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Engineering Surveying
Theory 4: Errors and Corrections

Errors and Corrections

Errors in Surveying:

Error is generally defined as the deviation of the measured value from the “exact” value of a quantity. The study of errors is important in surveying as it helps the surveyor understand the sources and exercise the necessary care and apply correction to minimize their effect so that an acceptable accuracy is achieved.

Error sources

Generally the errors in surveying measurements are classified as:

a. Personal: the error that occurs **due to lack of perfection in the surveyor’s** sense of sight, touch, hearing etc. during survey activity. Also mistakes due to **carelessness or fatigue of the surveyor** are classed under this category. This type of error can be minimized with care and vigilance by the part of the surveyor.

Errors and Corrections

b. Instrumental: it is the error type that occurs due to imperfection of the instruments in manufacture and during adjustments and due to wear and tear by usage. Also included are mistakes due to failure or damage of the instrument. This type of error can be minimized with careful handling, maintenance and adjustment and calibration of instruments and by applying corrections.

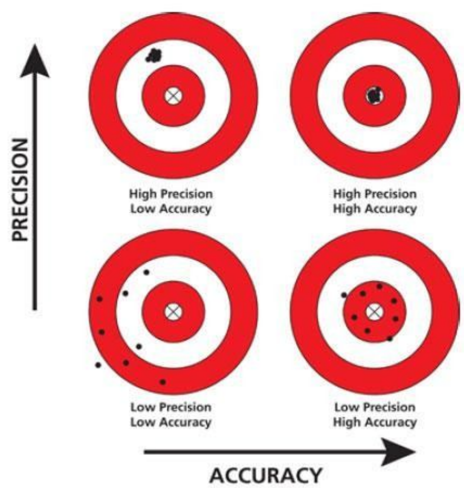
c. Natural: included these errors due to effect of temperature, pressure, humidity, magnetic variation, wind etc. this type of error can be minimized by applying correction and by carrying out the survey when their effect is minimal.

Errors and Corrections

Accuracy and Precision:

Why Measurements ≠ True value?
Because all the measurements include errors (i.e. technique error, instrument error, man mistake, etc.)

- **Real value:** standard or reference of known value or a theoretical value
- **Accuracy:** how close we are to the real value
- **Precise:** agreement of our measurements for multiple trials



Errors and Corrections

Accuracy = Estimated (measured) Value – Real Value

Precision = Shows the repeatability of the measurements – Indicates the spread of the measurements

- Expressed by standard deviation >>> $SD = \sqrt{\frac{\sum (x - \bar{x})^2}{n}}$

Where: x = individual measurement
$\bar{x}$ = the arithmetic mean (most probable value)
n = the number of samples in the data set

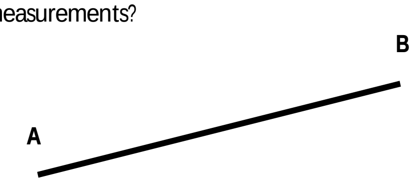
- The standard error is expressed by the standard deviation of the sample

$$s = \sqrt{\frac{\sum (x - \bar{x})^2}{n - 1}}$$

Errors and Corrections

Example: You are asked to measure a distance of AB of L=10.548 m, with a tape. What is the accuracy and the precision of your 5 tape measurements?

L1 = 10.550 m
L2 = 10.552 m
L3 = 10.547 m
L4 = 10.546 m
L5 = 10.549 m



Length estimation; Mean average: L mean = $\frac{\sum L}{n}$ = 10.549 m

Precision; Standard error : = $\sigma = \sqrt{\frac{\sum (L_{mean} - L_i)^2}{n - 1}}$ = 0.002 m

