation of each set-up. The check reading shall not differ from the initial reading by more than 1 minute. If the discrepancy exceeds 1 minute, all the survey shots observed prior to the check sight to the reference point shall be discarded. The survey instrument shall be checked, re-levelled/reset, if necessary, and the surveyed details shall be re-observed;

(f) Selected essential details for further reference and layout computation are to be surveyed by double radiation or with check by direct measurements;

(g) Radiation length shall not exceed 150 metres;

(h) Changing points of details/terrain shall be surveyed;

(i) All tie measurements shall be recorded in the field measurement books;

(j) Prepare sketches to facilitate the identification of surveyed details; and

(k) Ensure that all details within the required area are surveyed.

5.5.3.3 Detail Survey by GNSS-RTK/UAV/laser scanning

(a) The guidelines in Chapter 4 "Global Navigation Satellite Systems (GNSS) Survey", Chapter 14 "Unmanned Aerial Vehicle Survey" and Chapter 15 "Laser Scanning Survey" shall apply.

5.5.4 Office Work

(a) Compute the control stations, reduce the field observations and plot the detail survey plan by using programs, approved CAD software and GNSS Processing software or as directed by the Surveyor;

(b) All symbols and line types used on the final plan should comply with the CAD Standard for Works Projects (CSWP) (https://www.devb.gov.hk/en/construction_sector_matters/electronic_services/cad_standard/index.html) and the Drafting Specifications for Engineering Survey https://www.cedd.gov.hk/eng/publications/standards-spec-handbooks-cost/stan-svyspec/index.html); and

(c) Information such as railway protection limits, underground structures, etc., which would be useful for the Engineer to plan and manage the works, should be included on the detail survey plans, if necessary.

5.6 Deliverables

5.6.1 A set of initial, interim, as-built and/or other survey plans, if necessary, in both hardcopy and softcopy should be submitted to the Engineer upon phase completion of the works. The submitted survey plans should be presented in an acceptable professional standard and in an appropriate scale as specified by the Engineer. Upon the request of the Engineer, a copy of field notes, field data and resultant data arising from these surveys should be handed over to the Engineer in paper and digital format.

5.6.2 Drawing computer files with agreed format should be submitted to the Engineer and in compliance with the CSWP available on the website of Development Bureau and the Drafting Specifications for Engineering Survey available on the website of Civil Engineering and Development Department.

5.6.3 For the road works to be handed over to Highways Department for maintenance, the Surveyor of contractor should provide a set of as-built inventory records of completed road works in ArcGIS or other GIS format fully compatible with the Road Data Maintenance System of Highways Department in accordance with the GIS Specifications for Engineering Surveys of Highways Department available on Highways Department's website.

5.7 Quality Assurance

5.7.1 The General Principles in Chapter 2 should apply.

5.7.2 Field checks should be conducted to ensure the contents of survey plans are clear and sufficient to meet the scope of works without faults.

5.8 Survey Records

5.8.1 The General Principles in Chapter 2 should apply.

5.8.2 Upon phase completion of the work, a set of as-built record drawings should be submitted for the checking and endorsement by the Engineer in an agreed timeframe.

5.8.3 Change of versions and submitted survey plans should be recorded properly and traceable in a systematic filing system.

5.8.4 Appropriate number of site photos should be taken for better illustration of site condition and environment.

5.8.5 A copy of the as-built survey plans in graphical or in digital form should be passed to the Survey and Mapping Office (SMO) of the Lands Department (Attn: Technical Division, SMO) for updating the centralised land survey and mapping information by the relevant government departments or their consultants. See DEVB Technical Circular "Provision and Collation of Land Survey and Mapping Data" or its latest version for details.

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Chapter 6

Setting Out and Check Survey

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Chapter 6 Setting Out and Check Survey

6.1 Introduction

6.1.1 Setting out survey is the process of locating points or levels of the features (site boundary, roads, structures, buildings, etc., as specified by the Engineer) on ground according to the construction drawings or information provided by the Engineer. Checking of setting out work shall be carried out to ensure the points are set out in accurate positions and levels to comply with relevant survey standard and Engineer's requirement.

6.2 Scope

6.2.1 This chapter sets out the procedures and provide guidance for the setting out work and the checking of setting out work.

6.2.2 In works project, the Surveyor of contractor should be responsible for all survey setting out works associated with the project and afford the Engineer or Engineer's representative all facilities and equipment to attend the survey checks.

6.2.3 The Surveyor representing the Engineer should be responsible for checking the contractor's setting out works including but not limited to road works, drainage works, formation areas, retaining structures, structure works etc. as appropriate.

6.2.4 The Surveyor of contractor may propose other survey methods for setting out and checking setting out work. Under special circumstances, an alternative work standard may be set. However, it shall be agreed and recorded by the Engineer or Engineer's representative before adopting the alternation.

6.3 Accuracy and Standards

6.3.1 The setting out works and the checking of setting out work shall comply with the accuracy standard and quality requirements as stipulated in the General Specification for Civil Engineering Works unless otherwise specified by the Engineer.

6.4 Instrumentation

6.4.1 The General Principles in Chapter 2 should apply.

6.5 Survey Procedures

6.5.1 The survey shall be carried out in accordance with the procedures below or other specific requirements as stipulated in the instructions, guidelines, notes and relevant documents which are currently in use and acceptable by the Engineer. Under special circumstances, the Surveyor may propose other survey methods or set an alternative work standard for setting out / checking of setting out works if agreed by the Engineer.

6.5.2 Office Preparation

(a) The Surveyor shall review and examine the survey requests and Engineer's requirement carefully, choose appropriate survey method and equipment for setting out works / checking of setting out works;

(b) The Surveyor shall work out the setting out data from drawings and information provided by the Engineer;

(c) In works project, the Surveyor of contractor shall notify the Engineer for survey check by submitting a standard request form, "Inspection/Survey Check Request Form", when a check survey is required;

(d) The Surveyor of contractor shall work out and submit the setting out data which derived from the latest information and drawings to the Engineer;

(e) The Surveyor of the Engineer shall examine the submitted setting out data from the relevant engineering drawings, engineering sketches and/or other relevant sources;

(f) The Surveyor shall search the suitable horizontal and/or vertical control stations for the survey; and

(g) The Surveyor shall choose appropriate survey and office equipment for the work.

6.5.3 Field Survey

6.5.3.1 Establishment of Control Stations

(a) If necessary, new or additional horizontal and/or vertical control stations shall be established in accordance with Chapter 3 "Survey Datum and Survey Control".

6.5.3.2 Setting out / Checking setting out by Radiation

6.5.3.2.1 General requirements

(a) Record the type or model and identity number of survey equipment used and other administrative data on the field measurement books at the start of daily field operation;

(b) Check the equipment set-up carefully before survey, including the centering and levelling of the total station;

(c) Check and record on the field measurement book the horizontal collimation error and the vertical index error at the start of daily field operations (FL and FR readings shall not differ by more than 1 minute, request for calibration if necessary);

(d) Observe orientation bearing to at least 2 known control stations and measure the distance to at least 1 known control station for verification;

(e) Setting out mark should normally be observed on one face;

(f) Distance between instrument and setting out mark should normally not exceed 100m; and

(g) Observe a check bearing by sighting to a reference object at the start of set up for setting out. Check the bearing orientation after setting out 10 points or less and at the end of the setup of setting out to check the stability of the equipment. If the check bearing differs from the initial observed bearing by more than 1 minute, re-setting out shall be conducted.

6.5.3.2.2 Setting out / Checking setting out the position of setting out mark

(a) Computed setting out data (bearing and distance) shall be recorded in the field measurement book, or a copy of setting out data sheet attaching to the field measurement book;

(b) With correct orientation to two reference control stations, set the total station to the desired bearing, and guide the target to the position of the desired direction;

(c) Measure the distance from the total station to the target;

(d) Guide the target to the desired distance from the total station;

(e) Repeat (b), (c) and (d) in sequence until the target reaches the desired position of the setting out point;

(f) After the setting out marker is placed properly at the setting out point, the horizontal angle, vertical angle and slope distance from the instrument to the setting out point should be observed again and to be recorded in the field measurement book; and

(g) Survey the setting out point from another control station or take direct measurements as an independent check.

6.5.3.2.3 Checking level of setting out mark

(a) If the reduced level of a setting out mark is required for checking, the instrument height and all signal heights shall be measured and recorded properly;

(b) Observe and record horizontal and vertical angle to the setting out mark; and

(c) Take and record at least two consistent distance measurements from the observed station to the setting out mark.

6.5.3.3 Setting out/Checking setting out by GNSS –RTK

6.5.3.3.1 The survey procedures and requirements in Chapter 4 “Global Navigation Satellite Systems (GNSS) Survey” shall apply.

6.5.3.4 Setting out / Checking setting out by direct levelling

6.5.3.4.1 General Requirements

(a) The survey procedures and requirements of vertical survey control in Chapter 3 “Survey Datum and Survey Control” shall apply; and

(b) Before leaving the site, ensure that the levelling route is closed within the allowable misclosure.

6.5.3.4.2 Setting out the level of point by direct levelling

(a) Backsight to a known BM/TBM and record the staff reading;

(b) Place the levelling staff over the provisional level mark for the setting out point. Record the staff reading;

(c) Calculate the provisional level of the setting out mark by Height of Collimation Method;

(d) Adjust and set the provisional setting out level mark to the desired level;

(e) Place the levelling staff on the setting out level mark. Observe and record the staff reading for checking; and

(f) After setting out all level marks, backsight to the known BM/TBM again and record the staff reading for checking.

6.5.3.5 Check level of setting out mark by direct levelling

The levels of setting out marks shall either be surveyed as a turning point or by intermediate sight method. If the setting out marks are surveyed by the intermediate sight method, they shall be observed at least twice from different instrument setup.

6.5.4 Computation

6.5.4.1 Field Computation

(a) Compute coordinates / level of the setting out point; and

(b) Compare coordinates / level of the setting out point with the deduced setting out data.

6.5.4.2 Office Work

(a) Examine the completed survey works against the survey works specification and the agreed survey requirements;

(b) If discrepancies were found out of allowable tolerance, the Surveyor shall investigate the cause of discrepancies and record properly. The Surveyor shall inform the Engineer and re-survey if necessary;

(c) Provide appropriate information on the standard request form with all related record of survey work; and

(d) Compile all the relevant information in the computation folder.

6.6 Deliverables

6.6.1 The setting out marks on ground should be shown to the Engineer or Engineer's representative on site to take over.

6.6.2 The survey results should be submitted in accordance with the request as agreed with the Engineer, e.g. sketch or plan showing the nature of setting out marks, survey results comparing coordinates/level of the setting out marks, etc.

6.7 Quality Assurance

6.7.1 The General Principles in Chapter 2 should apply.

6.8 Survey Records

6.8.1 The General Principles in Chapter 2 should apply.

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Chapter 7

Monitoring Survey

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Chapter 7 Monitoring Survey

7.1 Introduction

7.1.1 Monitoring survey is commonly involved in engineering survey work to gauge the disturbance to existing structures by construction or to monitor the movement of the newly created structures. This chapter, to be consistent with the above, should be read in conjunction with Part 6: Geotechnical Instrumentation of Section 7 Geotechnical Works of General Specification for Civil Engineering Works Volume 1, Edition 2020.

7.2 Scope

7.2.1 This chapter defines the survey requirements for settlement monitoring, tilting monitoring survey and deformation survey of roads, bridges, buildings, slopes and structures as and when required.

7.2.2 Settlement monitoring is the systematic measurement to monitor settlement of roads, road pavements, bridges, buildings, slopes and structures.

7.2.3 Tilting monitoring survey is the systematic measurement of the verticality of columns, buildings and structures.

7.2.4 Deformation survey is the systematic measurement and tracking of the alteration in the shape or dimensions of any structures, roads, bridges, viaducts, tunnels or railways.

7.2.5 Instrument readings and processed data for geotechnical instrumentation shall be recorded on agreed record sheets, and shall be submitted to the Engineer as specified. The form of record sheets shall be as agreed by the Engineer.

7.2.6 The measurements for monitoring survey may be taken by automatic methods subject to the project requirements and shall be as agreed by the Engineer.

7.2.7 Initial readings shall be taken immediately or within the period as instructed by the Engineer after the instruments have been installed and after effects of installation have been subsided. The initial readings shall be submitted to the Engineer and shall form the basis of comparison of subsequent readings. The instruments and the initial readings shall be replaced if the initial readings are not repeatable.

7.2.8 The frequencies for monitoring survey shall be agreed with the Engineer. The Engineer shall be informed immediately of sudden or significant changes in the readings.

7.2.9 All installed instruments should be maintained in good working order until the expiry of Maintenance Period. They should be protected by suitable barricades, notices, signs, marker-buoys or by other methods agreed by the Engineer. Construction should be carried out in a manner that will avoid damage to the instruments.

7.3 Accuracy and Standards

7.3.1 Origin and Datum of Survey

7.3.1.1 The survey shall be carried out in terms of the Hong Kong 1980 Grid System and HKPD or otherwise as specified.

7.3.2 Survey Station

7.3.2.1 All survey stations (Horizontal and Vertical), bench marks shall be connected to existing Hong Kong Geodetic survey stations or otherwise as specified.

7.3.2.2 Bedrock bench marks are comparatively very stable and can last for years. Bedrock bench marks mentioned in Chapter 3 “Survey Datum and Survey Control” shall be established and used as origin and datum of survey for settlement monitoring.

7.3.2.3 No Hong Kong Geodetic survey stations, which are situated less than 100 metres from the site, shall be used as origin and datum of survey for a works project.

7.3.2.4 The horizontal and vertical survey stations shall be established in accordance with Chapter 3 “Survey Datum and Survey Control”.

7.3.3 Survey Specifications of Horizontal/ Vertical Survey Station

7.3.3.1 The survey procedures and specification shall follow Chapter 3 “Survey Datum and Survey Control” if survey stations are to be established by traditional surveying techniques, or Chapter 4 “Global Navigation Satellite Systems (GNSS) Survey” if survey stations are to be established by GNSS.

7.4 Instrumentation

7.4.1 The General Principles in Chapter 2 should apply.

7.5 Survey Procedures

7.5.1 The survey shall be carried out in accordance with the procedures below or other specific requirements. Under special circumstances, the Surveyor may propose other survey methods or set an alternative work standard for the monitoring survey.

7.5.2 Planning & Reconnaissance

7.5.2.1 General

(a) Identify the project location, area and the extent of the survey;

(b) Search and collect the data of survey origins for the project;

(c) Obtain appropriate maps for the area and identify the route of access;

(d) Verify and familiarise with the project area and the extent of the survey;

(e) Select essential details, which are for further reference and layout computation, if any;

(f) Locate existing control stations;

(g) Determine the positions & consider the monumentation of new control stations in accordance with Chapter 3 “Survey Datum and Survey Control”;

(h) Plan and select suitable survey equipment to be used; and

(i) Liaise with concerned parties if necessary.

