Topic 4 Section 8

Measurement: Testing/Acceptance

Contents

Units of Measurement 2

Measurement for Payment Purposes 8

Calculation of Earthworks Quantities 13

Section 9 – Assessment Activities 20

Units of Measurement

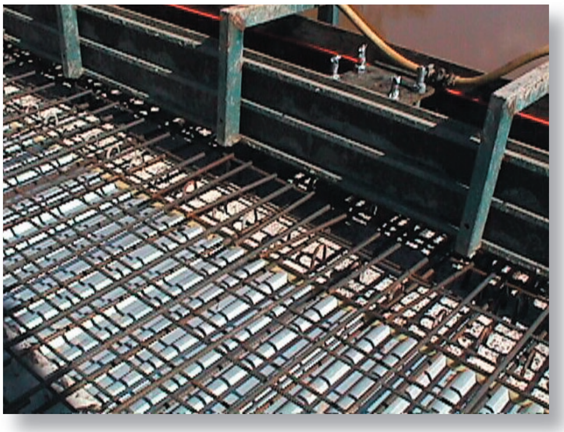
Regardless of whether measurements are made for the purpose of acceptance (i.e. ensuring that the work constructed conforms to the drawings and specification) or for payment, the units of measurement are the same.

Measurements may be linear, square, or cubic. Where work is measured by counting, the measurements are identified as a number. Where they are measured as units, each is known as an item.

Categories of Measurement

The Australian Standard AS 1181–1982 (Method of Measurement of Civil Engineering Works and Associated Building Works) describes the units and the methods of measurement used in the construction industry. The standard includes 21 categories of work, as follows:

- Site investigations
- Site clearance and demolition
- Excavation and filling
- Tunnels and shafts
- Dredging
- Piling and caissons
- Roads and paving
- Railway trackwork
- Concrete
- Brickwork and blockwork
- Structural steel and metalwork
- Carpentry, joinery and ironmongery
- Roofing, roof plumbing and wall cladding
- Sheet-metal work and sanitary plumbing and piped services
- Water Mains, sewerage and drainage
- Electrical conduits
- Engineering services
- Plastering
- Paving, tiling and terrazzo works
- Glazing
- Painting.



The units of measurement detailed in AS 1181 will be used throughout this discussion.

Measurement for Acceptance

Measurement for acceptance is part of the testing procedure, and is carried out at the request of the contractor on completion of defined sections of work. Measurement for acceptance of work may be based on actual construction dimensions, or upon the designed dimensions shown on the drawings and the tolerances that are applied to these dimensions, as set out in the specifications.

Some contract documents may specify the pay lines for work. This approach overcomes the possibility of a dispute arising over interpretations of dimensions in relation to quantities. (This will be discussed later).

Measurements for acceptance can take place at various stages of construction. For example, there is nothing to be gained by checking measurements for acceptance of concrete work after it has been poured and set. If there were any dimensional errors at this stage, they would be costly to rectify. It is therefore to the contractor's benefit to have the formwork and steel checked before the concrete is poured.

The following discussion identifies the stages at which various types of civil construction work should be checked.

Concrete Work

During concreting work, check:

- the setting out
- the reinforcement, prior to final assembly of the formwork
- the location of any fittings that are to be set in the concrete
- the formwork, before placement of the concrete. (This would also include a checking that it is structurally sound and mortar tight).
- that the form work is in the correct position in relation to the total structure.

Before the pour and during the early stages of construction, ensure that the false work supporting the formwork is adequately constructed, in accordance with the approved design.