Accuracy = Estimation – Real Value =10.549 – 10.548 = 0.001 m

Thus, L=10.549 m± 0.002

Errors and Corrections

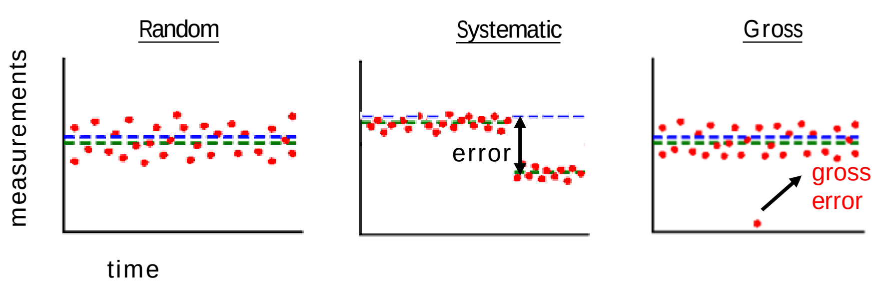
Types of errors:

a. Random errors: These are types of errors that remain after elimination of mistakes and systematic errors. They occur because **neither the surveyor nor his instruments are perfect**. They are random in their nature and are thought to have normal probability distribution. Their effect can be greatly decreased by exercising care and vigilance by the part of surveyors and by using high precision instruments.

b. Systematic errors: These are error types with relatively small magnitude compared to mistakes, and are result of some systems whose effect can be expressed in mathematical relations; hence **their magnitude and sign can be estimated (determined)**. In most cases, the system **causing the systematic error can be personal, instrumental or physical and environmental conditions or may be result of choice of geometric or mathematical model used.**

Errors and Corrections

c. Mistake (gross) : These actually are not error because they usually are so gross in magnitude compared to the other two types. These are rather **blunder made by surveyor or his equipment and can occur at any stage of the survey (during reading, recording computing and plotting).**



Errors and Corrections

Systematic Errors in Taping and Corrections:

1. **Tape is not of standard length:** a tape may be too short or too long when compared to a standard tape under specific conditions of tension, temperature and method of support. When the tape is too short the surveyor will actually measure a distance less than that shown on the graduations. Hence, a negative correction is needed. Similarly, when the tape is too long, a distance greater than that shown on the graduations is measured, hence a positive correction is applied.

The correction can be done by using the following formulas:

- For measuring length: $\frac{Actual\ length}{Measured\ length} = \frac{Length\ of\ used\ tape}{Length\ of\ standard\ tape}$
- For measuring area: $\frac{Actual\ area}{Measured\ area} = (\frac{Length\ of\ used\ tape}{Length\ of\ standard\ tape})^2$
- For measuring volume: $\frac{Actual\ volume}{Measured\ volume} = (\frac{Length\ of\ used\ tape}{Length\ of\ standard\ tape})^3$

Errors and Corrections

Example (1): A measurement was recorded as (171.278 m) with a (30 m) Tape length, that was only (29.996 m) under standard conditions. What is the correct measurement?

Solution:

$$\frac{Actual\ length}{Measured\ length} = \frac{Length\ of\ used\ tape}{Length\ of\ standard\ tape}$$

$$\frac{Actual\ length}{171.278} = \frac{29.996}{30}$$

$$\therefore Actual\ length = 171.255$$

Errors and Corrections

2. **Variation due to temperature:** this causes expansion or contraction of the material of which the tape is made.

$$C_t = \alpha * L * \Delta T$$

C_t = correction due to temperature, α = temperature expansion factor

L = measured distance, ΔT = difference in temperature (°C) or (°F),

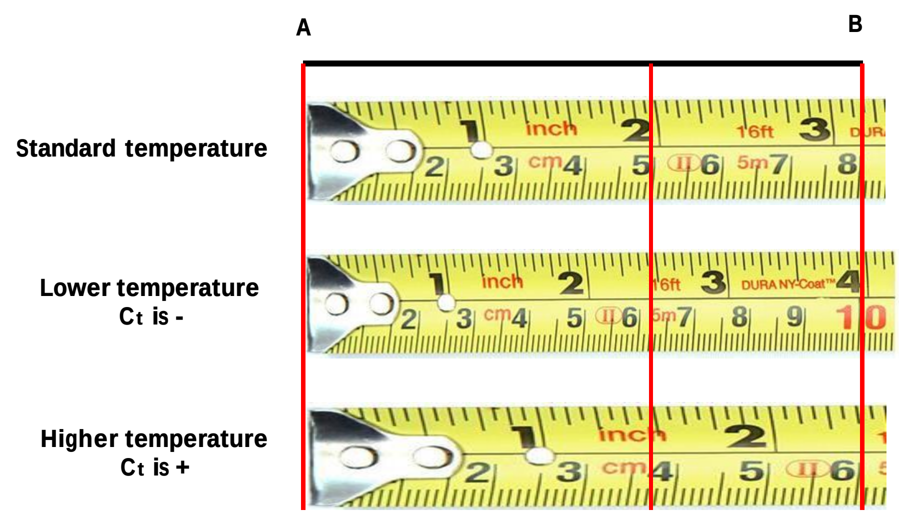
°F = 32 + (1.8 * °C)

$$\alpha = \frac{0.00000645}{unit\ length * °F} \quad , \quad \alpha = \frac{0.000064}{unit\ length * °C}$$

