Surveying-II

CE-205 (T)

Lecture 5
Geodetic Surveying

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Geodetic Surveying

- Geodetic or Trigonometrical surveying differs from plane surveying in that it takes into account the curvature of the earth, since very extensive areas and very large distances are involved.
- In work of this nature highly refined instruments and methods are used.
- Geodetic work is usually undertaken by state agency.
- Geodetic surveying involves two operations

  1)Triangulation 2) Precise Traversing

Geodetic Surveying

Object of Geodetic Surveying

- The object of geodetic surveying is to accurately determine the relative positions of a system of widely separated points on the surface of the earth, and also their absolute positions.
- The relative positions are determined in terms of the azimuths and lengths of the lines joining them.
- The absolute positions in terms of latitudes and longitudes and elevation above the mean sea level.
- In geodetic surveying distances are usually in m.
- The geodetic work so determined furnish the most precise control for a more detailed survey of the intervening country.

Geodetic Surveying

Methods employed in Geodetic Surveying

- The methods employed in geodetic surveying are

  1) Triangulation 2) Precise Traversing

- The Triangulation is the most accurate method and is invariably used (expensive),
- while the Precise Traversing is inferior and is mainly used in cases where triangulation is physically impossible or very expensive e.g densely wooded country or very flat country.

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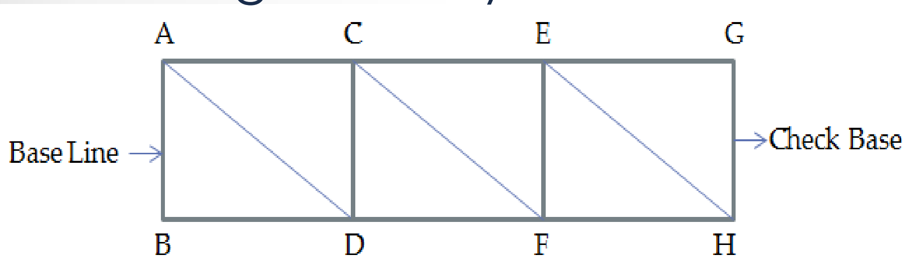
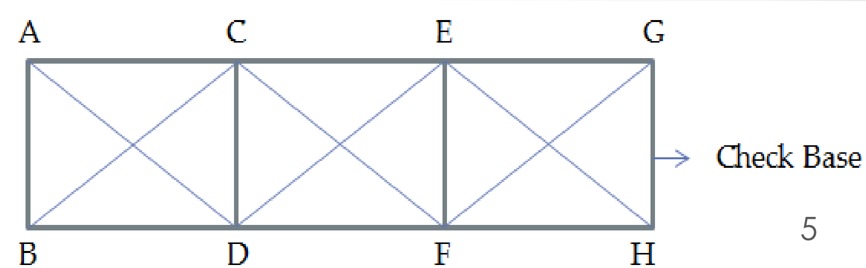
Triangulation

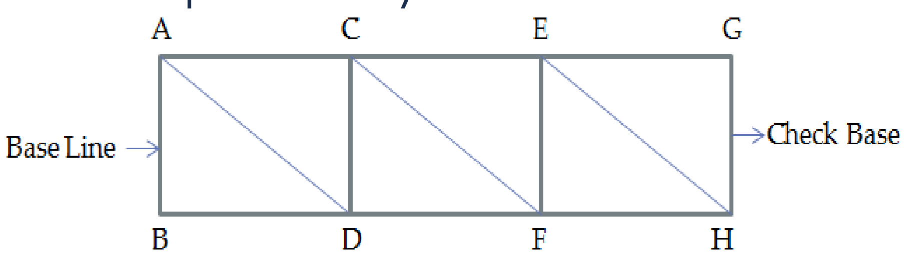
- Triangulation is based on the trignometical proposition that if one side and the three angles of a triangle be known, the remaining sides can be computed by the application of the sine rule.
- In this method suitable points called triangulation stations are selected and established throughout the area to be traversed.
- The station may be connected by a chain of triangles or chain of quadrilaterals.
- These stations form the vertices of a series of mutually connected triangles , the complete figures being called a Triangulation system

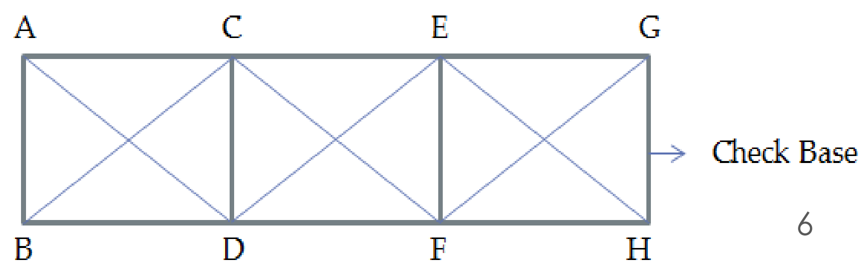




Geodetic Surveying
Triangulation

- In this system of triangles one line say AB and all the angles are measured with the greatest care and lengths of all the remaining lines in the system are then computed.
- For checking both the field work and computations another line such as GH is very accurately measured at the end of the system.
- The line whose lengths is actually measured is known as Base line or the base and that measured for checking purposed are called the check base.
- When the work is of large extent, intermediate check bases are introduced. The triangulation stations at which azimuth, latitude or longitude is directly determined by astronomical observations are called azimuth, latitude or longitude stations respectively.





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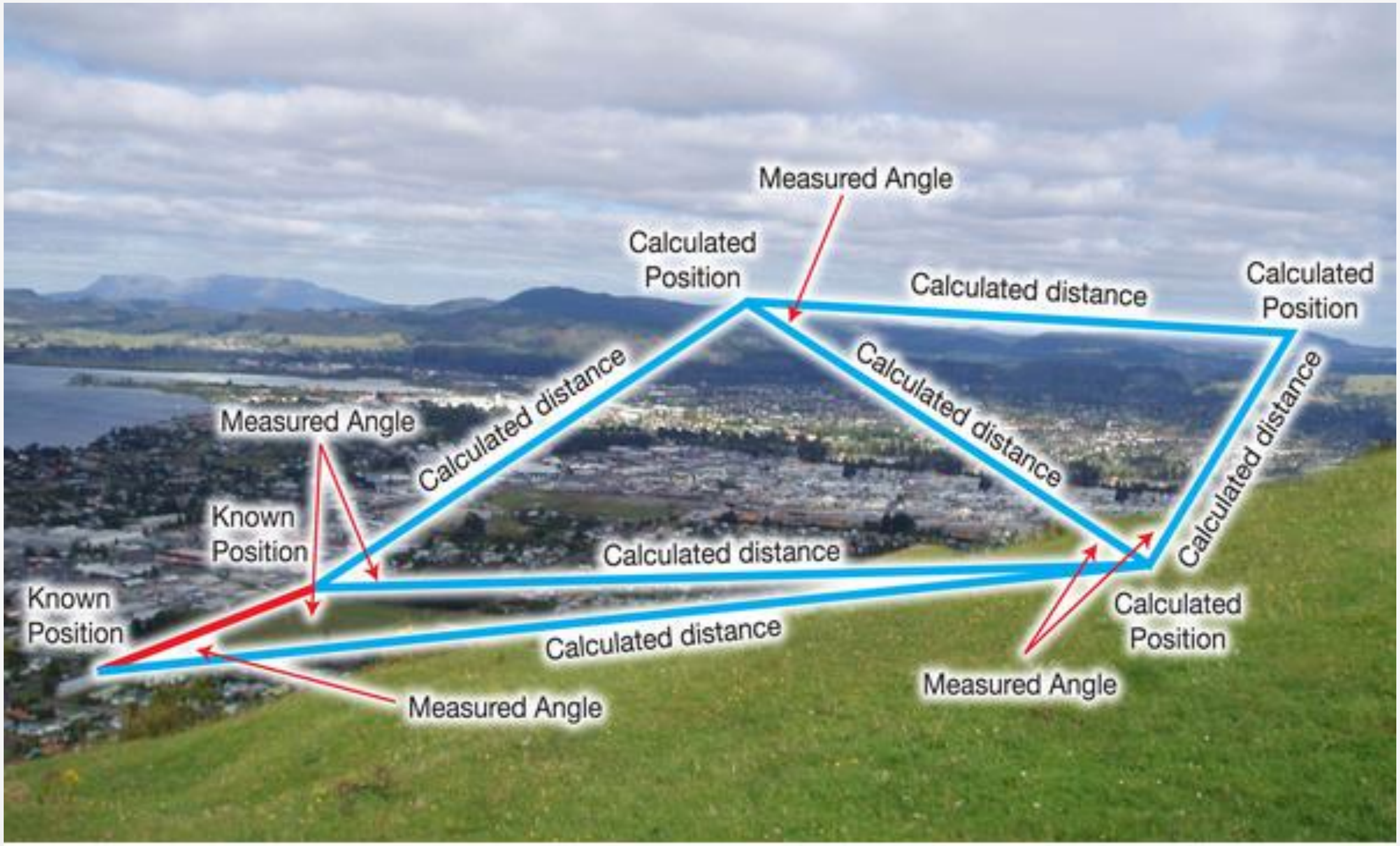
Triangulation



