HELVETAS

SWISS ASSOCIATION FOR DEVELOPMENT AND COOPERATION

INTRODUCTION

TO

SURVEYING

NUGEGODA, 31 July 1991

1 THEORETICAL PART

1.1 INTRODUCTION

For most activities in connection with water supply and sanitation, in fact in any area of field engineering, it is necessary to draw a plan of the proposed structures and the existing land and features. To get all details of the existing terrain one has to carry out a topographical survey of the area concerned. The method of the survey, the accuracy, etc. depend on the structures to be built and the topography of the area. It is obvious that a suspension bridge requires a much more detailed survey than a latrine for example.

For our introduction to surveying we will concentrate on a few basic activities:

- measuring of horizontal distances
- measuring of vertical distances

The process of surveying can be divided into three phases:

- observation
- measuring
- presentation

Observation: A general view of the area to be surveyed. The method and the accuracy of the survey have to be decided and a hand sketch is to be drawn (not necessarily to scale).

Measuring: All necessary measurements are taken, including some additional readings which allow the surveyor to check his work. All readings have to be recorded in such a way, that it is possible even for another person to draw the necessary plans/drawings.

Presentation: The required plans/drawings are plotted. Generally, these are:

- situation plan (with or without contourlines
- longitudinal section (along an axis line)
- cross section

1.2 ENGINEERING SURVEY INSTRUMENTS

1.2.1 Used for Water Supply and Sanitation

In this chapter we will give a list of the most widely used survey instruments used for water supply and sanitation. For specific details of instruments and their operation, please refer to the instruction manuals concerned.

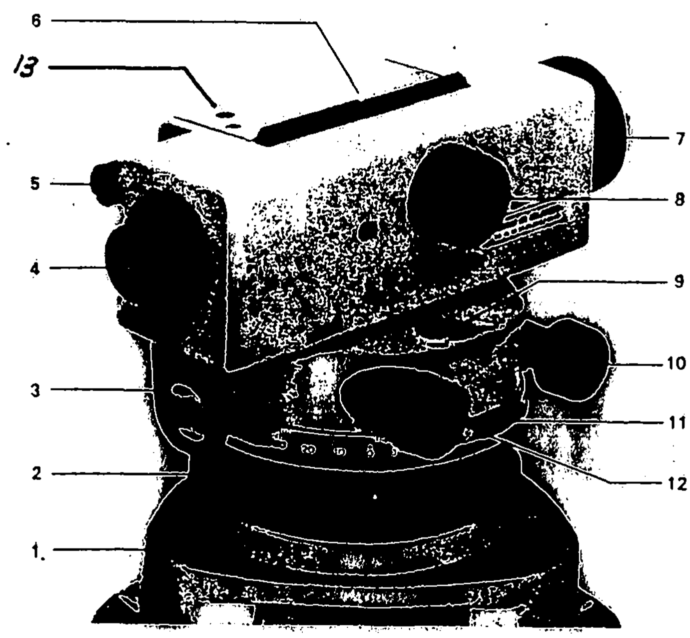
Instrument	*used to measure*	*Remarks*
Tape	Distances	Be careful to measure horizontally (if necessary) and don't allow the tape to sag
Bearing Compass	Horizontal angles	Compass has to be adjusted (declination). Steel objects may cause deviation
Pocket Altimeter	Altitudes, Vertical distances	Accuracy: ± 10 m Affected by atmospheric pressure fluctuations
Surveying Altimeter	Altitudes, Vertical distances	Accuracy: ± 2 m Affected by atmospheric pressure fluctuations
Clinometer	Vertical angles	Sometimes also called Abney Level Not very accurate but handy and convenient. Verify the scales (degree or grade).
Level	Vertical and horizontal distances	Very accurate, but time consuming

1.2.2 Other Instruments

Instrument	*used to measure*	*Remarks*
Plane Table	Horizontal angles and distances	No direct measurements are taken but plans/maps are prepared on the spot (fieldwork)
Theodolite	Distances and horizontal and vertical angles	Used to carry out a detailed topographical survey of an area
Electronic distance measuring instrument	Distances	Distances between two points can be measured very accurately

