

LEVELLING

Aim: to learn the basic levelling principles, theory and applications and to be able to book and reduce levelling data.

Levelling refers to height measurements for representing the relative difference in height (altitude) between various points on the earth's surface.

Basic equipment

- (a) A device which gives a truly horizontal level (the Level).
- (b) A suitably graduated staff for reading vertical heights (the Levelling Staff).

Types of levels

- (a) Tilting – adjustment of level bubble needed before every measurement.
- (b) Dumpy – adjustment of level bubble needed only once after level set up.
- (c) Automatic levels – self levelled instruments.

Bench Mark and Reference Datum

In order to calculate the heights of points a *datum* is required, i.e. a reference level. This is usually the mean sea level. For this purpose, the use of Bench Marks is necessary, and these are classified as follows:

Bench Mark (BM) – a point with known height above mean sea level (or other reference datum). These are permanent points (e.g. unchanged by weather conditions) and are provided by the Department of Lands and Surveys.

Temporary Bench Mark (TBM) – a point of known height above a pre-defined level. This level is not absolute and is defined locally by the surveyor for the purpose of the survey. Based on the TBM the survey may then later be reduced to absolute levels if the level of TBM is known.

The height of any target point is referred to as **Reduced Level (RL)**, because it is reduced to a known datum.

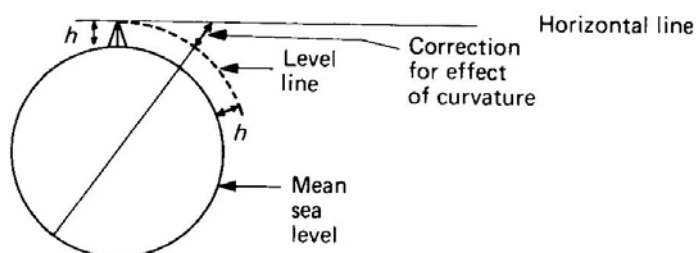


Fig.1 Levelling line. For large areas a correction is required for curvature of the earth.

Common sources of errors in levelling

1. Instrument not correctly levelled.
2. Telescope not correctly focused.
3. The wrong cross-hair reading recorded (e.g. top instead of middle).
4. Staff incorrectly read or not held vertical.
5. Staff incorrectly booked.

All the above are mistakes (blunders) and cannot be corrected unless the work is repeated. A systematic error in levelling is the *collimation error* of the level which is discussed later in detail.

Levelling operations

Level readings can be taken either from one location (one set-up levelling) or from various stations, if some points of interest are not visible. A level survey can be used for setting-out purposes, the presentation of soil profiles etc., as will be discussed later in the subject.

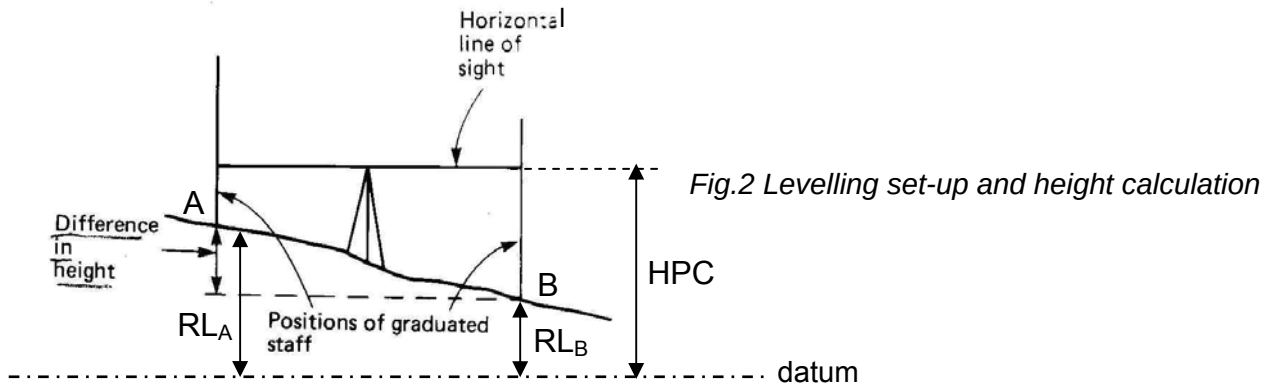
Basic definitions

Backsight (BS): first staff reading taken immediately *after* setting up the instrument.

Foresight (FS): last staff reading taken *before* moving the instrument to another location.

Intermediate sight (IS): all readings taken between a BS and a FS.

So, if the instrument is set up at one location only, there will be just one BS (first reading to a TBM), one FS (last reading) and several IS.



Now consider Figure 2 above. The level is set up as shown, and using the staff at points A and B, height readings are recorded. This is just the height read through the telescope horizontal line of sight (known as *line of collimation*). If no reduced level is known only the difference in height can be found between A and B, not their absolute levels.

