Geodesy 1 (GED203)

Lecture No: 9

TRIGONOMETRIC AND PRECISE LEVELING

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Overview of Previous lecture

DEFINITION OF GEODETIC CONTROL

TYPES OF GEODETIC CONTROL

TRIANGULATION VS TRILATERATION

ROUTINE OF TRIANGULATION SURVEY

PRINCIPLE OF TRIANGULATION

CLASSIFICATION OF TRIANGULATION NETWORKS

EGYPTIAN GEODETIC NETWORKS

APPLICATIONS OF GEODETIC NETWORKS

OVERVIEW OF TODAY'S LECTURE

TRIGONOMETRIC LEVELING

TRIGONOMETRIC LEVELING - **OBSERVATION METHODS**

TRIGONOMETRIC LEVELING – CORRECTIONS

TRIGONOMETRIC LEVELING – NUMERICAL EXERCISE

PRECISE LEVELING

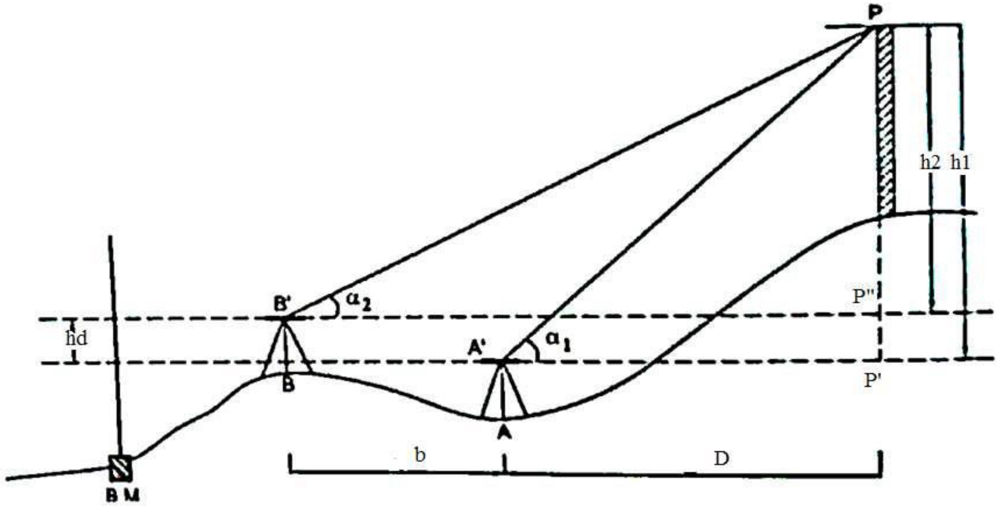
PRECISE LEVELING - EQUIPMENT

APPLICATIONS OF PRECISE LEVELING

Expected Learning Outcomes

1. Knowledge of the principles and concepts of trigonometric leveling.
2. Ability to apply trigonometric functions and calculations in the context of leveling.
3. Familiarity with different observation methods used in trigonometric leveling, such as angle measurements and distance measurements.
4. Understanding the advantages and limitations of various observation methods.
5. Knowledge of the various corrections applied in trigonometric leveling, such as refraction correction, curvature correction, and atmospheric correction.
6. Understanding the principles and techniques of precise leveling.
7. Knowledge of the differences between precise leveling and other leveling methods.
8. Understanding the practical applications of precise leveling in various fields, such as civil engineering, construction, surveying, and geodesy.
9. Ability to use precise leveling techniques for height determination, monitoring subsidence, establishing benchmarks, and other related applications.
10. Knowledge of the importance of precise leveling in geodetic networks and accurate elevation data acquisition.

