Fieldwork Surveying FS01

6. Lecture

Determination of heights I

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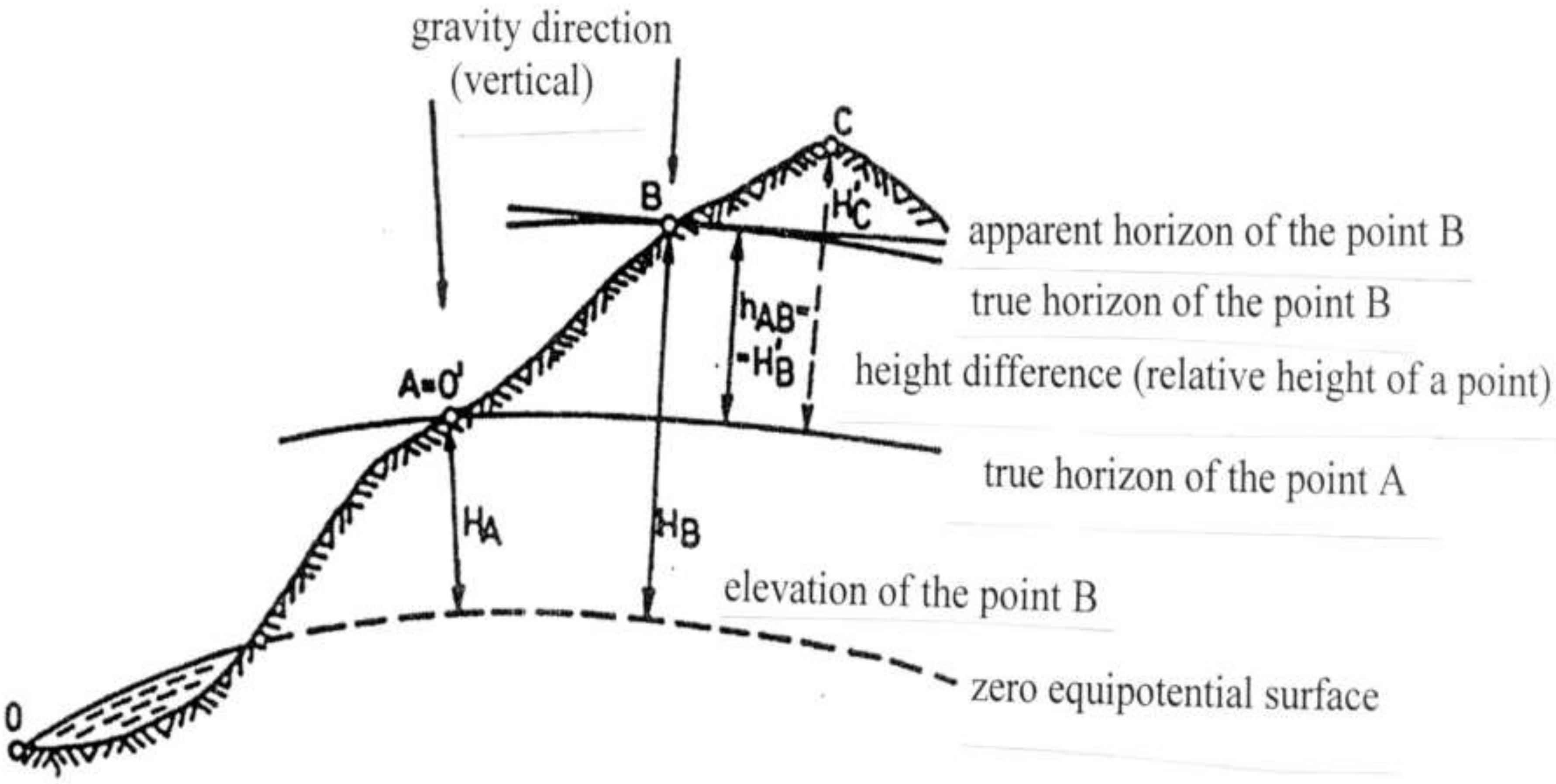
Determination of heights – essential terms



Equipotential surface = a surface with the invariable gravity potential (perpendicular to the force of gravity in each point).

Equipotential surfaces are not parallel mutually and they converge in the direction to the Pole.

For our purposes (i.e. for purposes of land surveying) the Earth is supposed to be a homogenous sphere. Then the zero equipotential surface is a spherical surface which comes through the zero height point and equipotential surfaces are concentric spherical surfaces.

Absolute height of a point = height of a point above a chosen zero surface. The zero equipotential surface is the mean sea level $\rightarrow$ absolute height of a point = **elevation (sea level height).**

Relative height of a point = height of a point above an arbitrarily chosen equipotential surface, relative height of a point is actually a **height difference**.

True horizon of a point = equipotential surface which comes through the point.