Staff Reading at A is 1.135m
Staff Reading at B is 1.875m $\Rightarrow$ difference in height is $= 1.875 - 1.135 = 0.740\text{m}$

If we know that $RL_A = +120.000\text{m}$ (above datum), then $RL_B = 120.00 - 0.740 = +119.260\text{m}$ i.e. a fall from A. If RL_B was known we would calculate a rise in level. Hence, the following can be defined:

Rise – staff reading is less than previous reading.

Fall – staff reading is greater than previous reading.

The above definitions are used in the *Rise & Fall method* a level booking and reduction.

A second way to calculate the reduced levels is by using the *Height (level) of collimation line* (or plane). From the above numerical example,

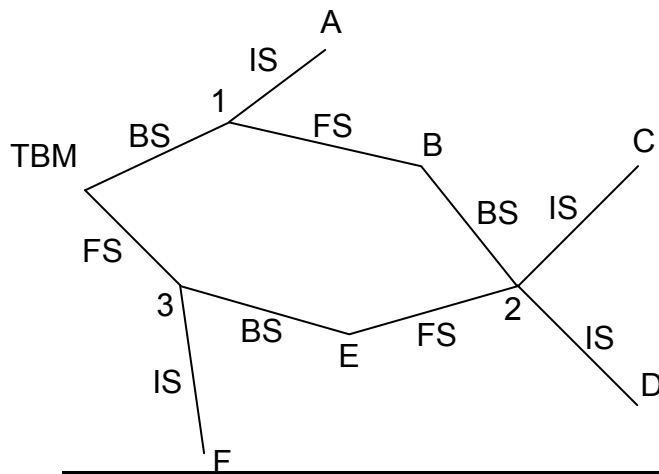
Height of Plane of Collimation (HPC) $= +120.000 + 1.135 = +121.135\text{m}$ (as from Figure 2)

$\Rightarrow RL_B = \text{HPC} - (\text{Staff Reading at B}) = +121.135 - 1.875 = +119.260\text{m}$

The above method is used in the relevant booking and reduction.

BOOKING AND REDUCTION METHODS

The two common methods are presented below using the same example. For vertical control the level survey should start and close on points of known height (same point or different). If the survey starts and closes on the same point (e.g. a TBM), as below, this is termed as a *closed level survey*.



RL(TBM) = +50.000m

Instrument stations: 1, 2, 3.

Target points: TBM, A, B, C, D, E, F.

(a) Rise & Fall method

(BOOKING)					(REDUCTION)		
Station	Point	BS	IS	FS	Rise	Fall	RL
1	TBM	1.000					+50.000
1	A		1.580			0.580	+49.420
1	B			1.420	0.160		+49.580
2	B	0.900					(+49.580)
2	C		1.100			0.200	+49.380
2	D		1.450			0.350	+49.030
2	E			1.300	0.150		+49.180
3	E	1.355					(+49.180)
3	F		1.585			0.230	+48.950
3	TBM			1.320	0.265		+49.215

(All heights in m)

Sum (Σ) 3.255 4.040 0.575 1.360

(Note that a FS always follows a BS in order to connect the survey with subsequent stations. Target points B and E are *change points* for the instrument.)

Arithmetic checks (necessary for checking the reduction)

$$\Sigma (\text{BS}) - \Sigma (\text{FS}) = 3.255 - 4.040 = -0.785\text{m}$$

$$\Sigma (\text{RISES}) - \Sigma (\text{FALLS}) = 0.575 - 1.360 = -0.785\text{m} \Rightarrow \text{OK}$$

$$\text{LAST (RL)} - \text{FIRST (RL)} = +49.215 - 50.000 = -0.785\text{m} \Rightarrow \text{OK.}$$

Since this is a closed survey the value calculated is the *misclosure error* (for perfect measurements it should have been zero since TBM is the same point!)

(b) Height of Plane of Collimation (HPC) method

This method is simpler but with one check less, so care should be taken in reduction. The booking part is the same. You should always remember that the HPC is constant for the *same* instrument station, so needs to be calculated only once.

For each station, $HPC = (\text{known RL}) + BS$, and each $RL = HPC - (IS \text{ or } FS)$

(BOOKING)					(REDUCTION)	
Station	Point	BS	IS	FS	HPC	RL
1	TBM	1.000			+51.000	+50.000
1	A		1.580		(+51.000)	+49.420
1	B			1.420	(+51.000)	+49.580
2	B	0.900			+50.480	+49.580
2	C		1.100		(+50.480)	+49.380
2	D		1.450		(+50.480)	+49.030
2	E			1.300	(+50.480)	+49.180
3	E	1.355			+50.535	+49.180
3	F		1.585			+48.950
3	TBM			1.320		+49.215

(All heights in m)

Sum (Σ) 3.255 4.040

Arithmetic checks (necessary for checking the reduction)

$$\Sigma (BS) - \Sigma (FS) = 3.255 - 4.040 = -0.785\text{m}$$

$$\text{LAST (RL)} - \text{FIRST (RL)} = +49.215 - 50.000 = -0.785\text{m} \Rightarrow \text{OK.}$$

So we can see that both methods give the same results for the RL of the target points. It is required to know and understand both methods of reduction.

A solved example follows for practicing the two methods. Additional examples will be solved in class.