1.3 LEVELLING INSTRUMENT

1.3.1 WILD N 1, TILTING LEVEL



Legend:

1 Base plate
2 Foot screw
3 Magnifying lens
4 Telescope eyepiece
5 Tubular level eyepiece
6 Sight for aiming (with centre notch)
7 Telescope
8 Focussing knob
9 Circular bubble
10 Horizontal drive screw
11 Circle for horizontal angles
12 Tilting screw
13 Tubular level adjusting screw

1.3.2 Setting up of Instrument

1.3.2.1 Setting Up

Set up tripod. Tread tripod shoes firmly into ground. Tripod legs should be extended so that the telescope will be at about eye level and that the tripod plate is roughly horizontal.
Tighten clamps of telescopic legs.
Take out instrument from container box and place it on tripod. With one hand still holding the instrument, fix it with central fixing screw.
Central fixing screw should be tightened moderately.

1.3.2.2 Centring

This chapter is only applicable if you are going to read horizontal angles with the levelling instrument. In this case, the instrument has to be centred over a particular ground point.

Take plumb bob from tripod pouch. Push bayonet plug of plumb bob into fixing screw and secure it by turning to the right.
Set up tripod so that tripod plate is approximately horizontal and that plumb bob is within two centimetres (2 cm) of ground point.
Tread tripod shoes firmly into ground. If shoes do not sink in equally, re-establish horizontality of tripod plate by extending or retracting legs of tripod.
Slacken central fixing screw and move instrument over tripod plate until plumb bob is exactly centred over ground point. Re-tighten central fixing screw.

1.3.2.3 Levelling Up with Circular Bubble

Turn telescope (7) parallel to two foot screws (2). Bring circular bubble (9) into a position in middle between the two foot screws (2) by turning these two foot screws (2) in opposite directions. As a memory aid in levelling up, note, that the bubble follows the direction of the left thumb when turning the foot screws.
Centre circular bubble (9) by turning the third foot screw. A good preliminary levelling up with the circular bubble (9) makes it easier to centre the tubular level (5).

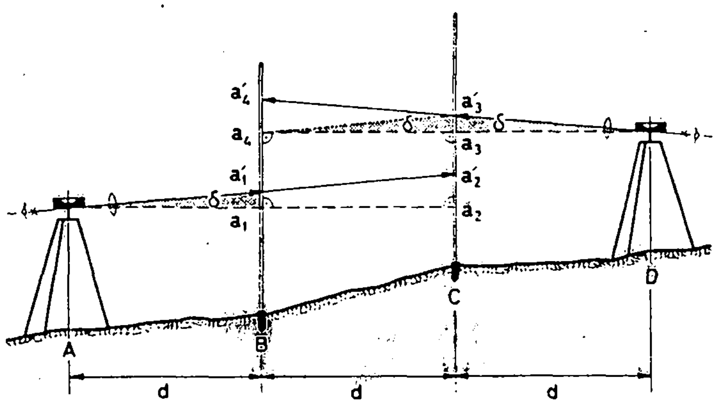
1.3.2.4 Focussing, Sighting and Reading

Point telescope (7) at a uniformly light surface, e.g. a wall or a piece of paper. Turn eyepiece (4) until cross hairs are sharp and black.
Turn instrument by hand until telescope (7) is pointed roughly at levelling staff. Turn focusing knob (8) until staff image appears sharp and free of parallax (i.e. there should be no apparent movement between horizontal cross hair and staff scale when the observer moves his eye slightly up and down).
Move vertical hair on to centre of staff by turning the horizontal drive screw (10).

On the left hand side of eyepiece of telescope (4) there is the eyepiece of tubular level (5). Tubular level (5) is adjusted with tilting screw (12). Both ends of bubbles have to coincide and form one single bubble. An arrow indicates direction in which tilting screw (12) has to be turned. Bubble of tubular level has to be centred before each reading.
The line of sight is now horizontal and the staff can be read where it is cut by the horizontal cross hair. Read the centimetres and estimate the millimetres.