Errors and Corrections

2. Variation due to temperature:

Actual distance = measured distance ± C_t



Errors and Corrections

Example (2): You must layout two points in the field that will be exactly (100 m) a part. Fields condition indicate that the temperature of the tape (27 C°). What distance will be layout? Which the standard temperature for the tape is (20 C°).

Solution:

$$C_t = a * L * \Delta T$$

$$C_t = 0.000064 * 100 * (27 - 20)$$

$$\Rightarrow C_t = 0.0448\, m$$

Measured distance = 100 - 0.0448 = 99.9552 m

Errors and Corrections

3. **Variations in tension/pull:** if the tension force that is used for pulling the tape is greater than the standard, tension errors exist which can be found by using the following formula:

$$C_p = \frac{(P - P_s)}{A * E} * L$$

C_p = correction due to tension, P = Applied tension, P_s = standard P

A = cross sectional area, E = elastic modulus (200 Gpa, or 29 Mpsi),

L = length of tape

Errors and Corrections

Example (3): A (30m) steel tape is used with a (100 N) force, instead of standard tension (50 N). If the Cross-sectional area of the tape is (0.02 cm²). What is the tension error per tape length? While its modulus of elasticity is 200 Gpa.

Solution:

$$C_p = \frac{(P - P_s) * L}{A.E} = \frac{(100 - 50) * 30}{0.02 * 10^{-4} * 200 * 10^{9}}$$

$$\therefore\ C_p = 3.75\ mm\ (+)$$

Errors and Corrections

4. Sag Correction:

$$C_s = \frac{-w^2 L^3}{24 * P^2} = \frac{-W^2 L}{24 * P^2}$$

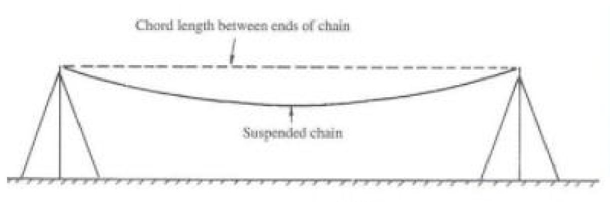
C_s = Sag correction per length (m or ft),

w = weignt of tape per unit length (N or lb)

W = weignt of tape (N or lb),

L = length of tape,

P = Applied tension (N or lb)



Errors and Corrections

Example (4): A 30 m tape weighing 10 N is used under a pull of 15 N which is sagged between two stands. Find the true distance measure from one tape length.

Solution:

$$C_s = \frac{-W^2 L}{24 * P^2}$$

$$C_s = \frac{-10^2 * 30}{24 * 15^2} = -0.55 \text{ m}$$

true length = 30 – 0.55 = 29.45 m

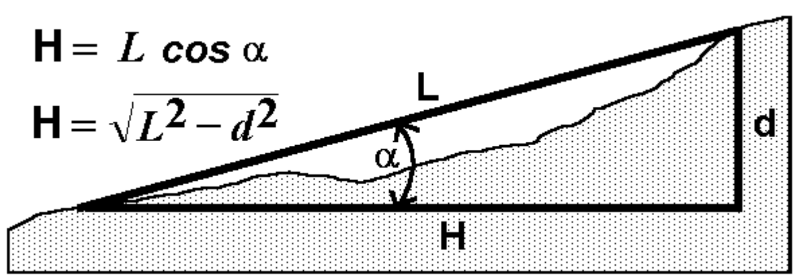
Errors and Corrections

5. Slope correction:

$$\cos\alpha = \frac{\textit{Horizontal distance } (H)}{\textit{Sloped distance } (L)} \Rightarrow H = L * \cos\alpha$$

$$H = L \cos\alpha$$

$$H = \sqrt{L^2 - d^2}$$



Errors and Corrections

Example (5): Find the horizontal distance, when a slope rise from one point a distance of (156.77 m) to another point at a rate of (+1.5%)?