PipeWork and Drainage

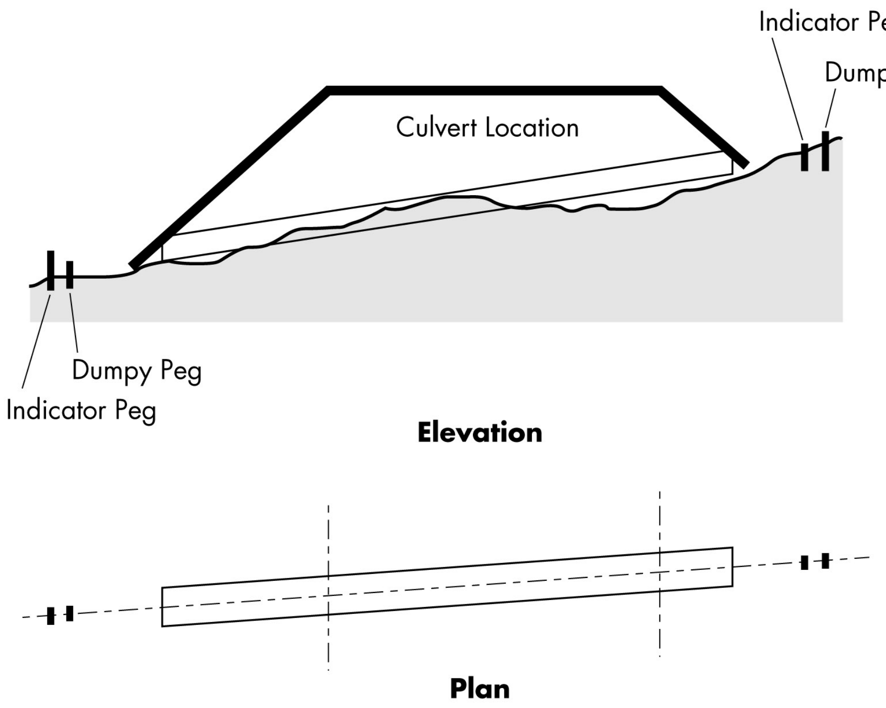
It will always be necessary to check the line and grade of pipelines and drainage works, to ensure that they are dimensionally correct. It is better to carry out the dimensional and other checks as soon as possible after laying or construction of the drainage work. In the majority of cases, the work will need to be buried before next phase of the job starts.

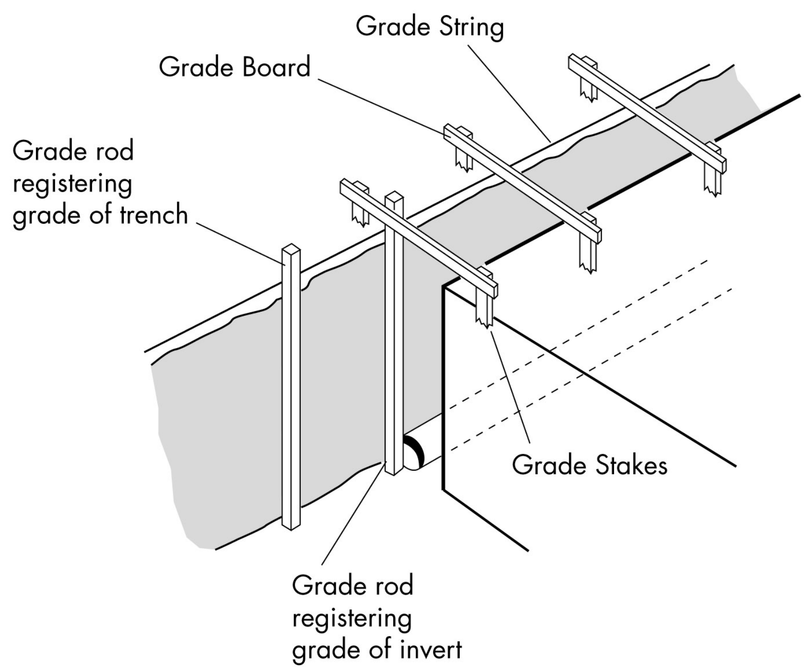
The following aspects of the work should be checked:

- location and setting out of the pipeline before excavation of the trench or pit begins
- depth and alignment after excavation
- diameter, class and condition of the pipe being laid
- bedding material including thickness of layer, and that the pipes are being correctly laid to grade during construction

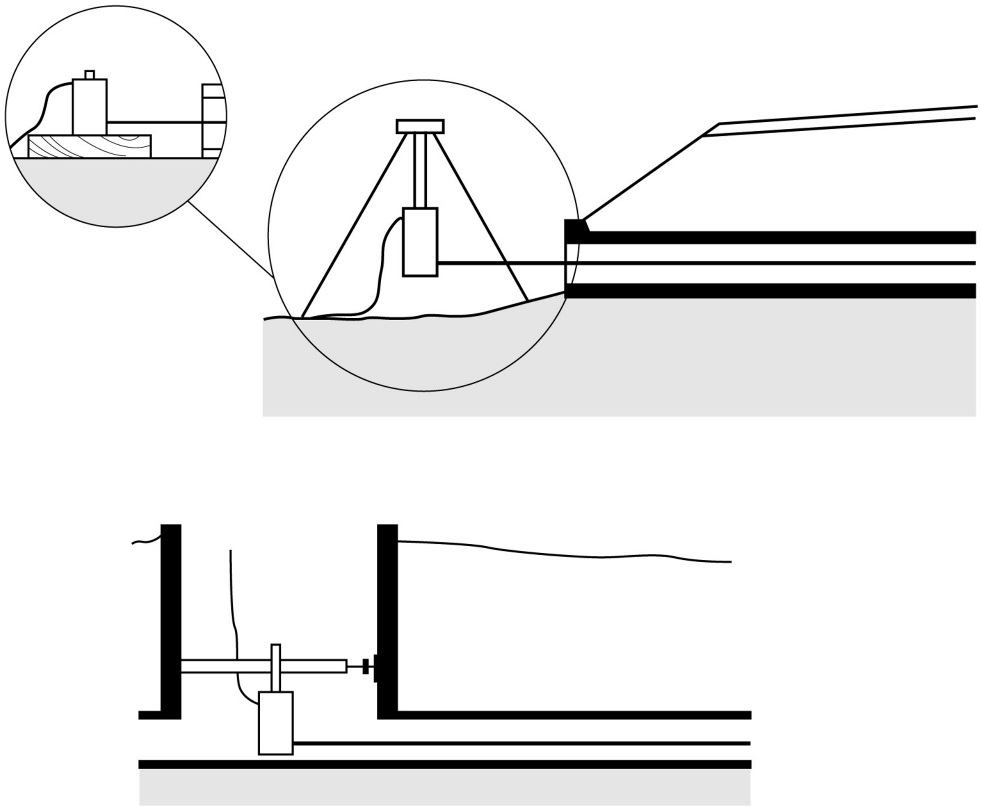
- backfill over the pipes, which should be placed to the correct thickness prior to compaction.
- location and setting out of manholes and/or chambers
- level of inverts, covers and depth of manholes or chambers
- location of valves and other equipment used in the construction of pipelines.