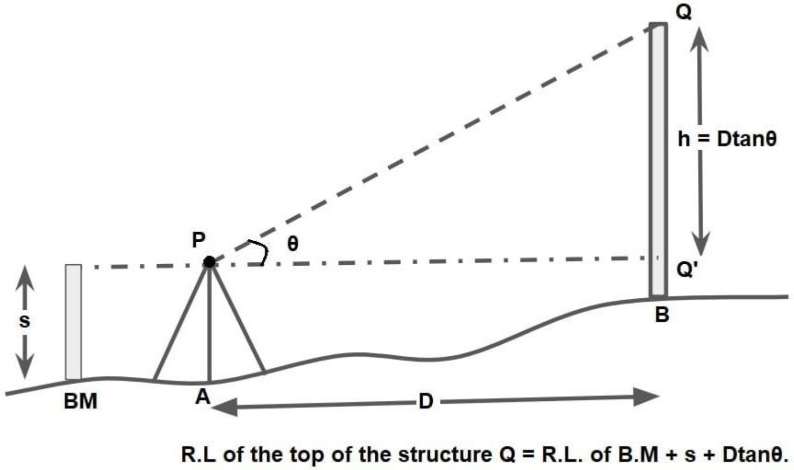
(1) Trigonometric Leveling



Trigonometric Leveling

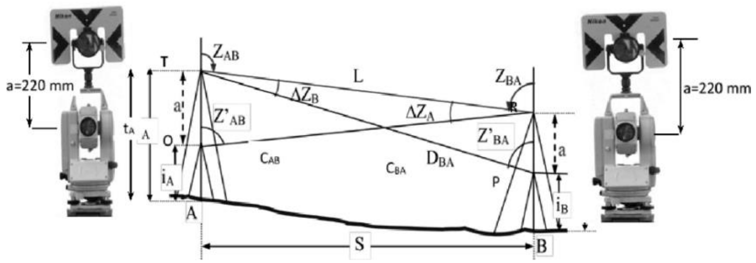
- Trigonometric leveling is the process of determining the different elevation of station from observed vertical angle and known distance.
- The vertical angle are measured by means of theodolite.
- The horizontal distance may either measured or computed.
- Relative heights are calculated using trigonometric formula.
- If the distance between the instrument station and object is ***small***, correction of earth ***curvature*** and reflection is not required.

Trigonometric Leveling - Observation Methods



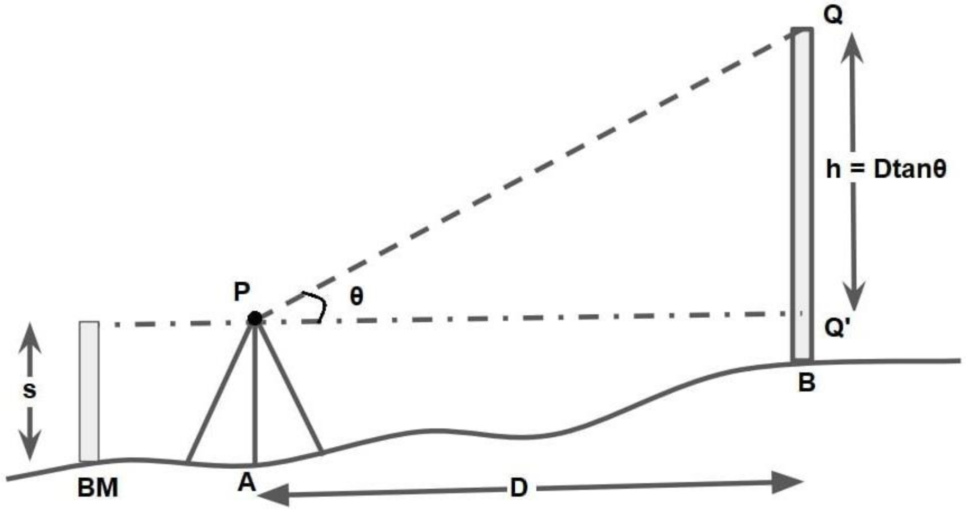
Direct method

Reciprocal method



TRIGONOMETRIC LEVELING – DIRECT METHOD

- This method is useful where it is not possible to set the instrument over the station, whose elevation is to be determined.
- The instrument is set on the station on the ground whose elevation is known.
- Example: To determine the height of the tower.

