CIV2202. 3: LINEAR MEASUREMENT (TAPING OR CHAINING)

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PREVIEW

Introduction

This chapter is about the skill of **producing a site plan** using just 2 tapes with the addition of a clinometer for measuring slope angles. (Distance shown on plans must always be horizontal distances).

The chapter is divided into two sections. The first (Distance Measurement) describes basic use of tapes, and adjustments for the effects of slope, temperature, tension etc. The second (Chaining) describes the application of these skills in producing a site plan. You will use these skills as part of your practical assignment.

These are useful skills for producing small site plans. However, most larger plans are now produced using a theodolite and EDM. More about that later.

You should notice that future chapters include a **Skill** section at the start. Hopefully, these will help you to identify what is most important in that chapter. These will be the skills you will be practising in your practical and camp assignments.

Objectives

After completing this topic you should be able to:

- obtain horizontal distances in sloping terrain
- correct linear measurements for site and environmental factors
- understand procedures for producing a site plan using only linear measurement

Readings

Read: *Muskett,* Sections 4.1, 4.2
(? Minutes)

REQUIRED

DISTANCE MEASUREMENT

2 Types Of Distance Measurement

1. **direct** - tapes, bands, chains

2. **indirect** - optical (theodolite), EDM

USE OF STEEL TAPES

*   typically 20, 30, 50, 100 m

*   many tapes are fibre reinforced plastic, but for accurate work, they **must be steel** (which are often be plastic coated). Plastic tapes stretch with age.

*   always check the exact position of the **zero mark**. It is usually at the end of the link on the end of the tape, not at the end of the steel ribbon.

*   **manufactured to give precise length when**
    (i)   new
    (ii)   standard temp (20°C)
    (iii)   standard tension (eg. 5kgf or 49N)

    *   corrections can be made for these (more about this later).

FIELD WORK CONSIDERATION

The aim is to measure the **straight-line**, **plan distance** between 2 points

*   so, you must be careful to measure in a **straight line**

*   **correct for slope angle** Θ to give plan length

For example ...
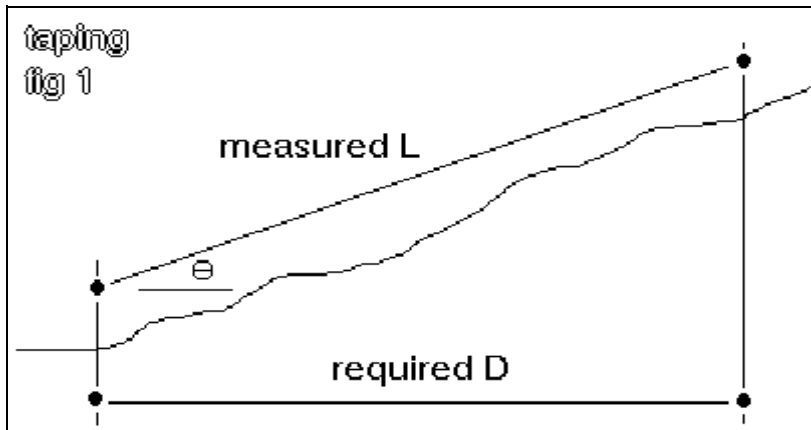
MEASURING LESS THAN ONE TAPE LENGTH

*   tape on the **ground**,
        pull to standard **tension**,
        on a **straight line**, tape must be straight in the vertical plane too.
        read the length (and remember to check the zero mark).