The checking of the grade can be undertaken either manually or by use of a laser beam, as shown below.





Checking Grade of Pipes Laid Using Stringline and Grade Boards



Checking Grade of Pipes Laid Using Laser

These checks are usually carried out in co-operation with the contractor, who will be using one of these methods to control the pipe-laying operation.

Buildings

During building work, check:

- that the site has been cleared and levelled to the correct dimensions
- the setting out of the work
- the position and location of the foundation structures at the formwork stage
- that the holding down bolts or starter bars for prefabricated structures are in the correct position relative to the whole structure
- the position of service ducts, drainage pipes and other equipment that will be cast into slabs, columns or beams
- the location of lift shafts, stairs and other structures that are to be constructed integrally with the main building structure
- that columns are vertical, and the level of beams and floors, as well as their length and cross section.

Roads

Check:

- the location and setting out, prior to the preparation of the formation and subgrade
- the formation levels after the preparation of the sub-grade and/or formation. (It will be necessary to retain these levels, as they become the basis for determination of earthwork quantities).
- the thickness of each layer of pavement constructed, and the grade and cross-falls
- the location and position of under-drains, drainage gullies and service ducts where these are to be constructed
- the grade and level of open surface drains and/or kerb and channel, including the cross section
- the position of lighting, traffic control systems and road signs including ducts, pits and islands.

Stages of Civil Construction Requiring Measurement

These examples demonstrate the measurements that need to be checked, along with other tests, for the acceptance of work undertaken and completed by the contractor. They are broad outlines and may not include all work undertaken under each of the headings.

Each job is different and inspectors must be fully aware and give consideration to each phase of construction in relation to the job on which they are employed.

However, as a general guide, civil engineering often includes six phases of construction:

- Site clearance
- Preparation of formation/foundations
- Underground work, ducts, pipes and services
- Construction of structures
  - Earthworks and piling
  - Concrete, steel and timber structures
  - Pavements and tracks
  - Jetties and wharves
  - Buildings, brick and masonry
- Surface drainage, river and sea entrainment works
- Finishing work.

Case Study— Measurement for Acceptance

The following example outlines a checking program set up to accept concrete-type structures.

Under the program, both the contractor and the resident engineer agreed on inspection procedures to ensure that, before concrete was placed, the:

- constituent materials of the concrete were of the required standard
- structural sections were of the correct dimensions, and
- correct amount of steel was placed and was correctly positioned.

The program was based on a pro-forma and check list, and operated as follows:

- The contractor submitted the check list to the resident engineer. At the time of submission, the supervisor signed the checklist to indicate that the works were correct and ready for an acceptance check.
- This enabled the resident engineer to program the surveying team and inspectors in advance, reducing delays in construction. It also ensured that the engineer's staff did not carry out unnecessary checks before the works were ready.
- It provided information (in advance) about the method of placing the concrete, and the resident engineer was able to discuss any anticipated problems with the contractor.
- Contractual friction was reduced, because it was understood by both parties that a pour would not take place until final approval had been given.

The pro-forma also served as an inspection record. A full historical record of the work undertaken was available, by combining the pro-forma with results of concrete sampling and other information related to the pour.

This example illustrates the need to effectively plan inspection and acceptance procedures, whether for large or small jobs.