Triangulation Network

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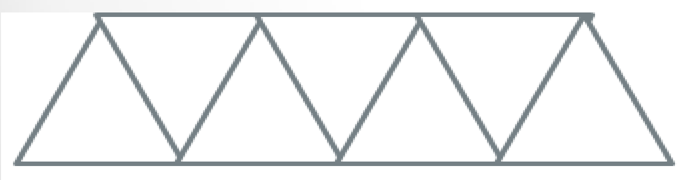
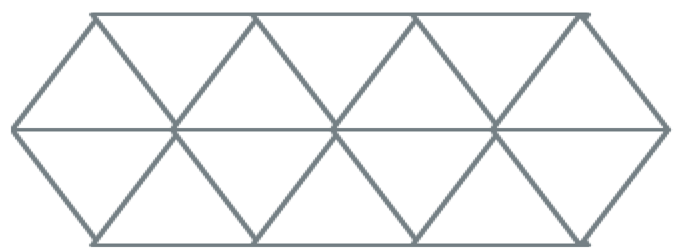
Triangulation Figures

- To minimize the effect of small errors in the measurement of angles the triangle should be well shaped or well proportion i.e. should not have angle less than 30^0 & nor greater than 120^0. The best shape of triangle is equilateral & best shape of quadrilateral is square.





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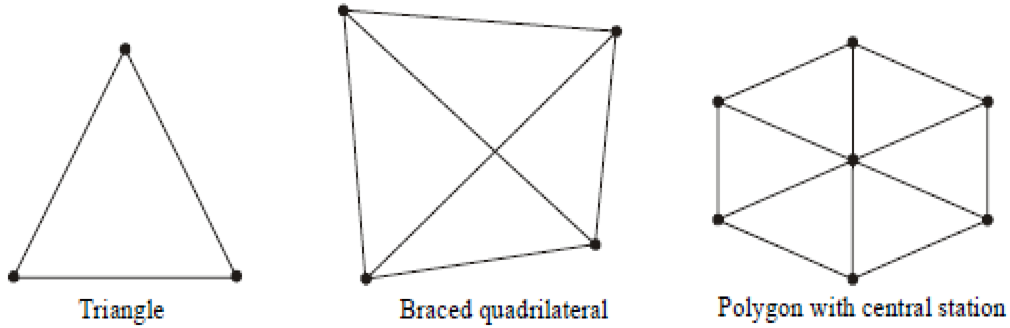
Triangulation Figures

- The basic figures used in triangulation networks are the triangle, braced or geodetic quadrilateral, and the polygon with a central station.



Basic triangulation figures

- The triangles in a triangulation system can be arranged in a number of ways. Some of the commonly used arrangements, also called layouts, are as follows :

    1. Single chain of triangles
    2. Double chain of triangles
    3. Braced quadrilaterals
    4. Centered triangles and polygons
    5. A combination of above systems.

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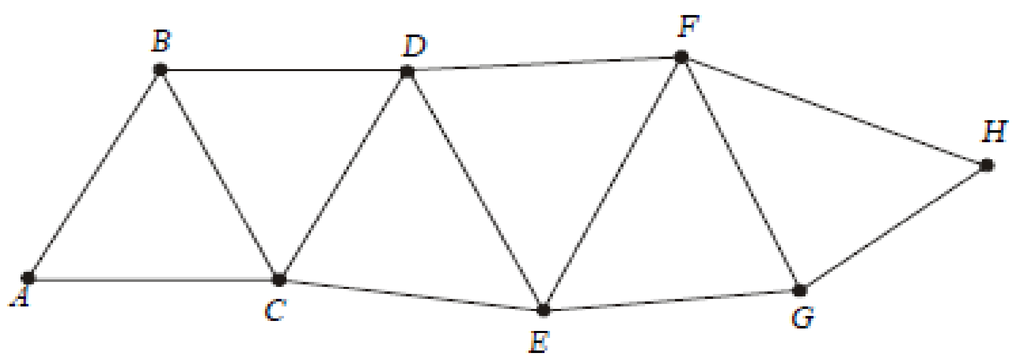
Triangulation Figures

Single chain of triangles

- When the control points are required to be established in a narrow strip of terrain such as a valley between ridges.
- This system is rapid and economical but does not involve observations of long diagonals.
- this system does not provide any check on the accuracy of observations.
- Check base lines and astronomical observations for azimuths have to be provided at frequent intervals to avoid excessive accumulation of errors in this layout.



Single chain oftriangles

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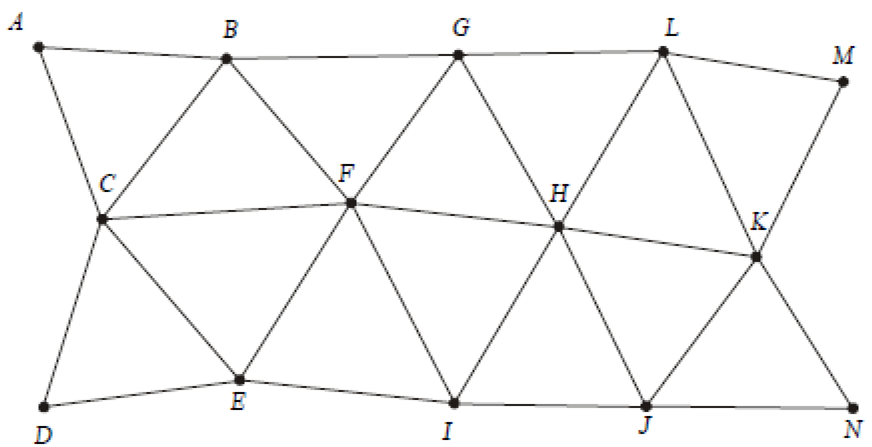
Triangulation Figures

Double chain of triangles

- A layout of double chain of triangles is shown in Fig. 1.5. This arrangement is used for covering the larger width of a belt.
- This system also has disadvantages of single chain of triangles system.



Double chain of triangles

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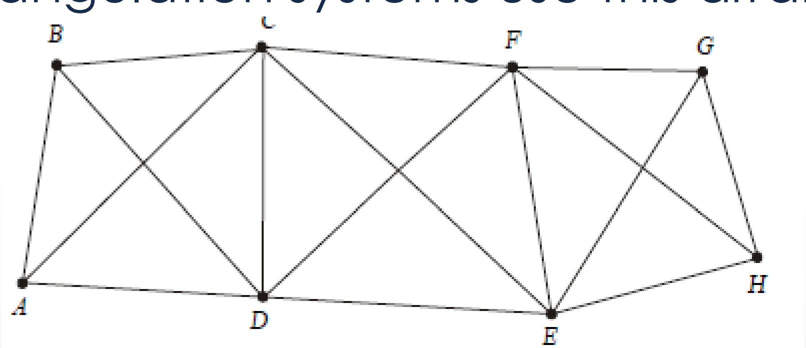
Triangulation Figures

Braced quadrilaterals

- A triangulation system consisting of figures containing four corner stations and observed diagonals shown in Fig, is known as a layout of braced quadrilaterals.
- In fact, braced quadrilateral consists of overlapping triangles.
- This system is treated to be the strongest and the best arrangement of triangles, and it provides a means of computing the lengths of the sides using different combinations of sides and angles.
- Most of the triangulation systems use this arrangement.