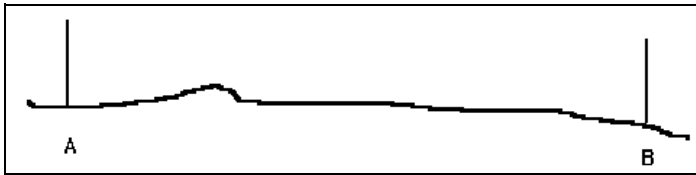## MEASURING MORE THAN ONE TAPE LENGTH

Need   (i)   3 (or more) ranging poles,
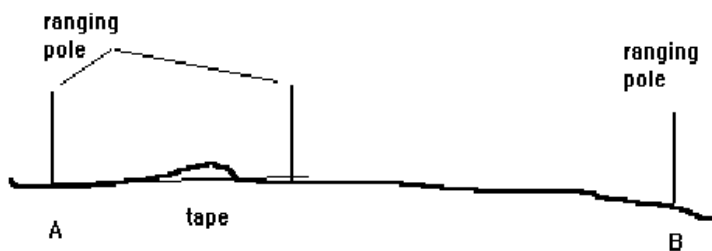   (ii)   some marking arrows:
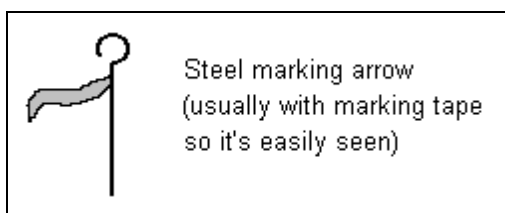
Procedure

(i)   need 2 people : **leader** and **follower**

(ii)   erect ranging poles at end points (A and B) - as near vertical as possible

(iii)   set zero end of tape at A by follower.

(iv)   leader moves forward and places a ranging pole a short distance from the end of the tape

(v)   follower sights the pole onto the line AB by stepping back from A (see next diagram).

(vi)   straighten tape against new pole, and place arrow at exact end of tape (**exactly** one whole tape length)
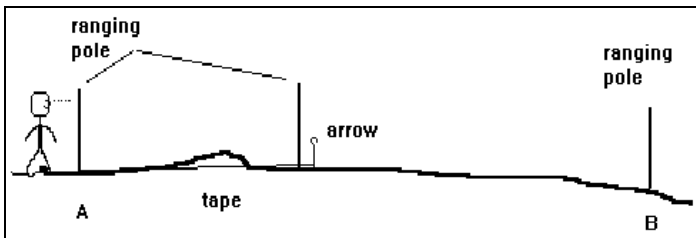
(vii)   leader and follower move forward and repeat from the last arrow position. The number of arrows eventually equals number of whole tape lengths. Miscounting the number of tape lengths or 10 m steps is a common source of error.

(viii)   repeat measurement from B to A as a **check**, if time and budget allow it. There are other ways of checking your work, which will be discussed in future topics.

Notes

Ranging with a theodolite (set at A) increases accuracy. For non-horizontal ground, this step may be essential, because it may not be possible (or at least difficult) to sight by eye, for example ...
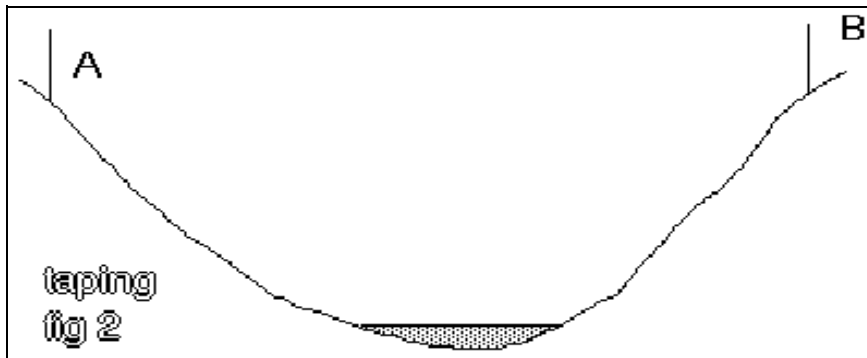
STEP CHAINING ON SLOPING GROUND

Procedure

(i)   Use previously ranged in poles

(ii)   Use horizontal tape (checked by third person some distance away).

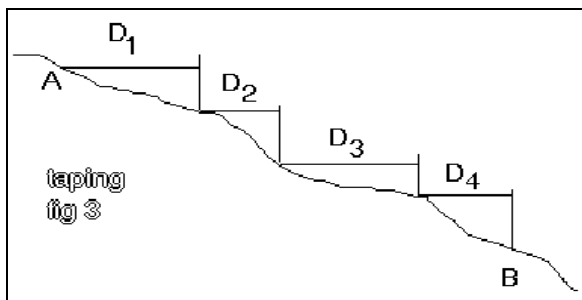- Compare the angle of the tape with the lines of buildings which are parallel to the line you are measuring, or

- Compare the angle of the tape, near the mid point of the span, with a plumbline - you should have four equal angles.