Construction methods are the same whether the job is large or small, and a large job is simply a series of small jobs. Acceptance procedures can be designed so that they are adaptable to jobs of any size, while maintaining the required work standards.

On jobs where quality assurance programs have been introduced, whether for small or large jobs, there will be testing and conformance documents. The responsibility for their completion is the contractor's in the first instance, unless audit checks are undertaken. The inspector is responsible for audit checks, on behalf of the project engineer.

Measurement for Payment Purposes

During the progress of a contract, it is normal practice to pay the contractor for parts of the work that have been completed to the satisfaction of the resident engineer.

Effect of Clause 42 in AS 2124

Clause 42 in AS 2124, Certificates and Payments, covers payment claims, payment certificates and time for payment. Two points in clause 42.1 affect measurement for payment:

- The contractor is responsible for delivering claims for payment to the superintendent and for providing supporting evidence for the amount due.
- Payment is not regarded as evidence or admission of liability, or that the work has been executed satisfactorily, but is simply payment on account.

Method of Delivering a Claim

The first condition implies that the contractor may carry out his or her own 'measure up', and submit a claim for payment, even before reaching an agreement on quantities with the resident engineer.

Under these circumstances the inspector will carry out independent measurements personally or organise other staff (e.g. surveyors) to do so.

A joint measure provides a more positive approach to this situation. Any discrepancies are then resolved during the course of the measure, before the contractor submits a claim. There is reduced potential for disputation and remeasure if the contractor's and resident engineer's measurements are in agreement.

Effect of Payment

The second condition implies that any payment made during the contract is "on account" only. This means although the contractor has been paid for certain sections of work, it is not an admission that the work is acceptable.

Schedule of Rates

The schedule of rates included in the contract documents has three main functions:

- to assist in the selection of a contractor who will undertake the work
- to provide a summary of the labour and material quantities necessary to carry out the work
- to provide the unit rate at which a scheduled item will be paid.

The rate submitted by the contractor should include full compensation for all costs associated with the item, including:

- Direct costs (materials, plant, and labour and sub-contract costs)
- Indirect costs (supervision, administration and field expenses, and other site charges)
- Overhead costs (head office and offsite costs and charges)
- Contingency costs and profit (sum added as a percentage of the total of the direct, indirect and overhead costs, to cover unknown factors and profit).

After examining the site, and identifying tangible and intangible costs, the contractor prepares an estimate for each of the scheduled items.

Schedule of Quantities as the Basis of Measurement

The schedule of quantities forms the basis of measurement for payment purposes. This document includes details of the quantities of work and materials that will be necessary to carry out the work under the contract and subcontracts (if any). However, it does not repeat the descriptive matter contained in other contract documents.

In the absence of specific directions to the contrary, the rates and prices contained in the schedule are the full, inclusive rates and prices for the finished work described under each of the items. The rates for each item cover the following cost components:

- Labour
- Materials
- Temporary work
- Plant
- Overhead charges
- Profit.

The rate should also include the anticipated costs arising out of the general conditions of contract associated with that item, including:

- Liabilities
- Obligations
- Risks
- Compliance with statutory requirements.

The items are grouped into sections under headings, according to the location of the individual parts of the works in the general scheme, or according to the nature of the works to be performed.

The items are then arranged in sub-sections according to the various classes of work. These subsections normally follow one another in accordance with Sections 3 to 23 (inclusive) of Australian Standard AS 1181–1982, as discussed previously under Units of Measurement.

In some documents, each of these sub-sections is totalled separately for payment; in other cases, distinct major sections at the work are totalled separately.

The description of each item is brief. The exact nature of the work is described in the specification or drawings.

Measurement and Payment Clauses

In the contract documents prepared for most schedule of rates contracts, a preamble to the schedule of rates sets out the methods of measurement and payment for various items. This must be read in conjunction with other documents forming the contract. If the contract does not contain such a section, then it must refer to each individual specification.

All quantities are measured net to the dimensions given, with no allowance for over-break, cutting, wastage and the like. The pay line is therefore the line shown on the drawing.

Examples of the kinds of calculations carried out as a result of a measurement and payment clause are given in Topic 3 of this training series.

Example — Preamble to Schedule of Rates (Excavation)

Excavation Generally

All excavation quantities shall be measured in place in the work.

For the purposes of payment for excavation in rock, the following definition of rock will be applied. Rock is that material which, in order to excavate it, requires, in the superintendent's opinion, the use of special rock-removal equipment.

