City Surveying

PART 2

By

A. DeGROOT

Fellow, American Society of Civil Engineers
Former Director, Civil Engineering School
International Correspondence Schools

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ICS

International Correspondence Schools, Scranton, Pennsylvania

International Correspondence Schools Canadian, Ltd., Montreal, Canada

What This Text Covers . . .

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PART 2

Traverses for Horizontal Control

General Features of Control Traverses

Use of Control Traverses

1. Traverse surveys for horizontal control, like triangulation sur
classified according to the required degree of accuracy as first-order
second-order traverses, and third-order traverses. Although first-order
tion is generally used as a basis for the horizontal control for the sur
city, the stations of a triangulation net are usually too widely scattered
enough monuments for the entire horizontal-control survey. Control
which are tied in to the triangulation stations, are therefore run along t
pal streets. The stations of these traverses are distributed throughout
so that they will be readily accessible for use as starting points for s
surveys. In a city where the ground is flat and triangulation stations w
to be located on special towers, triangulation work is sometimes omitte
and traverse surveys constitute the entire horizontal control. The ac
a traverse survey can be checked only by completing a circuit that
ends at a certain triangulation or traverse station, or by starting at o
station and closing on another known station.

Each first-order traverse is required either to close between two
located triangulation stations or to form a complete loop. Such tra
spaced at intervals of from ½ to 1 mile and are run along the princip
Stations of first-order traverses are used mainly for the control of sec
and third-order traverses.

A second-order traverse must close on stations of the triangulati
or of the first-order-traverse system, or must form a complete loop
order traverses are run along developed or built-up streets. If a ci
supplied with monuments that mark the street lines, those monume
be used as stations of second-order traverses. This practice is especia
tageous because the major uses of second-order traverses are to provi
of control for public and private property surveys and to tie in the
property monuments that have been previously established.

A third-order traverse should run between triangulation stations o
stations of traverses of either higher order, or should form a loop. T
traverses are usually located only in the undeveloped sections of the

TABLE 1

Requirements for Accuracy of Traverses

	Order of Accura	
	First	Second
Number of main stations between astronomic azimuths	15	25
Maximum probable error of astronomic azimuth, in seconds ..	0.5	2.0
Discrepancy in azimuth at check points, in seconds:		
Maximum for N stations	$2\sqrt{N}$	$10\sqrt{N}$
Average per main station not to exceed	1.0	3.0
Maximum error in distance measurement	1:35,000	1:15,000
Error of closure in position after azimuth adjustment, in feet:		
Maximum for M miles	$0.66\sqrt{M}$	$1.67\sqrt{M}$
Maximum expressed as ratio	1:25,000	1:10,000

principal use is for the control of topographic or photographic map are also used for the control of the less important construction and r surveys that do not involve street lines.

Required Accuracy of Traverses

2. The requirements for traverses of first-order, second-order, and accuracy are as given in Table 1. The total discrepancy in azimuth b stations at which astronomic azimuths are observed is determined by the observed astronomic azimuth of a line at the second such stati astronomic azimuth of the same line as computed from an observ at the first such station and the measured angles between the co part of the traverse that connects the two such stations. This total is divided by the number of main stations in that part of the traver to obtain the average azimuth discrepancy per station. The maxim closure in position after the azimuth adjustment has been made exceed either of the two values specified.

The explanations and procedures in the following articles apply to first-order traverses. Second-order traverses are similar to first-ord as far as the general features of the work are concerned. The prin ences are as follows: Sometimes, less precise angle-measuring instr tapes are used, and slightly less care may be taken in making the fie ments. Also, some of the corrections and elaborate adjustments that to the field measurements in first-order work may sometimes be second-order work.

Choice of Route for Traverse

3. For city work, a traverse is best routed along the main str several different routes are available and possible, the route that alignment and the flattest grades should be selected. Where the tra

forms a closed circuit, or loop, some attention must be given to th
shape of the loop. The least width of such a traverse should pref
not less than one-third of the length. If a single loop would be too
narrow, it should be divided into two or more loops of such size that
of the length to the width of each loop will be satisfactory. Divisi
traverse into two loops may be accomplished merely by running an
traverse course between two main stations of the original traverse. T
tional course is best located at a narrow portion of the survey.

Marking Traverse Stations

4. A permanent monument at a station of a first-order or second-
verse should be made similar to the monument described in *City S*
Part 1, for a triangulation station. Other satisfactory monuments fo
stations may consist of concrete or mortar deposited in a hole bor
ground by means of a post-hole auger. The exact point establishe
marked on the monument by embedding a copper bolt or a monel-m
in the concrete or mortar before the cement hardens, and stampin
on the head of the bolt or rivet. Granite may be used instead of con
bolt or rivet should then be set in a hole drilled in the stone and
held in place with lead.

