IX. — NOTES ON RAILROAD LOCATION AND CONSTRUCTION IN EASTERN CANADA.—BY WM. B. MACKENZIE, *Assistant Engineer I. C. Railway, Moncton, N. B., Canada.*

Reconnaissance.—It has been said that the engineer who can conduct a reconnaissance properly, is born, not made. He must have an eye for country, and depend mainly on his own natural tact and a judgment matured by experience.

Provided with the best available map of the country—the geological maps are the best so far published—one or more barometers, and a pocket-compass, the engineer notes the governing points and takes their height with the barometer. Two should be used, the readings being taken simultaneously at a series of intervals previously agreed upon.

While serving as a general guide, only approx. heights can be obtained by the barometer. One instrument alone should never be depended upon.

Sometimes when following a stream it is scarcely possible to go far astray, but when the waters run about at right angles to the line, the difficulties are much increased. Then the lowest points on the ridges and the highest banks at stream-crossings must be sought. Several routes are examined, that promising the greatest ultimate economy being generally selected, although, sometimes, for political and other equally reprehensible reasons, the best line is adorned with "curves of beauty," to the eventual discredit of the locating engineer, although he may be in no wise responsible for the mischief.

There is always one *best* line between any two points, and, generally speaking, not one-quarter enough money is spent in seeking it. The extra cost of the construction of the one *not* the best, like the sea-captain's mule-hire, "is there, but you can't see it." Some expert, standing on the platform of a Pullman car, 50 years after, may see it, when the country will have been cleared of wood, and the eye takes in miles at a glance.

Preliminary.—Next comes the preliminary survey, where the transit and level are employed. If location is at all likely to follow, an ordinary compass should not be used. The transit should be provided with a gradienter and a level on the telescope. The gradienter is very useful when running to a maximum grade. The preliminary should be run with such care that it will not deviate from the final location more than 200 or 300 feet at any point.

I will here give a description of the running of both preliminary and location simultaneously, by the writer. After the general reconnaissance had been made, and certain ruling points fixed, and when the preliminary party had been at work for one day, a location party was started. The engineer in charge provided himself with a wooden box 21″x28″ and $1\frac{3}{4}$″ thick, holding about 20 sheets of common drawing-paper, a brass ruler, protractor, 12″ scale, and a pair of 6″ compasses. On the front edge of the box were fastened a pair of leather handles, and a pair of brass hinges on the other edge. When this box was opened out and set up on four pegs, under the grateful shade of some wide-spreading tree by the boy who carried it, the engineer's office was located there for the time.

The engineer was almost constantly with the preliminary party, and gave directions to the location party from his own general notes and the results of the preliminary work. The sheets already referred to were 20″x27″ in size, numbered from 0 upwards. Every evening the transit-man of the preliminary party plotted his notes on these sheets, to a scale of 200 ft. to an inch. As the sheets were finished they were handed to the topographer, who recorded on both sides the line, the rise or fall above or below each station, or at distances two or three stations apart as the case might be, according to the roughness of the ground. These notes generally extended 100 to 300 ft. on each side of the line. While this was being done, the leveler had plotted up his profile. The engineer, then, with the help of the plan and profile, and a fine silk thread, laid down roughly the best grades possible between the most abrupt points on profile, and dotted on the plan the line which would give the least cut or fill for this grade.

Next the location was plotted on the plan, keeping as near to the dotted line as the limiting curves and grades would allow. Notes were then written on a slip of paper and sent back by the boy to the chief of the locating party. They would read somewhat as follows: "From Sta. 40 measure at right angles to the right, 36 ft. and fix a point. Then go to Sta. 45, measure 50 feet to the right, at right angles, and set up the transit here. Sight back to first point, run tangent to Sta. 65 of location. Then put in a 5° curve to right, to Sta. 75+50. Then run tangent to 80+40, and put in a 4° curve to left, etc.

By this means the engineer kept both parties hard at work, and, with the help of a saddle-horse, the box and the boy, did the necessary exploratory work ahead of the preliminary party, as well as making an occasional visit to the locating party.

Field-Books.—Both transit and level-books should begin at the bottom of the page, so that the topographical notes may be entered on the right-hand page, opposite the stations to which they refer. Both transit-man and leveler notes down crossings of streams and roads, and as much other topography as he has time for, without delaying his principal work, although the topographer is supposed to note everything necessary on preliminary work. On location, however, the transit-man takes all the topography, excepting land-lines and proprietors' names, which is best done by a land-surveyor.

Plans, Profiles, and Estimates.—Plans, profiles, and estimates of the located line are now made. The preliminary sheets are completed by laying down thereon the widths required for right-of-way, taking from the profile the widths of the widest banks and cuttings, and extra land for snow-fences, ballast-pits, etc. This, with the determining of the sizes and positions of culverts, bridge-spans, foundations, etc., calls for a special visit of the chief engineer, or an experienced assistant, to the ground, with plan and profile in hand. This is a point often neglected, or left to incompetent persons, and the results are unsuitable foundations and structures and an insufficiency of culvert-openings.