The scheduled rates for excavation shall apply for all materials, either naturally occurring or man made (unless separately scheduled), and shall be deemed to include full compensation for:

a. Keeping the excavation free of water at all times.
b. All necessary shoring (separate payment will be made for the value of materials which the superintendent orders left in place during backfilling).
c. Loading, depositing and spreading, without compaction, of all surplus excavated material, including cartage up to 1 km. Separate payment will be made for cartage beyond 1 km. All cartage distances shall be measured radially, and volume shall be measured as solid volume.
d. All necessary grading, levelling, trimming and compacting reduced surfaces and bottoms and walls of holes, trenches, etc. to receive concrete, bedding material or pavement material, etc.
e. Grubbing out of all stumps, roots, etc. and removal from site.
f. Stripping and stockpiling of re-useable topsoil when directed.
g. Repairing any slips or damage by flood or other causes.
h. Liaising with public utility authorities during excavation near public utility services and costs incurred in complying with utility authority requirements regarding method of working.

Excavation for Drainage Work

The quantity for excavation in trenches shall be measured as the volume of a trench to the dimensions shown on drawing WMS 51, up to existing or finished surface level or box level, whichever is the lower.

The quantity for excavation to manholes, chambers, culverts and gullies shall be measured as the volume of the structure (to the dimensions shown on the drawings) below existing or finished surface level or box level, whichever is the lower.

The scheduled rate for excavation to trenches, manholes, chambers, gullies and culverts shall be an inclusive rate as defined above and shall additionally include the costs of:

a. Clearing along the line of the drain, removal of obstacles, and cartage to and dumping at a legal tip (or approved site).
b. Cutting of asphaltic concrete or bitumen surfacing.
c. Backfilling to commencing surface with excavated or replacement material and compacting this material as specified.
d. Cleaning up and reinstatement along the line of the drain including reinstatement of constructed pavements.

The quantity for crushed rock to trenches shall be measured by multiplying the width of trench shown on Drawing WMS 51 by 300 mm thickness. The rate shall include the costs of placing and compacting the crushed rock as specified.

The quantity for asphaltic concrete to trenches shall be measured by multiplying the width of trench shown on Drawing WMS 51 by 50 mm thickness. The rate shall include the costs of supply, transport from plant, placing and compacting the asphaltic concrete as specified.

Removal and cartage for one kilometre of unsuitable backfill material applies to material which has been replaced by fill material supplied by the principal where suitable excavated backfill material is not available from the adjacent 50 metres of the trench. The quantity shall be measured as the solid volume of the material in place, calculated to the width of trench shown on WMS 51 with no allowance for over-break or battering. (Note: This item is intended as compensation for loading and carting of material additional to that which would normally be carted to spoil. Compensation for compaction of the replacement material is already included in the normal excavation item(s).)

Laying Pipes

The scheduled rate for laying of drainage pipes shall include full compensation for the costs of supply and placing of bedding, laying and jointing the pipes, irrespective of the lengths and types of pipes and types of joints actually supplied. It shall also include trimming of pipes to length to suit structures.

The pipe size scheduled is the nominal internal diameter.

Manholes

The scheduled rate for manholes complete shall include full compensation for all costs associated with the supply, placing and compaction etc. of concrete, supply and fixing etc. of reinforcing steel, the fixing of covers and frames and step irons, and the provisions of inlet and outlet openings and benching of the floor.

The diameters scheduled are the internal diameters. The depths scheduled are from the lowest invert to the top of lid.

SCHEDULE OF RATES
PART B - DRAINAGE

Item No.		Description of Work	Unit	Quantity	Rate	Amount $
	B1.00	**EXCAVATION**				
	B1.01	Excavation to:				
1		(a) trenches, manholes, chambers and gullies etc. (NB including backfilling) (1) in other than rock	m3	771		
2		(b) open cut (1)in other than rock	m3	45		
3	B1.02	Excavation and replacement of unsuitable foundation material (replacement material supplied) (Provisional Quantity)	m3	197		
4	B1.05	Removal and cartage for 1k m of unsuitable backfill material	m3km	236		
5	B1.06	Extra over excavation rates for cartage of spoil beyond 1km (Provisional Quantity)		4,052		
	B2.00	**LAYING PIPES**				
	B2.01	Laying and jointing of pipes (pipes supplied				
6		(a) 300mm dia.	m	54		
7		(b) 375mm dia.	m	26		
8		(c) 450mm dia.	m	37		
9		(d) 600 mm dia.	m	115		
10		(e) 675mm dia.	m	55		
11		(f) 750mm dia.	m	92		
12		(g) 825mm dia.	m	130		
	B3.00	**MANHOLE COMPLETE** (Covers, frames, roofs and step irons supplied)				
13	B3.01	(a) 1050mm dia (1) 0 – 2.0m deep	No.	3		
14		(b) 1350mm dia in existing 1050mm dia drain line (1) 0 – 2.0m deep	No.	2		
Carried forward$						

Calculation of Earthworks Quantities

Earthwork quantities must be measured in most civil engineering contracts.

