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8 SURVEY & SURVEY CONTROL

8.1 Functional Responsibilities

8.1.1 The planning, organisation and process of construction surveys shall be the sole responsibility of the Contractor. The Contractor is also responsible for any part of the works carried out by his agents, consultants or subcontractors. He shall at all times maintain a common survey interface with adjacent contracts and shall make available to System-wide Contractors accurate survey information for setting out subsequent works by others.

8.1.2 The Contractor shall appoint a competent Resident Project Surveyor based full time on Site to supervise the survey and setting out works for the duration of the Contract. The name, relevant experience and professional qualification of this surveyor shall be submitted to the Engineer for acceptance. If required, he shall be replaced by an equivalently qualified surveyor with the concurrence of the Engineer

8.1.3 Surveys and setting out of works shall be carried out by surveyors of appropriate experience and qualification under the direct supervision of the Contractor's Resident Project Surveyor. For completed works survey and as-built survey of the works that require statutory certification, the surveys shall be carried out and certified by a Registered Surveyor registered under the Land Surveyors Act.

8.1.4 It shall be the Contractor's responsibility to check each stage of the works for correct line and level before starting any further phase of construction. For the purpose of railway construction, the Contractor shall ensure that the railway structural gauge clearance is achieved at all times.

8.1.5 The Engineer may carry out random checks to verify the accuracy of the setting out and compliance of the completed works with the specification. Provisions and arrangements shall be made by the Contractor to facilitate the checks. However, failure by the Engineer to carry out such surveys shall not constitute a reason for the Contractor not to proceed with his next stage of work.

8.1.6 The Contractor shall note that some of the existing structures were not surveyed in SVY21 coordinate system and SHD. The Contractor shall carry out all necessary surveys using SVY21 and SHD, particularly for the modification works and interface connections with the existing RTS structures.

8.2 Survey Control In General

8.2.1 A reference co-ordinates system of the project area for the Works is defined by the Primary Survey Control Markers supplied by the Authority. Secondary Survey Control Markers are additional points established from these Primary Points for the purpose of identifying survey control for the works areas. There may also be established by the Contractor markers as local grids or reference system for setting out a particular sub-set of the works.

8.3 Primary Survey Controls

8.3.1 The Engineer will issue to the Contractor a set of Primary Survey Control Markers that shall be used project wide for the horizontal and vertical control of the Works. The Contractor shall verify the initial accuracy of the survey markers at the commencement of the Contract. A list of Primary Survey Control Markers established for the Contract will be issued at award of Contract.

8.3.2 All the primary survey markers provided shall be surveyed with survey computations based on the adopted co-ordinates system. Any changes to the values provided for in the Contract shall be supported by technical evidence and in consultation with all affected parties. In particular, any changes in co-ordinate values of Primary Survey Control Markers affecting adjacent contracts shall only be made with prior consultation with the adjacent contractor, and subject to the acceptance of the Engineer. Any revised values shall then be adopted with the concurrence of the Engineer. Such changes to the initial Primary Control co-ordinates and elevation shall not be subject to claims against the Authority.

8.3.3 It shall be the Contractor’s responsibility to protect and preserve the integrity of the Primary Survey Control Markers. In the event that any of the Primary Survey Control Markers are damaged, the Contractor shall replace and re-establish the markers at his own cost to the satisfaction of the Engineer. The Primary Survey Control Markers shall be surveyed and checked by the Contractor at a three-month frequency, or any shorter period as directed by the Engineer. Such results shall be submitted to the Engineer for acceptance.

8.4 Secondary Survey Controls

8.4.1 Secondary Survey Control Markers shall be established and surveyed from the Primary Control Survey Markers by the Contractor for the purpose of controlling works in a local area. The accuracy and quality of the markers shall be commensurate with the purpose and duration of the Works. In all cases the survey accuracy shall not be worse than 1:50,000 for horizontal misclosure and $3\sqrt{K}$ mm for vertical misclosure (where $\sqrt{K}$ is the square root of the distance in kilometres).

8.4.2 The Secondary Survey Control Markers shall be marked for easy identification and physically protected from damage. They shall be available for verification by the Engineer.

8.5 Setting-Out

8.5.1 Pre-computation shall be submitted to the Engineer prior to any setting-out works. Setting-out points are to be established by transfer from Survey Control Markers. The Contractor shall establish physically on Work Areas such setting-out points that may be either a structural grid or offset lines to be used as the reference system for the civil structures. In the event the original structural grid lines are destroyed or rendered unusable, the Contractor shall re-establish them at his own cost without delay.

8.5.2 At each Works Area, the position of the main reference setting-out points shall be maintained throughout the construction period. The Contractor shall check such points against the Survey Control Markers at regular intervals (3 monthly) to ensure reliability of subsequent works.