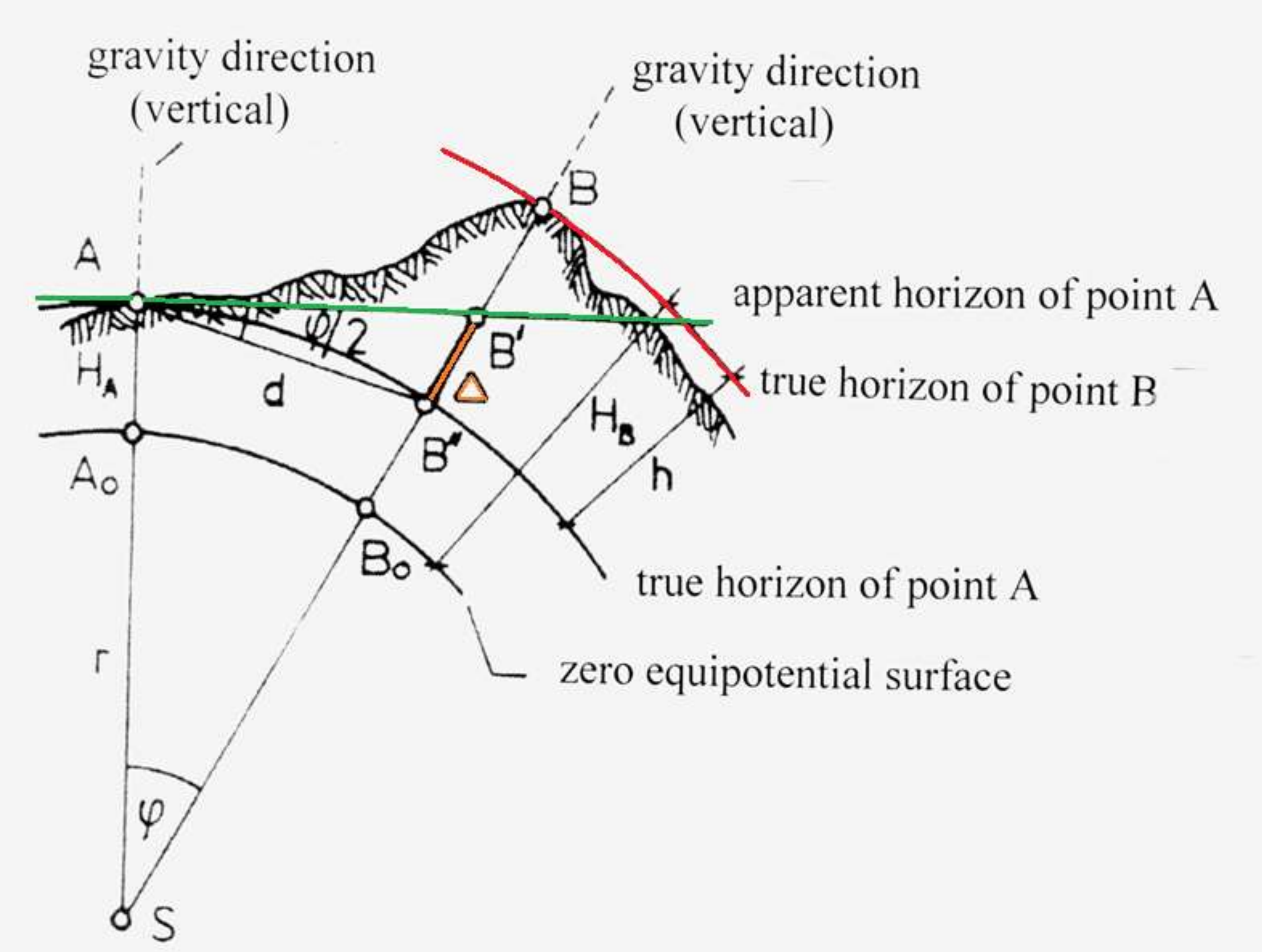
Apparent horizon of a point = horizontal tangent plane in the point.

The Earth is supposed to be a plane and then true horizons are supposed to be apparent horizons (it means that the Earth's curvature can be negleted) for surveying within the distance about 300 m – see p. 5, 6.

Height differences (of true horizons) are measured

$h_{AB} = H_B - H_A$

Influence of the Earth's curvature on heights



Influence of the Earth's curvature on heights

$\Delta = d \cdot tg\, \varphi/2 \cong d \cdot \varphi/2$

$\varphi/2 = d / 2r \quad \Rightarrow \quad \Delta = d^2 / 2r$

d [m]	Δ [mm]
50	0
350	10
1000	83

Vertical datum in the Czech Republic

1. Baltic Vertical Datum – after Adjustment (Bpv)

the zero height point = the zero point of the water gauge in Kronstadt (Russia)

2. Adriatic datum – effective until 2000 (in Prague)

the zero height point – in Trieste (Italy)

The height difference between Bpv and Adriatic datum is about 0,40 m (heights are higher in Adriatic datum).

