

10. SUPERVISION AND CONSTRUCTION SURVEYS FOR THE CONSTRUCTION OF ROADS AND BRIDGES

This chapter outlines the responsibilities of the Supervisory Surveyor who will form part of the Client's supervisory team on construction projects and of the Construction Surveyor who forms part of the construction team.

10.1 Supervision Surveys (RE Team)

This section will focus on the most important functions which must be undertaken so as to carry out the necessary quality control on the construction activities and for the verification of all survey related quantities as then claimed in the contractor's payment certificate.

The Resident Engineer (RE) will generally determine what is expected of the Surveyor and how the Surveyor may assist him and his team of Engineers on site with their obligations and functions and, where using advanced survey techniques, these are then made appreciably more efficient.

Note: Also refer to paragraph 10.2 for the responsibilities of the Construction Surveyor on construction sites.

10.1.1 The purpose of this survey is generally to gather sufficient and specific information by employing various survey techniques so as to assist the RE in ensuring that the Road Project and its entire ancillary works are constructed by a Contractor to within specified tolerances. Accordingly the Survey System established by the Supervisory Surveyor on site must act as an efficient management tool for the RE and his team which he and his team will then utilise in, *inter alia*, the control of all earthwork volumes, the evaluation of any claims from the Contractor, the checking of claims and the final payment certificates issued by the Contractor, the checking of designs from a setting out point of view, the checking of all relevant setting out work carried out by the Contractor's Surveyor, the determination of specific quantities where the material surfaces are rapidly 'covered' and generally to undertake any survey that will assist or enable the RE to make speedy and informed decisions when making an engineering type evaluation of any aspect relating to the Construction Project.

10.1.2 Phases of the survey

- a) The following is generally recognised as separate phases of this survey:
 - i) **The Construction Beacon Survey:** This being the establishment of a network of Permanent Survey Control beacons and the supply of all related records. The Permanent Survey Control beacons may either be pillar type beacons or be normal conical type beacons and where the choice is determined by the type of terrain. (See Chapter 5 "THE ESTABLISHMENT OF PERMANENT AND OTHER SURVEY CONTROL POINTS"). The Supervisory Surveyor shall

ensure that these beacons are always based on the same Survey Datum as the survey which was undertaken for the design phase of the project;

- ii) **The Survey of Ground Lines:** This is to serve as the reference datum for the determination of all quantities;
- iii) **The Preparation of a Design Model:** This entails the merging of the design DTM with the origin of ground line DTM and which shall then serves as the 3D survey model against which all construction related surveys and earthwork quantities are correlate to;
- iv) **The Checking of the Contractors Staking:** This entails a fully independent survey;
- v) **The Measurement:** This being the gathering of sufficient survey records at specific times/periods so as to monitor the Contractor's progress and to determine as to whether the construction works are being constructed to within specified tolerances;
- vi) **The Utilization of the Design Model:** This being the management tool utilised for supervision purposes and which includes the following:
 - Evaluation of the construction works in relation to the design;
 - Calculation and verification of quantities as per the payment items stipulated in the bill of quantities;
 - Design alterations and additional designs;
 - Evaluation of design alternatives to enable cost comparisons to be made; and
 - Generally a management tool for effective site supervision.
- vii) **The Collection of As-Built Data:** This includes the noting of all alterations made to the original design of the project.

10.1.3 General

- a) It is imperative that, at the start of the project, the Supervising Surveyor has made himself specifically and adequately acquainted with the relevant 'Standard Specifications for Road and Bridge Works' of the Client where particular attention should have been paid to the sections dealing with measurement and payments.
- b) The Supervisory Surveyor must also make himself fully acquainted with all contract documents, the bill of quantities, the detail drawings and all surveying information for the project.
- c) The Supervisory Surveyor must, in conjunction with the RE then evaluate the contractor's setting out procedures so as to ensure that the complicated elements of

the road design such as interchanges, structures and any other important aspects can be correctly and accurately placed. Refer to the relevant Standard Specifications.

- d) It is extremely important that agreement is reached between the Supervisory Surveyor's measurements and calculations and those of the Construction Surveyor before any material is removed or covered. Where agreement on any differences with respect to the measurements is reached then this must be in writing and submitted to the RE for his approval.

10.1.4 Supervision survey guidelines

The Client will decide which survey methods are to be applicable for supervision purposes where this depends largely on the extent and nature of the project. The survey may be undertaken by conventional or advanced survey methods.