7.5.2.2 Additional requirement with GNSS Application

(a) The guidelines in Chapter 4 "Global Navigation Satellite Systems (GNSS) Survey" shall apply.

7.5.3 Field Survey

7.5.3.1 Establishment of Control Stations

(a) The guidelines in Chapter 3 "Survey Datum and Survey Control" and the requirements in Paragraph 7.3 of this Chapter shall apply.

7.5.3.2 Settlement Monitoring by Precise Levelling

(a) Prior to commencement of every levelling survey, the levelling instrument set must be tested by 2-peg test. If the collimation error exceeds the tolerance of 1mm/30m or 6.9" of arc, then the instrument shall be adjusted until the collimation error falls within this tolerance. All the observations and calculations made for the purpose of this test shall be recorded and form part of the field notes;

(b) The levelling survey shall start from a known station and close on to another known station;

(c) Observation to reference stations shall be taken at even setup, the same levelling staff shall be used for starting and closing;

(d) The maximum sight distance for each levelling observation shall be 40 metres;

(e) 0.3m on both ends of invar staff shall not be used to avoid uncertainty resulting from refraction and/or bar-code reading;

(f) The difference between sum of backsight and sum of foresight distances for each levelling route shall not exceed 2 metres;

(g) The levelling of all settlement marks shall be surveyed as a turning point. If the settlement mark is surveyed by intermediate sight method, the mark shall be observed at least twice from different instrument setup. The discrepancy between the surveyed levels of the same settlement marks shall not exceed 2mm and mean value shall be adopted; and

(h) Initial readings of all settlement marks shall be surveyed at least twice by two independent levelling run and the discrepancy between the surveyed levels shall not exceed 2mm and mean value shall be adopted.

7.5.3.3 Settlement Monitoring by Ordinary Levelling

(a) Prior to commencement of every levelling survey, the levelling instrument set must be tested by 2-peg test. If the collimation error exceeds the tolerance of 3mm/30m, then the instrument shall be adjusted until the collimation error falls within this tolerance. All the observations and calculations made for the purpose of this test shall be recorded and form part of the field notes;

(b) The levelling survey shall start from a known station and close onto another known station. Self-closed levelling route is permitted provided that the BM/TBM used as the starting and closing origins has been further checked and tied to another BM/TBM;

(c) The backsight and foresight distances of each setup should be kept equal as far as practicable; and

(d) The levels of all settlement marks shall be surveyed as a turning point. If the settlement mark is surveyed by intermediate sight method, the mark shall be observed at least twice from different instrument setup.

7.5.3.4 Tilting Monitoring Survey (Plunge Down Angle Method)

(a) Observation station shall be established at a location less than 30 metres from the foot of the structural members to be checked. Displacement from alignment of the structural member shall not be more than 0.25 metres;

(b) The total station/theodolite used for the survey shall be a 3" precision or higher order;

(c) For tilting monitoring survey, an upper target and a lower target (linear scale) shall be firmly installed to the concerned structures;

(d) Before observation, the instrument shall be properly levelled;

(e) Check the horizontal collimation error of the instrument and adjusted the error to less than 10" of arc or according to manufacturer's user manual;

(f) Aim the cross-hair of the telescope to the upper target, turn the vertical drive of the instrument until the vertical cross hair cut the graduations on the linear scale bar (lower target is a linear scale bar). Record the reading from the lower target on field book;

(g) Two sets of readings at both faces should be taken and the spread of the readings shall be less than 5mm;

(h) The mean values shall be adopted as the final results and round off to the nearest centimetres; and

(i) The amount of displacement of the upper targets with respect to the reference marks (lower targets) of the structure shall be computed.

7.5.3.5 Deformation in General

(a) The position of the set-up station shall be checked by observing angles and distances to at least two known stations with an included angle and at least one distance measurement;

(b) Instrument height, target height and meteorological data shall be recorded;

(c) Angular observation of bearings and vertical angle observation shall be made with minimum of four arcs on both face left and face right to all monitoring points;

(d) Standard Deviation of the Mean, σ, of each reduced horizontal observed included angle shall not be greater than +/-3 second of arc;

(e) Distances must be measured by an EDM or Total Station. Each line is measured with at least one pointing with three measures. All necessary corrections shall be applied; and

(f) Standard Deviation of the Mean, σ, of each reduced observed distance shall not be greater than +/-2mm.

7.5.4 Office Work

7.5.4.1 Settlement Monitoring

(a) Reduce field data and compute the reduced level of monitoring marks;

(b) Compare the reduced levels of the same monitoring marks, which have been observed twice in the same survey, mean value shall be adopted;

(c) Tabulated survey results to date in accordance with the format as agreed by Engineer; and

(d) Compile all the relevant data and results in the computation folder for checking and approval.

7.5.4.2 Tilting Monitoring Survey (Plunge Down Angle Method)

(a) Reduce field data;

(b) Compare the amount of displacement of the upper targets with respect to the lower targets, which has been observed twice in the same survey, mean value shall be adopted;

(c) Tabulated survey results to date in accordance with the format as agreed by the Engineer; and

(d) Compile all the relevant data and results in the computation folder for checking and approval.

7.5.4.3 Deformation Survey

(a) Compute the coordinates of control stations from the captured field data;

(b) Tabulated survey results to date in accordance with the format as agreed by the Engineer; and

(c) Compile all the relevant data and results in the computation folder for checking and approval.

7.6 Deliverables

7.6.1 Control Diagram

7.6.1.1 A diagram of the levelling network on survey sheet based on all the connections between the Bench Marks, Reference Bench Marks (RBMs) and Temporary Bench Marks (TBMs) should be submitted

7.6.1.2 A diagram of survey control stations on survey sheet and showing all origin and datum of survey from Hong Kong Geodetic Survey Station and survey stations/bench marks newly established for the monitoring project should be prepared.

7.6.2 Station Sketch

7.6.2.1 Individual diagram of each RBM, TBM and survey station showing its general location with three tie measurements to three recognizable and durable points, and description should be prepared.

7.6.3 Instrumentation Diagram

7.6.3.1 A drawing showing all the settlement marks/ tilting monitoring marks/ deformation monitoring marks location and identification together with the associated Hong Kong Geodetic Survey Stations/ Survey Stations/ Bench Marks/ Reference Bench Marks/ Temporary Bench Marks should be prepared for the monitoring project.

7.6.4 Survey Result

7.6.4.1 The monitoring survey results in both hardcopy and softcopy should be submitted in accordance with the format as agreed by the Engineer.

7.7 Quality Assurance

7.7.1 The General Principles in Chapter 2 should apply.

7.8 Survey Records

7.8.1 The General Principles in Chapter 2 should apply.

7.8.2 Station Sketch

7.8.2.1 A record of station sketch of all Hong Kong Geodetic Survey Stations, further established survey stations, Reference Bench Marks, Temporary Bench Marks that are used for the monitoring project should be kept as stated in the above Paragraph 7.6.2.

7.8.3 Control Diagram and Instrumentation Diagram

7.8.3.1 A record of the Control Diagram and Instrumentation Diagram as stated in Paragraphs 7.6.1 and 7.6.3 respectively showing the locations and details of survey stations, monitoring marks and reference points with tabulated survey results in Easting, Northing and Reduced Level (RL) should be kept.

7.8.3.2 All Hong Kong Geodetic Survey stations, further established survey stations, Bench Marks, Reference Bench marks, Temporary Bench Marks and instrumentation installed should be tabulated with Easting, Northing and Reduced Level (RL) for record purpose.

7.8.3.3 Tabulated survey results to date in accordance with the format as agreed by the Engineer should be kept for record.

Chapter 8

Road Alignment

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Chapter 8 Road Alignment

8.1 Introduction

8.1.1 The design and computation of the road alignment always involve land survey input in the planning, design and construction stages. The geometric design of carriageway consists of horizontal and vertical alignments. It is usually defined by a series of elements including straights (tangents), curves and gradients. Before commencement of road alignment computation, the Surveyor should be responsible for carrying out a detail survey within the project areas and recording the topography and positions of existing features to facilitate alignment design and computation. The survey requirements in Chapter 5 "Record (Detail) Survey" and Chapter 13 "Tree Survey" should generally apply.

8.2 Scope

8.2.1 This chapter sets out the standards and procedures of survey activities on road alignment design and computation which are usually involved in road works project of works departments.

8.2.2 Horizontal Alignment Computation

8.2.2.1 Horizontal alignment for carriageway usually consists of straights (tangents) and curves. They should have been identified and follow the requirements from Engineer as specified in the general layout plan. To efficiently define the alignment strings, the constraints of the proposed alignments shall be identified and the parameters shall be defined referring to relevant specifications and guidelines.

8.2.3 Vertical Alignment Computation

8.2.3.1 It is to define the vertical profile of the road according to the specified standard. The vertical profile is usually defined under a combination of vertical curve along the reference line of the road with cross-fall / super-elevation. The suggested parameters for the computation (e.g. minimum gradient, minimum K-value) shall follow relevant specifications and guidelines.

8.3 Accuracy and Standards

8.3.1 The Surveyor shall consult Engineer for the information and requirements for geometric design and key transportation layouts.

8.3.2 Relevant standards and specifications shall be considered as specified by Engineer.

8.3.3 Road design works, alignment computations, cross falls, super-elevations, minimum clearances of road furniture along carriageways, headroom of overhead features, and so on shall refer to Transport Planning and Design Manual (TPDM) of the Transport Department. Alterations of road alignments in temporary traffic arrangement shall also consider the relevant clauses stated in TPDM.

8.3.4 The standards and guidelines that control the general field survey practices if necessary on road alignment survey in Chapter 3 "Survey Datum and Survey Control", Chapter 4 "Global Navigation Satellite Systems (GNSS) Survey", Chapter 5 "Record (Detail) Survey" and Chapter 13 "Tree Survey" shall apply.

8.4 Instrumentation

8.4.1 The General Principles in Chapter 2 should apply.

8.5 Survey Procedures

8.5.1 <u>Procedures for alignment computation</u>

8.5.1.1 Office Preparation

(a) Study the Engineer's request and the layout plan of the project;

(b) Study and collect geometric parameters and land boundary data, which are relevant to the road alignment computation;

(c) Check whether the collected information is sufficient and consult the Engineer if necessary; and

(d) Plan to carry out detail survey to collect existing ground features / levels for the road alignment computation if necessary.

8.5.1.2 Field Survey

(a) If necessary, carry out detail survey in compliance with the procedures in Chapter 5 "Record (Detail) Survey" and Chapter 13 "Tree Survey" ; and

(b) The details used for the road alignment computation should normally be surveyed by double radiations or with check by direct measurements.

8.5.1.3 Office Work

(a) Consider physical and/or land boundary constraints;

(b) Refer to Engineer's requirements and provided information to apply appropriate geometric parameters. These parameters should be recorded on the working plan or as an information sheet in the computation folder;

(c) Compute the road alignment by applying appropriate geometric parameters using road alignment computation software or manual method as appropriate;

(d) Based on the computed road alignments, calculate the relevant clearances and/or dimensions to address Engineer's concern by approved engineering survey computation software or other method for checking;

(e) If problems are encountered or the geometric parameters given by the user cannot be applied, report the case to the Engineer immediately for solution;

(f) Produce cross-section plans and contour plans along the computed alignment to ensure that the Engineer's requirements are met;

(g) Produce the Dimension Plan for the horizontal alignment and proposed road layout, produce the Longitudinal Plan for the vertical alignment in compliance with the CSWP available on the website of Development Bureau and the Drafting Specifications for Engineering Survey available on the website of Civil Engineering and Development Department; and

(h) Print the hardcopy of computation data, plot the sketch/working diagram of alignment computation, list the applied geometric parameters and compile all relevant information in a computation folder for checking and approval by the Surveyor.

8.6 Deliverables

8.6.1 A set of survey plan for the road alignment survey in an appropriate scale together with the associated survey information should be submitted. They should be presented according to the requirements as specified.

8.6.2 The field notes, field data, computation data, plotting the sketch / working diagram of the alignment computation, listing the applied geometric parameters and all relevant information should be compiled in a computation folder for checking.

8.6.3 Drawing computer files with format agreed with Engineer should be submitted. The survey drawings should be in compliance with the CSWP available on the website of Development Bureau and the Drafting Specifications for Engineering Survey available on the website of Civil Engineering and Development Department.

8.7 Quality Assurance

8.7.1 The General Principles in Chapter 2 should apply.

8.7.2 Refer to Engineer's requirements and the provided information, all the geometric parameters should be checked and complied with the standard.

8.7.3 Cross-section plans, longitudinal profile plans, or contour plans or water flow plan along the computed alignment are to be produced to ensure that the design is feasible and logical.

8.7.4 Design road surface with contours, longitudinal profile and cross sections should be generated to check the smoothness of road surface and to ensure all design criteria are met before submitting to Engineer.

8.7.5 Design road contours should be overlaid on existing road contour plan to check the consistency of road surface at interfacing areas such as junctions and merge lanes.

8.8 Survey Records

8.8.1 The General Principles in Chapter 2 should apply.

8.8.2 The final alignment record, deliverables, relevant documents and supporting information should be recorded in the project work file.

8.8.3 Change of versions and options of alignment computation should be recorded properly and traceable in a systematic filing system.

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Chapter 9

Earthwork Computation

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Chapter 9 Earthwork Computation

9.1 Introduction

9.1.1 Earthworks are engineering works created through the moving and/or processing of massive quantities of soil or unformed rock. Earthwork involving cutting and filling is done to reconfigure the topography of a site to achieve the design levels or the required topography.

9.1.2 With the very high costs of volumes of material involved in earthworks, it is vital that the Surveyor manages to make as accurate a measurement as possible of any such quantities of earthwork, to which the contract payment should in turn make reference. Typically, earthwork will be involved in different types of land and marine projects. They include road/railway works, site formation, quarrying, public fill management, services reservoir and pump house, drainage and river channel, marine facilities, marine mud disposal, landslip preventive measures, illegal dumping, etc.

9.2 Scope

9.2.1 Due to the fact that earthwork computations may be involved in different types of contractual arrangement, namely "Lump Sum Contracts with Drawings and Specification", "Lump Sum Contracts with Firm Bills of Quantities", "Re-measurement Contracts with Approximate Bills of Quantities", "Schedule of Rates Contracts" and "Design and Build Contracts" at different stages, this chapter attempts to focus on only the general principle and procedures of earthwork computation irrespective of the types and stages of the works in which an earthwork computation is engaged.

9.3 Accuracy and Standards

9.3.1 Accurate computation of earthwork quantity plays a critical part in contract payment. Attention of the Surveyor should be drawn to the relevant requirements in the project specific contract documents, i.e. General Specification, Particular Specification, Method of Measurement, or otherwise as specified by the Engineer in relation to the specification and tolerance of earthwork surfaces and formation.