8.5.3 For setting-out work involving property boundaries, the Contractor shall note the national cadastral system in Singapore. Cadastral information, Road Reserves lines, and Drainage Reserves available from government agencies are of lower accuracy and only locally consistent when compared to the precise survey controls established for the construction of the Rapid Transit Systems (RTS) Project. Due allowance in the form of specific field surveys to resolve critical differences shall be made by the Contractor in such setting-out works. The Contractor shall engage a Registered Surveyor to carry out such setting-out works. Prior to the construction of permanent structures, including pilings, ERSS and reinstatement works, that are within 1m from property boundaries, the Contractor shall engage a Registered Surveyor to prepare and submit to the Engineer a pre-computation plan and carry out setting out of the boundaries and structures on site. Prior to the pre-computations, the Registered Surveyor is required to verify the cadastral boundaries on site. If discrepancies found, he/she is required to consult SLA for the coordinate refinement survey. The precomputations shall be based on the latest refined coordinates. After the construction of such structures, the Contractor's Registered Surveyor shall carry out an as-built survey of the structures and relate it to the property boundaries. If there are any encroachments, the Contractor shall rectify the structures at his own cost.

8.6 Control of Civil Works

8.6.1 The Contractor shall ensure that critical dimensions for the RTS project are met. Regular checking should be carried out during the construction stages to ensure that the specified permissible deviations are not exceeded.

8.6.2 The Contractor shall ensure that all survey and setting out points shall be established at Works Areas to the required accuracy. He shall also be responsible for each stage of the setting-out works and for verifying compliance before construction starts.

8.6.3 All suspect values should be re-measured and checked for compliance.

8.7 Survey Instruments

8.7.1 Survey instruments used and the methodology adopted shall be appropriate to the intended measurement task and accuracy specification. Test measurements and instrument calibration shall be carried out under local field conditions.

8.7.2 It is essential that before starting any initial surveys, and at frequency intervals of not more than three (3) months, all measuring equipment shall be tested for their accuracy. Recommended test procedures and measurement techniques are outlined in latest ISO.

8.7.3 All instruments employed in the Contract shall be in good condition and properly calibrated. Calibration certificates and/or statements of service by local authorised instrument agents, which are not more than six (6) months old shall be sufficient proof that the instruments are in good service condition.

8.7.4 Notwithstanding the above, instruments shall again be checked to ensure good condition before the Contractor proceeds to carry out a critical survey task. In addition, an Electronic Distance Measuring (EDM) Calibration Base at Peirce Reservoir managed by SLA is available to the Contractor for field calibration to ensure scale conformity project wide.

8.7.5 Main horizontal and vertical control networks shall be carried out with precise survey instruments consisting of but not limited to the following:

(a) 1” arc robotic total station with coaxial EDM having an accuracy not inferior to $\pm$2mm and 2ppm;

(b) Precise digital level with a standard deviation of 0.4mm per km of double run levelling with an Invar staff; and

(c) All raw data readings shall be captured electronically on board the survey instrument or by data logger for download into a computer.

8.7.6 Contractor may propose the use of Static terrestrial laser scanning in the as-built surveys. A detailed method statement shall be prepared and submitted to the Authority for review and acceptance prior to the start of the scanning works.

8.8 Topographic Survey and Reinstatement Works

8.8.1 The Contractor shall carry out an initial topographic survey of the contract to satisfy himself as to the accuracy of site conditions to enable him to carry out his work. This survey shall be submitted to the Engineer for acceptance within three (3) calendar months from the award of Contract. These surveys together with any further detailed surveys shall be the basis for subsequent reinstatement works on completion of the project. Certified copies of the surveys together with a Computer-aided Design (CAD) file shall be submitted.

8.8.2 The Contractor is advised that in reinstating his worksites, he shall ensure no contentious issues on encroachment shall arise subsequently. It shall be the Contractor's responsibility to ensure he has obtained sufficient and accurate initial surveys to enable him to carry out reinstatement work. In the event of disputes by the landowner, the Contractor's Registered Surveyor shall set-out and resolve land boundary issues.

8.8.3 On Substantial Completion of the whole of the Works, the Contractor shall within three (3) calendar months submit a complete topographic survey of the contract area, the extent and level of detail to be similar to the initial topographic survey.

8.8.4 This Specification shall be read in conjunction with **Appendix N** of the General Specification on As-built Topographical Feature Survey to be submitted by the Contractor.

8.9 Quality Plan

8.9.1 The Contractor shall submit to the Engineer for acceptance a section in his Project Quality Plan related specifically to survey matters. This section shall be written, approved and maintained by the Resident Project Surveyor on site. The section of the Quality Plan shall address the following:

(a) Identification of the Contractor's Resident Project Surveyor and key survey staff and the lines of communication;

(b) Scope of the surveying section including how the surveying section interfaces with the Contractor's engineers;

(c) List of proposed surveying equipment and computer hardware/software;

(d) The Contractor's surveying procedures;

(e) List of detailed method statements for all critical surveying activities;

(f) Survey test and inspection plan;

(g) Control of survey data and records;

(h) Training of survey staff;

(i) Control of software used by surveyors; and

(j) Surveying safety awareness.