- a) Construction survey control beacon survey
 - i) The Client is obliged to and must ensure that Permanent Survey Control beacons are timeously established such that the construction works may be efficiently set out. The spacing of such control will not exceed 300m. This control can then be used to establish secondary and tertiary control so as to facilitate the efficient and practical setting out of the works.
 - ii) The Surveyor must therefore ensure that such control is established in accordance with the Client's requirements and must be in accordance with the specifications for the establishment of Permanent Survey Control as described in Chapter 5 "THE ESTABLISHMENT OF PERMANENT AND OTHER SURVEY CONTROL POINTS".
 - iii) The Permanent Survey Control beacons must be established on the same Survey System as that of the original survey for the design. In the event that there are other control beacons on site then the Supervisory Surveyor must first verify that these beacons are adequate and compliant before handing these over to the Contractor and the Contractor's Surveyor.
 - iv) Whilst the Supervisory Surveyor may undertake the survey of and establishment of the Permanent Survey Control beacons for the Construction Project, the planning thereof and the coordination of such survey shall be the responsibility of the Client. The RE will issue the final coordinate list and levels of such control to the Contractor prior to the commencement of any construction works. All surveys undertaken during the duration of the Construction Project must be based on this control.
 - v) It is often the case that adjacent construction projects are let simultaneously and accordingly the above named control must be carefully linked to the control of the adjacent contract. Should there be any discrepancies, these must be referred to the RE and the Client for further specific instructions.

b) Protection of beacons

- i) Where a Permanent Survey Control beacon is damaged during the construction phase then this must be replaced by the contractor at his cost, unless the RE has given written permission to the Contractor to remove/destroy such beacon. The Supervisory Surveyor must then confirm the new values of such a replaced beacon.
- ii) Where existing Cadastral beacons may be destroyed as a result of the construction works then these must first be referenced by a Professional Land Surveyor before they are removed/destroyed. This procedure will in no way whatsoever exempt the contractor from the requirements of the Standard Specifications and the Land Survey Act.

c) The ground line survey (reference plane)

The 'ground line' must be surveyed and the DTM created will serve as the reference datum for the determination of all earthwork quantities. The survey may be undertaken at regular cross section or by means of a random Digital Terrain Model (DTM) sufficiently accurate so as to create a true representation of the 'ground line' terrain. Such ground line surveys must be undertaken in all areas affected by the construction works and/or as dictated by the bill of quantities such as Quarries, Borrowpits, spoil areas, road and Bridgework areas etc.

d) The preparation of a design datum model

This entails the merging of the design DTM with the origin of ground line DTM and which shall then serve as the 3D survey model against which all construction related surveys and earthwork quantities are to correlate. All surveys then carried out to determine whether the construction of the works is within specified tolerances and all surveys carried out to determine/verify interim or final quantities (where a material layer to be measured will be covered over) must be entered into this model and is then utilised to determine such interim quantities (final as per the above). In addition this design datum model must be utilised for the check surveys on the Contractor's setting out and to determine as to whether the location of all structures, road works and allied works are in the correct position where related to the actual design.

e) Layer works and the checking thereof

Levels taken on layer works must be undertaken using conventional spirit levelled techniques. Levels are taken on the predetermined cross-sections and on points on each cross-section such that, when compared to the actual design on an absolute level, difference may be deduced.

These differences are presented to the RE or his nominee who will determine as to whether the specific layer passes or fails from a level quality/tolerance perspective. Accordingly, GPS type equipment may not be used for this survey.

DTM methodology may be employed under certain conditions. These are generally where a large project is underway and such larger works check are frequently required and where the tolerances are such that the interpolated cross-sections derived from the DTM meet the accuracy requirements.

f) Spirit-level Techniques

Where the determination of levels is achieved using standard spirit levelling techniques, then 'closed level runs' must be carried out i.e. circular runs where they 'close' back on the same start point are not permitted.

Levels to determine whether the works has been constructed to within the specified tolerances must be taken at predetermined positions which are derived from the design.

g) Digital Terrain Model (DTM) Technique

- i) Where the DTM is created using tachometric measurements, then the surveyed positions may be taken in a regular grid fashion across the area concerned or at predetermined cross-sections at regular intervals. In the latter case it is important that the design levels are then pre-calculated at those same positions so that a direct comparison may be made. DTM observations must be restricted to a sight distance of 100m.
- ii) DTM measurements may be undertaken with GPS instrumentation provided that such DTM is utilised only for the determination of progress/interim quantities and provided further that the local geoidal model determined from spirit levelling is utilised to correlate the GPS heights.