Braced quadrilaterals

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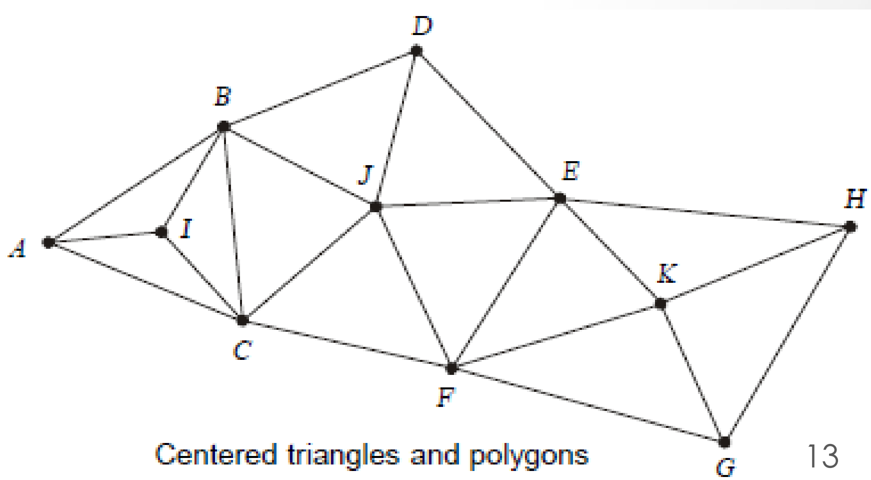
Triangulation Figures

Centered triangles and polygons

- This layout in a triangulation system is generally used when vast area in all directions is required to be covered.
- The centered figures generally are quadrilaterals, pentagons, or hexagons with central stations.
- Though this system provides checks on the accuracy of the work, generally it is not as strong as the braced quadrilateral arrangement. Moreover, the progress of work is quite slow due to the fact that more settings of the instrument are required.

A combination of all above systems

- Sometimes a combination of above systems may be used which may be according to the shape of the area and the accuracy requirements.



Centered triangles and polygons

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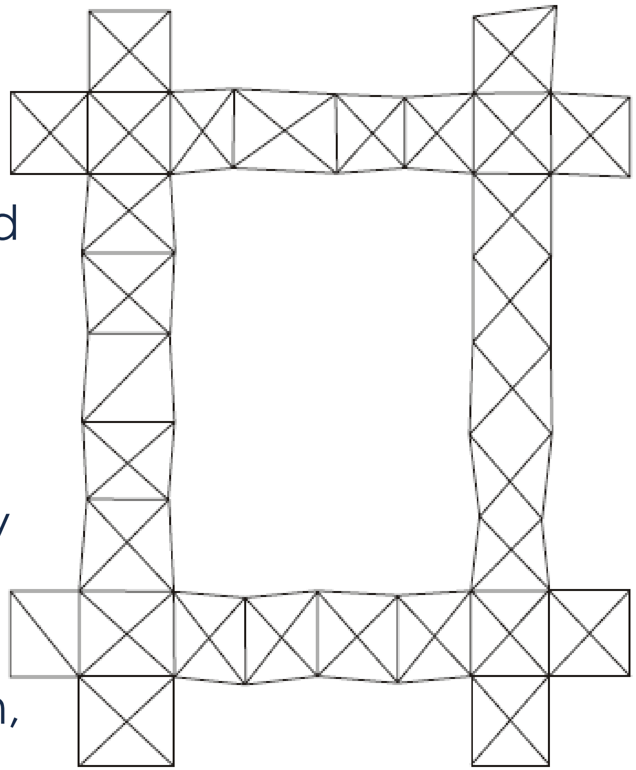
Layout of Primary Triangulation for Large Countries

The following two types of frameworks of primary triangulation are provided for a large country to cover the entire area.

1. Grid iron system
2. Central system.

Grid iron system

- In this system, the primary triangulation is laid in series of chains of triangles, which usually runs roughly along meridians (northsouth) and along perpendiculars to the meridians (east-west), throughout the country .
- The distance between two such chains may vary from 150 to 250 km.
- The area between the parallel and perpendicular series of primary triangulation, are filled by the secondary and tertiary triangulation systems.



Grid iron system of triangulation

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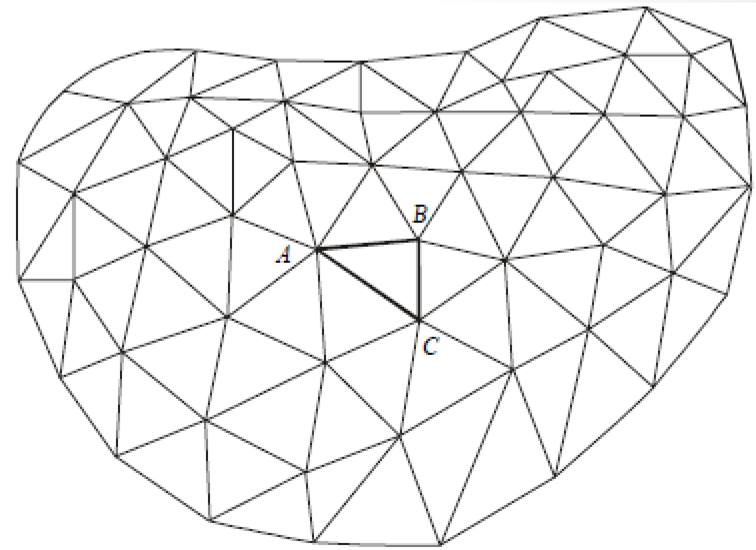
Layout of Primary Triangulation for Large Countries

Central system

- In this system, the whole area is covered by a network of primary triangulation extending in all directions from the initial triangulation figure ABC, which is generally laid at the centre of the country).
- This system is generally used for the survey of an area of moderate extent.



Central system of triangulation

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Classification of Triangulation System

It may be classified according to the

- Degree of accuracy required
- Magnitude of the work

a) Primary or 1st Order Triangulation

- In primary triangulation a very large areas (whole country) are covered & the highest possible accuracy is obtained.
- Well proportional triangles must refined, instrument & method of observation & computation are used.

  Average triangle closure = 1 sec

  Maximum triangle closure = 3 sec

  Length of the base line = 5 to 20 km

  Length of sides of triangle = 30 to 160 km

  Degree of accuracy =1 in 500,000

  Check on the base = 1 in 25,000

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Classification of Triangulation System

b) Secondary or 2nd Order Triangulation

- Within the primary triangles other points are fixed at closer interval so is to form a secondary series of triangles which are connected to the primary system at interval.
- Comparatively small triangles are used; the instrument & methods are not of the same refinement (accuracy)
- In this case

Average triangle closure = 3sec

Maximum triangle closure = 8 sec

Length of the base line = 2 to 6 km (1 to 3 miles)

Length of sides of triangle = 8 to 70 km (5 to 40 miles)

Degree of accuracy =1 in 50,000

Check on the base = 1 in 10,000

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Classification of Triangulation System

c) Tertiary or 3rd Order Triangulation

- Within the secondary triangles points are established in short intervals to obtain horizontal control for detail survey.

  Average triangle closure = 6 sec

  Maximum triangle closure = 12 sec

  Length of the base line = 1 to 3 km (1/2 to 3/2 miles)

  Length of sides of triangle = 1.5 to 10 km

  Degree of accuracy > 1 in 50,00

  Check on the base = 1 in 50,00

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Triangulation Work

The triangulation work is carried out in the following steps

1) Reconnaissance
2) Erections of towers
3) Measurement of horizontal angles
4) Astronomical observations necessary to determined the true meridian and the absolute positions of stations
5) Measurement of the base line
6) Computations including
    a) Adjustment of observed angles
    b) Computations of the lengths of the each triangles and
    c) Computations of the latitudes and longitudes of the stations.

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Triangulation Work

Reconnaissance:

It consists of

- Examination of the country to be surveyed.
- Selection of most favorable site for the base line.
- Selection of suitable position for triangulation stations.
- Determination of indivisibility of stations.

