RAPID ROUTE AND TOPOGRAPHIC SURVEYING.

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In the most ancient records of the world's history mention is made of the Surveyor's art, and in those referring to the history of Ancient Egypt and Babylonia in which countries it was developed into a real and necessary science, a fairly complete idea is given to us of its importance in the industrial and legal economy of these great nations, and of the methods adopted in defining the boundaries of land.

It is worth noting that these nations were great irrigationists, and even to this day the ruins of their vast enterprises in canals and other works are still in evidence of their greatness, and as it is obvious that such works could not have been constructed without a knowledge of Surveying, it may be safely inferred that this knowledge was extensive.

Like everything else in this world, the art of Surveying is an evolutionary one, and although progress is slow, it is sure.

Each generation of Surveyors may add only the minutest shade or fraction of an improvement to our methods; during some, there may be absolute stagnation, and even a set-back, but for all that the movement is a forward one on the whole, and we, when starting our work had not to commence "de novo," but took up the work where our predecessors left off, and so it will be with our successors.

In this age of rapid inter-communication it may be anticipated that the progress will be swifter than of yore, and that the Art will develop more along scientific lines.

The increased accuracy of mathematical and optical instruments and the greater range and power of telescopes all point towards the elimination of the chain or the system of direct measurement.

As illustrating the evolution of Surveying, we may refer to the ancient Egyptian proto-type who measured distances with ropes, or by stretching of lines, and were consequently called "Harpedonaptœ" or line stretchers, which system we have lately resuscitated and developed into the use of long steel wire ribands for hypotheneusal measurement, and which has come to supersede the use of all other methods in the measurement of Base lines, Just as the study of history is an infallible guide to progress, so is a study of the methods of contemporary nations, and it is appropriate that parallels should be drawn between our own and other countries' systems of performing Route and Topographic Surveys.

The present methods of executing Route Surveys in Australia are a long way behind the times, which nothing but a hide-bound conservatism could tolerate, and which is resulting in constant and ever growing loss in the operation of our railways and other public works.

In the prosecution of our Railway Surveys every effort appears to be made to secure mechanical accuracy in the measurement of lines, angles and levels, whilst the crudest means are adopted to secure the best location for the route, with the result, that after the line has been working for a little time, immense sums of money have to be paid for diversion works or for cutting out steep grades and sharp curvature.

It has not yet been recognised that Location should be the first, and all the time the principal consideration, and that the present system of conducting the Surveys is wasteful in effort and inefficient in the results aimed at. I am not blaming Surveyors for this state of affairs, because they have no say in the matter under our present system of monopolistic political control, but I am blaming the Administrators who have the temerity to control and direct highly technical and scientific operations, upon which the financial safety of our principal public works depends, but who have no knowledge of the technical conditions of such operations, and who will not seek the advice of their trained professional advisors.

The authorities seem to be quite ignorant of the great advances made in Surveying during the last ten years, and of the enlightened methods now adopted in America, Africa, and other advanced countries in the Survey and Location of Railway lines.

Our present system is to send out a Surveyor (often without a trained assistant), with half a dozen men, equipped with a theodolite, a level and a chain to find a suitable railway line between towns A and B which a political supporter of the Government is interested in, with instructions to get through with the work as quickly as possible.

The limiting grades and curves are laid down beforehand by an officer who has no knowledge of the country to be traversed and if they are conformed to, the location can "go hang." The prevailing idea is "Get the line through, with good location if you can, but in quick time you must."

The consequence is, the unfortunate surveyor has to explore the route, run the trial lines, and do all the mechanical work of chaining and levelling himself, without any assistance either in the field or the office, and with the aid of obsolete and cumbersome instruments.

Is it to be wondered at that unaided and alone, badly equipped and harassed by haste, he so often misses the best location, and another large coal consuming and small freight carrying line is added to the long list of unpayable railways?