(iii)   Transfer horizontal distance to ground using plumb bob, preferably at whole metre mark.

(iv)   Keep maximum length of tape to 10 m
         (reduces problem of catenary or sag).

         (may need to be less on steep ground to reduce the vertical step to a maximum of
         1.5m).

Applications:- short survey lines (eg. offsets, setting out of building etc.

STANDARD TAPE CORRECTIONS

How do we measure the slope angle Θ ?

The simplest method is the Abney level or **clinometer**
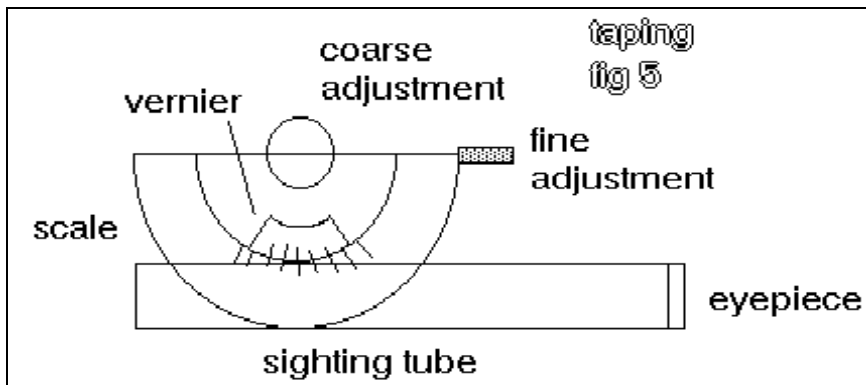
Procedure

1.   Mark the eye height of the observer on a ranging pole

2.   Sight from A to B. First adjust the coarse screw, then the fine adjustment
       screw, to bring the level bubble to the central position, so that target 'B',
       cross hair and bubble are coincident.

3.   Read the angle to the nearest 10' by the vernier scale.

4.   Check and eliminate Abney error by sighting from B to A and repeating process.
       Use the mean of the two angles.

Better accuracy by using a theodolite, but not justified in many cases. In this case, mark
the height of the trunnion axis on the ranging pole and sight of this mark.

Slope
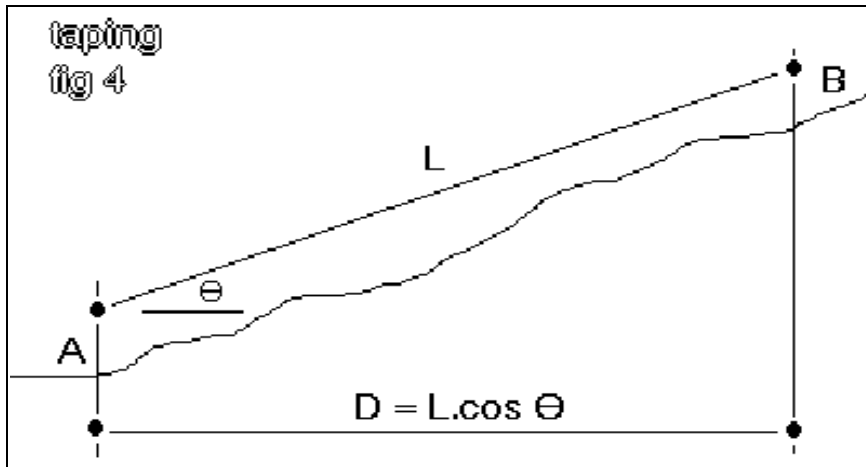
We define C, the correction, such that:
D = L + C
where   D = actual (corrected) length
             L = measured length
             C = correction (hence, C is always added)

or,   **C = D - L**
             = L.(cos Θ) - L
             = L.(cos Θ - 1)