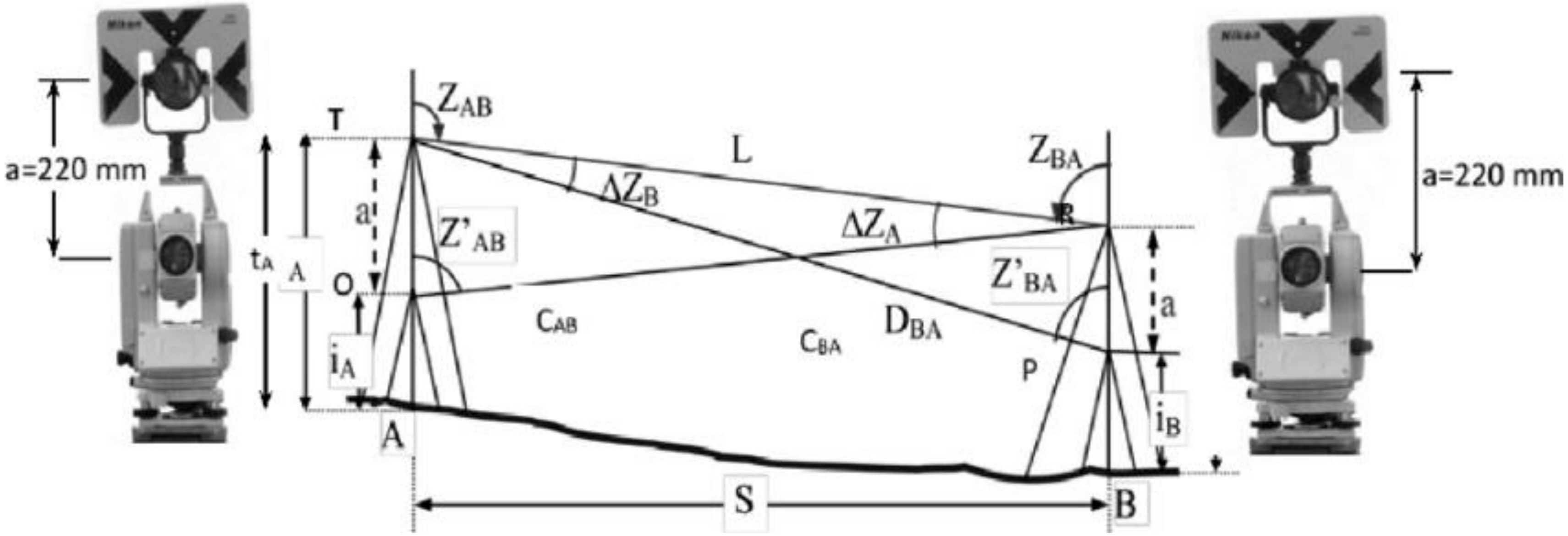


R.L of the top of the structure Q = R.L. of B.M + s + Dtanθ.

Have you experienced "***REM***" which is implemented in total station instruments

Trigonometric Leveling – Reciprocal Method

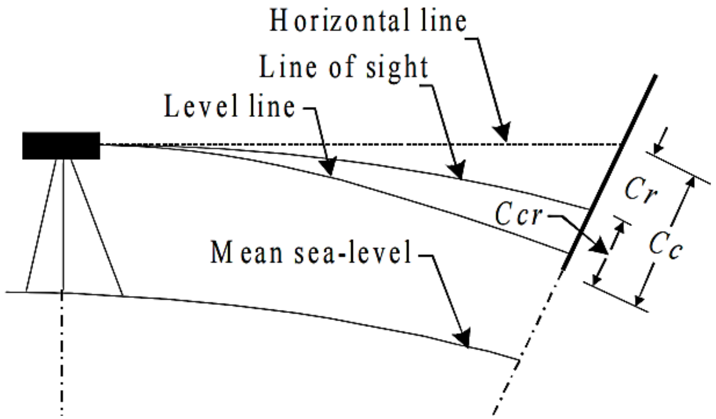
- The instrument is set on each of the two station alternatively and observation are taken.
- Difference in elevation between two station A and B is to be determined.
- **First,** set the instrument on A and take observation of B **then** set the instrument on B and take the observation of A.