But on the other hand, who is one whit the wiser? The survey is cheap and expeditiously performed, the Minister is pleased, the Member of Parliament is placated, the grades and curves are not exceeded, angles are observed to the nearest 10 seconds, the chainage work checks to two links to the mile and the levels to two-hundredths of a foot, "Let us eat and drink, because to-morrow we must die."

But what a contrast to the methods adopted in other countries, especially in America and Africa. When a railway is determined on between A and B the work is placed in the hands of an experienced Location Engineer, who has under him other engineers, their numbers depending upon the extent of the line to be explored; these men are placed in charge of various sections, subject to the authority of the Chief.

The Section Engineers have in each of their parties an observer who does all the instrumental work, a topographical sketcher, a recorder who keeps the field book, six staff men and sufficient line clearers, besides draftsmen who keep the work plotted as it proceeds; each party is equipped with a tacheometer and six staves, besides aneroids and such hand optical instruments as may be considered necessary.

Each Section Engineer explores his own section, and generally directs the operation of his party, deciding where the trial lines shall run and reporting and consulting with the Chief, who keeps in touch with all the Section Engineers, giving them the benefit of his greater experience and advice when and where necessary.

Each of these parties will do three times as much work in one day as the surveyor equipped with theodolite, level and chain.

It is true the daily cost will be much heavier, but the larger amount of work performed will more than cover the cost, and what is more to the point, it will be more efficiently done; more ground will be explored and no possible good location missed; and when the line is finally located, it is the best obtainable, and there is no hope of finding a better, and finally there will be no grades and curves for the Commissioners to curse or for the unemployed to rejoice over.

Until recently in Australia topographic and route surveys have been executed with the transit theodolite and chain, the latter having been superseded in more recent years by the long riband and hypotheneusal measurement, but owing to the great improvements in theodolite telescopes, that can now be supplied by instrument makers, the time has arrived for a serious consideration of telescopic measurements with a view, if possible, of introducing a more economical and rapid system for the class of surveys mentioned, and which it is claimed may be done without detriment to the essential value of the results.

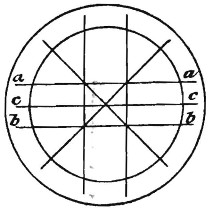
Mr. Thomas Kennedy, Assoc. M. Inst. C.E., read a valuable paper, entitled "Stadia Method of Surveying as applied to Railway Location," being more particularly a description of the use of a stadia theodolite, before the Institute of Surveyors in 1907, but made no allusion to the proportionate error of the system, and it is now proposed to state the case more amply, and by adducing comparisons with long wire measurements, to illustrate its value and encourage its more general use. The economic aspect of the question is deemed of sufficient importance for again, and so soon, bringing the matter under the notice of surveyors, and the author hopes that constant reiteration of the many advantages of telemetrical surveying will gain for it professional and official sanction.

The practicability of stadia and tacheometer measurement of heights and distances is quite out of the experimental stage, and whilst freely admitting that the results are not so precise and regular as those obtained by direct hypotheneusal chainage, yet they are good enough for the end to be achieved, and it is only necessary to overcome the inertia of professional conservatism in order to bring the said system into regular use within prescribed bounds.

As applied to preliminary route surveying and topography, the accuracy of the work performed by stadias and tacheometers is sufficiently good for all practical purposes, as will be illustrated hereafter.

There is an impression prevalent on the professional mind, that these methods are extremely difficult and involve elaborate calculations, and the object of this paper will be to try and remove these erroneous ideas and at the same time to prove the

Fig 1



sufficiency of the methods for those who have not fully considered them by giving actual comparisons of work done.

Before entering upon that part of the subject, it may be of interest to discuss briefly the theory of telescopic measurement.

Modern stadia measurements are obtained with the aid of a theodolite, the telescope of which is fitted with a special form of diaphragm and a staff graduated to one-hundredth of a foot.

In the diaphragm two horizontal and sometimes two vertical wires are added to the ordinary axial wires, the two horizontal wires being at certain equal distances on each side of the centre wire (see fig. 1), so that when readings of the upper and lower wires are obtained on a staff, the telescope being horizontal, the distance of the staff from the objective of the instrument bears the same ratio to the focal length of the telescope as the difference of the wire readings on the staff is to the difference between the wires.