h) Measurements and submission thereof

- i) Where quality control measurements are taken then such datasets must be submitted in a format where the adherence or non-adherence to specified tolerances is clearly recorded and where the non-adherence to respective tolerances is specifically highlighted. Such datasets must be 'signed off' by the Supervisory Surveyor prior to this being submitted to the RE.
- ii) It is imperative and indeed the responsibility of the Supervisory Surveyor to ensure that all datasets relating to quality control and the verification of quantities are properly filed (hard copy and in recognised digital formats). Suitable backups ('father and son') must be made monthly and stored off-site.
- iii) All phases of a construction project must be checked. Where 100% of the works cannot be checked as a result of circumstances or as directed by the RE, then a checking regime must be predetermined which is based on acceptable statistical methodologies and must be approved by the RE.

i) Staking of Road Reserve fence positions

The bend points of the Road Reserve fence which is to be erected by the contractor must be staked at the official Road Reserve coordinates. These co-ordinates are either Cadastral boundary positions, acquisition boundary positions and/or declaration positions.

It is the responsibility of the Supervisory Surveyor to check the setting out of these positions and to ensure that the fence is erected in the correct position. A comparison between the official boundary co-ordinates and the fence position as constructed must be submitted to the RE and Client and marked as As-Built data.

j) As-Built data

The As-Built survey is the responsibility of the Supervisory Surveyor. This process entails the survey of all variations to the original design and the noting of such variations on the hard-copies of the design which are generally held on site. Refer to Paragraph 10.4.9 "Staking of Road Reserve fence positions" for Road Reserve As-Built data.

10.1.5 Standards of accuracy

The accuracy standards for all such surveys shall be as specified in Chapter 3 "SURVEY REGULATIONS AND STANDARDS OF ACCURACY" as well as the Standard Specifications for Road and Bridge Works and the Project Specifications.

10.1.6 Records

- a) All relevant survey records compiled during the construction period shall be filed in an orderly manner so as to ensure that the information on all phases of the project may be readily extracted when and if required by the RE and/or Client.
- b) All such survey records must be regularly backed up (Dual Backup – backup of the backup system) and safely stored off-site.
- c) The final comparisons between the official Road Reserve coordinates and the comparative position of the erected fence must be submitted to the RE on completion of the project. The RE must sign off these records to indicate his acceptance of the results and so certifying that the fence has been erected in the correct position with reference to the published Road Reserve co-ordinates.

10.2 Construction Survey

The purposed of this chapter is:

- a) To give guidance to the Construction Surveyor and with specific regards to his responsibilities on a construction project.
- b) To give guidance to both the construction and supervisory engineering teams with regards to their responsibilities towards the Construction Surveyor and design information that will be supplied.

Note: All surveys carried out in terms of the construction project shall *inter alia* conform to the principals, requirements and standards as set out else in this document

Also refer to paragraph 10.1 for the responsibilities of the Supervisory Surveyor on construction sites.

10.2.1 Setting out principals

It is important that the Construction Surveyor strictly adheres to all principals and requirements as stipulated in this chapter and also in the rest of this document when undertaking the 'setting out' work of a road for construction purposes.

10.2.2 Survey control

- a) The Construction Surveyor must undertake all setting out work from the control points as per the original survey undertaken for design purposes unless otherwise instructed in writing by the Client.
- b) The Construction Surveyor must establish additional survey control points having regard to requirements for Permanent Survey Control as stipulated in Chapter 5 "THE ESTABLISHMENT OF PERMANENT AND OTHER CONTROL POINTS".
- c) The Construction Surveyor may be instructed by the Client to verify the quality and accuracy of the existing Permanent Survey Control as per paragraph 5.6 "Verification of existing Permanent Survey Control". A revised official co-ordinate list may then be issued by the Client in writing which is based on the findings of the verification survey.

10.2.3 Official co-ordinate list

- a) A copy of the original co-ordinate list and survey report, signed by the registered Surveyor who established the control for the design survey must be submitted to the Construction Surveyor by the Client.
- b) No setting out work may be commenced with until the Construction Surveyor has received the original or official co-ordinate list, unless otherwise specified by the Client in writing.
- c) Existing/official survey beacons must be suitably protected by the Construction Surveyor against damage during construction work.

Damaged/destroyed existing/official beacons shall be replaced by the Construction Surveyor. The final co-ordinate list, which shall be 'signed off' by a Registered Surveyor, must be submitted, within a reasonable time frame, to the Client after all construction activities have been completed

10.2.4 Instruments used for setting out

The Construction Surveyor must use appropriate instruments that are required for the setting out of the works so as to maintain the construction accuracy required. GPS equipment may not be used for setting out final levels for layer works or structures but may be used to set out the position of the profiles.

Where a Total Station is used to set out final levels then the range of all observations and readings must be limited and as defined by the instrument specification and a maximum distance from such Total Station may not exceed 100m.