Condition of Soil

The values set out in a schedule of quantities normally assume that the material is in one of three conditions:

- bank material is measured in its natural state
- compacted volume is used for embankments, dams and similar structures built from soils
- loose volume is used for the supply or transport of materials.

In the calculation of earthworks quantities, we need to consider two of the properties of soils:

- bulking
- compactability.

Bulking

Bulking (also known as swell) is the increase in the volume of the material when it is removed from its natural state. It is expressed as a percentage of the bank volume.

For example, if a material has a bulking factor of 25%, then one cubic metre of the material in the bank state will occupy 1.25m^3 in the loosened state.

Compactibility

Compactibility is the reduced volume of the material when it has been placed and compacted to a defined density. It is expressed as a percentage of the bank volume.

For example, if the compaction factor is 20%, then one cubic metre of the material in bank state will occupy 0.8m^3 in the compacted state.

Effect of Soil Condition on Quantities

It is essential to check the schedule when measuring volume. For example,

- Excavation will be bank volume.
- Pavement construction will be compacted volume.

If the excavation material is to be carted away and is scheduled as m^3.km, then it will be necessary to check whether it is bank or loose volume. Normally it is scheduled as bank, and the contractor makes the adjustment in the calculation of the unit rate for the material.

When excavations are for a pipe, the volume to be excavated from a trench will be bank measure.

Determining Earthworks Volumes— The Need for Caution

It is very easy to miscalculate quantities of earthworks, rock excavation or back fill.

Care must be exercised and the volumes measured in strict accordance with the contract documents in all cases where earthworks are undertaken at a specific unit rate.

Method of Measuring Volume

Obviously, a contractor who is excavating material from a borrow pit for use as embankment fill would rather be paid on loose volume than compacted volume.

It is therefore essential to establish the form of measurement and payment before the contractor commences the earthworks. The inspector should not yield to a request to count truck loads or scraper loads as the basis for measurement, because these are loose volumes.

A contractor may suggest the use of payment by weight. This may sound reasonable, but is an unreliable method unless the volume of water in the material can be controlled. If water must be added, it should be added at the point of deposit. Alternatively, the contractor may lose money if the unit weight is based upon the optimum moisture content, and the material is hauled at a moisture content less than optimum.

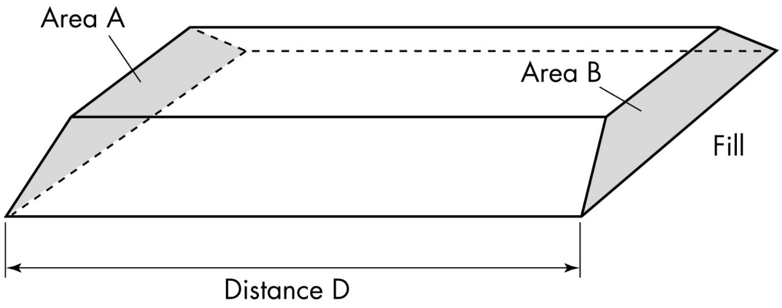
The most common way of combating this problem is to pay according to pay lines calculated from the drawings. The contractor must then determine all these factors when calculating a tender unit rate.

Calculations Involving Both Earthworks and Reinforced Concrete Quantities

An example of such a calculation is presented in Topic 3 in this training series.

Calculating Earthworks Volumes Using Average End Area Method

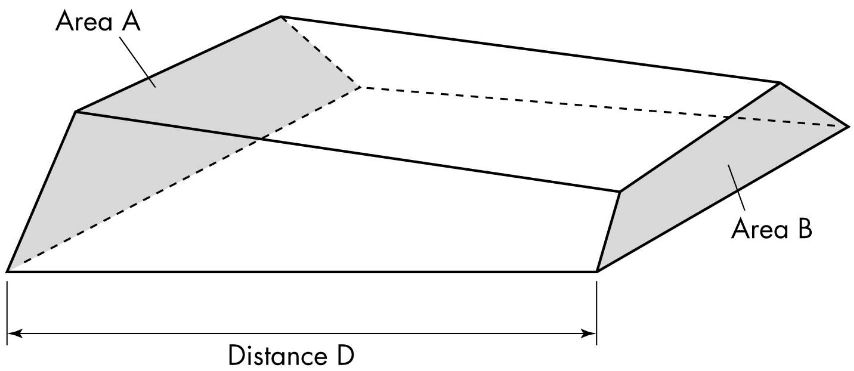
In calculating the volume of earthworks, we first calculate the area of a cross-section and then multiply by the distance between two cross-sections (i.e. the length).



In the sketches above, if the end areas A and B of the cut (or fill) are equal, the correct volume would be obtained by multiplying either area by the distance D.