9.4 Instrumentation

9.4.1 The General Principles in Chapter 2 should apply.

9.5 Survey Procedures

9.5.1 Field Survey

9.5.1.1 According to the specific requirements of different contracts, in which earthwork computation is engaged, various survey methods of data acquisition such as aerial survey, conventional survey, hydrographic survey and laser scanning may be employed. The Surveyor shall make reference to relevant chapters in this ESPG or other reference documents/ instructions, etc. as appropriate for the guidelines and standards in carrying out these surveys accordingly.

9.5.1.2 The integrity, correctness and accuracy of the data collected by whatever survey methods should have been checked and confirmed before the data is put into earthwork computation.

9.5.2 <u>Office Work and Data Processing</u>

9.5.2.1 Manual Method

(a) Measurement of regular volumes may be carried out by using the standard formulae shown at Appendix 9.1.

(b) Measurement of irregular volumes may be carried out by using one of the following methods, and then checked independently by using one of the four other methods:-

i) By dividing the volume into a number of regular volumes;
ii) By End Areas Methods;
iii) By Simpson's Rule to obtain the areas of contours;
iv) By Simpson's Rule to obtain the areas of equally spaced cross-sections; and
v) By planimeter, (iii) or (iv), for contours or cross sections

(c) The formulae of measuring irregular volume by End Area Methods and Simpson's Rule are shown at Appendix 9.1.

9.5.2.2 Computing Method

(a) Formation of two surface models, which can be initial ground model, interim ground model, final ground model and/or design formation model;

(b) Earthwork quantities can be determined by comparing the two surface models ("Triangle or Grid Volume") or by using the areas of cross sections created from the two surface models ("End-area Volume");

(c) For end-area volume, the result should be computed as follows:

i) Extraction of appropriate sections;
ii) Formation of sectional polygons;
iii) Apply correction for curvature if necessary; and
iv) Calculation of volumes;

(d) Use the standard form at Appendix 9.2 if cross section data are manually extracted from the relevant surface model plans;

(e) Volume of cut and volume of fill should be computed;

(f) Check the computed volume by other method, i.e. check Triangle or Grid Volume against End-area Volume or vice versa;

(g) The volume computation sheets should be compiled in a computation folder; and

(h) Cross section plans and associated key plan should be produced for checking.

9.6 Deliverables

9.6.1 Based on the specific requirements of different contracts where the earthwork computation will be involved, the Surveyor should agree with the Engineer on the details of survey deliverables to be submitted. Usually, the following deliverables should be submitted-

(a) Contour plans derived from respective surface models;

(b) Cut and fill volume report between the initial and current profile;

(c) Cut and fill volume report between the current and previous surface;

(d) Cross section plan; and

(e) Any other deliverables as specified by the Engineer.

9.7 Quality Assurance

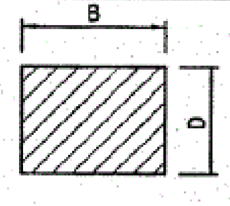
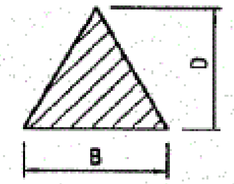
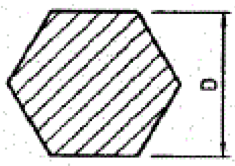
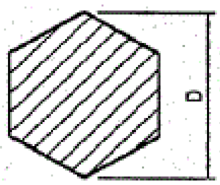
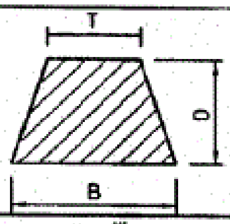
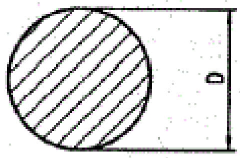
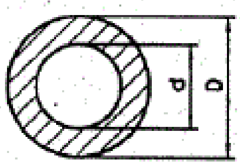
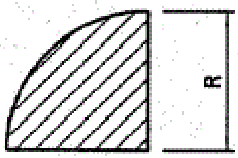
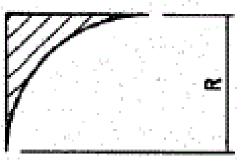
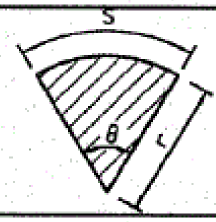
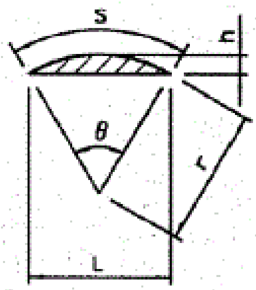
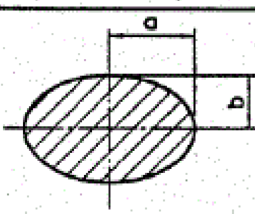
9.7.1 The General Principles in Chapter 2 should apply.

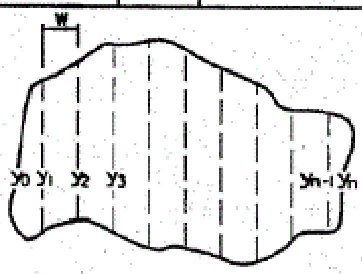
9.8 Survey Records

9.8.1 The General Principles in Chapter 2 should apply.

9.8.2 The final quantities calculated by the Surveyor and accepted by the Engineer should be recorded with signatures. The quantities should be fully cross-referenced, and the calculations taken to arrive at the final quantities should be kept in file by the Surveyor for future reference and surveillance audit.

Appendix 9.1
Measurement of Areas and Volumes

SECTION	AREA
	$A = B \times D$
	$A = \frac{BD}{2}$
	$A = 0.866\ D^2$
	$A = 0.65\ D^2$
	$A = \frac{D\ (T + B)}{2}$
	$A = 0.7854\ D^2$
	$A = 0.7854(D^2 - d^2)$
	$A = 0.7854\ R^2$
	$A = 0.2146\ R^2$
	$A = \frac{\theta}{360} \times \pi r^2$ $A = \frac{\theta}{360} \times 3.14 r^2$ $= \frac{sr}{2}$
	A = AREA OF SEGMENT = AREA OF SECTOR- AREA OF TRIANGLE $= \frac{1}{2}[sr \pm L(r-h)]$ (− If $h \leq r$; + If $h \geq r$) or $A = \frac{2Lh}{3}$ (APPROX. FORMULA)
	$A = \pi ab$ $= 3.14ab$



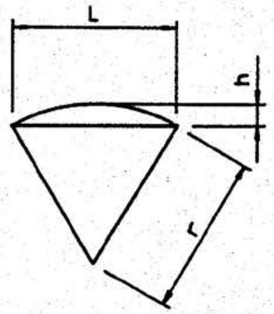
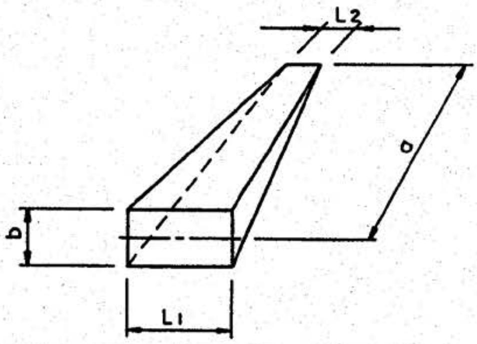
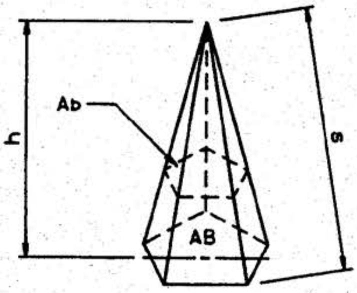
TRAPEZOIDAL RULE:-

$$A = w\left[\frac{y_0+y_n}{2} + y_1 + y_2 + \dots\dots\dots + y_{n-1}\right]$$

SIMPSON'S RULE:- (n MUST BE EVEN)

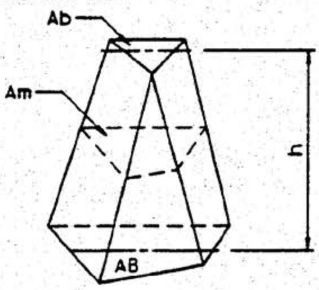
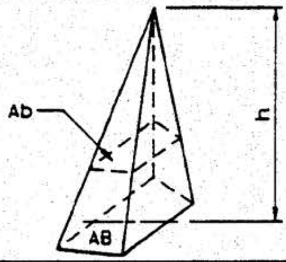
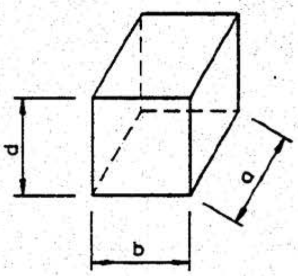
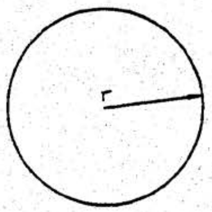
$$A = \frac{w}{3}\left[(y_0+y_n) + 4(y_1+y_3+\dots\dots\dots+y_{n-1}) + 2(y_2+y_4+\dots\dots\dots+y_{n-2})\right]$$

Appendix 9.1
Measurement of Areas and Volumes

SHAPE	VOLUME
SPHERICAL SECTOR (AND HEMISPHERE) 	FOR SPHERICAL SECTOR: $At = \frac{\pi r}{3}(4h+L)$; $V = \frac{2\pi r^2 h}{3}$ FOR HEMISPHERE (LETTING $h = \frac{L}{2} = r$); $At = 3\pi r^2$; $V = \frac{2\pi r^3}{3}$
WEDGE (AND RIGHT TRIANGULAR PRISM) 	FOR WEDGE (NARROW SIDE RECTANGULAR): $V = \frac{ab}{6}(2L_1 + L_2)$ FOR RIGHT TRIANGULAR PRISM (OR WEDGE HAVING PARALLEL TRIANGULAR BASES PERPENDICULAR TO SIDES) $L_2 = L_1 = L$: $V = \frac{abL}{2}$
RIGHT REGULAR PYRAMID (AND FRUSTUM OF RIGHT REGULAR PYRAMID) 	FOR RIGHT REGULAR PYRAMID: $AL = \frac{sPB}{2}$; $V = \frac{hAB}{3}$ FOR FRUSTUM OF REGULAR PYRAMID: $AL = \frac{s}{2}(PB + Pb)$ $V = \frac{h}{3}(AB + Ab + \sqrt{AB\ Ab})$

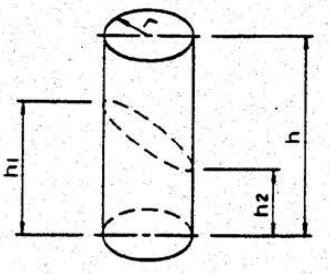
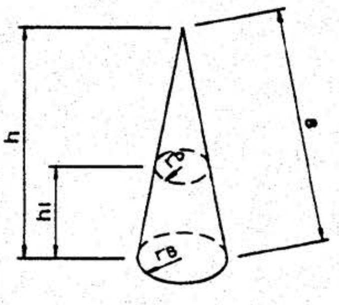
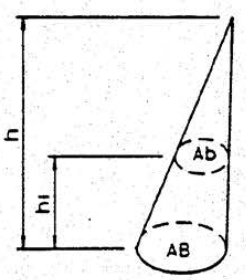
NOTATION : LINES, a, b,..........; ALTITUDE (PERPENDICULAR HEIGHT), h, h ....; SLANT HEIGHT, s; RADIUS, r; PERIMETER OF BASES, Pb OR PB ; CHORD OF SEGMENT, L; RISE, h; AREA OF BASE, Ab OR AB ; TOTAL AREA OF CONVEX SURFACE, AL ; TOTAL AREA OF ALL SURFACES, At ; VOLUME, V.

Appendix 9.1
Measurement of Areas and Volumes

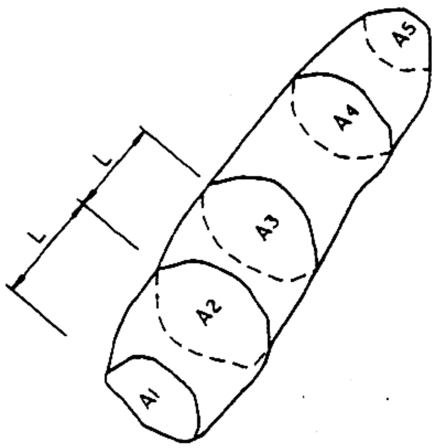
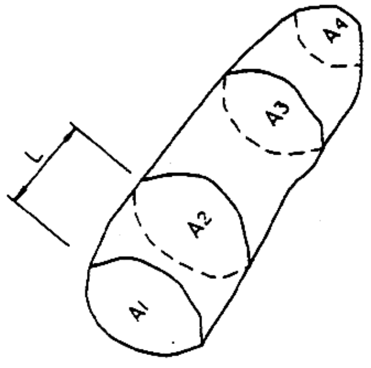
SHAPE	VOLUME
PRISMATOID 	LET AREA OF MID-SECTION = A $V = \frac{h}{6}(AB + Ab + 4Am)$
GENERAL PYRAMID (AND FRUSTUM OF PYRAMID) 	FOR GENERAL PYRAMID: $V = \frac{hAB}{3}$ FOR FRUSTUM OF GENERAL PYRAMID: $V = \frac{h}{3}(AB + Ab + \sqrt{AB\ Ab})$
CUBIC 	$V = a.b.d$
SPHERE 	LET DIAMETER = d $At = 4\pi r^2 = \pi d^2$ $V = \frac{4\pi r^3}{3} = \frac{\pi d^3}{6}$

NOTATION : LINES, a, b,..........; ALTITUDE (PERPENDICULAR HEIGHT), h, h ,..........; SLANT HEIGHT, s; RADIUS, r; PERIMETER OF BASES, Pb OR PB ; CHORD OF SEGMENT, L; RISE, h; AREA OF BASE, Ab OR AB ; TOTAL AREA OF CONVEX SURFACE, AL ; TOTAL AREA OF ALL SURFACES, At ; VOLUME, V.