10.2.5 Setting out data

The following information shall be submitted to the Construction Surveyor before any setting out work may be commenced with:

- a) A digital text spread sheet containing the complete horizontal and vertical alignment information. This information shall include, but not be limited to, all curve and super elevation information, the start and end positions and all cross-fall percentages of all super elevation elements.
- b) Profile templates for the road cross section (Template)
 - i) Road profile Template with all the relevant dimensions shall be supplied in digital or hard copy formats.
 - ii) The Templates shall be referenced to their relevant stake values (changes).
 - iii) The Templates must clearly define all relevant information of the road profile and must include but not be limited to the following:
 - Stake offsets
 - Design offsets
 - Road profile
 - Shoulders
 - Kerbs
 - Verges
 - Drains
 - Batters
 - iv) The stake values defining the transition from one Template to another must be supplied by the Client. This may be in the form of a drawing and/or digital spread sheet.

- c) Co-ordinates, in a digital text document, of all culvert inlet and outlet positions together with invert levels and pipe/box sizes.
- d) A plan view digital drawing in DWG or DGN format geo-referenced to suit grids of the project and which can then be used to verify co-ordinates of construction elements shown on any construction drawing.
- e) Any relevant information as requested by the Construction Surveyor, in writing to the Resident Engineer (RE), provided that such request is reasonable and will positively contribute to the quality and accuracy of all setting out work for the project and where the RE will be the sole judge of whether such request is reasonable.

10.2.6 Verification of design data prior to the setting out of the works

It is the responsibility of the Construction Surveyor to verify the completeness and functionality of the above information for setting out purposes in relation to the design drawings before commencing with the setting out of the works.

Discrepancies and/or incomplete information must be reported to the Client in writing who must then re-issue the outstanding data and/or corrected design information before the setting out work may be commenced with.

10.2.7 Quality Assurance and Verification of setting out of the construction work

- a) The Construction Surveyor must submit all relevant survey checks as required by the Client for quality control of the construction work. The Client may elect to undertake his own checks of the works to verify the Construction Surveyor's checks. (Refer to paragraph 10.1 for guidelines on supervision surveys for construction of roads and bridges).
- b) Such quality assurance checks shall include but not be limited to the following:
 - i) All setting out records (batter boards, profiles, etc.).
 - ii) Layer work checks with statistic analysis as per the Standard Specifications applicable to the construction project.
 - iii) Setting out of structures and piling.
 - iv) Pre and post concrete shutter checks.
 - v) Any other quality assurance information as required by the Client.

10.2.8 Quantities

- a) The Construction Surveyor must maintain and file all records of quantities calculated. The surveyed surfaces used to calculate the quantities and the quantity calculations may be requested by the Client for verification purposes.
- b) All relevant surfaces must be surveyed for the calculation of quantities and as defined in the Standard Specifications applicable to the construction project.

c) The following serves as a guide in the context of payment items for earthworks and which are ordinarily stipulated in the Standard Specifications for construction work. It is to be noted that the Client is within his rights to demand that all quantities measured may require verification and 'signing off' by a Registered Surveyor:

i) Original Ground Lines (OGLS)

Where minimal 'grubbing' is required in bush or plantation areas prior to the 'stripping' of topsoil, the Construction Surveyor must then survey the original ground lines and which will then be the 'base' information for the works.

The payment item is normally referred to as "Clear and Grub".

ii) After Topsoil Strip (ATS)

The thickness of topsoil to be stripped must be supplied by the Client. Topsoil is normally moved from the road prism to behind the batter boards for future use on the cut or fill batters, but is subject to the Client's instruction.

The survey data of the ground surface after the topsoil has been 'stripped' will form the base from which all other operations will be measured. This surface is normally known to be the "Payline Surface".

The difference between original ground line and the payline will determine the total quantity of stockpiled topsoil.

This payment item is normally referred to as "Cut to spoil".

iii) Treatment in Place (TIP)

After the pay item "Treatment in Place" is completed on the fill areas, the resulting surface becomes the payline from which the fills and undercuts are measured.

The Surveyor needs to survey this surface prior to any fill or undercut operations are commenced with.

This payment item is normally referred to as "Roadbed Preparation".

iv) Undercuts (UC)

Undercuts are normally done after a written or verbal instruction from the Resident Engineer has been received. The undercut depth in fill areas is quoted as the depth below the after topsoil strip level (Payline) or below finished road level.

The undercut depth in cuttings is quoted as the depth below formation (bottom of lowest layer) or below the finished road level.