In practice however, the end areas are rarely equal, and so the Average End Area Method of calculating the volumes of cuts and fill is used.

In the following sketch showing a length of fill, area A and area B represent the areas of the two adjacent cross-sections in square metres, and D is the distance in metres between the two cross-sections.



The approximate volume of the length of fill (in cubic metres) is obtained by taking the average of areas A and B, and multiplying by the distance D, i.e.

$$\text{Volume} = \frac{\text{Area A} + \text{Area B}}{2} \text{ x Distance D}$$

This average end area method of calculating volumes may be used to determine the solid volume of cuts, fills and side cuts as follows:

- Calculate area A
- Calculate area B
- Add A and B then divide by 2 to find the average area
- Multiply the average area by the distance (D) between the cross-sections.

When using the average end area method for volume calculations, it is desirable to use at least every cross-section given in the job documents for the section of roadway under consideration. The omission of any intermediate sections over a length of road can lead to noticeable errors in the calculated volumes.

Examples of the calculations involved in using the Average End Area Method, for both single and multiple sections, are shown in Topic 3.

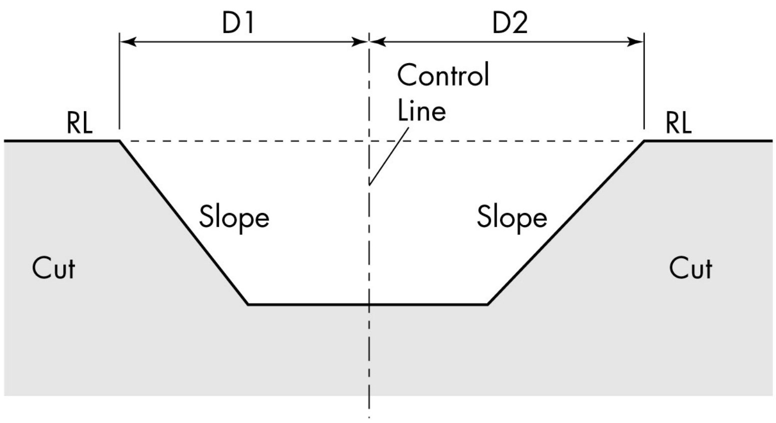
Cross-Sectional Areas of Cuts and Fills

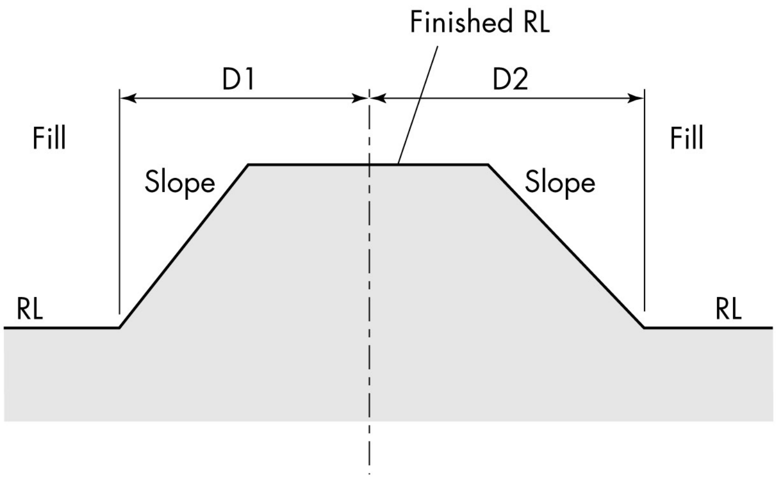
The most important component in the calculation of earthworks volumes is the cross-sectional area of a cut or fill.

It is normal practice to break down the cross-section into rectangles and triangles, to calculate the area of each separately, and then add them together to find the total area.

The following examples show how cross-sections are calculated in cuts, fills and side cuts.

The dimensions and levels normally given on cut and fill cross-sections are shown in the following drawing.





All other dimensions required to calculate the cross-section area are found by computation or scaling off the drawing, if it is drawn to scale.

Types of Cross-Section

The various types of cross-sections in cuts, fills and side cuts can be divided into:

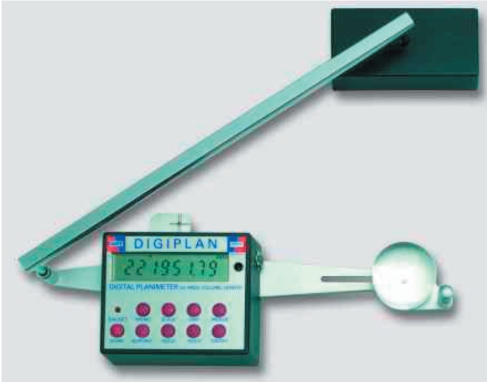
- Regular sections, where the ground is level and the control line is in the centre of the cross-section.
- Irregular sections:
  - Case 1— the ground is level and the control line is not in the centre of the cross-section
  - Case 2— the ground is not level and the control line is in the centre of the cross-section
  - Case 3— the ground is not level and the control line is not in the centre of the cross-section.
- Combination sections, where there is a double-carriageway embankment that can be a combination of regular and irregular cross-sections.