Appendix 9.1
Measurement of Areas and Volumes

SHAPE	VOLUME
RIGHT CIRCULAR CYLINDER (AND TRUNCATED RIGHT CIRCULAR CYLINDER) 	FOR RIGHT CIRCULAR CYLINDER: $AL = 2\pi r h$; $At = 2\pi r(r+h)$; $V = \pi r^2 h$ FOR TRUNCATED RIGHT CIRCULAR CYLINDER: $AL = \pi r(h_1 + h_2)$; $At = \pi r[h_1 + h_2 + r + \sqrt{r^2 + (\frac{h_1 - h_2}{2})^2}]$; $V = \frac{\pi r^2}{2}(h_1 + h_2)$
RIGHT·CIRCULAR CONE (AND FRUSTUM OF RIGHT CIRCULAR CONE) 	FOR RIGHT CIRCULAR CONE: $AL = \pi r_B s = \pi r_B \sqrt{r_B^2 + h^2}$; $At = \pi r_B(r_B + s)$; $V = \frac{\pi r_B^2 h}{3}$ FOR FRUSTUM OF RIGHT CIRCULAR CONE: $s = \sqrt{h_1^2 + (r_B - r_b)^2}$; $At = \pi s(r_B + r_b)$; $V = \frac{\pi h_1}{3}(r_B^2 + r_b^2 + r_B r_b)$
GENERAL CONE (AND FRUSTUM OF GENERAL CONE) 	FOR GENERAL CONE: $V = \frac{A_B h}{3}$ FOR FRUSTUM OF GENERAL CONE: $V = \frac{h_1}{3}(A_B + A_b + \sqrt{A_B A_b})$
NOTATION : LINES, a, b,..........; ALTITUDE (PERPENDICULAR HEIGHT), h, h ,..........; SLANT HEIGHT, s; RADIUS, r; PERIMETER OF BASES, Pb OR PB ; CHORD OF SEGMENT, L; RISE, h; AREA OF BASE, Ab OR AB ; TOTAL AREA OF CONVEX SURFACE, AL ; TOTAL AREA OF ALL SURFACES, At ; VOLUME, V.	

Appendix 9.1
Measurement of Areas and Volumes

<table>
<tr><th>SHAPE</th><th>VOLUME</th></tr>
<tr><td>IRREGULAR SHAPE

</td><td>L = THE DISTANCE BETWEEN THE SECTIONS
A1, A2, A3, A4 & A5 = THEIR AREAS
$V = \frac{L}{3}(A1+4A2+2A3+4A4+A5)$
N. B.
AN ODD NUMBER OF SECTIONS ARE REQUIRED FOR APPLICATION OF THIS RULE
SIMPSON'S RULE</td></tr>
<tr><td>IRREGULAR SHAPE

</td><td>L = THE DISTANCE BETWEEN THE SECTIONS
A1, A2, A3 & A4 = THEIR AREAS
$V = L(\frac{A1+A4}{2}+A2+A3)$
METHOD OF END AREAS</td></tr>
</table>

Appendix 9.2
Cross Section Data Sheet

Project No. : ______________ Job No. : ________________ Prepared by : ______________________

Project Name : ____

Chainage		L.H.S. (-)						℄	R.H.S.					
Profile 1	Distance from ℄													
	( )* Level													
Profile 2	Distance from ℄													
	( )* Level													

Chainage		L.H.S. (-)						℄	R.H.S.					
Profile 1	Distance from ℄													
	( )* Level													
Profile 2	Distance from ℄													
	( )* Level													

Chainage		L.H.S. (-)						℄	R.H.S.					
Profile 1	Distance from ℄													
	( )* Level													
Profile 2	Distance from ℄													
	( )* Level													

Chainage		L.H.S. (-)						℄	R.H.S.					
Profile 1	Distance from ℄													
	( )* Level													
Profile 2	Distance from ℄													
	( )* Level													

Chainage		L.H.S. (-)						℄	R.H.S.					
Profile 1	Distance from ℄													
	( )* Level													
Profile 2	Distance from ℄													
	( )* Level													

Notes

℄ Centre line

* Insert appropriate model surface. e.g. Initial, Existing, Formation, Final, etc.

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Chapter 10

Hydrographic Survey

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Chapter 10 Hydrographic Survey

10.1 Introduction

10.1.1 Hydrographic survey has been a key activity supporting marine engineering works in Hong Kong. Due to the dynamic condition in which the survey is conducted as well as the inaccessibility of the underwater target, the success of survey greatly depends on good planning, precise system design and instrumentations setup, practical procedures, systematic and logical data processing and effective quality control.

10.2 Scope

10.2.1 This chapter provides an overview of good practice for Surveyors either engaged in carrying out their own hydrographic survey, or to contract this work to a third party.

10.2.2 The information in this chapter details the minimum requirements for hydrographic surveys undertaken for engineering purpose and is to be used in conjunction with the relevant project-specific Contract Documents, i.e. General and Particular Specifications, to give complete guidance for undertaking such surveys.

10.2.3 Terminology used refers to International Hydrographic Organization (IHO) Standards for Hydrographic Surveys, Special Publication No. 44 (https://iho.int/uploads/user/pubs/standards/s-44/S-44_Edition_6.0.0_EN.pdf) and Manual on Hydrography, Publication No. C-13 (https://iho.int/uploads/user/pubs/cb/c-13/C-13.pdf).

10.2.4 This guideline does not cover hydrographic survey using wire sweep, or seismic/geological survey using low frequency echo sounder, pinger and boomer.

10.3 Accuracy and Standards

10.3.1 The Total Horizontal Uncertainty (THU) of soundings at 95% confidence level shall be less than 2m.

10.3.2 The Total Vertical Uncertainty (TVU) of soundings at 95% confidence level shall be less than 0.3m.

10.3.3 Cross lines shall be run, as far as possible, perpendicular to and at intervals no more than 20 times the line spacing of principle lines for detecting sounding and tidal level errors.

10.4 Instrumentation

10.4.1 The General Principles in Chapter 2 should apply.

10.4.2 Equipment to be used during hydrographic survey operations falls within the broad groupings of equipment to measure depth, to establish position, and to measure water level. In using the equipment for survey, it is required to identify, eliminate or reduce, and quantify remaining sources of error in an appropriate error budget through proper survey procedures.

10.4.3 Depth Measurement Equipment-
Single beam echo sounder, multibeam echo sounder or chain.

10.4.4 Positioning System Equipment-
GNSS or Total Station.

10.4.5 Motion Sensor Equipment-
Inertial navigation system or motion sensor and gyrocompass.

10.4.6 Tide Gauge Equipment-
Automatic tide gauge or tide pole.

10.4.7 Other Equipment-
Sound velocity profiler (SVP) or Conductivity, Temperature & Depth (CTD) meter.
Navigation and data acquisition software.
Data processing software.

10.5 Survey Procedures

10.5.1 Tidal Observation and Reduction

10.5.1.1 Tidal levels with reference to HKPD or CD shall be observed and recorded. They are used for the reduction of the measured depths to charted depths. At least 2 independent tidal stations nearby the survey area shall be used for recording tidal levels. The interval of tidal observation shall not be longer than 10 minutes.

10.5.1.2 RTK tide may also be used to record the instantaneous height of the vessel above ellipsoid. Geoid-ellipsoid separation shall be established for reduction of sounding data to HKPD or CD.

10.5.2 Horizontal Positioning

10.5.2.1 GNSS

(a) Horizontal position can be fixed by using GNSS in differential or RTK modes. To ensure proper functioning of the system, measurements and observations shall be made to not less than 1 known position at the beginning and at the end of the sounding survey.

(b) Results of measurements obtained from the two epochs shall be compared with the known values. Mean linear deviation shall be less than 1m and 0.2m for differential and RTK modes respectively.

10.5.2.2 Radiation

(a) Radiation method can be employed if the sky view of the survey area is obstructed by nearby physical features.

(b) Suitably calibrated total station/auto tracking positioning equipment occupying a control station shall be used.

(c) The origin of the control station shall be checked by taking at least one distance measurement and two orientation observations to other known control points.

To ensure proper functioning of the system, measurements and observations shall be made to not less than 1 known position at the beginning and at the end of the sounding survey.

(d) Results of measurements obtained from the two epochs shall be compared with the known values. Mean linear deviation shall be less than 0.2m.

10.5.3 Depth Determination

10.5.3.1 Due to limitation of water depth and vessel draught, contract requirements or otherwise as specified by the Engineer, single-beam echo sounder may be used. In this connection, the single-beam echo sounder must be calibrated by a bar check to correct for errors in the speed of sound in the water column and to set the correct transducer draught. It shall be carried out at least daily. When ascertaining the siltation situation of the seabed is required, the single-beam echo sounder shall be operated at 2 frequencies, one at 40 kHz or lower and the other at 200 kHz or higher, or otherwise as specified by the Engineer. The principle line spacing shall be 1 cm at the scale of the sounding plan, which shall be at least 1: 1,000 or as approved otherwise.

10.5.3.2 With the exception of paragraph 10.5.3.1 mentioned above, all hydrographic survey shall be carried out using multibeam echo sounder. Patch test shall be appropriately carried out and documented so as to determine the offset angles of roll, pitch, yaw (heading) of the motion sensor with respect to the sonar head and the system time latency. It shall be carried out at least once before the commencement of the project or after the equipment has been serviced or installed. Speed of sound in the water column over the entire depth range of the surveyed area shall be measured by Sound Velocity Profiler (SVP) or CTD Meter, and recorded.

10.5.3.3 For multibeam echo sounding, 200% swath to swath coverage is required in the planning of principle line spacing such that optimally there will be at least 2 independent swaths covering every individual feature. However, when actual path deviates from the pre-planned principle line to a situation that gap exists (i.e. less than 100% coverage) in the bottom coverage, re-running of the principle line is required. Moreover, for along track coverage, with the consideration of transmit beamwidth and ping rate, the speed of vessel shall be appropriately set to eliminate any inter-ping gap.

10.5.3.4 With the exception of paragraph 10.5.3.1 mentioned above, frequency of single beam and multibeam echo sounders shall be of 200 kHz or higher for all type of hydrographic surveys.

10.5.3.5 In case when echo sounding as mentioned in paragraphs 10.5.3.1 and 10.5.3.2 above is not applicable, or otherwise as specified by the Engineer, chain may be used to determine the depth. The chain used in depth measurement shall preferably be made of stainless steel and attached with a weight of suitable dimensions. Suitable markings shall be made along the chain at the regular interval of not less than every 0.2m. The markings shall be properly checked before use. Chain sounding shall only be used when the raw depth is less than 10m. Whenever the difference between two consecutive depth measurements (<5m apart) is greater than 2m, the measurements shall be reaffirmed by taking additional observations.

10.5.4 Other Observations

Field information such as identification of survey equipment, runline numbers, locations of tide gauges, etc. shall be recorded on board.

10.5.5 Data Processing

10.5.5.1 All sounding data shall be examined for noise and validated with reference to the measured data from other runlines or cross check lines. Data identified as erroneous shall be flagged to facilitate suppression in the subsequent filtering process.

10.5.5.2 Sounding values shown on sounding plan should be shoal-biased selected with true position preserved or otherwise as specified by the Engineer.

10.5.6 Output

10.5.6.1 The sounding plan should be at scales of 1:1000, 1:2500 or any other scales as specified by the Engineer. The density of sounding shall be as dense as possible to ensure legibility at the scale of the sounding plan.

10.5.6.2 For volume computation and comparison, gridded or binned sounding of cell sizes less than 2m x 2m shall be generated and used.

10.5.6.3 For 3D visualization of seabed topography, shoal-biased, gridded or binned soundings of cell size less than 2m x 2m, or otherwise as specified by the Engineer shall be generated and used for the formation of model.

10.5.6.4 Other output as required by the contract, such as cross-section drawings.

10.6 Deliverables

10.6.1 The submitted sounding plan should be in A3 size or larger and bear the signature of the Surveyor in charge. A column of notes should be included in the right-handed side of the plan face stating the particulars of the survey which includes:-

(a) The horizontal and vertical datum used;

(b) The tidal stations used;

(c) The survey standard adopted;

(d) The survey equipment used and its particulars; and

(e) The sounding presentation method.

10.6.2 Digital copy of the sounding plan should be in format of DGN/PDF or other formats specified by the Engineer.

10.6.3 Soundings shown on the drawings are displayed with one place of decimal. Soundings above datum (HKPD or CD) should be shown with their values underlined. The position of the sounding should be denoted by the dot of the value.

10.6.4 List of common deliverables of sounding surveys for charting and engineering purposes-

(a) Sounding data (i.e. Northing, Easting and Depth) in ASCII format;

(b) Raw sounding data of time, position and depth in format readable by the common hydrographic survey packages;

(c) Tide data and data for speed of sound in water column (for multibeam) in ASCII format;

(d) Echo trace if single beam echo sounder is used;

(e) Hard copy and softcopy of sounding plan, cross-section plan and track plot of actual runlines; and

(f) Survey report detailing the assessment of horizontal and vertical positioning accuracies.

10.7 Quality Assurance

10.7.1 The General Principles in Chapter 2 should apply.

10.7.2 Survey report detailing the evidence of the survey meeting the required accuracy standard should be submitted together with all relevant instrument calibration reports, check lists and statistics showing difference of sounding values between cross line and principal line.

10.8 Survey Records

10.8.1 The General Principles in Chapter 2 should apply.

10.8.2 <u>Raw data files</u>
Raw data include data of multibeam echo sounding system, echo trace of single beam echo sounding system, SVP or CTD records, tide observation record, and any other items as required by the Engineer.

10.8.3 <u>Edited data files</u>
Edited data of soundings is one of the survey records and must be kept for further checking.

10.8.4 <u>Computation Folders</u>
The computation folders should be compiled with calibration parameters, tide record, log sheet, track plot, sounding plans, survey report and other relevant information for the survey.

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Chapter 11

Drainage Record Survey

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Chapter 11 Drainage Record Survey

11.1 **Introduction**

11.1.1 Drainage Record Survey recorded the position and level of the drainage facilities which include manholes, drainage pipes and tunnels, culverts, catchpits, gullies and surface drains, etc. A set of comprehensive drainage record is required for an effective maintenance of drainage and sewerage system. When there is an alteration of the existing drains/sewers or a new set of drains/sewers is built, a record survey has to be conducted to record the new drains/sewers.

11.2 **Scope**

11.2.1 This chapter describes the procedures to carry out drainage record survey.

11.3 **Accuracy and Standards**

11.3.1 Drainage Record Survey shall be carried out with reference to the Hong Kong 1980 Grid System and HKPD or otherwise as specified.

11.3.2 Drainage Record Survey shall comply with the accuracy standard and quality requirements as stipulated in the General Specification for Civil Engineering Works unless otherwise specified by the Engineer.

11.4 **Instrumentation**

11.4.1 The General Principles in Chapter 2 should apply.

11.5 **Survey Procedures**

11.5.1 The position and level of the cover of the manhole, chamber, catchpit and culvert shall be surveyed.

11.5.2 The cover of manhole/ chamber/ catchpit/ culvert shall be opened with appropriate tools. The following items shall be measured and recorded.

(a) Measure the dimension and invert level of all inlet and outlet pipes inside the manhole chamber;

(b) Record the orientation of the inlets and outlets inside the manhole chamber with sketches; and

(c) Trace the flow of drains.