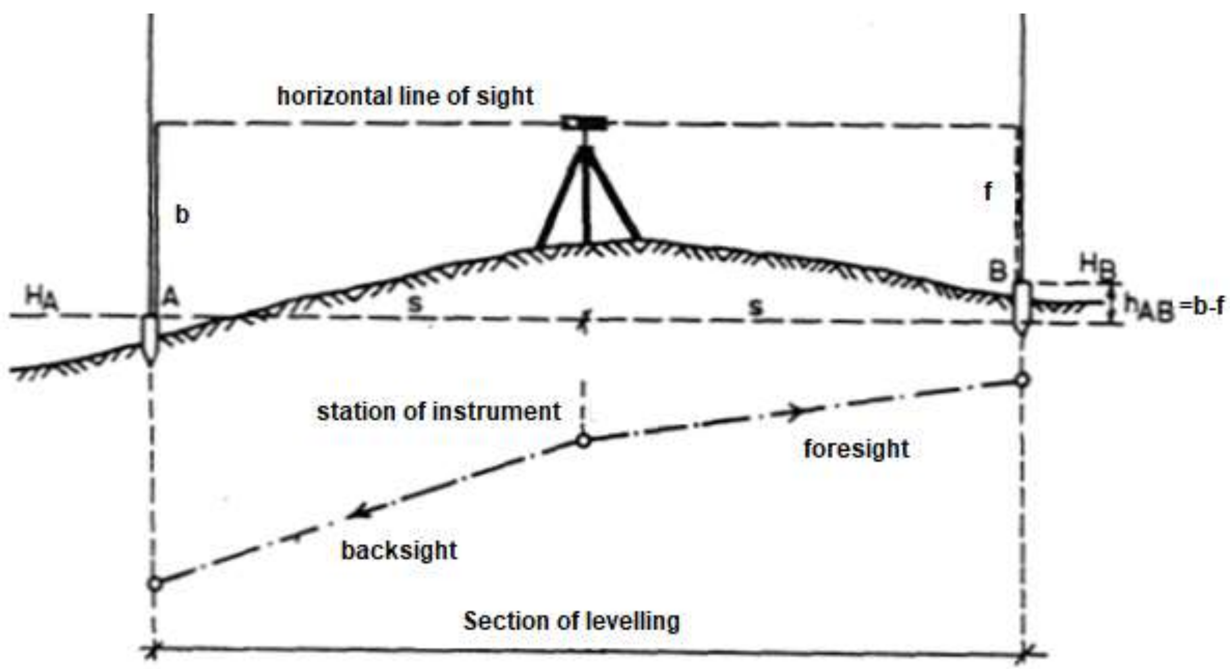
Methods of a height difference determination

1. direct levelling
2. barometric levelling
3. hydrostatic levelling
4. trigonometric method
5. Global Navigation Satellite Systems (GNSS)

Direct levelling from the center between the rods

$h_{AB} = H_B – H_A = b – f$ $\qquad$ $H_B = H_A + h_{AB} = H_A + b – f$

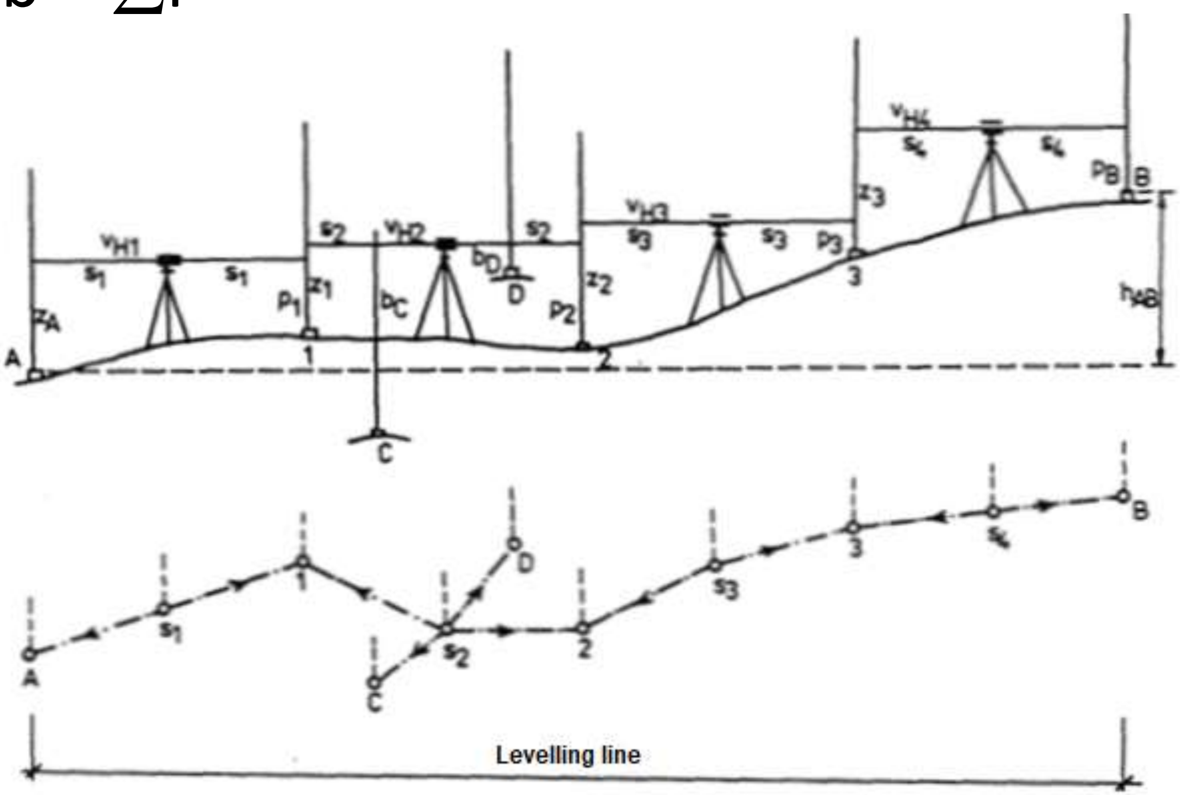
Section of levelling = backward levelling rod + levelling instrument + forward levelling rod.