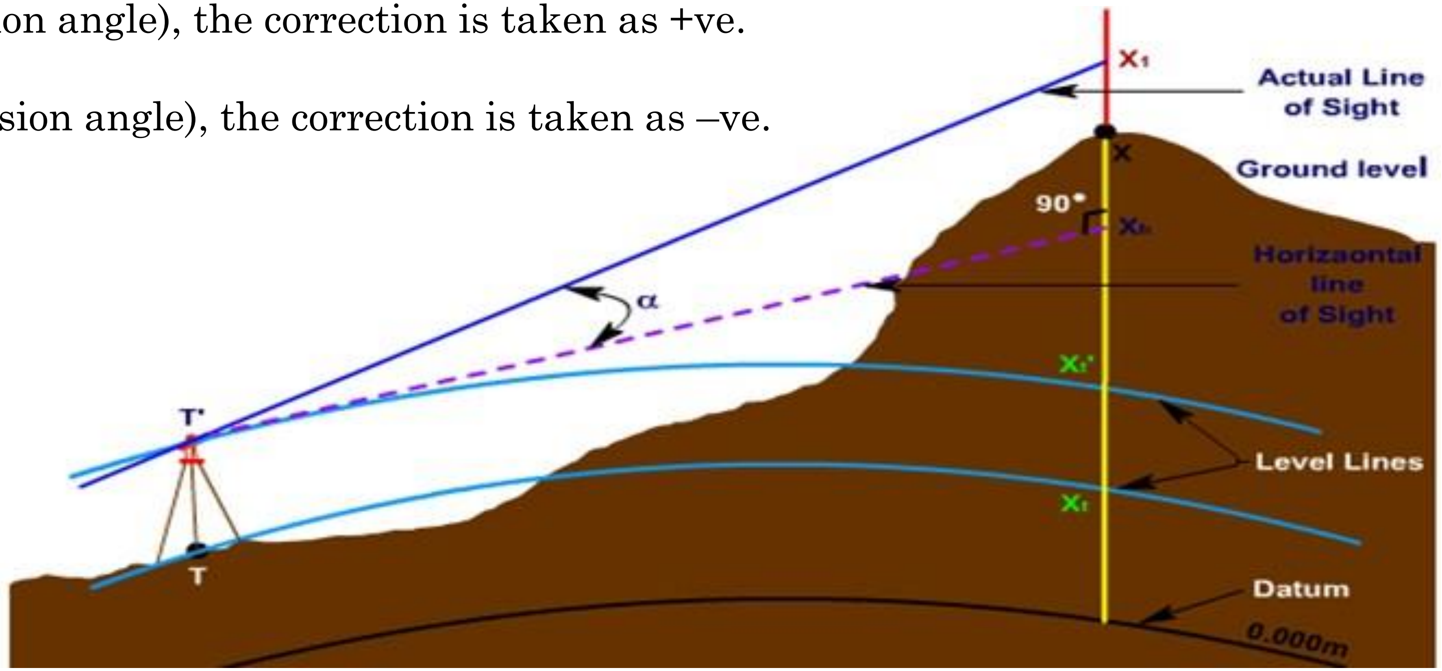


Trigonometric Leveling – Corrections

1. **Correction for curvature (c) and refraction (r)**
2. **Axis signal correction**

- The combined correction = 0.0673 D^2, for earth's curvature and reflection is required, were D = distance in Km.
- If the vertical angle is +ve (elevation angle), the correction is taken as +ve.
- If the vertical angle is –ve (depression angle), the correction is taken as –ve.





Trigonometric Leveling – Numerical Exercise

1. ***Determine the level of point B***, where the level of A = 300 m and the horizontal distance between A and B = 50 m, the zenith angle = 115º, the height of the instrument at A = 1.5 m, and the height of signal at B = 1.2 m.
2. The slope distance and zenith angle measured from point P to point Q were 1823.316 m and 84º23'16", respectively. The instrument and rod target heights were equal. If the elevation of point P is 487.623 m above datum, ***what is the elevation of point Q***?
3. A vane 3.0 m above the foot of a staff was sighted at a point 3000 m away from the instrument. The observed angle of elevation was 2° 30′. The reduced level of the trunnion axis being 200 m. ***Find the reduced level of the staff station***.
4. An instrument was set up at a point 200 m away from a transmission tower. The angle of elevation to the top of the tower was 30° 42′, whereas the angle of depression to the bottom was 2° 30′. ***Calculate the total height of the tower***.

Trigonometric Leveling – Numerical Exercise

3. A vane 3.0 m above the foot of a staff was sighted at a point 3000 m away from the instrument. The observed angle of elevation was 2° 30′. The reduced level of the trunnion axis being 200 m. ***<u>Find the reduced level of the staff station</u>***.

Solution Let O be the instrument station and A be the staff station.

$$V = 3000 \tan 2°30' = 130.98 \text{ m}$$

Since, the distance of 3000 m is quite large, the correction for curvature and refraction must be applied.