11.5.3 All manhole covers shall be reinstated to the original position after completion of the work.

11.5.4 All field observations and measurements shall be properly computed and shown on drainage record plans.

11.6 Deliverables

11.6.1 A set of drainage record plans in both hardcopy and softcopy should be prepared to show the concerned drainage facilities. The position and level of the cover of the manhole, chamber, and culvert should be shown on the plan. Information of the drainage facilities (such as the diameter of the pile, invert level of the inlets and outlets inside the manhole, the flow of drain, etc.) should also be shown on the plan.

11.6.2 All symbols and line-styles used on the plan should be in compliance with the Drafting Specifications for Engineering Survey. All non-standard symbols should be clearly explained in the notes column of the plan.

11.6.3 The plan should comply with the CSWP available on the website of Development Bureau and the Drafting Specifications for Engineering Survey available on the website of Civil Engineering and Development Department.

11.7 Quality Assurance

11.7.1 The General Principles in Chapter 2 should apply.

11.8 Survey Records

11.8.1 The General Principles in Chapter 2 should apply.

Chapter 12

Water Mains Record Survey

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Chapter 12 Water Mains Record Survey

12.1 Introduction

12.1.1 In mainlaying projects, record survey for as-built water mains should be conducted immediately as and when the respective parts of the works are properly installed on site. As-built drawings for the water mains and valves should be prepared in accordance with the requirements stipulated in the relevant contract documents and should be produced to the satisfaction of the Engineer.

12.2 Scope

12.2.1 This chapter describes the relevant guidelines on record surveys for preparation of as-built plans for as-built water mains.

12.3 Accuracy and Standards

12.3.1 Water mains record survey shall be carried out with reference to the Hong Kong 1980 Grid System and HKPD or otherwise as specified.

12.3.2 The as-built plans shall comprise of the following information:

(a) General arrangements showing horizontal alignment and crown levels;

(b) Pipe sizes with classification of material;

(c) Fittings such as valves, bends, tees for washouts, tees for fire hydrants and tees for branches, etc.;

(d) Chambers/pits for inspection tees, valves and pump pits for washout, etc.;

(e) Chainages of pipelines;

(f) Ground levels;

(g) Scale of plan and key plan; and

(h) Any other details as specified by the Engineer.

12.3.3 The scale of as-built plans should be in 1:200, 1:500, 1:1000 or as specified by the Engineer.

12.3.4 Due to the possibility of re-alignment of water mains, chainages shown on as-built plans are only for general reference.

12.3.5 Accuracy Requirements
The acceptable tolerance for each type of as-built survey information shall not be greater than the value tabulated below:

	Description	Accuracy
Horizontal alignment	New water mains as-constructed, existing water mains checked/surveyed on-site and/or existing water mains to be abandoned/removed checked/surveyed on-site.	±50mm
Crown level	Crown level for vertical alignment with change in cover level >300mm, or otherwise at intervals not exceeding 40 metres and at all points of change of the horizontal alignment, valves and fittings.	±50mm
Ground level	Ground level near the as-constructed water mains.	±50mm

12.4 Instrumentation

12.4.1 The General Principles in Chapter 2 should apply.

12.5 Survey Procedures

12.5.1 The survey procedures of water mains record survey shall follow Chapter 5 “Record (Detail) Survey”.

12.6 Deliverables

12.6.1 The as-built plans in both hardcopy and softcopy should be submitted to the Engineer. The softcopy of as-built alignment files should be delivered in MicroStation (.dgn) file format or AutoCAD (.dwg) file format as specified by the Engineer. The as-built plans should be prepared in compliance with the CSWP available on the website of Development Bureau and the Drafting Specifications for Engineering Survey available on the website of Civil Engineering and Development Department.

12.7 Quality Assurance

12.7.1 The General Principles in Chapter 2 should apply.

12.8 Survey Records

12.8.1 The General Principles in Chapter 2 should apply.

Chapter 13

Tree Survey

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Chapter 13 Tree Survey

13.1 Introduction

13.1.1 Tree survey provides detailed information for preservation and protection of existing trees in a works project.

13.2 Scope

13.2.1 This chapter attempts to focus on the general principle and procedures for tree survey which comprises the tagging of tree identification tags ("tree tagging"), tree location measurement and tree dimensions measurement. The Surveyor should be responsible for carrying out the tree survey. The boundary and methodology of a tree survey should be agreed with the Engineer prior to undertaking the survey on site.

13.3 Accuracy and Standards

13.3.1 <u>Definitions</u>

13.3.1.1 "Tree" means a plant with diameter at breast height measuring 95 mm or more. Plants growing on retaining structures shall also be measured and considered.

13.3.1.2 "Diameter at Breast Height" (DBH) means the diameter of the trunk of the plant measured at height of 1.3m above ground level. For trunk with an obviously elliptical cross-section, the DBH is the average of any two-diameter measurements taken at right angle.

13.3.1.3 "Tree crown spread" means the spread of the tree crown defined by the outermost branches of the tree. For tree crown with an obviously elliptical cross-section, the spread of the tree crown is the average of any two-spread measurements taken at right angle.

13.3.2 The requirements of the survey can be referred to the Clause 26.03, "Tree Survey", in the General Specification for Civil Engineering Works Volume 2, 2006 Edition available on the website of Civil Engineering and Development Department (https://www.cedd.gov.hk/eng/publications/standards-spec-handbooks-cost/stan-gs-2006/index.html).

13.3.3 The survey shall be carried out in terms of the Hong Kong 1980 Grid System and HKPD or otherwise as specified.

13.3.4 All Survey Stations (Horizontal and Vertical) and/or Temporary Bench Marks (TBMs) established in the tree survey shall be connected to existing Hong Kong Geodetic survey stations, Permanent Bench Marks (PBMs), or otherwise as specified. The Geodetic survey stations and/or PBMs used as the origin of the survey shall be stated in the tree survey report. A summary of Survey Stations and TBMs established in the tree survey with their positional accuracy and method of survey shall be prepared for record purpose.

13.3.5 Accuracy for Planimetric Information

The acceptable tolerance shall not be greater than the value tabulated below unless or otherwise specified by the Engineer:

Description	Accuracy
Tree co-ordinate in Easting and Northing	+/-0.3m
DBH of the tree	+/-25mm
Tree crown spread	+/-1m

13.3.6 Accuracy for Vertical Information

The acceptable tolerance shall not be greater than the value tabulated below unless or otherwise specified by the Engineer:

Description	Accuracy
Reduced level at trunk base	+/-0.5m
Tree height	+/-0.5m

13.4 **Instrumentation**

13.4.1 The General Principles in Chapter 2 should apply.

13.5 **Survey Procedures**

13.5.1 The survey procedures of the tree location measurement shall follow Chapter 5 “Record (Detail) Survey”.

13.5.2 The measurement of DBH of tree should be referred to the Nature Conservation Practice Note No. 2 available on Agriculture, Fisheries and Conservation Department’s web-site for guidance on measurement of tree trunk diameter.

13.5.3 All individual trees shall be surveyed. If it can be justified that individual tree survey is impracticable (e.g. inaccessible area) and tree group survey has to be resorted to, the Surveyor shall obtain the prior approval of the Engineer before adopting tree group survey for any part of the site.

13.5.4 For tree tagging, the Surveyor shall provide and attach tree identification tag on each tree within the agreed survey boundary. The identification tags shall be made of weather resistant materials which are non-injurious to the trees, be tied on each tree at a height of approximately 1.3m above ground level, and be attached in such a manner that allows for the growth of the trees and does not injure the trees. The tree identification tag on each tree shall show the tree identification number in a clear and distinguishable way.

13.5.5 For tree location measurement, the Surveyor shall survey the co-ordinates and reduced level of the tree at the trunk base using the approved survey methods. The following survey information shall also be required to allot/collect during the tree dimension measurement:

(a) Tree identification number;

(a) DBH of the tree;

(b) Tree height, i.e. from ground to the top of the tree crown; and

(c) Tree Crown Spread.

13.5.6 There shall be at least one photograph taking for each tree. All photographs shall be of reasonable size and quality, in colour and date-stamped to indicate the dates that the photographs are taken and shall be well-annotated with the respective tree identification numbers.

13.5.7 The photograph of each tree shall show clearly the whole tree as far as possible (including the tree crown, the tree trunk and the surrounding ground near the root collar of each tree) and the tree identification number as identified by the tree identification tag at site. Where necessary, blow-up image to illustrate particular features, e.g. cavity at tree trunk of the surveyed trees, shall also be submitted.

13.5.8 The Surveyor shall prepare a drawing showing the location of trees and the existing ground levels at trunk bases with their tree identification numbers, DBHs, tree heights, and tree crown spreads.

13.6 **Deliverables**

13.6.1 The tree location and dimension measurement results which are presented in the specified or agreed standard should be submitted. Upon the request of the Engineer, a copy of field notes, field data and resultant data arising from the tree survey should be provided to the Engineer in hard copy and digital format.

13.6.2 Drawing computer files which should be delivered on compact disc or DVD in MicroStation (.dgn) file format unless or otherwise specified by the Engineer should be submitted. The survey drawings should comply with the CSWP available on the website of Development Bureau and the Drafting Specifications for Engineering Survey available on the website of Civil Engineering and Development Department.

13.6.3 For the road works to be handed over to HyD for maintenance, a set of the tree survey records in ArcGIS or other GIS format fully compatible with the Road Data Maintenance System of Highways Department and the GIS Specifications for Engineering Surveys of Highways Department, available on the Highways Department’s website, should be submitted.

13.7 Quality Assurance

13.7.1 The General Principles in Chapter 2 should apply.

13.8 Survey Records

13.8.1 The General Principles in Chapter 2 should apply.

Chapter 14

Unmanned Aerial Vehicle (UAV) Survey

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Chapter 14 Unmanned Aerial Vehicle Survey

14.1 Introduction

14.1.1 A UAV is classified as a type of unmanned aircraft mounted with a camera, LiDAR sensor or other types of sensors. It is used as a survey equipment to capture data such as photos, videos and point cloud of ground features for engineering and development works, such as project progress record, development study, topographic updating, earthwork computation, 3D mesh model generation and animation, etc.

14.1.2 In view of the commencement of Small Unmanned Aircraft (SUA) Order, i.e. Chapter 448G of the Laws of Hong Kong, in June 2022, operations of UAV in Hong Kong, including aerial survey using UAV, are regulated under a risk-based approach and classified according to the weight of the UAV and the operational risk level. Operations of different risk levels are subject to the corresponding regulatory requirements. Those requirements include registration and labelling of UAV, registration of remote pilots, training and assessment, equipment, operating requirements and insurance.

14.1.3 To facilitate the industry to perform UAV operations while ensuring aviation and public safety, Civil Aviation Department has published a series of guidance materials including the Safety Requirements Document (SRD), a number of Advisory Circulars (ACs) and a sample Operations Manual (OM) attached to an Advisory Circular namely AC-002. These documents provide clear guidance with a reference for the land and engineering survey practitioners to conduct UAV operation complying the stipulated requirements. These documents could be retrieved from the website of CAD as follow:

https://www.cad.gov.hk/english/sua_new.html

14.2 Scope

14.2.1 The composition of a flight team involved in UAV operations, and the responsibilities and duties of team members could be referred to the sample OM attached to AC-002.

14.2.2 The requirements for SUA registration and labelling, and registration and rating of Remote Pilots could be referred to the SRD.

If the land and engineering survey practitioners considered their UAV operation would be categorized as advanced operation, they should apply to CAD for obtaining advanced operations permission by completing an application form and preparing an OM. Detailed procedures and materials could be referred to AC-002.

14.3 Accuracy and Standard

14.3.1 The acceptance criteria for the raw data and the processed data shall be defined by the Surveyor to comply with the specified tolerances of the associating works.

14.3.2 For production of photogrammetric survey products such as digital surface model (DSM) in form of point cloud, mesh model and / or orthophoto, the acceptance criteria are listed below unless otherwise specified by the Surveyor in consideration of the objective and requirements of the survey.

(a) The root mean square error of all image measurement should be less than 1.0 pixel resolution.
(b) The root mean square error of check points should be less than 2 times the required accuracy of ground control points.
(c) The root mean square error of coordinates difference of check points measured from the products and their surveyed coordinates should be less than 4 times the required accuracy of ground control points.

14.4 Instrumentation

14.4.1 The General Principles in Chapter 2 should apply.

14.4.2 The Surveyor should be responsible for using appropriate type of UAV with necessary accessories and software meeting the requirements and specifications of the task. Besides, operating the UAV for the task should comply the stipulated requirements in SUA Order.

14.4.3 All the checking, maintenance works and repairs of the UAV and related accessories should be properly recorded. Sample of Maintenance Record of UAV could be referred to Form C of the sample OM attached to AC-002.

14.5 Survey Procedures

14.5.1 Flight Planning

14.5.1.1 The Surveyor should assess the suitability of deploying UAV for the task and conduct site safety assessment and risk assessment for each individual task in order to identify and mitigate against a full range of risks which may be present at a given site. Sample of Site Safety Assessment and Risk Assessment could be referred to Form D and E of the sample OM attached to AC-002.

14.5.1.2 If deploying UAV for the task is considered to be applicable, the Surveyor or the Remote Pilot should design the flight plan for achieving the purpose of the survey request, obtaining relevant permission(s) and determine an effective means of audio communication within the flight team during operation. Details could be referred to the sample OM attached to AC-002.

14.5.1.3 Other than the flight parameters, the Surveyor or Remote Pilot should design the distribution of ground control points and conduct the survey to facilitate the post-processing of data, if applicable.

14.5.2 Flight Operation

14.5.2.1 Before commencement of the flight operation, the Surveyor or the Remote Pilot should confirm the site safety assessment and risk assessment prepared at the flight planning stage are still valid.

14.5.2.2 The Surveyor or the Remote Pilot should conduct pre-flight and post-flight checking before and after the field operations. The procedure of pre-flight and post-flight check as well as other requirements for on-site procedure and flight procedure could be referred to the sample OM attached to AC-002.

14.5.2.3 The Surveyor or the Remote Pilot should follow the emergency procedure stipulated in the sample OM. All incidents should be properly recorded and reported to the

Surveyor. Details of the emergency procedure and handling of incident could be referred to the sample OM attached to AC-002.

14.5.2.4 From the perspective of protecting personal data privacy, the Surveyor shall make reference to the Guidance on CCTV Surveillance and Use of Drones in website of Office of the Privacy Commissioner for Personal Data as follow:

http://www.pcpd.org.hk/english/resources_centre/publications/guidance/guidance.html

14.5.3 Data Processing

14.5.3.1 The data captured by UAV should be processed or analyzed by photogrammetric or point cloud data processing software approved by the Surveyor.

14.5.3.2 In case any personal data such as faces of people and vehicle plate numbers etc. is accidentally captured in the aerial photos or videos, the Surveyor should ensure those unwanted personal data on the deliverables were masked out, blurred or deleted as appropriate.