Solution:

$$\tan a = \frac{1.5}{100}$$

$$a = \tan^{-1}\frac{1.5}{100} = 0.85937^{o}$$

$$H = S * \cos(0.85937^{o})$$

$$H = 156.77 * \cos(0.85937^{o})$$

$$\Rightarrow H = 156.759\, m$$

Correction	Sign	Formula
Absolute length (c_a)	$\pm$	$\frac{c}{l}L$
Temperature (c_t)	$\pm$	$\alpha(t_m - t_0)L$
Pull (c_p)	$\pm$	$\frac{(P - P_0)}{AE}L$
Sag (c_g)	$-$	$\frac{1}{24}\left(\frac{W}{P}\right)^2 L$
Slope (c_s)	$-$	$(1 - \cos\theta)L$ $(exact)$
Alignment (c_m)	$-$	$\frac{h^2}{2L}$ $(approximate)$
Mean sea level (c_{msl})	$-$	$\frac{d^2}{2L}$ $(approximate)$
		$\frac{HL}{R}$ $(approximate)$

Engineering Surveying Mr. Diyari Burhan

Errors and Corrections

Question 1: A (20 m) standard tape was used for measuring line AB and measured (679.88 m) while the actual length is (681.24 m) at temperature (40 C°). Use a=0.0002 m/m/C°. **Find the used tape length. At which temperature should the tape be used so that the error approaches to zero?**

1. Find the used tape length.

$$\frac{Actual\ length}{Measured\ length} = \frac{Length\ of\ used\ tape}{Length\ of\ standard\ tape} \rightarrow \frac{681.24}{679.88} = \frac{Length\ of\ used\ tape}{20}$$

$$Length\ of\ used\ tape = 20.04m$$

$$C_t = a\ L\ \Delta T = 0.0002 * 20 * 20 = 0.08\ \text{m}$$

2. At which temperature should the tape be used so that the error approaches to zero?

$$C_t = a\ L\ \Delta T \rightarrow 0.0002 * 20 * (T2 - 20) = 0.04 \qquad > \therefore T2 = 30\ C°$$

Errors and Corrections

Question 2: A survey line measured with a 20 m chain, and 30 m chain was found to be 998 m and 1002 m respectively. If the 20 m chain was 0.1 m short, find the error of other chain?

Solution:

$$\frac{Actual\ length}{Measured\ length} = \frac{Length\ of\ used\ tape}{Length\ of\ standard\ tape} \rightarrow \frac{Actual\ length}{998} = \frac{(20 - 0.1)}{20}$$

$$True\ length = 993.01\ m$$

$$error\ \ in\ the\ other\ measurement = 1002 - 993.01 = 6.99\ m$$

Hence , error in 30 m chain = $\frac{30}{1002} * 6.99 = 0.209$ m

Errors and Corrections

Question 3: A line was measured with a steel tape which was exactly 30 m at 20 C^0 at a pull of 98.1 N , the measured length being 1650 m . The temperature during measurement was 30 C^0 and pull was 147.15 N . Find the true length of the line is cross sectional area if the tape is 0.025 cm^2. The coefficient of expansion of the material of the tape α = 3.5 * 10^{-6} and modulus of elasticity of the material of the tape = 2.06 * 10^6 N/m^2 .

Solution:

$$\text{Correction for temperature, } C_t = \alpha(t_m - t_0)L$$

$$C_t = 3.5 \times 10^{-6}(30 - 20)\ 1650 = 0.05775 \text{ m}$$

$$\text{Correction for pull, } C_p = \frac{(P - P_0)L}{AE} = \left[\frac{(147.15 - 98.1) \times 1650}{(0.025 \times 10^{-4}) \times 2.06 \times 10^6 \times 10^{-9}}\right]$$

$$= 0.15715 \text{ m}$$

$$\text{Total correction} = C_t + C_p = (0.05776 + 0.15715)\text{m} = 0.2149\text{m}$$

$$\text{True length of the line} = (1650 + 0.2149)\text{m} = 1650.2149\text{m}$$