since cos Θ ≤ 1, **C is always negative (or zero) - as expected!**

Measuring Θ: Levels at A and B are known :
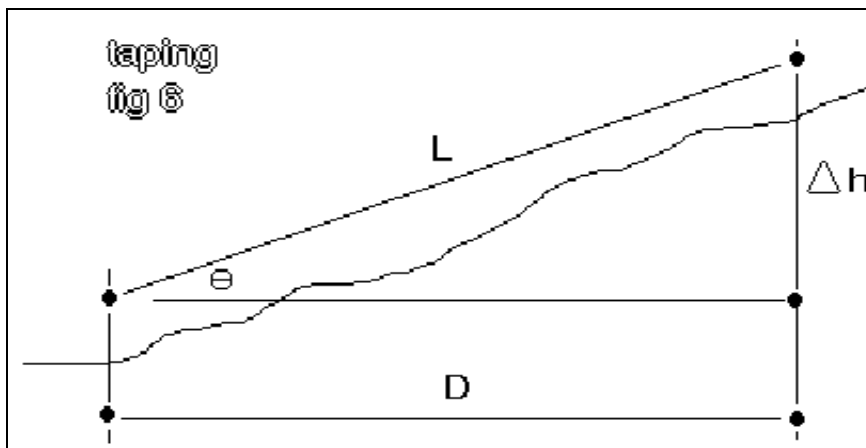
if Δh = difference in level

then, correction, $C = -\dfrac{\Delta h^2}{2L}$ (for small Δh)

Note that the **correction is negative** as before.

Use/Age

Tapes tend to stretch with age. We need a reference tape or standard length for comparison. We can check the tape on a **flat surface** (if reference tape is the same material, temp differences from standard (eg. 20°C) won't matter).

Say tape measures 30.011 m instead of 30 m, measurements must be corrected as follows.

$$L_c = L \cdot (l_a / l_n)$$

L_c = real or corrected length
L = measured length
l_a = actual length (30.011 m)
l_n = nominal length (30 m)

Expressed as a correction, C:

C = L_c - L
        = $L \cdot (l_a/l_n - 1)$
C = 0.00037 L for the above example

Note: Correction is positive in this case, because the tape has stretched, ie. the actual distances are **larger** than measured ones.

Take care to make sure that the **sign** of the correction is correct.

Tension

Tapes and bands are designed for standard tension (in our case 5 kgf or 49 N).

Use a spring balance and roller grip to achieve this.

Use the spring balance at the leader's end of the tape, not the follower's or zero end.

For other than standard tension, correction, C is:

$$C = \frac{L(T_F - T_S)}{A.E}$$

L = Length measured
T_F = Tension in the Field
T_S = Tension, Standard
A = cross-sectional Area
E = Young's modulus

Note: if $T_F > T_S$, actual length is more than what was measured and hence C is positive.

Temperature

Tapes are correct usually at 20°C.
For non-standard temperature:

$$C = a.L.(t_F - t_S)$$
a = coefficient of thermal expansion
= 0.0000112 /°C for steel
t_S = standard temp
t_F = field temp

Note: if $t_F > t_S$, tape is longer, so actual lengths are more than measurements, and hence C must be positive.

Sag of the tape

A tape suspended by its ends forms a catenary under gravity
It is possible to derive the actual shape from structural theory:

taping
fig 7
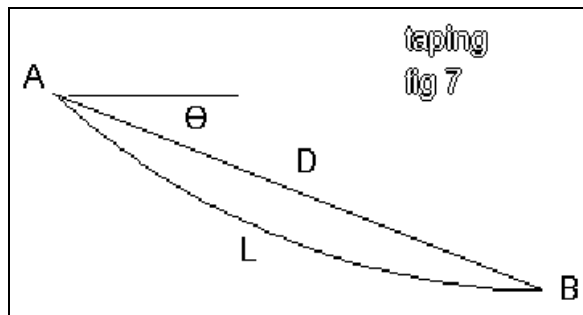
$$C \approx - \frac{w^2.L^3.\cos\Theta}{24.T_F^2}$$

w = unit weight of tape (N/m)
Θ = angle from A to B (as shown above)
T_F = field tension (N)

Note that this corrections is always negative (ie. actual distances are always shorter than the measurements).

BOOKING

In surveying it is very important to follow a **systematic** and **standard** method of recording information, because :

(i)   things are usually plotted some time after the survey,

(ii)   the plotter is often not the surveyor (often a drafter).