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Triangulation Work

Selection of Station:

The selection of station is based upon the following conditions:

- The stations should be clearly visible from each other. For this purpose the highest commanding position i.e. top of the hill or mountain is selected.
- They should form well shaped triangles.
- They should be easily accessible.
- They should be useful for detail survey.
- They should be so fixed that the length of sight is not too short or too long.
-

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Triangulation Work

Intervisibilty and Height of stations:

- For intervisibility of two stations, they should be fixed on highest available ground i.e. summit, mountain peak or top of the hill .
- When the distance between the two stations is greater or difference in elevation between them is small, it is necessary to raise both the instrument & the signal to overcome the curvature of the earth & to clear all the intervening obstruction.
- The height of both the instrument & signal above the ground depends upon

  A) Distance between the stations

  B) The relative elevation of the stations

  C) The profile of intervening ground

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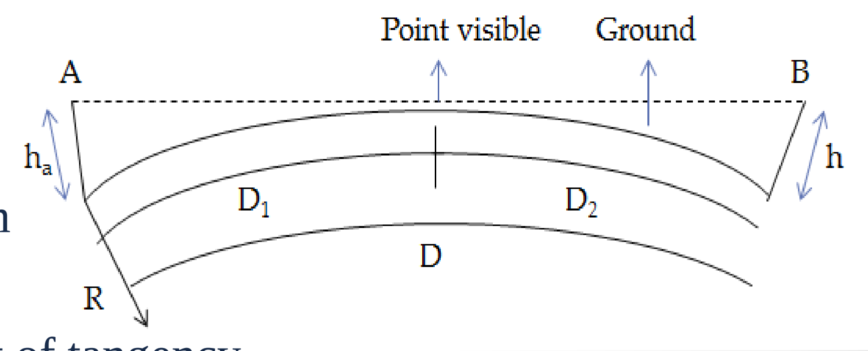
Triangulation Work

Intervisibilty and Height of stations:

a) Distance between the stations:

- If the intervening ground is free from any obstructions, the distance of the visible horizon from the station of known elevation above datum as well as elevation of signal which may be just visible at a given distance can be determine from the formula.



$$ha = (1 - 2m)\frac{D_1^2}{2R}$$

Where ha = height of the station above datum

D = distance between A and B

D1= distance from station to the point of tangency

R = mean radius of the earth

m = coefficient of refraction (0.07 for sights over land and 0.08 over water)

$ha = 0.0673\ D_1^2$, h in m and D_1 in km

$ha = 0.574\ D_1^2$ h in ft and D_1 in miles

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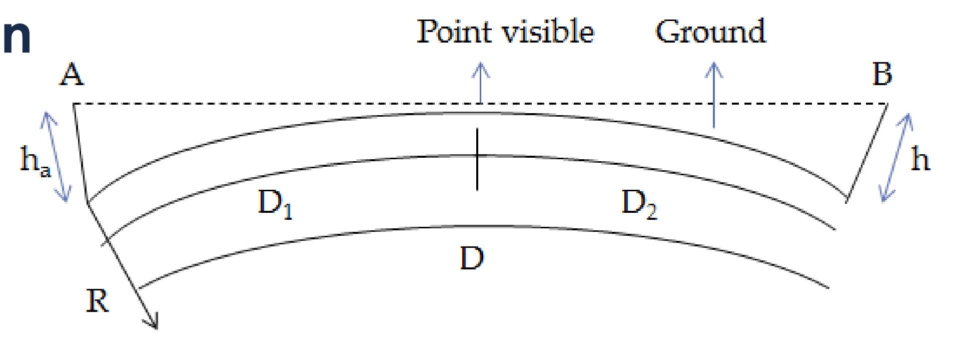
Triangulation Work

Intervisibilty and Height of stations:

b) Relative elevation of the station



A and B two stations.

D = distance in km between A and B

h_A = required elevation of A above datum

h = required elevation at B above datum

D_1 = distance in km from A to point P of tangency

D_2 = distance in km from B to the point P of tangency

Distance D_1 may be calculated from $h = 0.0673\ D^2$

$$\mathbf{h_A = 0.0673\ D_1^2} \quad \text{0r} \quad \mathbf{D_1 = \sqrt{\frac{h_A}{0.0673}}}$$

Now $\mathbf{D_2 = D - D_1}$ so

Required elevation = $\mathbf{h = 0.0673\ D_2^2}$

- The line of the right should not be near the surface of ground at point of tangency (P) on account of disturbed air strata & should be kept at least 2m above the ground , preferably 3m & this allowance (clearance) should be made in determining the height of the stations.

Geodetic Surveying

Triangulation Work

Intervisibilty and Height of stations:

c) Profile of intervening ground

- If the peak in the inrervening ground are likely to obstruct the line of sight, their elevation & location must be determined.
- The elevation of the line of sight at the respected points may they computed & the result compared with the ground elevation at those points to determine whether the line of sight clear all the intervening obstructions.

Geodetic Surveying

Problem 01:

Two triangulation stations A and B, 30 miles apart have elevation 810 feet and 860 feet respectively. The intervening ground may be assumed to have uniform elevation of 720 feet. Find the minimum height of signal required at B so that the line of signal may not pass nearer the ground than 8 feet.

Solution:

Min elevation of line of sight = 780 + 8 = 728 feet

Thus elevation is taken as datum

Elevation of A = h_1 = 810 – 728 = 82 feet

Tangent distance D_1 corresponding to h may be calculated as

h_1(feet) = 0.574 D_1^2 (miles)

$D_1 = \sqrt{\frac{h_1}{0.574}} = \sqrt{\frac{82}{0.574}} = 11.95$ miles

$D = D_1 + D_2$

$30 = 11.95 + D_2$

$D_2 = 18.05$ miles

$h_2 = 0.574\, D_2^2 = 0.574\, (18.05)^2 = 187.01$ feet

Geodetic Surveying

Triangulation Work

Intervisibilty and Height of stations:

- **Example** Two stations *A* and *B*, 80 km apart, have elevations 15 m and 270 m above mean sea level, respectively. Calculate the minimum height of the signal at *B*.

Solution:

It is given that

$$h_A = 15\,\text{m}$$

$$h_B = 270\,\text{m}$$

$$D = 80\,\text{km}$$

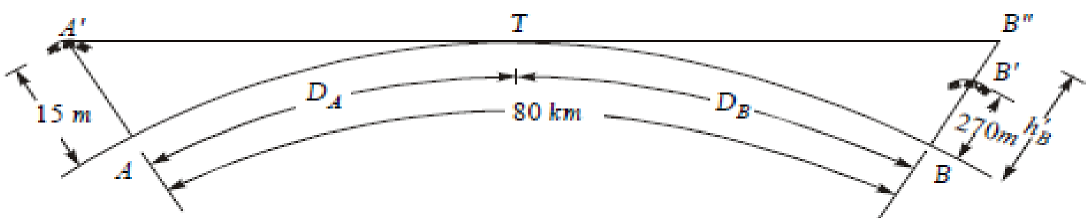


Fig.

$$D_A = 3.853\sqrt{h_A} = 3.853 \times \sqrt{15} = 14.92\,\text{km}$$

We have

$$D_B = D - D_A$$

or

$$= 80 - 14.92$$

$$= 65.08\,\text{km}$$

Therefore

$$h'_B = 0.06735\,D_B^2$$

$$= 0.06735 \times 65.08^2 = 285.25\,\text{m}$$

Hence, since the elevation of *B* is 270 m, the height of signal required at *B*, is

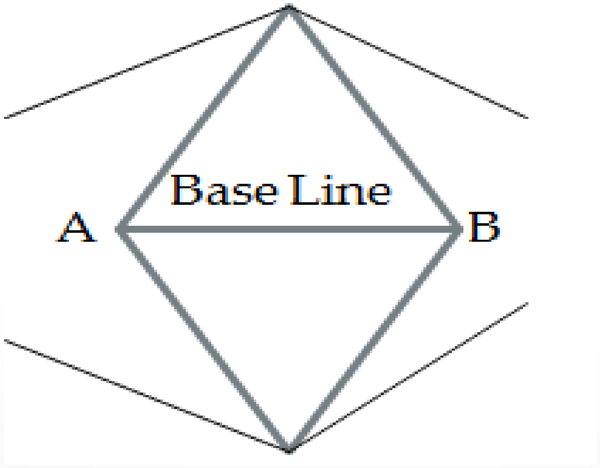
$$= 285.25 - 270 = 15.25 \simeq \mathbf{15.5\,m}.$$

Geodetic Surveying

Base Line

Base Line Measurement:

- In triangulation the base line is of prime importance.
- It should be measured very accurately since the accuracy of the computed sides of the triangulation systems depends on it.
- The length of the base line varies from the fraction of a 1.5 to 10 km according to the grade of triangulation.
- It generally lye between $\frac{1}{3}$ & $\frac{2}{3}$ of the length of the average sides of the triangulation systems.