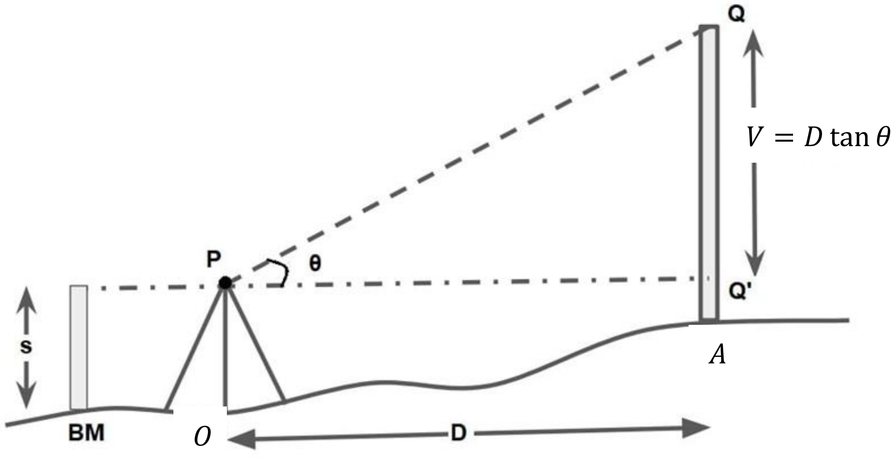
Correction, $C = 0.0673\, D^2$, where D is in km

$$= 0.0673 \times \left(\frac{3000}{1000}\right)^2 = 0.6057 \text{ m}$$

Hence, R.L. of staff station A = R.L. of O + H.I. + V – 3 + C

= R.L. of instrument axis + V – 3 + C

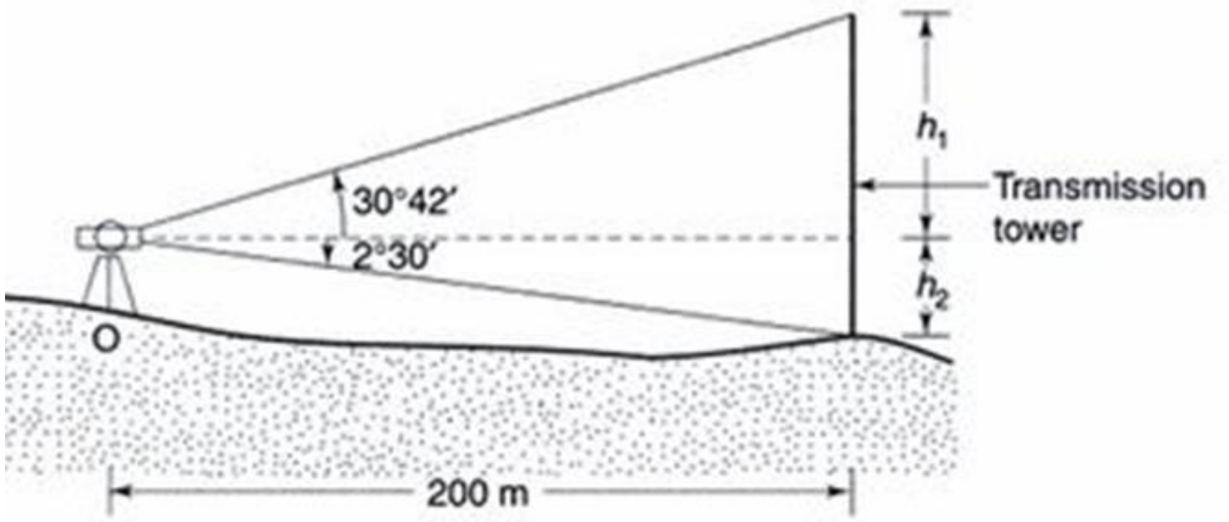
= 200 + 130.98 – 3 + 0.6057 = 328.5857 m



R.L of the top of the structure Q = R.L. of B.M + s + Dtanθ.

Trigonometric Leveling – Numerical Exercise

4. An instrument was set up at a point 200 m away from a transmission tower. The angle of elevation to the top of the tower was 30° 42′, whereas the angle of depression to the bottom was 2° 30′. ***Calculate the total height of the tower***.



Let the height of the tower be h.