Direct levelling from the center between the rods

If there are several sections of levelling (levelling line), then

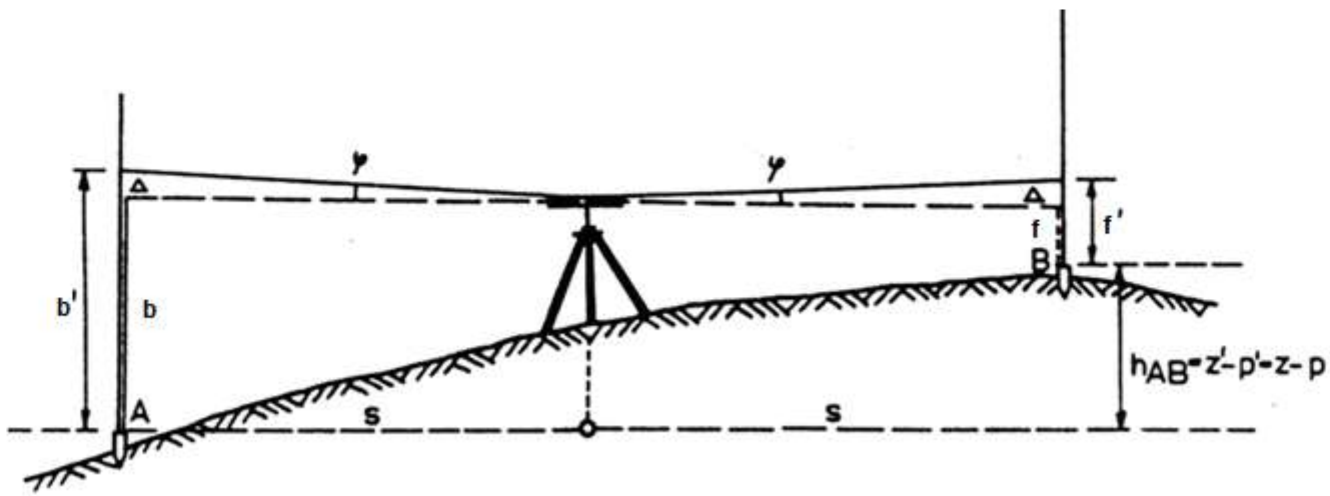
$h_{AB} = \sum b - \sum f$



Advantages of direct levelling from the center between the rods

The Earth's curvature and an inclination of the line of sight are eliminated using this method.

$$h_{AB} = b' - f'$$
$$b' = b + \Delta$$
$$f' = f + \Delta$$



$$h_{AB} = (b + \Delta) - (f + \Delta) = b - f + \Delta - \Delta = b - f$$

Types of direct levelling according to precision

1. special-precision levelling
2. high-precision levelling
3. precise levelling
4. technical levelling (TL)

Accuracy criterion of TL – maximum difference between height differences determined twice

$\Delta_M = 40\sqrt{r}$

r … length of a levelling line (if the levelling line is measured twice) or half-length of a levelling line (if the levelling line is measured once) in km

Δ_M … in mm

Levelling instruments

Principle – a horizontal plane is set out by a levelling instrument.

1. optical levelling instruments
2. electronic levelling instruments
3. laser levelling instruments

1. Optical levelling instruments

1. levelling instruments

   The line of sight is levelled to the horizontal position by a levelling bubble.

2. self-compensating levelling instruments

   The line of sight is levelled to the horizontal position automatically by a compensator (pendulum). The circular level of the instrument has to be levelled in order that the compensator works.