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Base Line

Base Line Sites:

In selecting the site for the base line , the following requirement should be considered:

- The site should be fairly level or uniformly
- The site Should be free from obstructions through out the entire length.
- The ground should be firm & smooth.
- The site should be such that the whole length can be laid out, the extremity of the line being intervisible at the ground level.
- The site should be such that well shaped triangles can be obtained in connecting the end stations of the base to the main triangulation stations..

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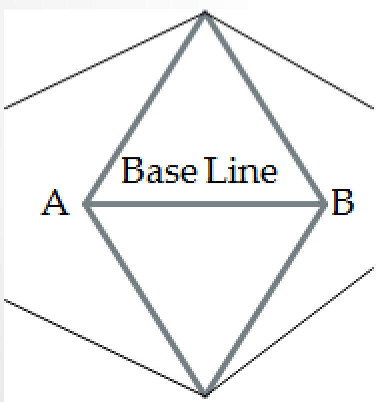
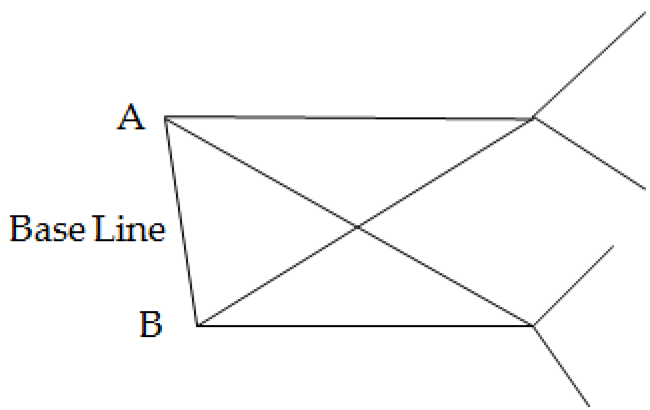
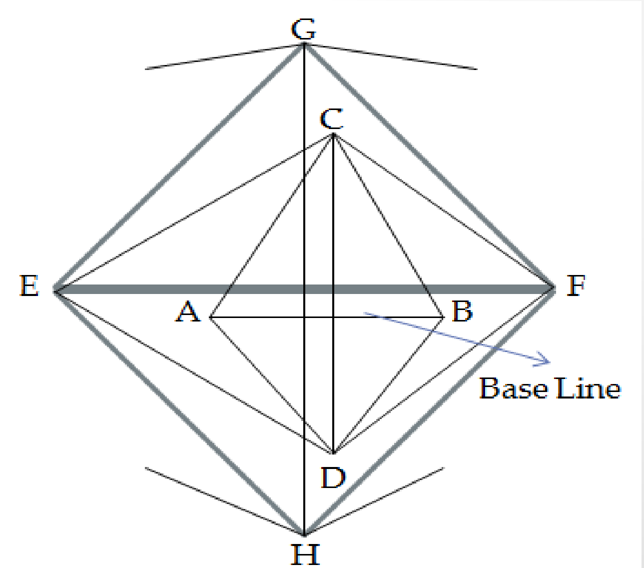
Base Line

Base Net:

- A series of triangles connecting a base line to the main triangulation is called base net.
- The base line should be expanded gradually by triangulation as shown in the following figures







Geodetic Surveying

Base Line

Equipment for Base Line Measurement:

It consists of

- Tapes
- Straining device
- Spring balance or weight or pulley.
- Thermometer & finely divided scale.
- Marking tripod or stake.
- Supporting tripod or stake.

Geodetic Surveying

Base Line

Field Work:

The survey personnel consists of

1) A setting out party.
2) A measuring party.

- The setting out party places the tripod or stakes in advance of measurement at correct intervals,
- While actual measurement of the line (base line) is done by the measuring party.
- Base line is divided into section of 0.8km to 1.2km [1/2 to ¾ mile in length]
  Marking Stakes = 10cm x 10cm (4 in x 4 in)
  Supporting Stakes = 2.5 cm x 5cm (1in x 2in)
- Another method of measuring the base is to measure the distance between the fine marks on two successive tripods.

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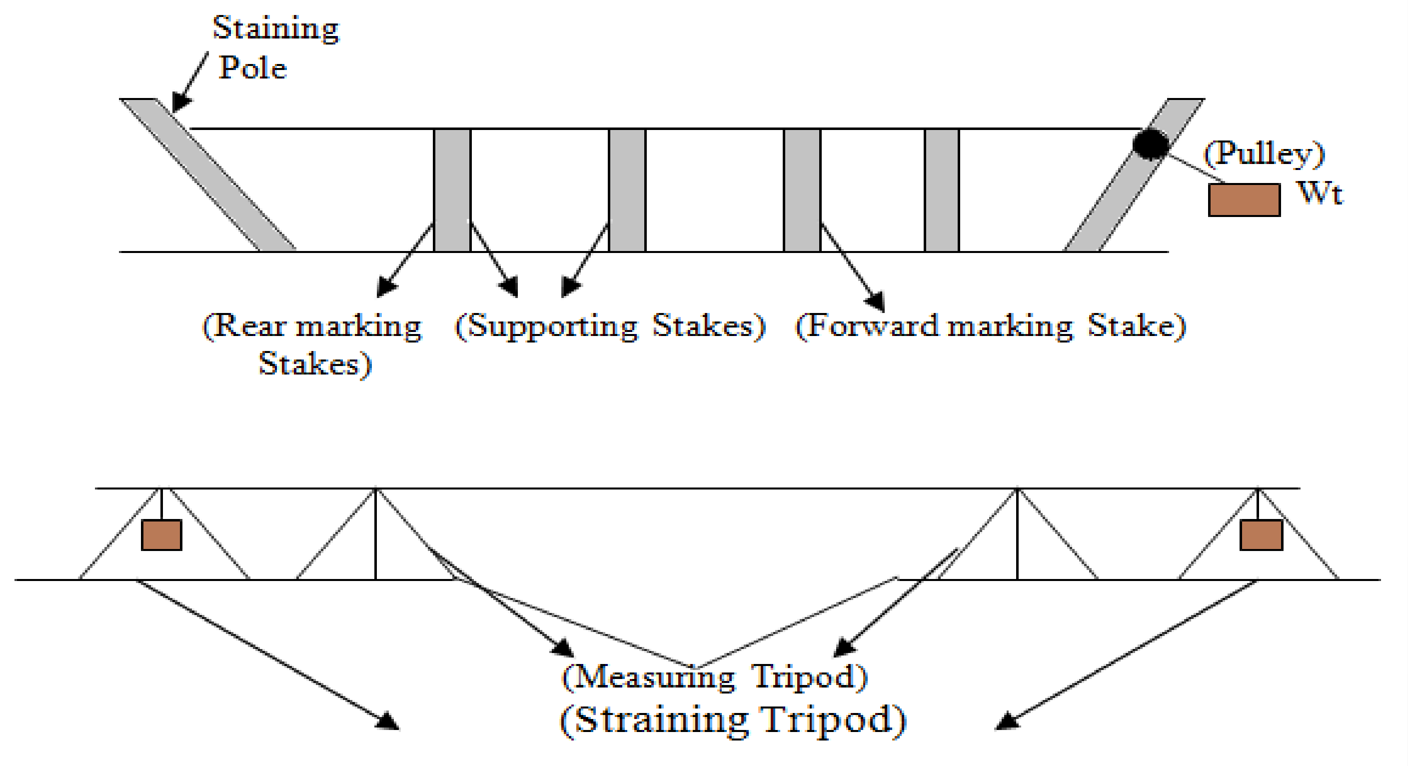
Base Line

Field Work:



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Base Line

Correction to Base Line:

It is necessary to apply the following corrections to the field measurements of base line order its true length:

1) Correction for absolute length
2) Correction for temperature
3) Correction of tension or pull
4) Correction for Sag
5) Correction for slope of vertical alignment
6) Correction for horizontal alignment
7) Reduction to sea level

It may be noted that each section of a base line is separately corrected.