1.3.3 Checking of the Line of Sight

From time to time, and particularly before each important job, the horizontality of the line of sight of the instrument has to be checked and if necessary adjusted.



In a flat area, a stretch of about 45 to 60 m is divided into three equal lengths (d). A peg should be driven in at points B and C.
Set up instrument at A. Hold staff on peg B. Take reading at a'_1. Hold staff on peg C and take reading a'_2.
Move instrument to D. Take reading a'_3 (staff on C) and a'_4 (staff on B).

If the line of sight were absolutely horizontal, the readings would be the correct readings a_1, a_2, a_3, a_4 and $a_4 - a_1 = a_3 - a_2$ or $\underline{a_4 = a_1 - a_2 + a_3}$.

If the line of sight is inclined to the horizontal by the angle δ the reading a'_4 will not coincide with a_4. If a line is drawn through a'_3, parallel to $a'_2 - a'_1$, it will cut the staff at B at a_4. a_4 is the required staff reading for a truly horizontal line of sight from D. We can write the formula:

$$a_4 - a'_1 = a'_3 - a'_2$$

and, therefore, $$\underline{\underline{a_4 = a'_1 - a'_2 + a'_3}}$$

If the difference between a'_4 and a_4 is too big (more than 3 mm in 30 m) the whole procedure has to be repeated. If the result is the same, the instrument has to be adjusted.

The instrument is still set up at D. Turn the tilting screw (12) to set the horizontal cross hair to the calculated staff reading $a_4 = a'_1 - a'_2 + a'_3$. Then turn the tubular level adjusting screw (13) to centre the bubble (use the screw driver stored in the instrument container box).

Repeat checking of line of sight!

1.3.4 Distance Measurement with Stadia Hairs

There are two short stadia hairs slightly above and below the cross hair. These stadia hairs can be used to measure the horizontal distance between staff and instrument.

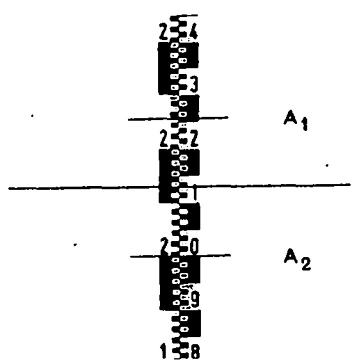
Read the staff where it is cut by the upper A_1 and lower A_2 stadia hairs. The distance D from instrument to staff is:

$$D = (A_1 - A_2) * 100$$

To simplify the readings, set the lower stadia hair to the next full decimetre with the help of the tilting screw (12).

The accuracy of this distance measurement is 10 to 20 cm in 100 m.

Exemple:



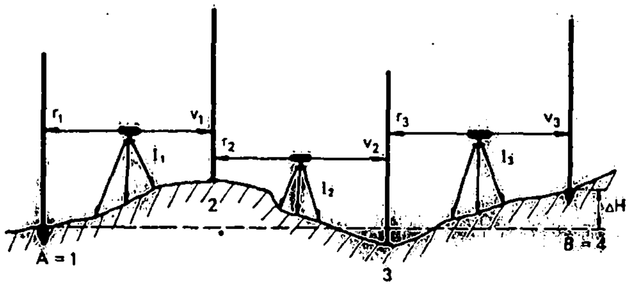
Readings: upper stadia hair A_1 = 225.7 cm
lower stadia hair A_2 = 200.0 cm

$A_1 - A_2$ = 25.7 cm

Distance D = 25.7 m

1.3.5 Line Levelling

To measure the difference in height between points A and B, a certain number of intermediate points has to be selected, so that the sighting distances are 30 - 50 m. In steep terrain the sighting distance will have to be much shorter.



Hold a staff on the starting point A = 1. Set up the instrument at I_1. Make sure the line of sight is horizontal by centring the tubular level and take the backsight reading r_1 to the staff at 1. The staffman can now move the staff to 2. He paces the distance to the instrument and proceeds approximately the same number of paces past the instrument and sets up the staff on the next point 2. Turn the instrument towards 2, set the line of sight horizontal and take the foresight reading v_1. Move the instrument to I_2. The staff remains on point 2 but is turned to face the instrument at I_2. Take backsight reading r_2. Move the staff to point 3 and take foresight v_2. Proceed in the same manner until you reach the end point B = 4.