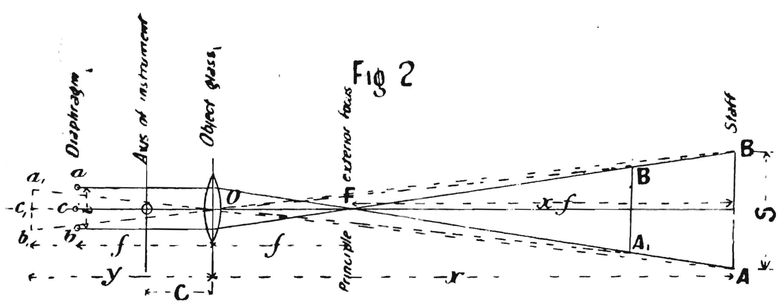


Fig 2

Let fig. 2 represent the general principles of a stadia telescope, in which "a" and "b" represents the upper and lower stadia wires of the diaphragm fixed at a distance i apart and at equal distances from c the central wire.

O represents the object glass, and S a portion of a staff, divided to feet and hundredths of a foot, the points B and A being the extremities of the intercept, which are intersected by the stadia wires "b" and "a" respectively.

Let x and y be the relative distances of the outer and inner foci or the conjugate foci of the lens O, then ab is the position of the image of AB at the diaphragm for parallel rays when AB is at an infinite distance away and f is the focal length; aob is the visual angle and is equal to AOB. If the object AB approaches closer to the lens O the distance X is decreased and y is increased by the receding of the image from the lens, and vice versa.

But as the image recedes from or approaches to the lens according as the object varies in distance from the lens, so the visual angle aob or AOB is variable and the conjugate focus y is also variable.

If the visual angles were constant, the space S intercepted on the staff AB and the distance x of the staff from the lens would be in a constant ratio and we should have

$$i : y :: s : x \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

but from the law of optics we have

$$\frac{1}{f} = \frac{1}{y} + \frac{1}{x} \quad \ldots \quad \ldots \quad (2)$$

From the equation (1) we have $\frac{x}{y} = \frac{S}{i}$

From equation (2) multiplying by x we have $\frac{x}{f} = \frac{x}{y} + 1$

Substituting value of $\frac{x}{y}$ we have $\frac{x}{f} = \frac{S}{i} + 1$

$$\therefore x = \frac{Sf}{i} + f \quad \ldots \quad \ldots \quad (3)$$

So that the distance of the staff from the object glass of the instrument is equal to the intercepted space on the staff multiplied by the constant ratio $\frac{f}{i}$ plus the constant f or the focal length of the lens.

If a distance f is measured in front of the object glass to the principal exterior focus of the lens at F and the staff held at any distance, its distance from F, and the space intercepted on the staff will be in a constant ratio.

The distance of the staff from the object glass being thus determined, if we add the distance C from the object glass to the central axis of the instrument we get the distance of the staff from the station over which the instrument is plumb.

Hence the formula for distance becomes

$$x + C = \frac{Sf}{i} + f + C. \quad (4)$$

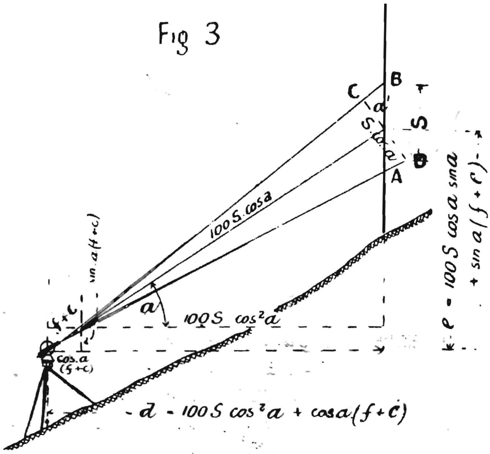
The wires are generally adjusted so that $\frac{f}{i} = 100$, and $f + c$ for a 5-inch theodolite $= 1.25$ feet, so that $X + C = 100S + 1.25$.