Geodetic Surveying

Base Line

Correction to Base Line:

1) Correction for absolute length:

- It is the usual practice to express the absolute length of a base measuring unit as its nominal or designated length plus or minus a correction.
- The correction is given by the formula

$$C_A = \frac{L\,c}{l}$$

Where C_A = Correction for absolute length

L = measured length of base

l = Nominal length of measuring unit

c = Correction to measuring unit

Sign of C_A is the same as that of c

Nominal length: The designated length i.e 50 tape, 100 tape (30 m tape)

Absolute length: The actual length under specified conditions

Geodetic Surveying

Base Line

Correction to Base Line:

2) Correction for temperature:

- It is necessary to apply the correction since the length of a tape is increased as its temperature is raised, and consequently the measured distance is too small.
- It is given by the formula

$$C_t = \alpha\,(T_m - To)\,L \qquad \text{(+ve or-ve)}$$

Where

C_t = Correction for temperature

α = co-efficient of thermal expansion

T_m = Mean Temperature during measurement

T_o = Temp at which the measuring unit is standardized

α for Steel = 0.0000099-0.000012 / ^{o}C

Steel = 0.0000055 – 0.0000070 / ^{o}F

The sign of 'C_t' is plus or minus according to as 'T_m' is greater or less then 'T_o'

Geodetic Surveying

Base Line

Correction to Base Line:

3) Correction of tension or pull :

- The correction is necessary when the pull used during measurement is different from that at which the tape or wire is standardized.
- It is given by $$C_p = \frac{(P - Po)\,L}{A\,E} \quad (+ve)$$

Where

C_P = Correction for pull (m)
P = Pull applied during measurement (kg)
P_o = Pull at which the measurement unit (tape) is standardized (kg)
L = length measured (m)
A = Cross-Sectional area of measuring unit (cm^2)
E = Modulus of elasticity of measuring unit

$E_{steel} = 21 \times 10^5\ kg/cm^2$

$E_{steel} = 30 \times 10^6\ lbs/in^2$

- The sign of this correction is always plus (T) as the effect of pull is to increase the length of the tape and consequently to decrease the measured length of the base

Geodetic Surveying

Base Line

Correction to Base Line:

4) Correction for Sag:

- Correction for sag is the deference in length between the arc and its chord i.e between the curved length of the laps and the distance between the supports.
- It is required only when the tape is suspended during measurement.
- Since the effect of sag is to make the measured length too large, it is always subtractive.
- It is given by the formula.

$$C_s = \frac{l_1 (w\, l_1)^2}{24\, P^2} = \frac{(w^2 l_1{}^3)}{24\, P^2} = \frac{(W^2 l_1)}{24\, P^2} (\text{ - ve})$$

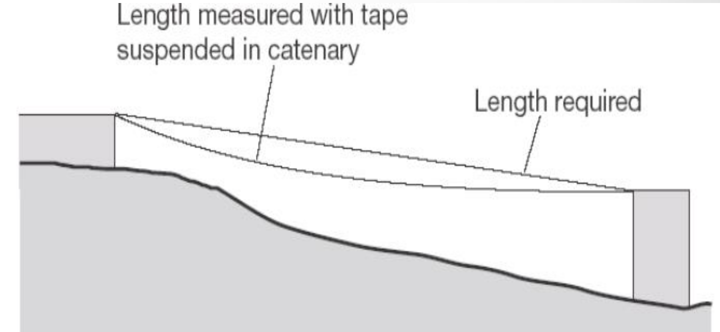
Where C_s = Correction for Sag (m)

l_1 = Distance between supports (m)

w = weight of tape per unit length (kg/m)

W = Total weight of tape (kg)

P = applied pull (kg)



Geodetic Surveying

Base Line

Correction to Base Line:

4) Correction for Sag:

- If there are 'n' equal space per tape length i.e $l = nl_1$

The sag correction per unit length is given by :

$$C_s = \frac{nl_1 (w\, l_1)^2}{24\ P^2}$$

$$C_s = \frac{l(w\, l_1)^2}{24\ P^2}$$

$$C_s = \frac{l\ (wl)^2}{24\ n^2\ P^2}$$

l = length of the tape

Total sag correction to measured length **L**:

Total sag correction = N x sag correction per tape length + sag correction for any tape length

Where N = no of whole tape length

Geodetic Surveying

Base Line

Correction to Base Line:

5) Normal tension:

- The normal tension of a tape is a tension which will cause the effects of pull and sag to neutralize each other.
- The corrections for pull and sag being of opposite sign, the elongation due to increase in tension is exactly counter by the shortening due to sag.
- It may be obtained by equating the corrections for pull and sag.

$$\frac{(W^2 L)}{24\, pn2} = \frac{(P_n - Po)\, L}{A\, E}$$

$$P_n = \frac{0.204\, W \sqrt{A\, E}}{\sqrt{p_n - po}}$$

Where Pn = normal tension

W = weight of tape between supports

P_n is determine by trial method.

Geodetic Surveying

Base Line

Correction to Base Line:

6) Correction for Slope or Vertical Alignment

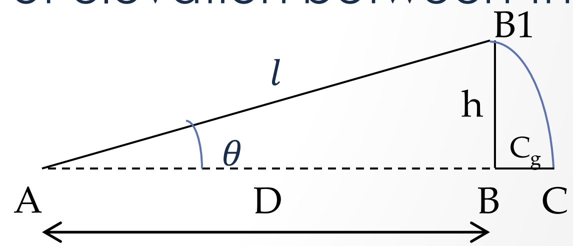
This corrections required when the points of support are not exactly at the same level

Let $l_1, l_2, l_3 \ldots$ = successive length of uniform grades

$h_1, h_2, h_3 \ldots$ =difference of elevation between thee extremities of each these grades

C_g = total correction for slope

l = length of any one grade and h is difference of elevation between the ends of the grade

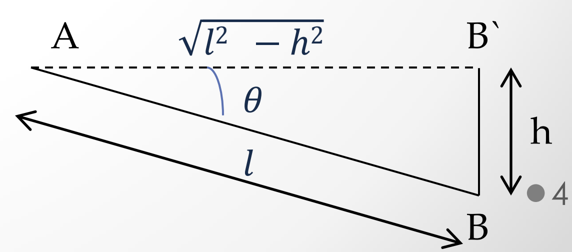


Slope correction = BC =AC - AB = $l - D$

Slope correction = $l - \sqrt{l^2 - h^2}$

Slope correction = l - $\sqrt{l^2 - h^2}$

Slope correction = $l - l\sqrt{1 - \frac{h^2}{2l^2} - \frac{h^4}{8l^4} - \ldots}$

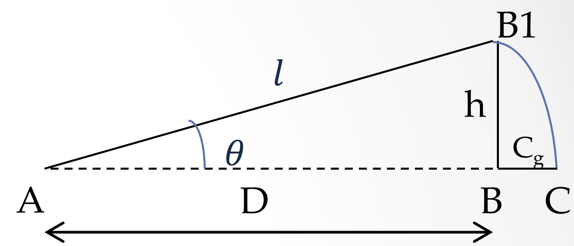


Geodetic Surveying

Base Line

Correction to Base Line:

6) Correction for Slope or Vertical Alignment



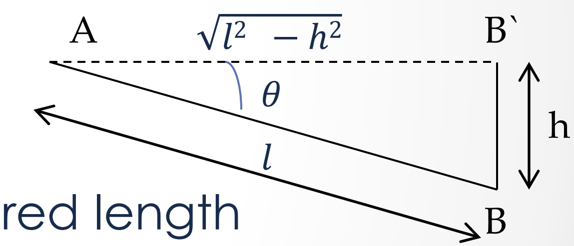
Slope correction $= \; = \frac{h^2}{2l} + \frac{h^4}{8l^3} + \ldots = \frac{h^2}{2l}$ (-ve)

Where $C_g = \frac{h_1{}^2}{2l_1} + \frac{h_2{}^4}{8l_2{}^3} + \ldots + \frac{h_n{}^2}{2ln}$ (-ve)

When the grade are of uniform length l , we have

$C_g = \frac{1}{2\,l}\,(h_1{}^2 + h_2{}^2 + \ldots. + h_n{}^2\,)$

$C_g = \frac{\sum h^2}{2\,l}$ (-ve)



This correction is always subtractive from the measured length

If the grades are given in terms of vertical angle (plus or minus angle), the following formula may be used.