Plan.—The plan shows the stations at every 1000 ft., the plus stations at every land-line, change of width in right-of-way, stream and road-crossings, and cultivated or wooded land.

Profile.—The profile shows the cut or fill at every station in figures, the number of cubic yards in every cutting and embankment, and whether of rock or earth, the rates and changes of grades, the land-lines and the proprietors' names, kind of country—whether wooded or cultivated—names of roads and streams, together with every bridge, culvert, cattle-guard, etc., all in their proper places.

Estimates.—An estimate of cost is now made, and just here judgment and experience are much needed; an inexperienced man will estimate too low, and a timid or conservative man too high. Contracts are generally given to the lowest tenderer, although the engineer often knows he cannot but fail to complete the work.

Construction generally.—In an ordinary rolling country, railways can be built having stone culverts, steel bridges and 56-pound steel rails, ready for traffic, for about $16,000 per mile, exclusive of right-of-way.

Before the clearing is done, a plug is driven at every station, so that if the stakes are burned the plugs may still be found. After the burning is done, the stakes at the end of all curves, and also a few on the tangents, are referenced by carefully measuring to other stakes set outside the road-bed. From these latter, the original points are found after the stakes and plugs have been dug up by the workmen.

Every foundation for bridge or culvert is staked out, and the depths of excavation marked on the stakes. Each foundation is a special study, and should be tested with a boring apparatus before deciding upon the character of the foundation. If the bottom is gravel, or rock, nothing more is required. If, on the contrary, it is soft, then loose stone, concrete, a wooden platform or piles may be necessary. In no part of railway work is experience more needed than here.

Earth-work.—Shallow embankments are made up by scrapers from the sides, and shallow cuts are ploughed and scraped off from the top. Deeper cuttings are removed by trollies drawn by horses.

Sometimes, in a heavy cutting, the track is laid over the top of the hill, and some distance to one side, if it can be done without exceeding a grade of 3 or 4 ft. per 100, and steam-shovels are put to work at both ends, while the material is hauled away by locomotives and cars to make embankments at a distance. For this purpose temporary trestles are built over unfinished culverts and over depressions near which no material is obtainable for embankments. These trestles are finally left in place when banks are completed.

Ballasting.—Gravel ballast is generally brought by train. It is loaded on the cars by a steam-shovel, and unloaded by a plow, or by side-dump cars. The track is lifted twice, and the ballast packed under the ties with shovels, to a depth of 12 or 14 inches.

Approximate cost of grading the Road-bed:—

Kind of material.	Price per cubic yard.
Earth in cuttings	22c. to 28c
Frozen earth	31c. additional.
Earth in foundations	30c.
Hard clay	35c.
Hard pan	55c. to 70c.
Rock (loose)	55c. to 70c.
Rock (solid)	$1.15 to $1.50.
Excavation in water	80c, plus dry price.
Extra haul over 1000 ft.	$\frac{3}{4}$c. per c. yd. over 1000 ft.
Filling by train from borrow-pit 1000 ft. from centre of bank	35c.
do. do. (3 mile haul)	40c.
Ballast	30c.

Box Culverts.—Dry stone work for box culverts has had its day, and it is not probable that in future it will be used to any great extent in this country. Culverts are now laid in lime and cement mortar, designed to vent water under a head, as an iron pipe would; no dry stone culvert can do this, and the attempt generally results in a washout. The side walls of box culverts are extended out beyond the end, or head walls, equal to height of culvert, so that in freshets, the opening cannot be obstructed by drift-wood, for the water will rise, flow over, and fall into the opening between the obstruction and the head or end wall of the culvert.

Fixing the sizes of culvert-openings is a matter requiring great care. If possible, the engineer in charge should personally examine the ground and the character of the country drained by the stream, whether rough, rolling or flat. If county or geological maps exist, the drainage area can be gotten approximately. Then as a rough approximation we use Major E. T. D. Myers' formula :

$$A = C \sqrt{M}$$

A = Area of opening in square feet.

M = Drainage area in acres.

C = Variable coefficient = 1 for flat ground, and $1\frac{6}{10}$ for hilly compact ground.

Highway-bridges and openings over the same stream are examined, and the highest freshet-level obtained from "the oldest inhabitant." With this information, Myers' formula, and some brains, the openings will not be far wrong.