14.6 Deliverables

14.6.1 The survey deliverables may include, but not limited to the following-

(a) Raw data including UAV photos, video, positioning data, other data captured from the UAV, etc.; and

(b) Derived products such as stitched panoramic images, drawing, orthophoto, DTM, 3D mesh model, animation, etc.

14.7 Quality Assurance

14.7.1 The General Principles in Chapter 2 should apply.

14.8 Survey Records

14.8.1 The General Principles in Chapter 2 should apply.

14.8.2 Raw data

Raw data include UAV photos, video, LiDAR point clouds and other data captured from the UAV, operation parameters of UAV and camera/sensor, survey data of ground control points and any other items as required by the Surveyor.

14.8.3 Derived Product

Derived products include stitched panoramic images, drawings, orthophoto, DTM, 3D mesh model, animation, earthwork computation, etc.

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Chapter 15

Laser Scanning Survey

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Chapter 15 Laser Scanning Survey

15.1 Introduction

15.1.1 Laser scanning survey is a contact-free measuring technique which effectively collects photographs and high density point cloud of ground features. In many engineering projects, it is useful in capturing profiles of natural terrain and artificial features, mapping those structures/features that are hard to access, computing earthwork volume, etc.

15.2 Scope

15.2.1 This chapter is to set out the procedures and to provide guidance for terrestrial laser scanning survey. Other types of laser scanning surveys, which operate on moving platforms, are not included in this chapter.

15.2.2 The Surveyor should be responsible to determine using laser scanner on various survey tasks associated with the project.

15.2.3 The Surveyor may propose other survey procedures for carrying out the laser scanning survey. Under special circumstances, he/she may set an alternative work standard to his/her satisfaction that such a work standard will not adversely affect the job requirements and the quality of the final product.

15.3 Accuracy and Standards

15.3.1 Definitions

15.3.1.1 "Laser scanner" means a device emits laser beam continuously to measure the 3D coordinates of distant objects/terrain which can then be presented as point cloud(s) in a scanworld(s).

15.3.1.2 "Point cloud" means cluster of 3D points sampled by laser scanning survey on scanned objects/terrain.

15.3.1.3 "Scanworld" means collection of point clouds that are aligned with respect to a common coordinate system.

15.3.1.4 "Registration" means the process to align multiple scanworlds to a user-defined coordinate system.

15.3.1.5 "Control point" means point in a scanworld with known user-defined coordinate or HK 1980 Grid coordinate and HKPD for registration purpose.

15.3.1.6 "Tie-point" means common point located at the overlapping area of scanworlds that provides constraint for aligning multiple scanworlds together. A tie-point can also be a control point.

15.3.1.7 "Check point" means point in a scanworld with known user-defined coordinate or HK

1980 Grid coordinate and HKPD for quality assessment of laser scanning survey.

15.3.1.8 "Laser scanner target" means tailor made circular, square or sphere target setup within the scan range and being scanned for acquiring control/tie point(s).

15.3.1.9 "Edge effect" means the effect that the beam divergence, edges are usually not measured exactly due to the scanner resolution. A variety of wrong points may be produced in the vicinity of edges.

15.3.2 Unless or otherwise agreed by the Engineer, the laser scanning survey shall be carried out in terms of the Hong Kong 1980 Grid System and HKPD.

15.3.3 The horizontal and/or vertical control stations shall be established in accordance with Chapter 3 "Survey Datum and Survey Control".

15.3.4 Accuracy of Registration/ Reference Object

The acceptance criteria are listed below or as specified by the equipment manual for the laser scanner.

Range (d) (m)	Tolerance		Recommended Cyra target type(s) **1** – 3"x3" square planar **2** – 6" Circular planar
	Registration mean Absolute error (mm)	Reference Object start/close Discrepancy (mm)	
$0 \leq d < 50$	24	12	**1, 2**
$50 \leq d < 100$	36	18	**1, 2**
$100 \leq d < 150$	52	26	**2**
$150 \leq d < 200$	68	34	**2**

15.4 Instrumentation

15.4.1 The General Principles in Chapter 2 should apply.

15.5 Survey Procedures

15.5.1 <u>Planning & Reconnaissance</u>

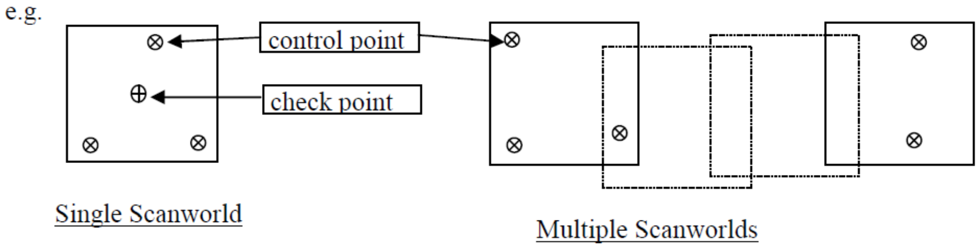
15.5.1.1 The Surveyor assigned to carry out the laser scanning survey shall determine the maximum scanning range and point density depending on accuracy and level of details required. The scanning range should preferably not exceed 200m for short-range laser scanner and 1000m for long-range laser scanner;

15.5.1.2 The Surveyor shall plan the scanning coverage, scanning range, overlapping area between consecutive scans and identify appropriate positions to set up the scanner within the maximum scanning range;

15.5.1.3 The Surveyor shall decide optimum number of scanworlds taking into account the view angle of the scanner, the site situation and registration criteria; and

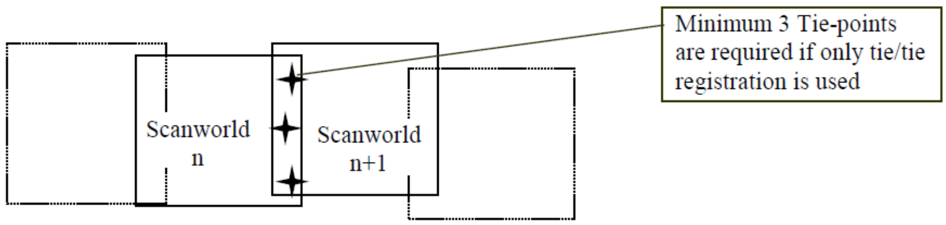
15.5.1.4 The Surveyor shall plan for the position and optimum number of tie-points and control points for each scanworld in order to carry out registration. Tie-points or control points shall be distributed at the extent of the survey area to provide better geometry for registration. For short-range laser scanner with scanning range not exceeding 200m, the acceptance criteria for registration are shown below:-

Total no. of scanworld(s)	Minimum no. of control and check points required for registration to defined coordinate system		
	Starting scanworld	Closing scanworld	Check point
1	3	-	1
Multiple	3	2	-

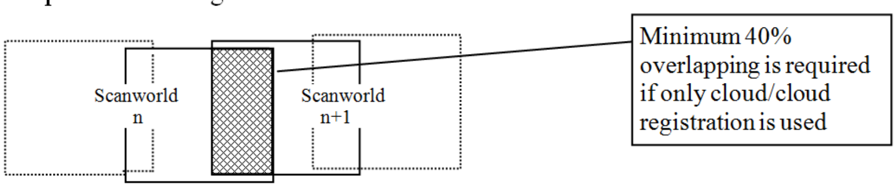


15.5.1.5 Registration of scanworlds is constrained by tie-point/ tie-point or point cloud/ point cloud method. The two methods as illustrated below can be applied simultaneously. The Surveyor shall plan for the position and optimum number of tie-points and control points for each scanworld in order to carry out registration.

Tie-point/tie-point registration



Point cloud/point cloud registration



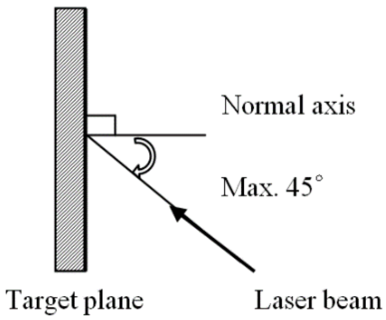
15.5.1.6 The above acceptance criteria are only applicable for short-range laser scanners with scanning range not exceeding 200m. For other types of laser scanners, the Surveyor shall adopt the specific requirements as stipulated in the instructions, guidelines, notes and relevant documents which are currently in use by the Engineer, if any.

15.5.2 <u>Field Survey</u>

15.5.2.1 The Surveyor should prepare an equipment checklist to check out/in of all equipment used;

15.5.2.2 The Surveyor should check equipment set-up carefully before survey;

15.5.2.3 The Surveyor shall avoid laser scanner target with an incident angle larger than 45 degrees from the normal axis of the target plane;

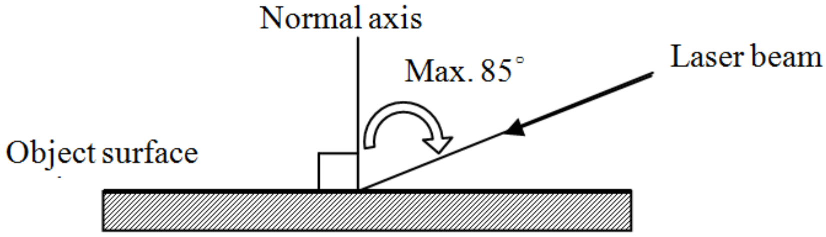


15.5.2.4 For each target acquisition, the Surveyor shall check if its vertex is situated at the centre of the acquired target point cloud. If not, redo the target acquisition;

15.5.2.5 After target acquisition, the Surveyor shall compare the slope distance between 2 laser scanner targets from scanworld against its computed distance (for targets with known coordinates). The distance discrepancy shall not be more than 10 mm. If the laser scanner targets do not have known coordinates, an object with known geometric dimension (e.g. the dimensions of laser scanner target, or 2 well defined points on ground) shall be scanned within the scan range for checking. The distance discrepancy shall not be more than 10 mm;

15.5.2.6 Before conducting a full scan, a reference object shall be acquired. After completion of each scan, the same reference object shall be acquired again in order to check if the scanner is moved during scanning process. If the target vertex differs more than the acceptance criteria listed in paragraph 15.3.4, the whole scanworld shall be abandoned and re-surveyed;

15.5.2.7 The Surveyor shall avoid scanning object with an incident angle larger than 85 degrees from the normal axis of the object surface; and



15.5.2.8 For the survey with scanning range over 200m, the Surveyor should be aware of any abnormal size exaggeration of ground feature in the model due to the edge effect of laser scanning survey. This may happen to ground feature of material with high reflectivity being scanned over a long range.

15.5.3 Data Processing

15.5.3.1 The data captured by the laser scanning survey shall be processed or analysed by point cloud data processing software by the Surveyor; and

15.5.3.2 The Surveyor should carry out the noise removal of the data to ensure that the unwanted/ inaccurate point clouds are deleted from the survey deliverables.

15.6 Deliverables

15.6.1 The Surveyor should agree with the Engineer on the details of the survey deliverables to be submitted and in the appropriate format. The survey deliverables may include, but not limited to the following-

(a) Raw data including photos and laser scanning data collected by the survey etc.; and

(b) Derived products such as 2D plan, sectional drawing, 3D model, animation etc.

15.7 Quality Assurance

15.7.1 The General Principles in Chapter 2 should apply.

15.8 Survey Records

15.8.1 The General Principles in Chapter 2 should apply.

15.8.2 Raw Data

Raw data include photos and laser scanning data captured by the survey, field operation and data processing parameters, survey data of control stations and any other items should be compiled and kept in the computation folder for record. Survey requests and Engineer's requirement such as extent of site should be recorded properly.

15.8.3 Derived Product

Derived products should be in format agreed with the Engineer such as 2D plan, sectional drawing, 3D model, animation etc.

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Chapter 16

Building Information Modelling (BIM)

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Chapter 16 Building Information Modelling (BIM)

16.1 Introduction

16.1.1 Building Information Modelling (BIM) is the process of creating and managing the data in an architecture, engineering and construction (AEC) project during its design, construction and operation of the building and infrastructure. This three-dimensional (3D) digital model-based process provides a solution for the collaboration in the AEC industry with an information backbone.

16.1.2 The Government is firmly committed to the promotion and adoption of BIM technology in capital works projects with a view to enhancing the design, construction, project management, asset management and improving the overall productivity of the construction industry. Consultants and contractors are required to use this modelling technology when undertaking design of major government capital works projects from 2018 onwards. Subsequently, the use of BIM technology in certain applications in the investigation, feasibility study and construction stages of public works projects has become mandatory.

16.1.3 The role of the Surveyor in adoption of BIM technology is to appreciate how surveying fits in with the BIM process and look into the complete life cycle of a project from conception through handover to operation. At all stages of this cycle, the Surveyor shall identify the requirements for fit-for-purpose survey information and tender necessary input for tender purpose.

16.2 Scope

16.2.1 This chapter is to set out the procedures and provide guidelines for “Existing Conditions Modelling” and “As-Built Modelling” as a mandatory use of BIM in the respective stages of public works projects.

16.3 Accuracy and Standards

16.3.1 The Surveyor should adopt the survey accuracy of BIM objects or models with respect to the same of the survey methodology employed and the related practices specified in the relevant chapters of this ESPG.

16.3.2 All BIM models or their project base point must be geo-referenced to the Hong Kong 1980 Grid System and the HKPD.

16.3.3 The Surveyor shall adopt the BIM standards of object naming, model naming, layer naming, colour scheme, LOD/LOIN definition and folder structure, etc. as specified in the up-to-date version of the following documents in order of priority-

(a) BIM Project Execution Plan (BEP)

(b) Departmental/Organizational BIM Specification

(c) DEVB BIM Harmonisation Guidelines for Works Departments

(d) Drafting Specifications for Engineering Survey

(e) Relevant DEVB(W) Technical Circulars

(f) Construction Industry Council (CIC) BIM Standards and Guides

(g) BS EN ISO 19650

16.4 Instrumentation

16.4.1 The General Principles in Chapter 2 should apply.

16.4.2 The Surveyor shall be responsible for choosing of survey methodology and instrument as well as BIM software and hardware for the construction of BIM objects and models.

16.4.3 The BIM software employed should be capable of constructing the design and/or surveyed models of the project and facilitating other BIM uses such as clash analysis, collaboration, communication and data exchange.

16.4.4 The BIM software should comply with the latest industry interoperability standards, e.g. Industry Foundation Classes (IFC) and Construction Operations Building Information Exchange (COBie).

16.4.5 2D drawings of BIM models generated by the BIM software should comply with the Drafting Specifications for Engineering Survey if technically practicable.

16.4.6 Before any BIM software upgrade, its impact to the existing BIM models should be reviewed.

16.4.7 The "Guideline for BIM Modelling Computer" provided by DEVB(WB) should be made reference to when procuring BIM modelling computer. Depending on the BIM operations needed such as viewing, model building and animation rendering, different grade and configuration of computer are to be specified.