Correction for slope, $C_g = l - D$

$C_g = l - l\cos\theta$

$C_g = \; l\,(1 - \cos\theta)$

$C_g = 2\,l\,\sin^2\frac{\theta}{2}$ (-ve)

$\cos\theta = \frac{D}{l}$

l = length of section

θ =grade (angle of slope) of section

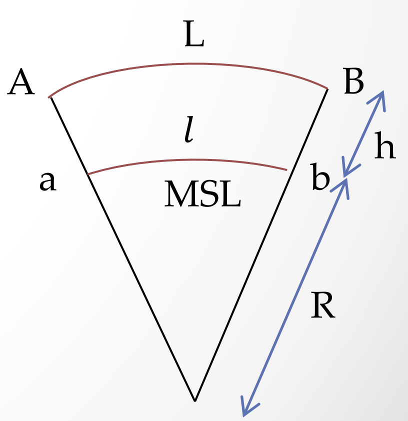
Geodetic Surveying
Base Line

Correction to Base Line:

7) Reduction to mean sea level

- In geodetic work all the horizontal distance are reduced to their equivalent distance at mean sea level called geodetic distance .
- If the length of the base be reduced to its equivalent length at mean sea level, the computed length of all others lines of triangulation system will correspond to this level. The mean elevation of the base must therefore be determined.
- This correction is required for comparison of various bases.

$$C_{msl} = \frac{L\,h}{R}\;(-ve)$$



Where,

C_{msl} = correction to length L

L = measured length of the base

h = average height of the base above mean sea level

R = mean radius of earth

Geodetic Surveying

Problem 01:

A tape 30m long of standard length a 29°C was used to measure a line the mean temp during measurement was 15°C, the measured distance was 221.65 m, the following being the slopes:

1°10' for 60 m,

2°20' for 30m

5°18' for 30 m,

4°40' for 12 m

1°30' for 30 m

3°48' for 30m

7°20' for 18m

1°20' for 11.65 m

Find the true length of the line if the coefficient of expansion is 116×10^{-7} per 1°C .

Geodetic Surveying

Problem 01:Solution:

1) Correction for Temperature:

$$C_t = \alpha\,(T_m - To)\,L$$

$$C_t = 116 \text{ x } 10^{-7} \text{ x } 221.65 \text{ x } (15 - 29) = -0.036$$

$$C_t = 0.036 \text{ m (-ve)},$$

Mean temp became less as compared to standard at the time of measurement therefore it will contract, will show more reading

2) Correction for Slope:

$$Cg = l\,(1 - \cos\theta)\ (\text{-ve})$$

C_{g1}, for 60 m = 60 (1 - cos 1°10') = 0.012 m

C_{g2}, for 30 m = 30 (1 - cos 2°20') = 0.025 m

C_{g3}, for 30 m = 30 (1 - cos 5°18') = 0.128 m

C_{g4}, for 12 m = 12 (1 - cos 4°40') = 0.039 m

C_{g5}, for 30 m = 30 (1 - cos 1°30') = 0.01 m

C_{g6}, for 30 m = 30 (1 - cos 3°48') = 0.066 m

C_{g7}, for 18 m = 18 (1 - cos 7°20' ') = 0.147 m

C_{g8}, for 11.65 m = 11.65 (1 - cos 1°20')= 0.003 m

Total = 0.43

True length = 221.65 – 0.036 – 0.43
=221.184 m

Geodetic Surveying

Problem 02

A Steel tape 30 m long, standardized at 10°C with a pull of 10 kg was used for measuring a base line. Find the correction per tape length, if the temperature at the time of measurement was 20°C, and pull applied was 15 kg. Weight of 1 cm^3 of steel = 8 grams, Weight of tape = 600 grams

E = 21 x 10^5 kg /cm^2 , Coeff. Of expansion of tape per 1°C = 12 x 10^{-5}

Solution:

1) **Correction for pull :**

$$\mathbf{C_p} = \frac{\mathbf{(P - Po)\ L}}{\mathbf{A\ E}} \quad (+\text{ve})$$

$P = 15$ kg , Po=10kg, $L = 30$m

$W = AL \times \gamma$

$600 = A \times 30(m) \times 8\ gram/cm3$

If A is the area of cross section of tape in cm^2

$$A \times (30 \times 100\ (cm)) \times 8 \frac{gram}{cm^3} = 600\ gram$$

$A = 0.025\ cm^2$

$$\mathbf{C_p} = \frac{\mathbf{(P - Po)\ L}}{\mathbf{A\ E}} = \frac{(15 - 10)\ 30}{0.025 \times 21 \times 105} = 0.0029\ m(+\text{ve})$$

Geodetic Surveying

Problem 02: Solution:

2) Correction for temperature :

$C_t = \alpha (T_m - To) L$

$C_t = 12 \times 10^{-6} (20^o - 10^o) \times 30 = 0.0036$ m (+ve)

3) Correction for sag:

$C_s = \frac{(W^2 L)}{24 P^2} = \frac{30\ x (0.6)^2}{24\ x\ 152} = 0.002$ m (-ve)

Total Correction to be applied = 0.0029 + 0.0036 – 0.002 = 0.0015 m (+ve)

Example 2, and 4, page 386, 387

Geodetic Surveying

Base Line

Extension of base line

- Usually the length of the base lines is much shorter than the average length of the sides of the triangles.
- This is mainly due to the following reasons:

  (a) It is often not possible to get a suitable site for a longer base.

  (b) Measurement of a long base line is difficult and expensive.

- The extension of short base is done through forming a base net consisting of well-conditioned triangles.

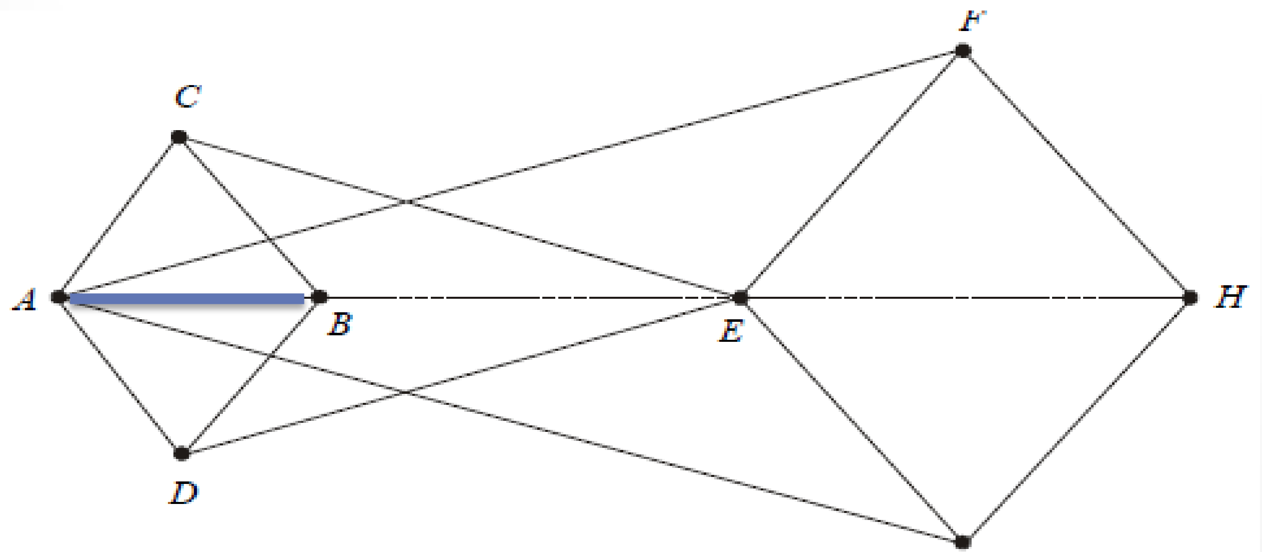
Geodetic Surveying

Base Line

- There are two ways of connecting the selected base to the triangulation stations. There are
  - (a) extension by prolongation, and
  - (b) extension by double sighting.

(a) Extension by prolongation

- Let up suppose that AB is a short base line which is required to be extended .



Base extension by prolongation

Geodetic Surveying

Base Line

(a) Extension by prolongation

- The following steps are involved to extend AB.

(i) Select C and D two points on either side of AB such that the triangles BAC and BAD are wellconditioned.

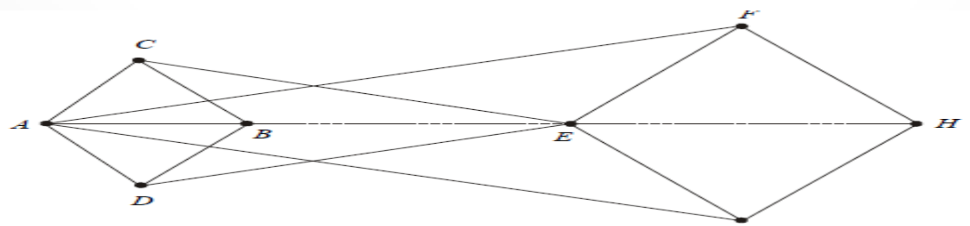
(ii) Set up the theodolite over the station A, and prolong the line AB accurately to a point E which is visible from points C and D, ensuring that triangles AEC and AED are well-conditioned.