Booking a Baseline

Corrections:		Date: 5 Mar 91
		Team: RGH & DBC
1. Standardisation		**Booked:** DBC
nominal L = 30.000 m		**Notes:**
actual L = 30.012m		(i) mean temp 30°C
		(ii) tape on ground
		at standard tension
C = 101.234[(30.012/30) - 1]		
= +0.040 m		
2. Temperature		
C = 0.0000112 x 101.234		
x (30 - 20)		
= + 0.011 m		
3. Slope:	Y	
C = 30(cos 1°20' - 1)	101.234	----------------
+ 45.5 (cos 1°50' - 1)		
+ 25.73 (cos 2°30' - 1)	90	2°30' slope
= - 0.055 m		
	75.5	----------------
	60	
XY = 101.234 + 0.040		1°50' slope
+ 0.011 - 0.055		
= 101.230 m	30	----------------
		1°20' slope
	0	----------------
	X	

ERRORS AND ACCURACY

Sources of Errors

(i) incorrect tape length (eg. the tape has stretched) - **standardize**

(ii) **incorrect slope** (a clinometer gives 1:5000 accuracy for angles up to 4°).

For example, the maximum error with a clinometer is 5' (with 10' graduations)

Slope	max. error (mm/100 m)
1°	3
3°	8
5°	12

(iii) tapes must be **correctly tensioned** for better than **1:5000** accuracy.

(iv) similarly for **temperature**

(v) take care to measure in a **straight line**.

(vi) make **sag correction** for accurate work.

(vii) **check for gross errors** by measuring each line (at least) twice.

TYPICAL ACCURACY FIGURES

Accuracy	Required for	Corrections
1:500	soil heaps soft detail	slope
1:5000	sewer pipes	slope + standardize
1:10000	hard detail traverse legs, road centrelines, grids, baselines, setting out,	+ tension + temp
1:20000	secondary control	horiz. surfaces
better than 1: 20000	primary control	sag corrections use EDM

EXERCISE

> ✎   ***Do Problem 4/1 from Muskett.*** *This exercise lets you practise some of these corrections.*

CHAINING AND DETAIL SURVEY

> 📖   *Read* Muskett, sections 6.1, 6.2
>
> REQUIRED

> 📖   Read: *Fryer & Elfick*
>
> SUGGESTED

To produce a plan or map of an area showing the important features using just linear measurement (often called a detail survey).

Basic Approach

a.   establish **control lines** and control points (located by triangulation).

b.   pick up detail using offsets (be careful to measure true horizontal distances).


chaining fig 1
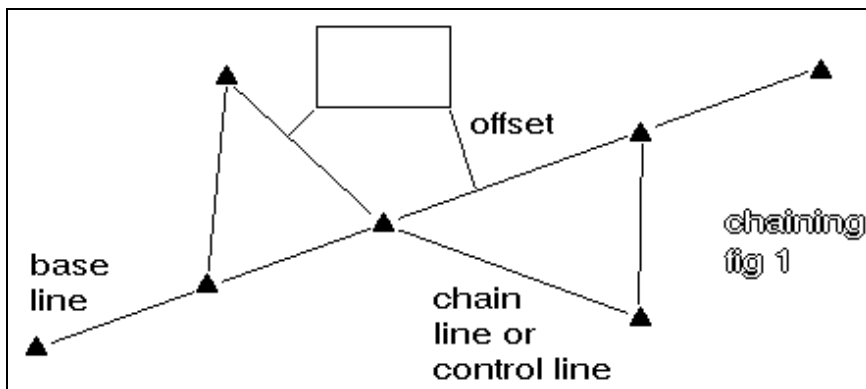
Principles

1. there should be at least one **good line** through the area, on which the survey is based.

2. if the survey is extensive, develop a **few long lines** rather than many short ones (eg. a large triangle)

3. try for **well-conditioned triangles** (close to equilateral) - no angles less than 30°.

4. where possible measure some check lines (redundancy).
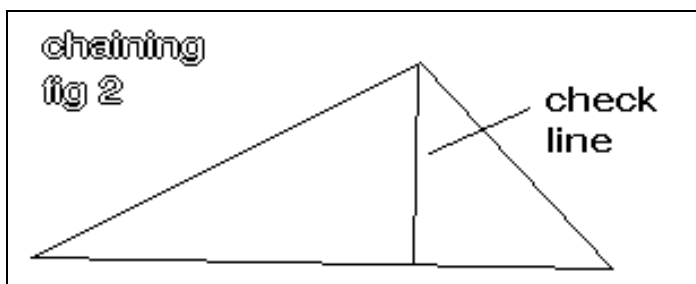
5. put control lines as close as possible to detail, so offsets are short.