16.5 Survey Procedures

16.5.1 Planning and Reconnaissance

16.5.1.1 The Surveyor shall make reference to the BIM standards and specification as detailed in the documents listed in paragraph 16.3 and adopt the following guidelines for planning and reconnaissance of a BIM project-

(h) Identify the project scope, site extent and BIM requirements;

(i) Identify the BIM scope, modelling extent and LOD/LOIN specification;

(j) Conduct site reconnaissance to familiarise with the site conditions and identify those existing conditions or as-built features to be modelled by preparing a list of BIM objects or making reference to BIM Objects in Construction Industry Council for the use in the project;

(k) Consult the Engineer for any special requirements in the BIM modelling and information collection if necessary;

(l) Devise appropriate survey methodology for the collection of BIM data; and

(m) Agree with the Engineer on the BIM software packages, software versions, file naming convention and file formats for delivery.

16.5.2 Field Survey

16.5.2.1 If field survey is necessary to collect the BIM data, reference should be made to the relevant chapters in this ESPG for the guidelines and standards in carrying out the survey. The integrity, correctness and accuracy of the BIM data collected must be checked and confirmed meeting such specified standards before the data is accepted for modelling.

16.5.3 Creation of BIM Objects

16.5.3.1 Based on the BIM object list prepared at paragraph 16.5.1.1(c), the Surveyor shall create the BIM objects according to the following guidelines:

(a) For each object type in the existing conditions or as-built model, the Surveyor shall define the requirements of the geometric and non-geometric components of the object in accordance with the LOD/LOIN specified;

(b) The BIM object shall not be modelled with excessive details or higher LOD/LOIN than is required for its intended purpose. Exact replication of all life details is NOT recommended and is not necessary;

(c) The BIM object shall be parametric and with suitable connectors for system creation and analysis;

(d) The BIM object shall be created in accordance with the latest requirements and specifications of the guidelines and standards as specified in paragraph 16.3;

(e) The BIM object created should be reusable across different projects with the similar BIM requirements as far as practicable;

(f) The geometry of BIM object shall be created using the field survey data with reference to the standard BIM objects library, standard drawings or construction drawings if available;

(g) The insertion point of the BIM object should normally be located at the survey point of the feature;

(h) The BIM object shall contain 3D components of geometry, 2D components of symbol and tag/label/annotation to enable generation of 2D drawing from the BIM objects in various scales. The 2D representations shall comply with the symbol catalogue commonly adopted by the government (e.g. CSWP standard) as far as practicable;

(i) The BIM object shall contain necessary properties/parameters in accordance with the relevant standards and specifications in paragraph 16.3.3;

(j) The BIM object shall be named systematically and logically for easy BIM management. Unless otherwise required, the Surveyor shall adopt the naming convention specified in the relevant standards and specifications in paragraph 16.3;

(k) To facilitate data exchange, the BIM object shall be assigned with appropriate predefined IFC parameters.

(l) The newly created BIM objects should be submitted to CIC BIM Objects Library; and

(m) The BIM object should be provided together with a comprehensive BIM object sheet to convince clients, receivers and users that the BIM object is complete and satisfies all requirements and functions for drawing production.

16.5.4 Existing Conditions Modelling

16.5.4.1 Existing conditions modelling is the process of creating a 3D model with geometric and non-geometric information of the existing site conditions at different stages of the construction life cycle. The following guidelines should be followed in the practice of existing conditions modelling-

(a) The BIM existing conditions model shall be created in accordance with the latest requirements and specifications of the guidelines and standards as specified in paragraph 16.3;

(b) The Surveyor shall devise a suitable and cost-effective surveying approach to construct the existing conditions model.

(c) The Digital Terrain Model (DTM) of the existing site topography shall be formed using the survey data;

(d) BIM objects created shall be placed into the model based on the survey point and the reference lines generated from the survey data;

(e) The specified properties/attributes of the BIM object shall be captured and entered into the object;

(f) When applicable, the 3D Spatial Data supplied by Lands Department should be used to mock up the surroundings of the modelling site at suitable extent for visualization or visual impact analysis;

(g) To maintain the BIM model with manageable file size and for the sake of computing performance, large or complex projects should be modelled with logical division into separate parts, zones, phases or levels as necessary;

(h) The BIM model shall be named systematically and logically for easy BIM management. Unless otherwise required, the Surveyor shall adopt the naming convention specified in the relevant standards and specifications in paragraph 16.3;

16.5.5 As-Built Modelling

16.5.5.1 As-built modelling is the process of preparing a field verified BIM model which shall be an accurate record of the physical conditions and assets of a project after the construction work is completed. The following guidelines should be followed in the practice of as-built modelling:

(a) The Surveyor shall comprehend the requirements of the as-built model by referring to the latest requirements and specifications of the guidelines and standards as specified in paragraph 16.3;

(b) The Surveyor shall devise a suitable and cost-effective surveying approach to construct the as-built BIM model;

(c) The Surveyor shall determine the allowable discrepancy of the as-built condition with reference to the allowable error specified for the BIM features;

(d) If design BIM model is available, it should be based on to construct the as-built BIM model with dimensional, positional or rotational adjustment as appropriate for those parts exceeding the allowable discrepancy;

(e) If design BIM model is not available, the guidelines for Existing Conditions Modelling in paragraph 16.5.4 should be followed to construct the as-built BIM model taking into consideration of the subsequent use of the model, such as for asset management purpose; and

(f) If 2D as-built drawings are to be generated from the as-built BIM model, the 2D drawings produced by the BIM software should conform with the Drafting Specifications for Engineering Survey if technically practicable.

16.6 Deliverables

16.6.1 The existing conditions or as-built model including but not limited to the DTM, surveyed features/objects, building mass of the surroundings and source data such as 3D point cloud and aerial photographs in their native and editable formats should be submitted to the Engineer;

16.6.2 BIM documentation of the existing conditions or as-built model including but not limited to a BIM object list, a BIM object sheet for each BIM object created, the object/layer naming conventions adopted and other geometric and non-geometric information of the model as necessary should be prepared. For as-built models, a field verification report of the as-built condition and its discrepancy with the design model should be prepared.

16.6.3 If open format (e.g. IFC) is specified for delivery, the completeness and integrity of the open format data exported from the BIM software used or converted by a conversion program should be checked. Any loss of information by the conversion should be minimised as far as the modelling approach and conversion software allow. While loss of information is sometimes unavoidable, such discrepancies should be reported to the Engineer for acceptance.

16.7 Quality Assurance

16.7.1 The General Principles in Chapter 2 should apply.

16.7.2 A quality assurance plan should be established to ensure appropriate checks on compliance, information and geometry of the existing conditions or as-built BIM model. The following checks and the responsible personnel should be specified in the plan:

Checks	Definition
Compliance Check	To ensure that the model objects/elements, modelling approach, naming convention, colour scheme, fonts, modelling tools and file versions, modelling units, coordinate system, etc. are in compliance with the standards and guidelines as specified in 16.3.
Information Check	To check whether the completeness of the Project Information, properties/attributes for each BIM

Checks	Definition
	object/element are completed and in compliance with the standards and guidelines as specified in 16.3. To ensure that they are populated with correct information.
Geometry Check	To ensure that the model and its objects/elements are constructed with correct dimensions, placed at the correct positions and their accuracy requirements are met. Where necessary, sections and profiles of the model should be generated to facilitate the checking.

16.8 **Survey Records**

16.8.1 The General Principles in Chapter 2 should apply.

16.8.2 The BEP, incoming record and construction drawings, field survey observations and measurements, survey data computation, object sheets of the BIM objects deployed for modelling, the object list of the model, the geometric and non-geometric specifications of each object and its modelling methodology, and all documentations prepared for the quality assurance in paragraph 16.7 as well as the field verification report, if available should be well maintained for record purpose.

16.9 **Remarks**

16.9.1 The Surveyor should establish and manage a library to store and archive the BIM elements/ objects created from the published existing conditions models. Development of the BIM existing conditions model by extracting the previous created BIM objects from the library would reduce processing time and cost of the project and maintaining the consistency of the models;

16.9.2 The Surveyor should ensure that the BIM Objects downloaded from the CIC BIM Objects Library are in the latest version when preparing the existing conditions model and as-built model.

16.9.3 All project model files, drawings, references and data, regardless of project size or type, should be organised and filed into a standard folder structure. The defined structure followed the concept of ISO19650-1:2018's 'WIP', 'Shared', 'Published' and 'Archive' segregation of data within a designated set of folders.

16.9.4 BIM models contain rich information which can facilitate the integration between BIM and GIS as well as the development of Common Spatial Data Infrastructure. The Surveyor should prepare the as-built BIM models which should be in compliance with the sharable standards specified by the DEVB BIM Harmonisation Guidelines for WDs for submitting and storing in the Government BIM Data Repository (GBDR) of Hong Kong.

16.9.5 The BIM model developed under Common Data Environment (CDE) can serve as a single source of truth for collaboration throughout the whole project life cycle. The Surveyor shall encourage project owner to develop a GIS-enabled CDE as far as practicable in order to facilitate the development of digital twin for smart city.

16.9.6 BIM models would ultimately be included as part of tender information for electronic tendering. The Surveyor shall ensure that the BIM models are completed for tender purpose and in compliance with the standards and guidelines as specified in 16.3.

16.9.7 GBDR provides open BIM and open GIS format of as-built data to facilitate data exchange across different BIM and GIS application software. Those open data formats can be obtained via Works Departments under official approval for government projects.

Chapter 17

Tunnel Survey

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Chapter 17 Tunnel Survey

17.1 Introduction

17.1.1 A tunnel survey refers to the surveying activities covering ground surface and underground operations to ensure the correctness of the tunnel alignment before/after breakthrough. Owing to site constraints where the access to the underground tunnel level is by way of a vertical shaft, higher order horizontal and vertical survey controls at underground before tunnel breakthrough are only available at one end of the tunnel. In this connection, unlike ordinary survey work, short baselines, open traverses in undesirable geometry are sometimes unavoidable. Therefore, the appropriate survey design and procedures and the proper choice of instruments are the major considerations to ensure the survey errors accumulated before breakthrough are well within the error budget.

17.2 Scope

17.2.1 This chapter sets out the general principles and major considerations of the critical survey activities including horizontal and vertical control survey, monitoring survey, record survey, check survey for automatic tunnel guidance systems, which are commonly encountered in tunnel construction works.

17.3 Accuracy and Standards

17.3.1 The accuracy of survey shall comply with the accuracy standard and quality requirements as stipulated in the General Specification for Civil Engineering Works or otherwise specified to suit the type and purpose of the tunnel project.

17.4 Instrumentation

17.4.1 The General Principles in Chapter 2 should apply.

17.4.2 In addition, the following specific types of equipment are normally required for tunnel survey.

(a) Plumb bob with thin steel wire or precise optical / laser plummet;

(b) Precise (at least 3-second angular accuracy) Gyroscope (if applicable);

(c) Standardized steel tape; and

(d) Forced-centering brackets.

17.5 Survey Procedures

17.5.1 <u>Control Survey on Ground Surface</u>

17.5.1.1 <u>Control Origins</u>

(a) Unless otherwise specified in contract document or agreed with Engineer, the Trigonometric Stations and Bench Marks of the Survey and Mapping Office, Lands Department or other control stations with higher order of accuracy shall be adopted as the master survey control stations to serve as the control origins on ground surface of a project.

17.5.1.2 Pre-analysis

(a) A pre-analysis, in accordance with the proposed layout of the survey control networks and proposed survey measurements, shall be conducted to ensure the estimated accuracies of the control point of an underground open traverse or levels at the proposed breakthrough position are within the allowable tolerances set out in contract document. The choices of network geometry and instruments shall be determined based on the computed error ellipses of the control points with the aid of least squares adjustment software.

17.5.1.3 Horizontal Controls

(a) A primary horizontal survey control network would be firstly established based on the master survey control stations to cover the site areas and for breaking down into secondary horizontal survey control points. These horizontal survey control points are established on ground surface.

(b) The primary control points shall be established at the locations with good accessibility and stability as well as far away from the tunnel alignment and excavation sites for minimizing the risk of missing/disturbance introduced by tunnel works.

(c) The secondary control points shall be established within the work sites and vertical shaft openings to facilitate subsequent correlation surveys taking into account the accessibility, inter-visibility and monument installation.

(d) The control network survey and traverse survey shall be carried out in accordance with Chapter 3 "Survey Datum and Survey Control" while GNSS survey shall be in accordance with Chapter 4 "Global Navigation Satellite Systems (GNSS) Survey". The choice of survey methods depends on the accuracy requirements with reference to the results of the pre-analysis.

17.5.1.4 Vertical Controls

(a) A vertical control network shall be established to cover all sites of the project on ground surface, e.g. the portals at both ends of the tunnel and other site areas to facilitate subsequent correlation surveys taking into account the accessibility, inter-visibility and monument installation.

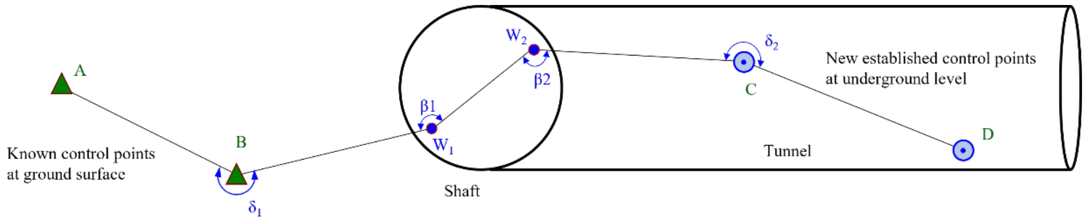
(b) Precise levelling method shall be applied in accordance with Chapter 3 "Survey Datum and Survey Control".

17.5.2 Correlation Survey

17.5.2.1 Tunnel excavation is usually started from a portal or a shaft. In a tunnel excavation starting from a shaft, direct traversing and levelling from the surface to the underground is impossible due to steep vertical angle and very large height difference, a correlation survey aims to connect the survey controls on ground surface and the underground tunnel level, so as to maintain the same control system at these two levels of space.

17.5.2.2 Transfer of Bearing/coordinates

(a) The shaft plumbing procedure by Weisbach triangle method is one of common method to transfer the ground control stations to the tunnel level. The basic idea of the shaft plumbing through vertical shaft is illustrated below. Plumb lines at points W1 & W2 serve as intermediate traverse stations between the known control stations A & B on the surface and unknown stations C &D underground, to be established as reference baseline in tunnel level as control origin. See Appendix 17.1 for a detailed explanation of the application of the Weisbach triangle method.



The Weisbach Triangle method

17.5.2.3 Transfer of Height

(a) Temporary benchmarks on the surface are firstly established near the shaft opening and tied to the existing levelling network by precise levelling.