Culverts are seldom made less than $2\frac{1}{2}$x$2\frac{1}{2}$ ft., so that a man can get through to clean them out, and their fall not less than 3ins. per 100 ft. The head walls of box culverts are carried down 4 ft. below paving, and the side walls 3 ft., to prevent frost from acting on them. Where they are over 3 ft. span, the two upper courses are corbeled out to reduce the span of the covers. Proportions and quantities are about as follows :

Area sq. ft.	Size of opening in ft.	Thickness of Walls in ft.	Thickness of Covers, inches.	Length of Covers, in ft.	Masonry in shaft per ft. run, Cubic yards.	Masonry in two ends, Cubic yards.	Paving per ft. run, Cubic yards.	Paving at both ends, Cubic yards.
4	2 x 2	$2\frac{1}{2}$	12	5	0.963	10.963	0.074	3.12
5	2 x $2\frac{1}{2}$	$2\frac{1}{2}$	12	5	1.053	11.660	0.074	3.12
8	2 x 4	$2\frac{1}{2}$	12	5	1.340	13.920	0.080	6.80
9	3 x 3	$2\frac{1}{2}$	16	6	1.225	14.000	0.080	6.80
10	$2\frac{1}{2}$ x 4	$2\frac{1}{2}$	12	$5\frac{1}{2}$	1.380	14.200	0.100	8.00
12	3 x 4	$2\frac{1}{2}$	16	6	1.410	14.540	0.110	8.40

Double box culverts are now rarely used; the middle wall collects driftwood and may cause trouble. Arches are used instead. The cost of box culvert masonry may be estimated as follows :—

Coursed masonry laid in lime and pointed with cement,	$8.00	p.c.y.
Paving in bottom and at ends	5.00	"
Riprap at ends (hand-laid)........................	2.00	"
Excavation in earth	0.30	"

Arch Culverts.—Arch culverts should be built, generally, with splayed and stepped wings deflecting 30 degrees from the longitudinal line of the culvert. Right-angled wings, with buttresses, for upper end, and straight stepped wings for lower end, have been much used in Canada, but splayed wings are now considered the best practice. There should be no recess or shoulder where the wings join the head wall, to collect drift-wood and cause scour. When the ends are funnel-shaped, as above described, the discharge is increased 100 % over the square-end culvert, when discharging under a head.

The following dimensions may be used for arch culverts :

Culvert Opening.	Thickness of Wall at Springing.	Thickness of Wall at Upper Surface of Paving.	Thickness of Arch Stones.	Remarks.
4 ft.	2½ ft.	3 ft.	15 ins.	Circular Arch.
5 "	3 "	3½ "	18 "	"
6 "	3¼ "	3¾ "	18 "	"
8 "	4 "	5 "	21 "	"
10 "	4¼ "	5¼ "	21 "	"
12 "	4¼ "	6 "	24 "	"
15 "	5½ "	6½ "	24 "	"
20 "	7 "	7 "	18 "	Segmental brick arch Rad. 12½ ft., Rise 5 ft.

Iron Pipes for Culverts.—When iron pipes are used the following sizes will be sufficient for the given area, in places where water can be backed up to discharge under a head:

Area drained up to	Iron pipe.	Embankment exceeding nine feet.
15 acres.	2 ft. dia.	"
25 "	2½ "	"
60 "	3 "	"
90 "	3½ "	"
150 "	4 "	"

The dimensions given in the foregoing tables have been extensively used on first-class work in this part of the country.

Arch culvert stone masonry costs about as follows:

DESCRIPTION.	Cost of Stone per cubic yard.	Labor per cubic yard.	Freight per cubic yard.	Total per cubic yard.
Abutment walls.........	$5.00	$4.13	$......	$......
Arch	5.00	5.13	......	......
Cement concrete	5.00	to 8.00	per cubic	yard.

Retaining-Walls.—For retaining earth, the mean thickness of stone walls are usually made one-third of the height, the top, middle, and bottom thicknesses varying, as 3, 5, and 7. Walls should be calculated to resist overturning, and also sliding at the base, using the following:

Co-efficient of friction of rubble masonry	on	wet clay,	0·2 to 0·33
"	"	moist clay,	0·33
"	"	dry clay,	0·51
"	"	dry earth,	0·50 to 0·66
"	"	sand,	0·66 to 0·75
"	"	gravel,	0·66 to 0·75
"	"	dry wooden platform,	0·60
"	"	wet "	0·75

The ground in front of the wall should not be counted upon to assist in the support of the wall, and a factor of safety of not less than 3 should be used.

Safe pressures on foundations under walls.—

Safe pressure on		Gravel..........	2 to 3	tons	per	sq. ft.
"	"	Sand.	"	"		"
"	"	Loam.	$1\frac{1}{2}$	"		"
"	"	Silt and Alluvium	1 ton			"
"	"	Clay	1 to $2\frac{1}{2}$ tons			"

Bridge-Piers and their foundations.—Masonry piers for bridges will cost from $8 to $15 per cubic yard, exclusive of the foundations on which they rest.