(iii) In triangle ABC, side AB is measured. The length of AC and AD are computed using the measured angles of the triangles ABC and ABD, respectively.

(iv) The length of AE is calculated using the measured angles of triangles ACE and ADE, and taking mean value.

(v) Length of BE is also computed in similar manner using the measured angles of the triangles BEC and BDE. The sum of lengths of AB and BE should agree with the length of AE obtained in step (iv).

(vi) If found necessary, the base can be extended to H in the similar way.



Base extension by prolongation

Geodetic Surveying

Base Line

(b) Extension by double sighting

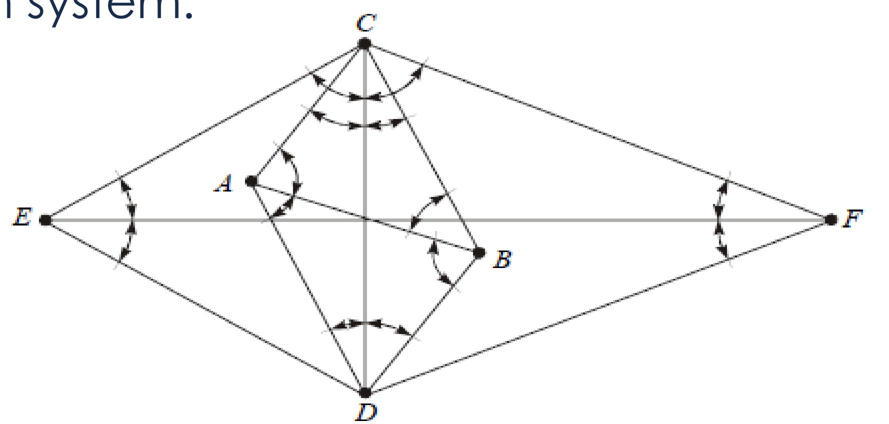
- Let AB be the base line .To extend the base to the length of side EF, following steps are involved.

(i) Chose intervisible points C, D, E, and F.

(ii) Measure all the angles marked in triangles ABC and ABD

(iii) Calculate the length of CD from these angles and the measured length AB, by applying the sine law to triangles ACB and ADB first, and then to triangles ADC and BDC.

(iv) The new base line CD can be further extended to the length EF following the same procedure as above. The line EF may from a side of the triangulation system.



Base extension by double sighting

Geodetic Surveying

Application of Triangulation

- The establishment of accurately located central point for survey of large areas.
- The accurate location of engineering works such as
    - a) central lines, horizontal points and shaft for large tunnels
    - b) central lines and abutments for bridges of large span
    - c) complex highway interchanges
- The establishment of accurately located central points in connection with aerial surveys.
- Measurement of deformation of structures such as dams.

Geodetic Surveying

Trilateration

- A trilateration system also consists of a series of joined or overlapping triangles. However, for trilateration the lengths of all the sides of the triangle are measured and few directions or angles are measured to establish azimuth.
- Trilateration has become feasible with the development of electronic distance measuring (EDM)equipment which has made possible the measurement of all lengths with high order of accuracy under almost all field conditions.
- A combined triangulation and trilateration system consists of a network of triangles in which all the angles and all the lengths are measured. Such a combined system represents the strongest network for creating horizontal control.
- Since a triangulation or trilateration system covers very large area, the curvature of the earth has to be taken into account. These surveys are, therefore, invariably geodetic.
- Field procedures for the establishment of trilateration station are similar to the procedures used for triangulation.

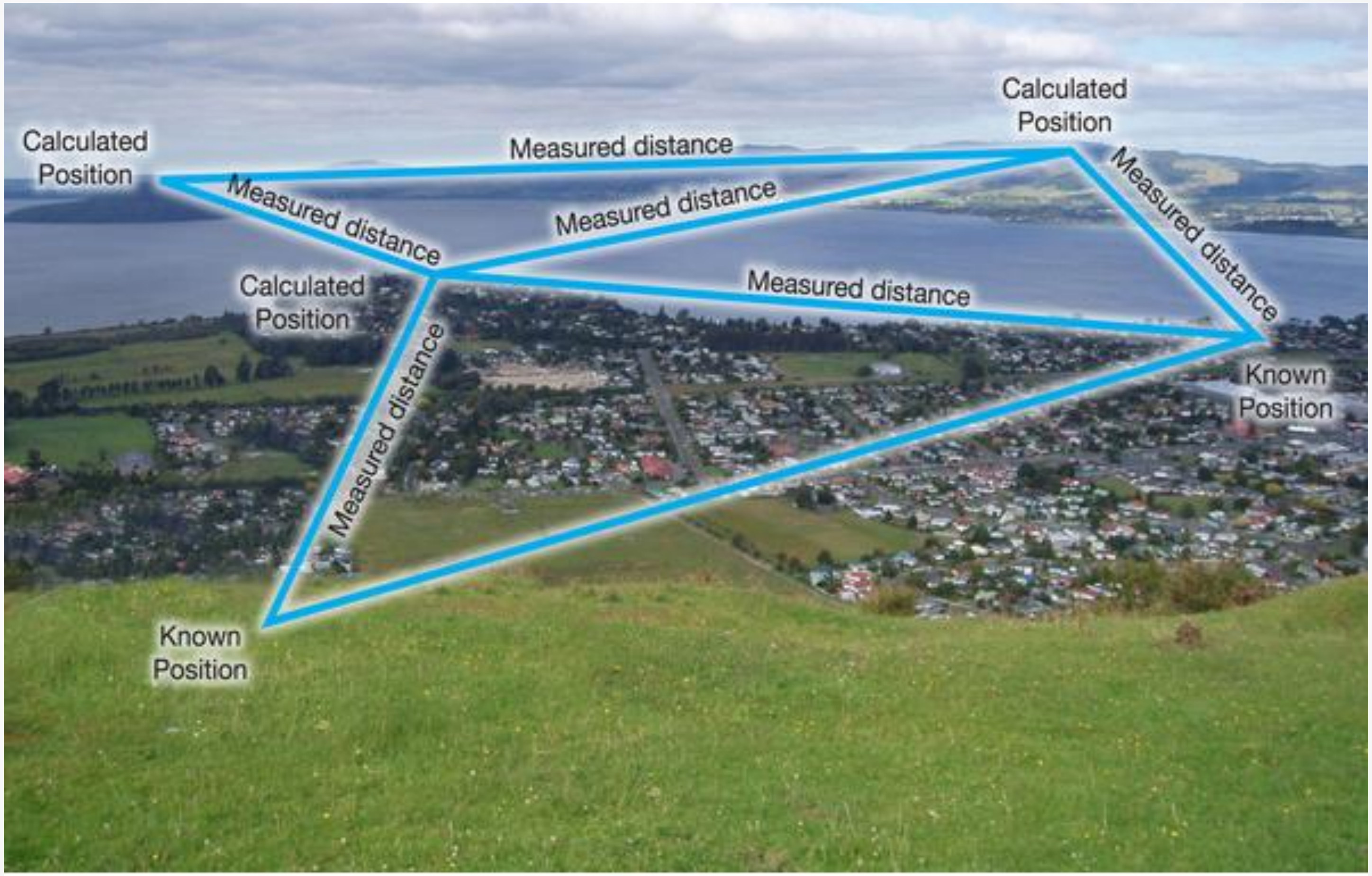
Geodetic Surveying

Trilateration

- In the 1950s, accurate methods of measuring long distances (typically 30 to 50 km) were developed. They used the known speed of light (299,792.458 km per second) and the timed reflection of a microwave or light wave along the measured line. Known as Electromagnetic Distance Measurement (EDM),
- The distances in a triangle could then be measured directly instead of calculating them from the observed angles. If needed the angles could be calculated. The process of calculating positions through the chain of triangles is then the same as for triangulation.
- Sometimes both angles and distances were measured in some triangles to check on the observations and improve the accuracy of the calculations

Geodetic Surveying

Trilateration



Trilateration Network

Geodetic Surveying

Assignment

Triangulation Work

Field wok for Base Line Measurement

Example 2, and 4, page 386, 387