Note:
- Keep the backsight and foresight distances roughly equal. This helps to eliminate small adjustment mistakes.
- Enter the readings into a level book (see example below).
- Try to close the measurements (end point = starting point). This allows to check the accuracy of your measurements.

Example of Entries into Level Book

Station	Backsight r	Intermediate	Foresight v	Height of Instrument	Altitude of point	Remarks
A	2.326			102.326	100	Assumed altit. of starting point
1		3.784			98.542	Bed of stream
2		.835			101.491	Gate of farm
3		2.640			99.686	Road junction
B	3.792		.924	105.194	101.402	Corner of field
4		3.821			101.373	Corner of road
5			2.773		102.421	Mark on rock
Sum	6.118	Sum	3.697			

The difference in height between Points A and B is equal to the sum of all backsights minus the sum of all foresights.

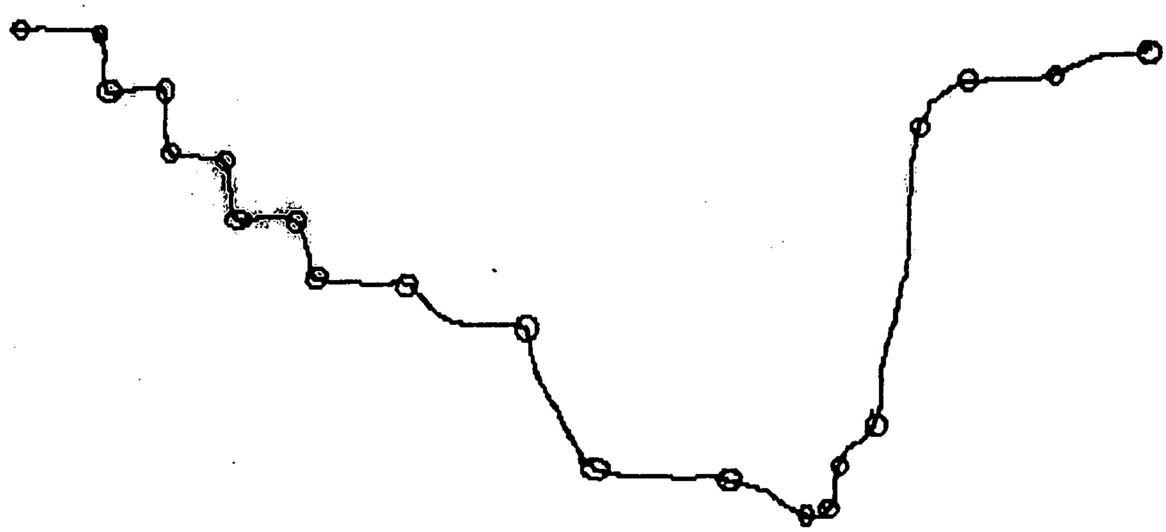
In our example:

$$\underline{\underline{H = \Sigma r - \Sigma v}} = 6.118 - 3.697 = \underline{\underline{2.421 \text{ m}}}$$

1.3.6 Selection of Points to be Measured

While selecting the points to be measured keep in mind that all significant changes in the topography should be measured. Also, remember that while preparing the drawing/plan you will link the different points with strait lines. Therefore, wherever the gradient of the terrain changes you have to put up the staff and take the necessary readings!

In the sketch below, all points which should be measured, are marked with a small circle:



Note: Always try to include some control measurements!

2 P R A C T I C A L   P A R T

The participants of this surveying course should form groups of 3 - 5 members each.

2.1 CHECKING OF LINE OF SIGHT

Each group has to check the line of sight of their levelling instrument according to the instructions given in the theoretical part.

2.2 SURVEY OF A POSSIBLE BRIDGE LOCATION SITE

Each group has to survey a possible site location for a bridge. A level book has to be kept and a sketch has to be drawn up. With the results of the survey a plan of the terrain (longitudinal section) has to be drawn.