Levelling instruments - optical

2. Electronic levelling instruments

- levelling rods with a barcode are used
- the barcode is read by a CCD camera automatically, the reading is recorded and calculation is performed automatically
- errors caused by the observer are reduced

Levelling instruments - electronic

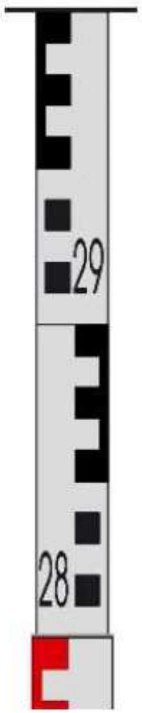
3. Laser levelling instruments

- line of sight = visible laser beam (most often He-Ne, semiconductor)
- a visible plane of sight can be realized
- a sensor is placed on the rod for determination of the beam’s centre (a divergence of the laser beam is about 30 mm for 200 m)
- accuracy of instruments is about 2 mm/100 m

Levelling instruments - laser

Levelling instruments - equipment

Levelling rods, footplates



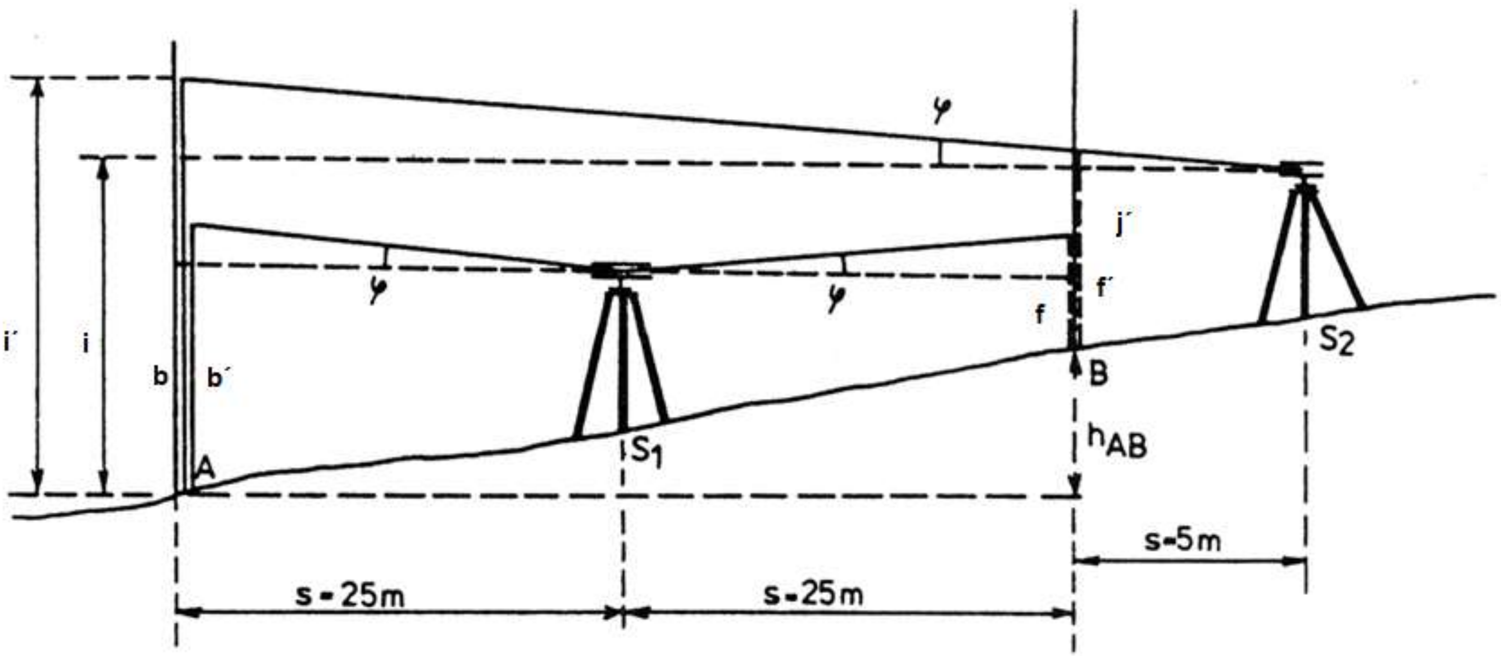
Test of levelling instrument

Is the line of sight horizontal?

$$h_{AB} = b' - f'$$
$$h'_{AB} = i' - j'$$

$$o = \frac{h_{AB} - h'_{AB}}{2s}$$

The correction of reading *o* for the distance 1 m of asymmetry



Types of direct levelling with respect to procedure

1. **traverse levelling** – sections of levelling with backsights, foresights and intermediate sights (exceptionally) – see practical classes
2. **longitudinal profiles and cross section levelling**
3. **surface levelling**