After inspection by the RE, and where possible treatment in place is done, the Surveyor must survey this surface as determined by the RE.

This payment item is normally referred to as "Remove Unsuitables/Undercut".

v) Backfill of Undercuts

If a specialised type of material is used for backfill, such as rock fill, rock toes, 8 pass material, graded sand or stone the compacted surface must be surveyed.

This payment item is normally referred to as "Cut to fill" and is measured in the fill and not from the source (cut).

vi) In Cuts

In cuts the after topsoil strip surface would become the first surface.

The material in the cut can be classified in various surface groups:

- Fill material

This may be placed directly into fills where it is paid for in the fill after the surface has been surveyed for final quantities.

This payment item is normally referred to as "Cut to fill".

- Cut to spoil

Material not suitable for fill.

Subject to instruction from the RE, this top surface must be surveyed before it is moved from the cut.

Likewise as soon as good material is encountered, the Construction Surveyor must survey this surface, thereby establishing the quantity of "Cut to spoil".

This payment item is normally referred to as "Cut to spoil".

- Intermediate or rock material or boulders

When harder material is encountered in the cut, this surface should be classified by the RE. These surfaces must be surveyed. Further surveys may be required so as to accurately determine this quantity.

- Material to be place into a stockpile

As specified by the RE, there are two scenarios requiring survey:

The top surface area before any material is moved from the cut, must be surveyed in the cut. The bottom surface area after the stockpiling is complete, must be surveyed in the cut to determine the new reference plane for future measurements.

The cleaned, grubbed surface of the stockpile site is to be surveyed before any material is stockpiled. The stockpile can be surveyed afterward to determine the volume stockpiled. Bulking factors agreed with the RE should be applied to determine the “tight volume” alternately it can be measured at the source (cut).

This payment item is normally referred to as “Stockpiling material”.

- Roadbed preparation or treatment in place will be done, if required, when the cut reaches the formation level. No survey of this surface is required. This is quantified by reference to the design.

This payment item is normally referred to as “Roadbed preparation”.

vii) In Fills

- Benching

The width of benches in the roadbed is to be determined by the Engineer where slopes of greater than 1:10 are found. The method for claiming the bench quantities must be agreed with the RE (paid as “cut to fill” or “cut to spoil”) and determined by surveyed measurements. A better option would however be to determine the quantities by reference to the design.

The material to construct fills may also be classified into different surface groups:

- 90% fill

This fill material is soft material from a borrowpit, quarry or cuts.

Any change of surface (type of fill), must be surveyed for quantity purposes.

This payment item is normally referred to as “Cut to fill”.

- 8 Pass material

This is rock with a layer thickness of not more than 500mm.

The Surveyor needs to survey the bottom surface before 8 pass material is placed and then again after the surface is completed.

- Rock fill or rock toe

Rock layer thickness of greater than 500mm.

Any change of surface (type of fill), must be surveyed.

viii) Borrow areas

The borrow area must be grubbed where the original ground line remains undisturbed before the Construction Surveyor surveys the original ground line surface.

The borrow area must be surveyed after the topsoil and overburden material has been removed and importantly prior to any useable material is removed from the borrow area.

This payment item is normally referred to as “overburden” or “cut to stockpile” as determined by the RE.

ix) Non pay item operations

Survey records shall be maintained/filed where any earthwork operation carried out is not determined by a payment item or where an operation has to be repeated for any reason.

Where work is to be claimed for under “Dayworks”, the RE must be informed before the operation takes place. The quantities and hours that are claimed under “Dayworks” must be submitted to the Construction Quantity Surveyor immediately so that the quantities and hours may be ‘signed off’ by the RE.

10.2.9 As built information

- a) On instruction by the Client, the Construction Surveyor must submit all relevant as built data of the constructed works. The Client may elect to undertake his own as built surveys of the works so as to satisfy himself that the data submitted by the Construction Surveyor is within defined tolerances. All as built information shall be signed off by a registered Surveyor before submission.
- b) Such as built checks by the Client may include but not be limited to the following:
 - i) All underground services laid
 - ii) All above ground services constructed
 - iii) Pipe culverts, box culverts and head walls
 - All inverts
 - Structure type
 - Pipe diameter
 - All relevant co-ordinates and levels shown on a construction drawing

- vi) Drains and other drainage structures
- vii) Pile positions and cut off levels
- viii) Final road and earthworks profile
- ix) Road reserve boundary fence
- x) Any other information requested by the Client

10.2.10 Data to be supplied

The Construction Surveyor shall submit all relevant survey data to the Client. Unless otherwise instructed, all survey and other data sets as specified in this document, shall be submitted to the Client.