Each of these types may have a number of variations, according to whether the cut or fill is on sloping ground, and whether the control line is central or offset.

Examples of calculations used for regular, irregular and combination cross-sections are shown in Topic 3.

Using a Planimeter to Calculate Cross-sections

The planimeter is an instrument used to calculate areas; depending on the skill of the user, it can achieve a high degree of accuracy. It can be applied to figures of any shapes, whether regular or irregular.



Many site offices now have digital planimeters, which directly read the area enclosed within an outline. Reading the vernier scale and calculation of scale factor is not required. However, these procedures are described below, as some may still be using older-style planimeters where the calculation is performed manually.

Parts of the Planimeter

The Planimeter consists of:

- A pole block, which is fixed in position on the paper by a fine retaining needle.
- The pole arm, which is pivoted about the pole block at one end and supports the integrating unit at the other.
- The tracing arm, attached at one end to the integrating unit and carrying the tracing point at the other end.
- The measuring unit, consisting of a hardened steel integrating disc carried on cone pivots.

Principles and Operation

It can be readily shown that if the pole is placed near the area being measured and the tracing point is moved around the outline of the figure. The integrating disc will register an amount that is proportional to the area of the figure.

A planimeter can be used in two ways:

- with the pole outside the figure to be measured
- with the pole inside the figure to be measured.

The first method is the most convenient and should be used whenever possible.

Using the Planimeter with the Pole Outside the Figure

The procedure for using a planimeter with the pole outside the figure is:

- Place the plan on a flat, horizontal surface.
- Place the pole of the planimeter outside the area in such a position that the tracing point can reach any part of the outline.
- With the tracing point on a known point on the outline, read the vernier.
- Move the tracing point clockwise around the outline, back to the known point, and read the vernier again.

The difference between the two readings, multiplied by the scale factor, gives the area.

Repeat this procedure until you obtain three consistent values. Use the mean of the three values to give the area.

To calculate the scale factor:

- Place a figure of known area (e.g. 10 cm x 10 cm) on a flat, horizontal surface.
- Trace around the figure three times, and obtain an average vernier reading.

Each time you calculate another area, this amount on the vernier scale represents 100 cm^2.

Section 8 – Assessment Activities

For information on how these assessment activities may be used as part of the learning process, see the section on 'Assessment' in the 'Topic Descriptor' section at the front of this topic.

Theory Questions

The following questions allow you to assess your progress in understanding the material presented in Section 8. The questions may be of any of the following types:

- multiple choice (identify correct answer or answers)
- multiple choice (identify incorrect answer or answers)
- fill in the gaps in a sentence or statement
- identify a sentence or statement as TRUE or FALSE
- write a few sentences or a short paragraph.

Answers to the question are shown in the separate 'Answer' section.

Question 1

An estimate of costs might contain the following components:

1. Direct costs ☐
2. Indirect costs ☐
3. Overhead costs ☐
4. Contingency costs ☐

Match these headings with the descriptions below:

a. Costs related to head office and other off-site costs and charges.

b. Costs related to supervision, administration, field expenses and other site charges.

c. A sum that is normally added as a percentage of the total, indirect and overhead costs, to cover unknown factors.

d. Costs related to materials, plant, labour and sub-contract payments.

Question 2

The values set out in a schedule normally assume that the material is in one of three conditions (bank, compacted or loose). In which of these states would the material occupy the greatest volume and in which state would it occupy the least?

Greatest volume —

Least volume —

Question 3

If a material has a compaction factor of 20%, then one cubic metre of the material in the bank state will occupy how many cubic metres in the compacted state?

1.2 m^3 ☐

0.98 m^3 ☐

0.8 m^3 ☐

Question 4

If a material has a bulking factor of 20%, then one cubic metre of the material in the bank state will occupy how many cubic metres in the loosened state?

1.12 m^3 ☐

1.2 m^3 ☐

0.8 m^3 ☐

Question 5

List four aspects of concrete work that should be checked for acceptance.

Question 6

List four aspects of building that should be checked for acceptance.

Question 7

List the four phases of civil engineering construction.

Question 8

List the four costs that a contractor must consider when calculating rates.

Question 9

List four costs that must be given for each item listed on a schedule of quantities.