$$h = h_1 + h_2$$

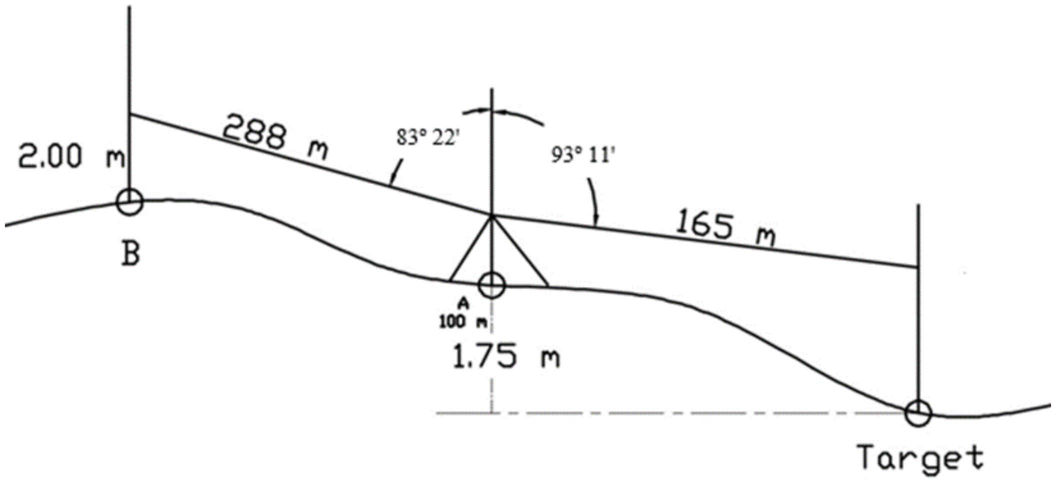
$$h_1 = 200 \tan 30°42' = 118.75 \text{ m}$$

$$h_2 = 200 \tan 2°30' = 8.732 \text{ m}$$

$$h = 118.75 + 8.732 = 127.482 \text{ m}$$

Trigonometric Leveling – Numerical Exercise

5. A zenith angle of 93º 11′ is measured to a target whose vertical distance above point A is 1.75 m. The slope distance from the instrument to the target is 165 m. The reduced level of point A is 100 m. without moving the instrument a zenith angle of 83º 22′ is measured to a target set at 2 m vertically above point B. The slope distance from the instrument to this target is 288 m. ***<u>what the reduced level of point B?</u>***



Trigonometric Leveling – Numerical Exercise

5. ***<u>what the reduced level of point B?</u>***

- Height of Plane of Collimation (HPC) = Elevation of Station (A) + Vertical Distance Between A & Target + 165 Sin (93º 11' - 90º)
- Height of Plane of Collimation = 100 + 1.75 + 165 Sin (93º 11' - 90º) = 110.913 m
- Horizontal Distance AB = 165 Cos (93º 11' - 90º) = 164.745 m
- Horizontal Distance AB = 288 Cos (83º 22' - 90º) = 286.072 m
- All Horizontal Distances are less than 300 m (No Curvature and Refraction Correction will be applied)
- Elevation of Station (B) = HPC + 288 Sin (90º - 83º 22') – 2 = 142.181 m
- RL_B = 142.181 m

(2) Precise Leveling

Precise Leveling

A particularly accurate method of differential levelling which uses highly accurate levels and a more rigorous observing procedure than general engineering levelling.

It aims to achieve high orders of accuracy such as 1 mm per 1 km traverse.

Orders of leveling

ORDER	PURPOSE	MAXIMUM CLOSE (m)
Precision Order	Deformation surveys	0.001 x km
First Order	Major levelling control	0.003 x km
Second Order	Minor levelling control	0.007 x km
Third Order	Levelling for construction	0.012 x km

Precise Leveling - Equipment

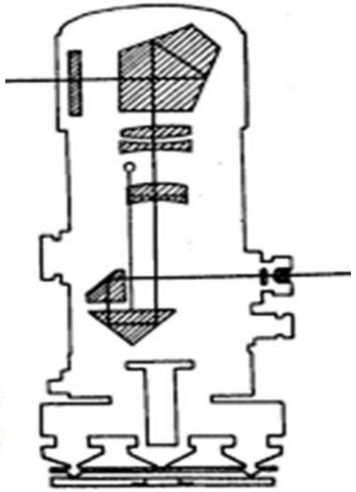
- Level Instrument
- Tripod
- Staff/Pole
- Change plate
- Pole staff bubble
- Marker

Precise Leveling - Equipment

- **Level Instrument**
- **Tripod**
- **Staff/Pole**
- **Change plate**
- **Pole staff bubble**
- **Marker**

Precise Leveling – Equipment (Level Instrument)

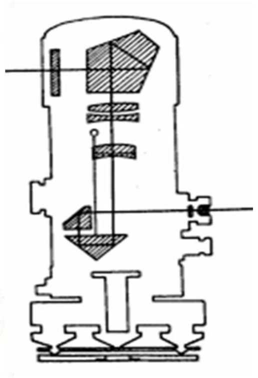
- **Automated Levels**
  - Easy to use (not power!)
  - Needs experience
  - Robust even in hostile environment



Precise Leveling – Equipment (Level Instrument)