For 50 ft.	span,	make piers	4 ft.	thick	under coping.
" 100	"	"	5	"	"
" 150	"	"	6	"	"
" 200	"	"	7	"	"
" 250	"	"	$7\frac{1}{2}$ to 8 for piers 80 ft. high.		

Sides and ends of piers batter half inch or three-quarter inch per ft. Abutments batter one inch per ft.

Where sloping ice-breakers are not required, a round-ended pier is the best shape.

Grouting should not be used in first-class work, but flush up fully with cement mortar as built.

Foundation piles driven and cut off with a saw, under 12 to 14 ft. of water, will cost 35 cents per lineal ft. of part remaining in the work (say 17 ft.)

The best formula for pile driving is—

$$L = \frac{2\ WH}{S + 1}$$

in which

L = safe load in lbs.

W = weight of hammer in lbs.

H = fall of hammer in feet.

S = penetration in inches under last blow.

Where piles are driven under abutments on land, 12 inches of concrete is placed around pile-heads, 12″x12″ caps are then put on, and a course of timber laid close, to carry the masonry.

In calculating the weight on the earth under the abutment, draw lines from outer edges of bed-plates on an angle of 30 degrees with the vertical, down to the foundation, and assume that the live and dead loads, and also the weight of the masonry within those lines are all concentrated on the space between the points where these lines meet the foundation. This length multiplied by the thickness of the wall, or width of grillage, etc., gives the number of square feet over which the whole weight is supposed to be distributed.

The weight of rolling-stock has so increased in the last twenty years that iron bridges are now being removed and replaced by heavier steel structures, all over the country. The designer has now to ask himself: "Am I designing for five, ten, or for fifty years?" If a thoughtful man, he will not sail too close to the wind in proportioning his bridges, but provide a margin to meet future increased weight of rolling-stock.

Types.—For spans up to 15 ft., use rolled beams.
" from 15 to 80 ft., use plate-girders 8 ft. c. to c.
" from 80 to 100 ft., riveted Warren girders.
" from 100 to 150 ft., single intersection pin-connected Pratt trusses, with parallel or arched top chord, 14 ft. to 16 ft. clear width inside.
" from 150 to 550 ft., double intersection pin-connected Pratt trusses, with parallel or arched top chord.

Up to 225 ft., 14 ft. clear width min. Max. 16 ft.
225 to 320 ft., 18 ft. center to center.
320 to 420 ft., 21 ft. "
420 to 550 ft., 25 ft. "

Cost, etc., of Steel Bridges (metal only), designed for Typical Consolidation Locomotives. Compiled from formulas by G. H. Pegram, C. E. (Trans. A. S. C. Engrs., Feb. 1886.)

Length ft. (1)	Deck or Through. (2)	Type. (3)	Steel or Iron. (4)	Weight per ft. lbs. (5)	Total weight lbs. (6)	Cost per lb. (variable.) (7)	Price per ft. run. (8)	Cost for Metal erected. (9)
30	Deck.	Plate girders	Steel	425	12,750	4 cts.	$17 00	$510 00
35	"	"	"	460	16,100	4 "	18 40	644 00
40	"	"	"	525	21,000	4 "	21 00	840 00
45	"	"	"	550	24,750	4 "	22 00	990 00
50	"	"	"	580	29,000	4 "	23 20	1160 00
55	"	"	"	620	34,100	4 "	24 80	1364 00
60	"	"	"	650	39,000	4 "	26 00	1560 00
65	"	"	"	675	43,575	4 "	27 00	1743 00
70	"	"	"	715	50,050	4 "	28 60	2002 00
75	"	"	"	750	56,250	4 "	30 00	2250 00
80	Thro' riveted	Warren	"	775	62,000	4½ "	34 88	2790 00
85	"	"	"	800	68,000	4½ "	36 00	3060 00
90	"	"	"	830	74,700	4½ "	37 35	3361 50
95	"	"	"	860	81,700	4½ "	38 70	3676 50
100	"	"	"	900	90,000	4½ "	40 50	4050 00

For double track add 90 %.—Cols. 7, 8 and 9 will vary with the market price of steel.

Bridge-Erection on Railways in operation.—Plate-girders up to 75 feet span are usually riveted up complete, run into place on cars, and lowered on to the masonry by four screws working through overhead caps, supported on two posts at each end of bridge.

Deck bridges from 75 feet to 100 feet are riveted up complete, run into place on cars, jacked up, and the weight taken on blocks hung from overhead gallows-frames. The cars are then run out and the old bridge removed, when the new bridge is lowered to its place on the masonry by means of the blocks.

Through bridges may be placed the same as Decks, by spreading the old trusses far enough to let the new bridge in between