2. Longitudinal profiles and cross section levelling

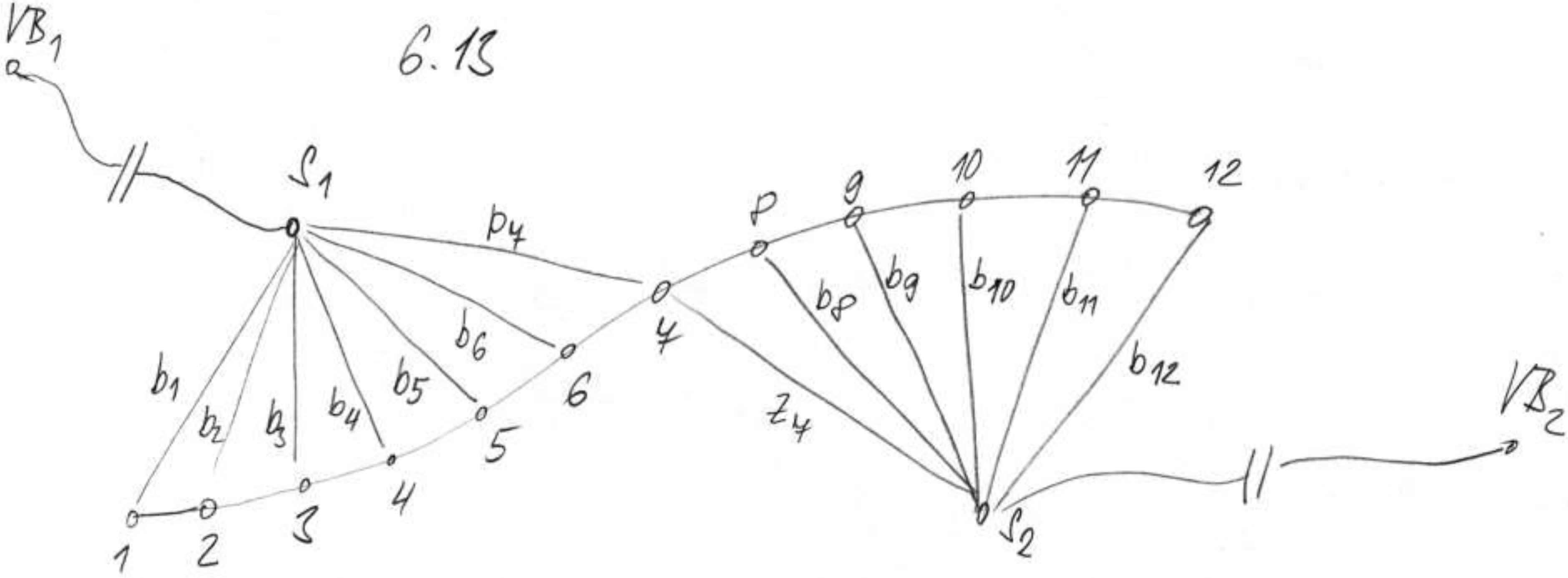
- often used for design and building of linear constructions (roads, railways), for a regulation of watercourse, ...

longitudinal profile = vertical section of a terrain which comes through the axis of the construction

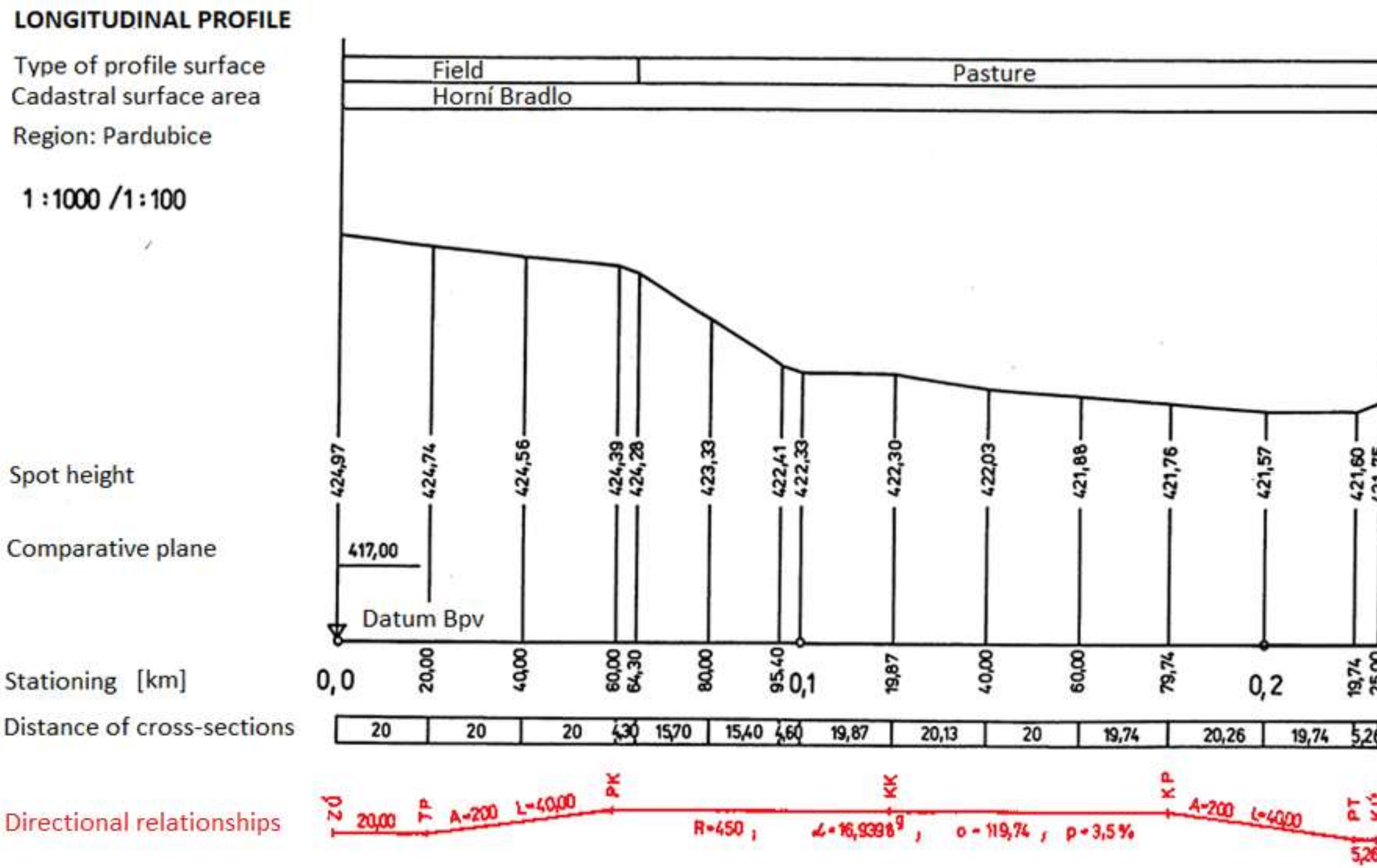
cross section = vertical section of a terrain which is perpendicular to the axis of the construction