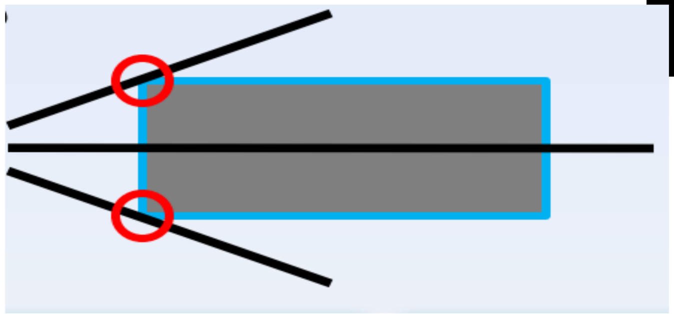
Automated Levels – Cross hairs

- Focusing the division on the horizontal cross hair is replaced by focusing on the tangency of the wedge cross hair with the staff division
- Micrometer readings are always added whatever
- focusing on upper or lower division



Micrometer

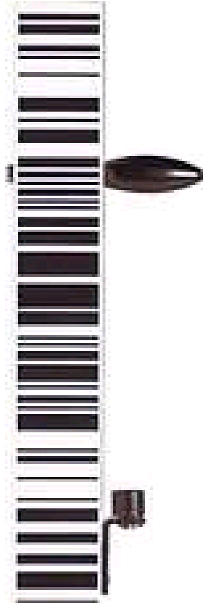
Wedge cross-hair



PRECISE LEVELING – EQUIPMENT (LEVEL INSTRUMENT)

- **Digital Levels**
  - Push-button technique
  - No reading errors, special staff
  - Readings are stored and analyzed digitally

- Uses Barcode staffs
- Internal storage of data
  - Download to the computer
  - Automated height computation + adjustment
  - *No feeling for quality anymore*
  - *You frequently need power plugs*



Precise Leveling - Equipment

- Level Instrument
- **Tripod**
- Staff/Pole
- Change plate
- Pole staff bubble
- Marker

Precise Leveling – Equipment (Tripod)

- Wooden design or aluminum
  - From "easy to sit" to "this is high!"

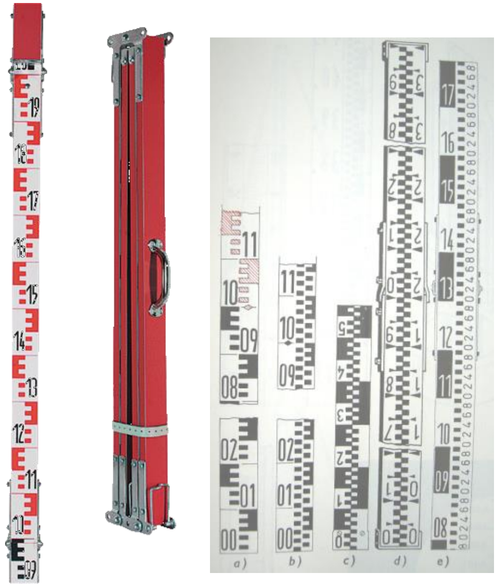


Precise Leveling - Equipment

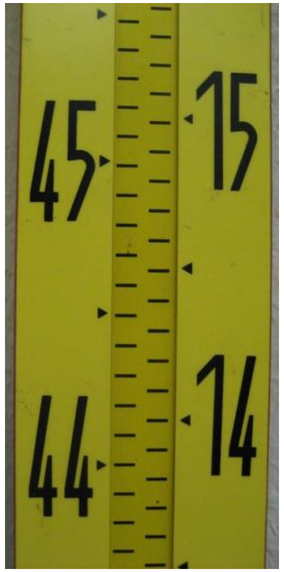
- Level Instrument
- Tripod
- **Staff/Pole**
- Change plate
- Pole staff bubble
- Marker

PRECISE LEVELING – EQUIPMENT (STAVES)

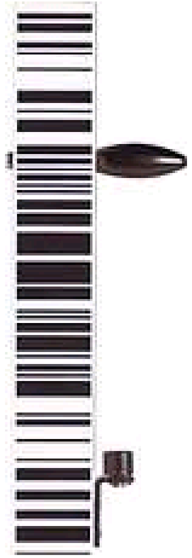
- Wood, aluminum
- INVAR type for high precision leveling



Conventional (“E”-type)



INVAR



Barcode
for Digital Levels

Precise Leveling - Equipment

- Level Instrument
- Tripod
- Staff/Pole
- **Change plate**
- Pole staff bubble
- Marker