(b) A standardized steel tape shall be fixed on a customized bracket along the side of the shaft.

(c) A weight shall be suspended at the lower end of the standardized steel tape. The sum of the weight and the steel tape shall be equal to the tension used during the standardization of the tape.

(d) Survey markers for the underground temporary benchmarks are installed at the tunnel taking into account the ease of access and recovery.

(e) Two precise levels shall be deployed to take simultaneous reading on the steel tape at the surface and at the tunnel level. Usually, a set of 10 readings each is taken on different sections of the tape by shifting a few centimetres between the readings to avoid mistakes in reading.

(f) The reduced level of the underground temporary benchmark shall be calculated by the observed height differences.

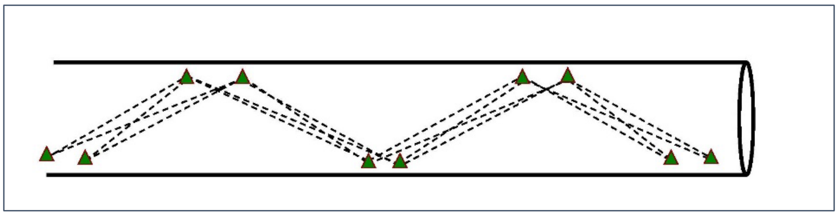
17.5.3 Underground Survey Controls

17.5.3.1 Horizontal Controls

(a) The establishment of an underground horizontal control network is done in a reversed sequence from that used on the surface. The lowest order stations shall be established first during tunnel excavation and subsequently replaced by the higher-order control once the breakthrough of the tunnel allows for longer sights and closure of the traverses.

(b) After the correlation survey, a preliminary third order control network is established to support daily survey activities including setting out, record of excavated areas and daily checks of tunnel progress. Nevertheless, such preliminary control network shall be established to the best endeavour for the control of tunnel construction works to meet the project requirement, for example, conducting the “Double Zig-Zag Traversing” to avoid observation mistakes and minimize the refraction error of an observation ray which is close to a wall surface for achieving the most accurate results in open traverses.

(c) The “Double Zig-Zag Traversing”, which can enhance the geometry of an open traverse with a chain of rigid quadrilateral network, shall be used to advance the survey control stations during the progressive construction of the tunnel. The traverse consists of a number of pairs of control stations about 10 meters apart and they are connected to the next pair of control stations on the other side of the tunnel. The dotted lines as shown in the diagram below represent the observed rays. The length of traverse legs are dictated by the curvature of the tunnel alignment and other site conditions.



Configuration of the Double Zig-Zag Traverse

(d) Brackets, supporting forced-centering traversing, shall be installed under the roof or on the wall of tunnel and used as a marker for survey control station. Interchangeable theodolite and targets fitted with detachable tribrachs shall be used.

(e) At least 4 arc of angular measurement and reciprocal distance measurements shall be observed with a total station with 1-second angular accuracy and 1mm + 2ppm distance accuracy or better.

(f) Precise gyroscope, with an accuracy better than 3 seconds of arc in azimuth measurements, shall be used to measure and verify the reference bearing of underground baseline aiming to serve as an independent azimuth measurement in the network adjustment for minimizing the effect of the errors introduced in the shaft plumbing other observation errors existed in open traverses unless other independent checking methods could be justified to ascertain the required accuracy of the project is achievable. Azimuth measurements using a gyroscope shall be taken at the initial stage of tunnel excavation after the correlation survey. In addition, it shall be conducted after running a certain chainage of an open traverse as determined based on the result of pre-analysis or say, approximately 1 km for long traverse length; and certain distance before tunnel breakthrough to allow for the adjustment of the open traverse if necessary.

(g) After the tunnel breakthrough, the open traverses of opposite directions of excavations shall be connected to form a closed traverse. The coordinates of all control stations of the closed traverse shall be recomputed by the method of least square adjustment. This set of control stations to be deemed to be final and would be used for subsequent tunnel lining as-built survey, installation works, electrical and mechanical services, etc.

17.5.3.2 Vertical Controls

(a) Precise levelling method shall be adopted in accordance with Chapter 3 "Survey Datum and Survey Control".

(b) Same as horizontal controls described at 17.5.3.1 (g), the final set of vertical controls shall be obtained after closing to the other survey stations at the other ends after the tunnel breakthrough.

17.5.4 Monitoring Survey

17.5.5 The monitoring survey for tunnelling works includes settlement monitoring, tilting monitoring survey, deformation survey for ground, buildings, utilities and convergence of the tunnel. The survey shall be carried out in compliance with the requirements stipulated in Chapter 7 Monitoring Survey.

17.5.6 Convergence monitoring, which is to measure the shape of the tunnel section reflecting the tendency for deformation of the section area of the void formed in tunnel excavation, has specific requirements as follows. A minimum of 5 monitoring points shall be placed with an even distribution along the internal arch of the tunnel to detect the movement of the rock mass. The change of positions between the points over time, in terms of Δx, Δy and Δz, shall be presented in a table form.

17.5.7 Record (Detail) Survey

17.5.7.1 The survey procedures of various types of record survey shall be carried out in compliance with the requirements stipulated in Chapter 5 "Record (Detail) Survey".

17.5.7.2 Cross-sectional record survey of rock profile for drill and blast tunnel and detail survey on the as-built profile of the tunnel lining (also known as a wriggle survey) are specific types of record survey for construction tolerance check and dimension tolerance check of the diameter encountered in tunnelling works. There shall be eight survey points at the locations evenly distributed around the cross section of the tunnel.

17.5.8 Check Survey for Automatic Tunnel Guidance Systems

17.5.8.1 The automatic tunnel guidance systems of the excavation machines such as Tunnel Boring Machine, Tunnel Shield and Tunneling Jumbo are to control the orientation of excavation with reference to the tunnel alignment. In this connection, a total station shall be employed to provide some reference points with known coordinates situated on the machines or the tunnel for checking the position and orientation angles of the system throughout the tunnel construction.

17.6 Deliverables

17.6.1 The record of survey control shall be prepared in accordance with Chapter 3 "Survey Datum and Survey Control" for contract interface and site handover.

17.6.2 The deliverables of record detail survey, monitoring survey or other types of survey conducted should refer to the relevant chapters of this ESPG.

17.6.3 Cross-sectional record survey, including profiles of as-excavated rock surfaces, shotcreted surface, and permanent lining surface for drill and blast tunnel and the permanent lining surface of TBM Tunnel are permanent records of the tunnel in different stages and conditions. The results of the cross-sectional record shall be checked against the construction tolerance for determining the clearance available for subsequent works. The designed structural gauges, horizontal/vertical clearance suggested in manuals or construction drawings should be shown on as-built section drawings.

17.7 Quality Assurance

17.7.1 The General Principles in Chapter 2 should apply.

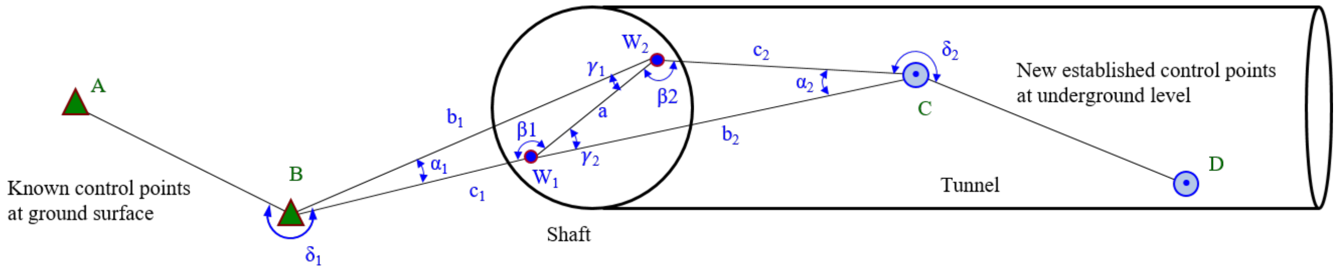
17.7.2 In addition, particular tunnel surveying activities are carried out for the fundamental control of the tunnel alignment, for example, control survey with gyroscope observations, record detail survey of permanent works etc., they shall be executed with the utmost care. The critical survey tasks shall be defined as quality hold points in the quality assurance system and agreed with the Engineer's representative at the commencement of the project, where the quality hold points must be independently checked by an alternative survey method before proceed to the next construction stage. For example, the underground control network shall be established and agreed by the Engineer's representative before proceeding to the next stage of construction works e.g. tunnel drainage, railway, walkway and electrical and mechanical (E&M) installation works etc.

17.8 Survey Records

17.8.1 The General Principles in Chapter 2 should apply.

Appendix 17.1 Shaft plumbing procedure by Weisbach method

1. The Weisbach method is commonly used to transfer the ground control stations to the tunnel level, which determines the angles β_1 and β_2, from the measurements of angles α_1 and δ_1 at Station B and distances a and b_1 in the triangle B-W_2-W_1 on ground surface; and measurements of angles α_2 and δ_2 at Station C and distances b_2 in the underground tunnel triangle C-W_1-W_2.



Weisbach method of orientation

2. The angles β_1 and β_2 could be calculated from trigonometric relationships:

$$\sin\beta_1 = \frac{b_1 \sin\alpha_1}{a} \quad and \quad \sin\beta_2 = \frac{b_2 \sin\alpha_2}{a} \text{ ; while } \sin\Upsilon_1 = \frac{c_1 \sin\alpha_1}{a} \quad and \quad \sin\Upsilon_2 = \frac{c_2 \sin\alpha_2}{a}$$

and a closure to 180° should be obtained in both triangles.

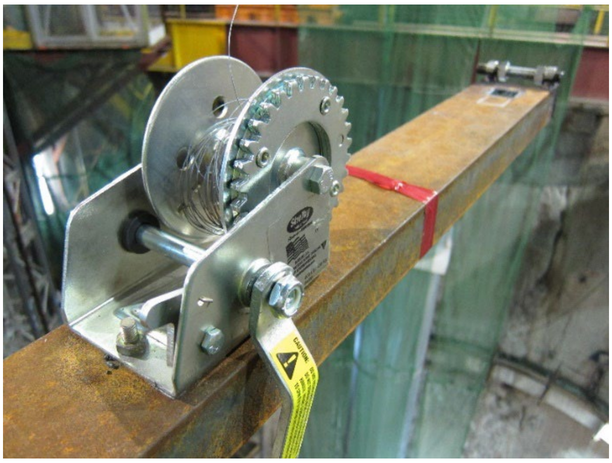
For optimum results, the shape and important elements of the Weisbach method are as follows:

a) Stations B and C should be as close as possible to the nearer wire, W1 and W2 while the distance between the wires should be as long as possible such that the ratio $\frac{c_1}{a}$ & $\frac{c_2}{a}$ are minimized and the resulting angular error at β_1 and β_2 are smaller, typically, the ratio of $\frac{c_1}{a}$ & $\frac{c_2}{a}$ are not larger than 3.

b) Stations B and C should almost in line with both wires, α_1 and α_2 are generally around 120”.

3. Once the angles β_1 and β_2 are determined, the tunnel orientation procedure is completed by calculating the azimuth of the baseline CD and the coordinates of Stations C & D could be obtained by traverse A-B-W_1-W_2-C-D.

4. The intermediate traverse stations W_1 & W_2 are plumb lines using thin steel wire with a heavy suspended plumb bob. Steel wires with very high tensile strength (e.g. 200kg/mm2 or larger piano wire) should be used for shaft plumbing. The weight of the plumb bob is usually selected as equal to H/3 in kg where H is the depth of plumbing in meters. The wire should be stored on special drums to allow for a slow lowering of the plumb bob to a desired tunnel level.

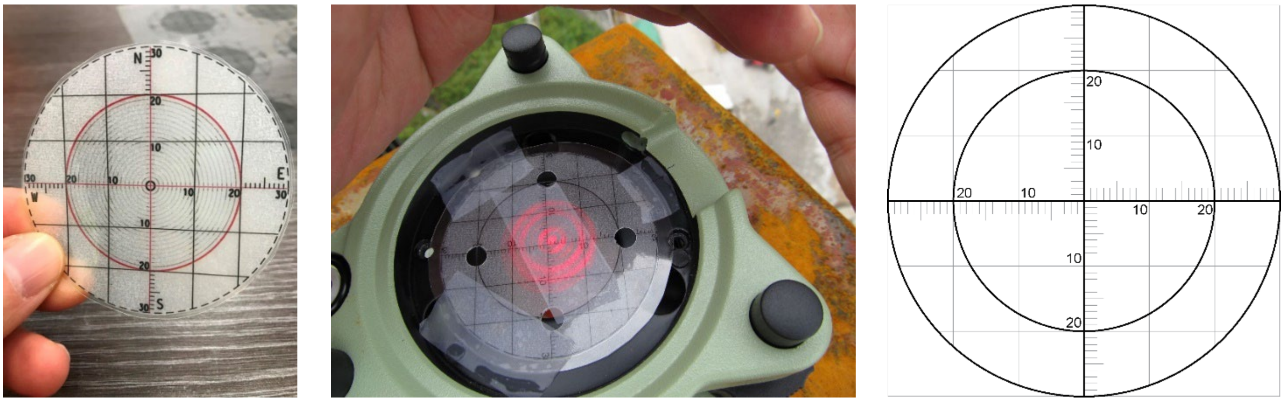


A wire reel for shaft plumbing

5. When a plumb bob is used in setting out the baseline, it should be submerged in a container of oil to dampen the oscillations caused by air current in the shaft. When it is impossible to completely dampen the oscillations due to air current in the tunnel, and the plumb line swings continually in an orbit of elliptical shape, the plan position of the wire can be determined by the mean of the two extreme positions of the swinging wire each with at least 10 readings.

A heavy plumb bob with fins (left) and submerged in a container of oil during the observation (right).

6. Forced ventilation current and natural air stream inside tunnel would exert a force on the plumb wires and affecting the verticality of the plumb line, meanwhile shutting down of ventilation system is not advised due to safety concerns. Alternatively, when a precise optical or laser plummet is used to replace the plumb wires as intermediate stations, angular and linear observations shall be taken directly onto these points using plummet with accuracy of 1:200,000 typically. This method is not as popular as mechanical plumb wire as the accuracy is subject to various error sources, including verticality of plummet, divergence of laser point / blurred optical point, refraction in the shaft, etc. The observations of sighting mark or the laser dot of plummets should be repeated by turning the instrument through 90˚ to 270˚ to obtain the mean of centering circle in order to reduce verticality error; and a customized reading aid could be used to deal with diverged laser points to obtain the position of the centre of the laser dot.



A template with gridlines for reducing reading error in diverged laser points.

7. Considered the site constraints mentioned above and the achievable accuracy of shaft plumbing, the bearing of baseline CD at underground level shall be verified with a 3-second gyroscope unless other independent checking methods could be justified to ascertain the required accuracy of the project is achievable.