- technical levelling with intermediate sights is used for the heights determination of longitudinal and cross profiles points
- characteristic points (the beginning and the end of the arc) and other points in periodic space (e.g. 20 m) are measured
- requirement = accuracy should be in cm $\rightarrow$ the fundamental of the levelling from the centre between the rods can be contravened

Measurement of a longitudinal profile



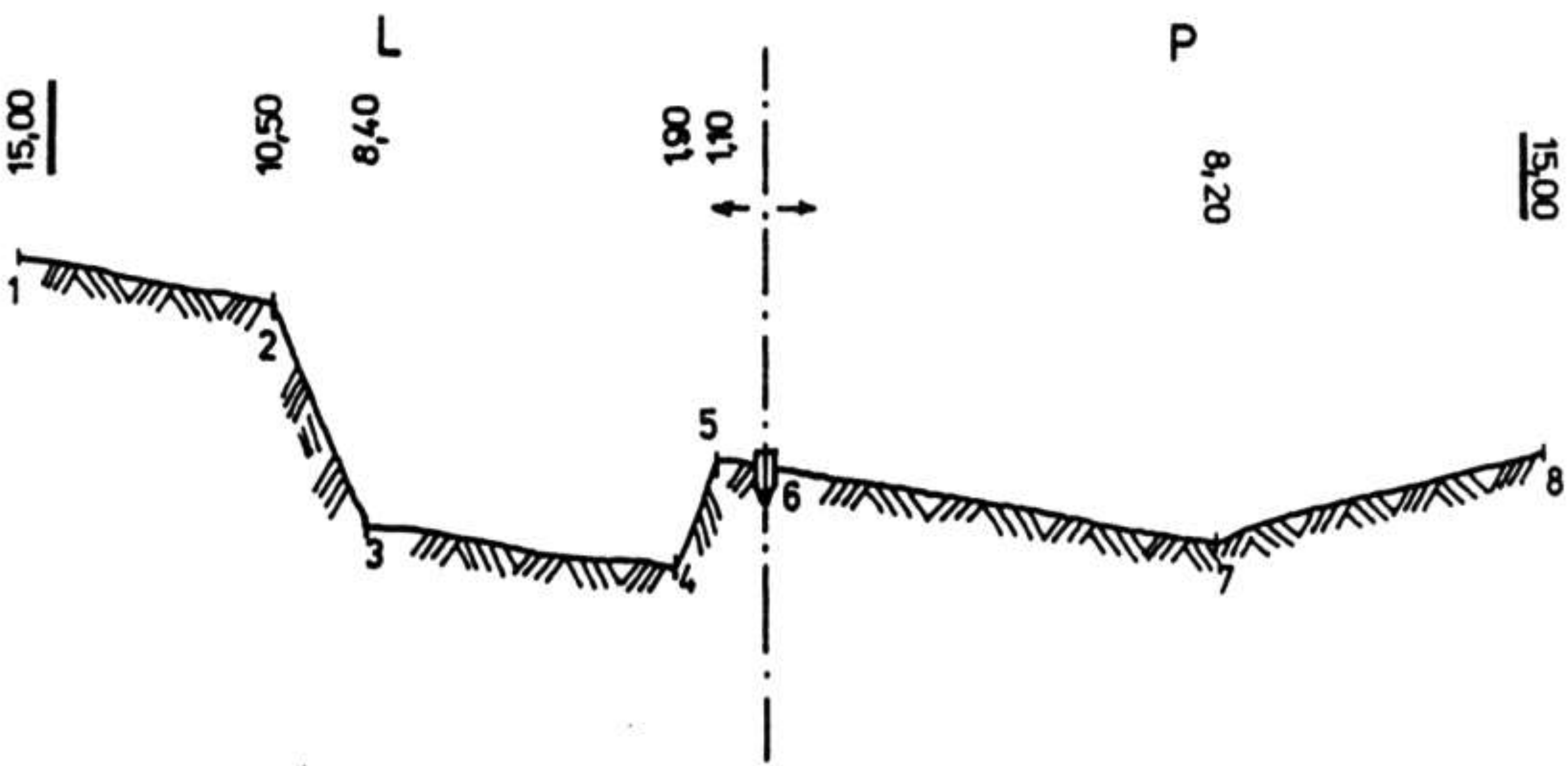
- longitudinal profile is displayed on a graph paper (cross-section paper)
- heights are ususally displayed using larger scale (e.g. 1:100) than scale for distances (e.g. 1:1000) to **stress** altitudinal component
- vertical alignment of the linear construction axis is designed to the longitudinal profile and then earthwork is calculated
- vertical alignment is usually designed to have fills the same as cuts approximately (equal cubages = minimal earthwork)