In a city survey, the intermediate stations often are made semi
in one of the following ways: Marks are chiseled in the pavement,
or the sidewalk; copper bolts are placed in holes in the pavemen
held in place by pouring molten lead around the bolts and permit
harden; or long iron pins are driven into the ground. Temporary m
be made by means of tacks, nails, or scratches. Usually, the most
consideration in selecting the location of an intermediate station is co
in running the original traverse. It is desirable to attain the longes
courses with the flattest possible slopes and, at the same time, to have
ment setups on ground that is free from vibrations caused by traffic

All traverse stations should be fully described and referenced, as
for triangulation stations.

It is not necessary to set a permanent monument at every station
order traverse. However, in order that permanent monuments may
most effectively as starting points of new surveys, the permanent st
usually set in pairs. At least one pair of permanent monuments shoul
vided for each linear mile of traverse. The monuments for the sta
pair must be intervisible and from 500 ft (feet) to $\frac{1}{2}$ mile apart. When
survey is marked by pairs of monuments in this manner, a startin
for a new survey may be obtained at any monument in the followin
A transit or theodolite is set up at that monument, the vernier on the
circle is set to read the azimuth of the line between the point of setu

other monument in the pair, and a sight is taken on that other
The location of a station that is to be marked by a monument should
for its permanence, its freedom from probable disturbance or destru
its utility for future surveys.

Existing monuments that mark property boundaries along the
may be used for marking stations of second-order traverses. If the
enough street-line monuments for this purpose, a few permanent
must be set. In second-order traverses, semipermanent markers are
for marking the intermediate instrument stations that are not at
intersections or other critical points. Markers at all stations of
traverses may be semipermanent.

Taping Distances

5. For taping distances in a first-order traverse, the measuring
should, in general, be the same as that for measuring a base line in a
tion survey. In traverse work in a city survey, however, only o
measurement of each course is required, and measurements are usu
in feet instead of meters. Invar or steel tapes 100 ft long are standard
for making linear measurements in city surveys. An invar tape is pr
first-order and second-order surveys, but not for surveys of lesser accu
tapes 50 ft long are also used in city surveys.

All tapes that are to be used for important city surveys must
tested and standardized by the United States Bureau of Standard
other responsible testing laboratory. For a small fee, the Bureau of
will test a tape and furnish a certificate for the tape. Such a certifi
the absolute length of the tape when it is supplied throughout its
a horizontal flat surface at a temperature of 68 F (degrees Fahrenheit
(degrees centigrade), and under a tension of 10 lb (pounds); it
also the length for a few other desired conditions of support and
is usually desirable to have the length of the tape certified when
supported at the ends only and is subjected to a tension of 20 lb at a te
of 68 F.

Tapes are graduated in one of the following three ways: 1) in
of a foot, and hundredths of a foot; 2) in feet and tenths of a foot;
only, but with a 1-ft distance at each end divided into tenths and
of a foot. However, the manufacturer will graduate any tape to ord
that is commonly used for control surveys in city work is graduated
in one of the three general ways just described, and on the other side
decimeters, and centimeters. Only the side containing the usual gra
used for tape-length measurements. When a distance that is less th
length is measured, both sides of the tape are read. The metric re

then be converted into feet and a decimal part of a foot and used as a on the ordinary reading in feet and a decimal part of a foot. When this n is used, there is little chance for error in reading the fractional distance. A method of guarding against a fairly large mistake in a distance is to a check measurement by stadia or by rough taping with a 300-ft tape.

During the field work, the temperature and the pull on the tape m observed, the tape must be stretched between portable tape supports, a points must be marked carefuly with a sharp pencil or a scratch awl. Te tures are observed on tape thermometers, which either have been test the United States Bureau of Standards or are frequently checked with ther ters tested by the bureau. When measurements are made with a 100-ft the tension that is applied usually should be 20 lb. The required length o course of a first-order traverse is its geodetic length, or the distance spheroid representing the earth.

To obtain geodetic lengths, the distances measured in the field m corrected for inclination, absolute length, pull, sag, temperature, and red to sea level. However, in a control traverse for a city survey, the cor for reduction to sea level may not always be necessary. It may someti sufficient to reduce all distances to some other datum, which is usua average elevation for the locality. The formulas for computing the corrections are the same as those given in *City Surveying*, Part 1, for ba measurements. When these formulas are applied, however, it is necess substitute consistent English units for metric units.

Formulas for Corrections

6. For convenience, the formulas for the corrections to taped distanc given here in English units. The inclination correction is

$$C_1 = \frac{h^2}{2l_s} + \frac{h^4}{8l_s^3}$$

in which C_1 = inclination correction, in feet
h = difference in elevation, in feet
l_s = measured length along the slope, in feet

The correction for pull is

$$C_p = \frac{(P_m - P_s)L_t}{SE}$$

in which C_p = correction to the length of the tape for pull, in feet
P_m = actual tension on the tape, in pounds
P_s = standard tension, in pounds
L_t = nominal length of the tape, in feet
S = cross-sectional area of the tape, in square inches
E = modulus of elasticity, in pounds per square inch