Method

1. **Reconnoitre** the area and decide where lines will go. Draw a rough **sketch**.

2. **Establish stations** (points of triangles) as wooden pegs, and give each a letter on the sketch.

3. **Measure all the control lines**, and check lines, once in each direction. Don't forget **corrections**.

4. Finer detail can be measured by **offsets** (swing the tape over the offset line - the shortest distance will occur for the perpendicular).
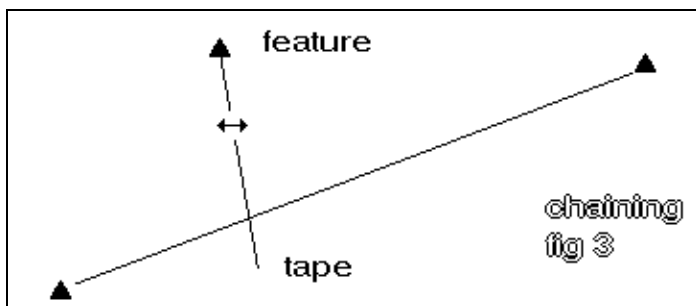
NB: Offsets should be kept short to avoid making corrections (less than 20 m).

5.   Develop **additional triangles** as needed to keep offsets short.

6.   Measure **widths of features** (eg. roads, drains, trees, etc), lengths of sides of buildings, radius of circular features.

7.   A **level** (or similar) must be used if elevations are required.

Booking

Booking must be **neat** and **consistent**.

It must be capable of being plotted by **someone else**.

Use **explanatory notes** and **sketches** liberally.

Continue long lines over as many pages as necessary.

Use a column up the centre of the page for the chained line distance, and show offsets or ties to detail on either side. See Muskett 2ed. P157.

Add dimensions around buildings in parentheses.

Include slopes on overall sketch so corrections can be made.

Don't forget miscellaneous data - name, date, location, and initials.

Add a compass bearing of at least one line for plotting purposes.

Plotting

Do not, under any circumstances, use a plan scale of 1:300, 1:150, etc, no matter how attractive it may seem! Suitable scales are 1:100, 1:200, 1:250, 1:500, 1:1000.

1.   Start with longest line and build framework of major lines.

2.   Position longest line on sheet in an appropriate position.

3.   Plotting may show errors in original data - remeasure if necessary.

4.   Include offsets to features.

5.   Fill in detail, with notes, legend, etc.

EXERCISE

> *Activity*
>
> Do exercise 6.1 from Muskett, p183.

SUMMARY

Horizontal distances are required for map and plan preparation, and for most engineering purposes. In sloping terrain, horizontal distances may be obtained either by step measuring with the tape set horizontal, or by measuring along the slope and applying trigonometry to obtain the horizontal distance.

In practice, corrections may have to be applied to taped measurements to compensate for:
- a tape that is either too long or too short
- measurements taken along sloping ground
- sag in the tape, when measuring across a gully or similar feature
- measurements made when the temperature is either greater of less than the tape's standard temperature
- measurements made with tape tension other than standard.

REVIEW QUESTIONS

1. If you measure with a steel tape between two ground marks approx. 500 m apart when the field temperature is 30°c, will your recorded measurement be too short or too long? What is the magnitude of the difference from standard measurement.

2. You measure across a gully to pegs placed on the centreline of a proposed dam. Your recorded distance is 70.25 m, at a tension of 50 kN. Your 100 m long tape weighs 1.2 kg. What is the correction to your distance? Will you add or subtract this amount?

ANSWERS TO REVIEW QUESTIONS

1.   The steel tape is standard length at a temperature of 20°c.

   Correction = 500 x 0.0000112 x (30 –20) = 0.056

   This must be added to the recorded distance.

2.   Mass of tape   = 1.2 kg

   Weight of tape per metre $= \dfrac{1.2 x 9.8}{100}$

   $= 0.1176$ kN

   Correction $= \dfrac{(0.1176)^2 x (70.25)^3}{24 x 50^2}$

   $= 0.080$ m