LONGITUDINAL PROFILE
Type of profile surface
Cadastral surface area
Region: Pardubice
1 : 1000 / 1 : 100
Field
Pasture
Horní Bradlo
Spot height
424,97
424,74
424,56
424,39
424,28
423,33
422,41
422,33
422,30
422,03
421,88
421,76
421,57
421,60
421,75
Comparative plane
417,00
Datum Bpv
Stationing [km]
0,0
20,00
40,00
60,00
64,30
80,00
95,40
0,1
19,87
40,00
60,00
79,74
0,2
19,74
25,00
Distance of cross-sections
20
20
20
4,30
15,70
15,40
4,60
19,87
20,13
20
19,74
20,26
19,74
5,26
Directional relationships
ZÚ
20,00
TP
A=200
L=40,00
PK
R=450 ,
KK
o = 119,74 , p = 3,5 %
KP
A=200
L=40,00
PT
KÚ
5,26

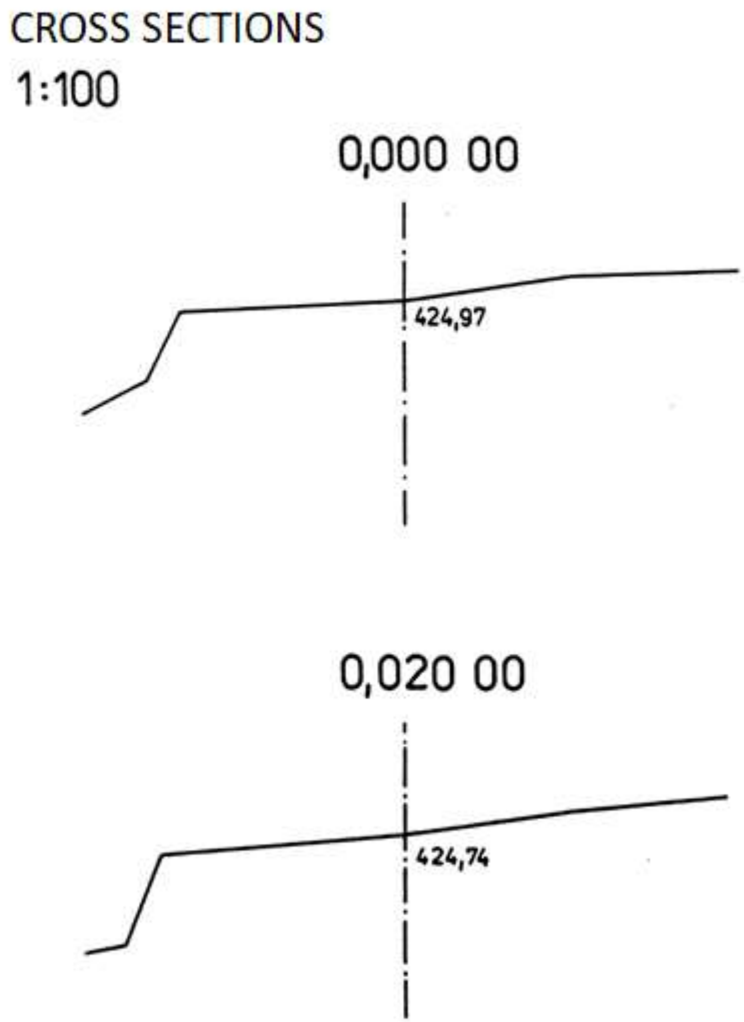
Cross section

- number of cross sections depends on the fact if the relief is broken or plane. A choice of places for cross profiles supports a calculation of earthwork cubages as precisely as necessary.
- length of a cross profile depends on earthwork, it ranges usually from 20 m to 200 m
- perpendicular to the building axis is set out in the point of longitudinal profile and outer points and points which lie on breaks of the terrain are measured
- it is possible to measure cross section points simultaneously with longitudinal profile points

Choice of cross section points



The cross section is displayed on a graph paper (cross-section paper), the scale is the same both for heights and distances (e.g. 1:100).



Thank you for your attention!