Most instruments are generally constructed so that when the telescope is at stellar focus the ratio of $\frac{f}{i} = 100$, for simplicity of calculation; accordingly in a 10 inch telescope the wires are placed 5/100ths of an inch above and 5/100ths of an inch below the axial wire, so that the distance between "a" and "b" = 1/10th of an inch.

The distance f may be measured on the telescope from the outer surface of the object glass to the surface of the diaphragm, adjusting screws without any sensible error.

When the stadia instrument is used on sloping ground, other reductions must be made.

Fig 3



Thus in fig. 3. Let S = the intercept AB on the staff, the angle a^1 will sensibly equal the angle of elevation a ; and if f + c = 1.25

Then with sufficient precision CD=S.cos a. and the horizontal distance $d = 100S \cos^2 a + 1.25 \cos a$. (5)

The elevation of the axial wire reading on the staff above the centre of instrument $e = 100\ S \cos a . \sin a + 1.25 \sin a$. (6)

These equations may with sufficient accuracy for slopes up to 15 degrees be written

$$d = (100\ S + 1.25) \cos^2 a \quad (7)$$

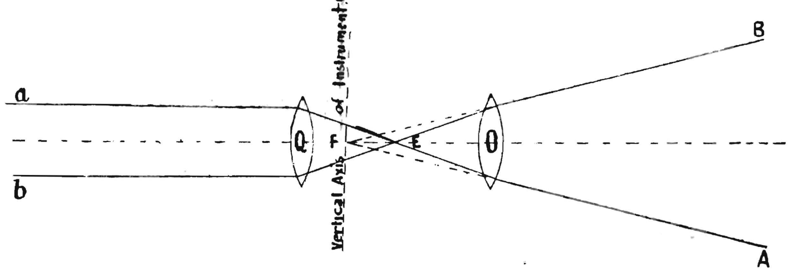
$$e = (100\ S + 1.25) \sin a \cos a \quad (8)$$

For slopes steeper than 15 degrees it will be advisable to use equations (5) and (6).

The formulae for horizontal distance and elevation even in their simplified form (7) and (8) appear to involve a great deal of calculation and labour for reduction, but by the aid of a stadia computer the calculations are altogether eliminated and the task is rendered quite easy and rapid.

When an anallatic lens is introduced into the telescpoe between the object glass and the eye piece, the point F is removed to the vertical axis of the instrument, and there is no necessity for the correction f + c, and when an instrument is thus equipped, it is called a tacheometer.

Fig 4



In fig. 4 Q is the anallatic lens, a simple converging lens so situated that the focal distances QE and OF of the lenses Q and O overlap one another, and F the principal inner focus of the object glass O coincides with the vertical axis of the instrument.

Rays from A and B entering the object glass are converged by the anallatic lens Q as parallel lines to the diaphragm. The direction of the rays from A and B, if produced, will meet at F at the vertical axis of the instrument and form thereat the measuring angle BFA.

In tacheometers the telescope is generally a powerful one, hence greater accuracy can be obtained, but the Author's experience is that even with high powered telescopes, sights longer than 300 or 350 feet do not give good, consistent results. Another advantage in tacheometers is that they are built more solidly than the ordinary theodolite and give greater steadiness, which of course is one of the essentials with a powerful telescope.

Of the disadvantages of the tacheometer may be cited the loss of light in the telescope and the difficulty of getting at the anallatic lens for cleaning it.

The Author, when lately called upon to make a railway location, determined to give the method of stadia survey a severe test, in order that its value might be definitely illustrated.

The instrument he had at his disposal was an ordinary 5 inch theodolite, converted for stadia work by having the stadia wires introduced in the telescope and a longer bubble added to the vertical alidade.

The theodolite was not a very good instrument for the purpose, the telescope being defective in power, and the stadia wires being on a separate diaphgram in a different plane to the diaphragm of the axial wire, rendered it difficult to focus, so