PRECISE LEVELING – EQUIPMENT (CHANGE PLATE)

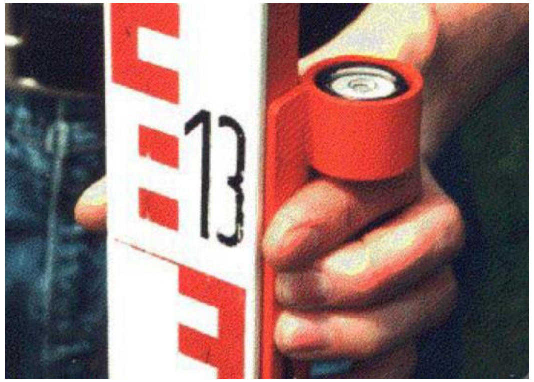
- For long survey lines
- Allows change of instruments
  - Best is a metal change plate
  - Screws
  - Sharp stones or nails

Precise Leveling - Equipment

- Level Instrument
- Tripod
- Staff/Pole
- Change plate
- **Pole staff bubble**
- Marker

PRECISE LEVELING – EQUIPMENT (BUBBLE)

- Keep the pole upright
  - Any tilt will disturb your readings



Precise Leveling - Equipment

- Level Instrument
- Tripod
- Staff/Pole
- Change plate
- Pole staff bubble
- **Marker**

Precise Leveling – Equipment (Marker)

- Gives you a fixed point
  - Should be of good quality
  - Should be long-term
  - Preferable in bedrock, settled buildings, or bridges
  - Do not use fences or walls

Applications of Precise Leveling

PRECISE LEVELING – APPLICATIONS

- **Vertical Control Network Standards**

Classification	Relative Accuracy Between Directly Connected Points or Benchmarks (Standard Error)
First - Order, Class I	0.5 mm √K
First - Order, Class II	0.7 mm √ K
Second - Order, Class I	1.0 mm √ K
Second - Order, Class II	1.3 mm √ K
Third - Order	2.0 mm √ K

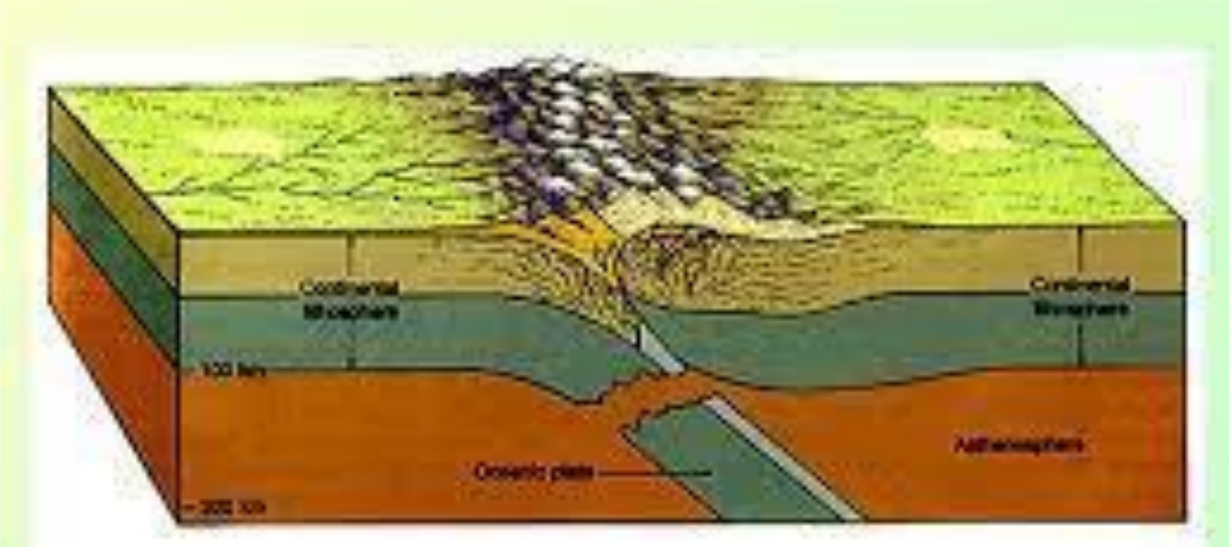
(K is the distance in Kilometers between points traced along existing leveling routes)

Precise Leveling – Applications

- **Bridge Load Testing**

Precise Leveling – Applications

- **Crustal Deformation (Land subsidence)**



THANK YOU

End of Presentation