CANADIAN RAILWAYS.—No. XLIX.

HAMILTON AND NORTH-WESTERN.—I.

IN "Bradshaw's Railway Manual" for 1862 or 1863, may be seen amongst the list of Canadian railways the following brief notice: "Hamilton and Port Dover Railway, seventeen miles long, under construction from Hamilton to Caledonia, on the Grand River. Works not proceeding." This was nearly all that could be said about this road for the first thirty years of its existence, for it was one of the earliest projects in the country, chartered in 1836, and apparently one of the most desirable and necessary either to the business of the "ambitious city" Hamilton, where it was to commence, or of the Great Western, with which it was to connect. The parent Act of Parliament, which ultimately developed into the Great Western Charter, promoted principally by Allan Napier (afterwards Sir Allan) M'Nab in the interest of Hamilton, was for a railway from the head of Lake Ontario at that place to the navigable waters of the River Thames, a due east and west line, connecting lakes Ontario and St Clair. Shortly afterwards, and before any commencement was made to the works, the Niagara and Detroit Rivers Railway Company was incorporated April 26 1836, to construct a railway from the former of these rivers in the township of Bertie opposite to the city of Buffalo, to the Detroit river at Sandwich (the first inception of the present Canada Southern), and with this latter company, unfortunately for itself, the Hamilton and Port Dover was affiliated. All these original schemes and companies, however, lay in abeyance, and when, ten years afterwards, the Great Western Railway was commenced, the very obvious connexion with Lake Erie was looked upon with disfavour, as calculated to draw off a certain amount of through traffic between the west and Lake Ontario which would thus find its way between the two great lakes by a comparatively short road, only 40 miles in length, as against the 180 miles of the Great Western. Railway men in those days had no confidence in these routes in competition with steamers, and hence the erroneous reasoning which deterred the Great Western from assisting and helping forward this very promising tributary and complement of their own system. The Port Dover line from Hamilton is the natural extension of the Toronto branch of the main line, and the two together would have formed with it a St. Andrew's cross at Hamilton, mutually giving and receiving on each of the four converging lines the traffic and connexions of the other three. It is clear now that had the Great Western taken up this railway in its then shape, they might have retained their monopoly of the Hamilton traffic in every direction for years yet to come. The Hamilton and Port Dover Railway consequently remained for years with some inconsiderable amount of work done upon the sixteen miles between the proposed junction with the Great Western Railway at Hamilton and the Buffalo and Lake Huron at Caledonia, to either of which roads it would have been an excellent feeder, but neither of which seemed to care for its alliance or completion.

By an Act passed December 24th, 1869, the charter of the Hamilton and Port Dover Railway, which had expired, was revived for certain purposes, and as a necessity for the winding up of the company, and the same day a new company, the Hamilton and Lake Erie Railway, was created to construct a railway over the same ground and to take over the incomplete works. On completion of these negotiations the former company ceased to exist, and the new one commenced, free from all obligations, with a considerable amount of work and property already acquired, and with power to mortgage the whole concern and start with a fresh issue of bonds. To this new scheme the city of Hamilton voted as a gift 100,000 dols., the county of Haldimand contributed 65,000 dols., and the Ontario Government subsidised it to the extent of 2000 dols. per mile of completed road. With this assistance the road was completed in 1874 between Hamilton and Jervis, 33 miles, the point of intersection of the "air line" of the Great Western, when financial disputes culminated between the company and the contractors, and threw the affairs of the company again into confusion. By a return made to the Government, June 30, 1875, when the only work done was this 33 miles, without a single heavy or expensive structure upon it, a surface line throughout, there had been raised:

	dols.
By shares	112,241
By bonds	855,000
From the Government	67,000
From municipalities	165,000
And, there was in addition a floating debt of	555,000
A total of	1,754,241

whilst the total cost of the railway and rolling stock is put down at 850,000 dols. In other words, whilst the contractor had received 374,241 dols. in cash and claimed as a debt due to him more than the balance of the whole work done, a mortgage of 25,000 dols. per mile had been fastened upon the road for which no value whatever was shown in the works. At the same time the receipts for the previous year had been 88,025 dols., and the expenses 48,285 dols. To save expense the road had been carried through Hamilton principally on the line of the public streets, the "depot" in that city being a mere platform and shed extending from one cross street to the other, and the whole work as poor and imperfect as would pass under the name of a railway and secure the Government subsidy, whilst the capital swelled to nearly 60,000 dols. per mile, was sufficient twice over to have completed a good honest line between the two points, finished and furnished with adequate rolling stock, and able to have paid its way and returned a fair amount of interest to the outside investors. The traffic indeed for a new line without running arrangements with the roads at either end had proved fairly remunerative, and the line was developing a business which showed that it was a necessity for the country, and a desirable acquisition to any of the intersecting railways.

In the year 1872 a company had been organised to complete a railway from Hamilton to Barrie and Collingwood, the two termini at that time of the Northern Railway from Toronto. There was, it is true, no very obvious necessity, as far as the country was concerned, for this line, no traffic existed between those northern points and Hamilton, and if there had been, the Northern and Great Western Railways had a junction station two miles west of Toronto, at which such traffic could have been interchanged. The distances from Hamilton to Barrie and Collingwood by the existing route were 99 and 129 miles respectively; by the new road it was to be 95 and 108 miles, scarcely sufficient apparently to justify the proposed outlay. But Hamilton wanted all that Toronto had, and if the Northern had grown into an important line and developed a traffic sufficient to maintain itself and enrich Toronto, the new line it was expected could do as much for the city of Hamilton. The new company aimed in fact at more than this. Their Act empowered them to construct their railway to one of the bays in the township of Say, 30 miles to the north of Barrie, and to continue the same in the direction of Lake Nipissing to a junction with the Canada Central and Canada Pacific Railways, thus placing their road on the great highway between the Canadian Transcontinental line, and the State of New York, the shortest and perhaps best route between the Pacific and the principal Atlantic ports. In the early part of 1876 the works on this line were commenced, and though delayed at first by some difficulties as to the route to be adopted on leaving Hamilton, before the close of the year the rails were laid 35 miles almost to the crossing of the Grand Trunk Railway at Georgetown. Previous to this, however, an amalgamation had taken place between the two railways centring at Hamilton, the Hamilton and Lake Erie being merged into the newer and more important line, and its financial affairs being placed on a better basis. During 1877 the portion of new line to Georgetown was opened for traffic, and 88 miles more were placed under construction, the whole line in work by the end of the year extending from Jervis 33 miles south of Hamilton to Barrie 65½ miles to the north, besides 18½ miles on the Collingwood branch; and before the close of 1878 the complete line was in operation from Lake Erie at Port Dover to Lake Huron at Collingwood, with a branch to Lake Simcoe at Barrie, a total of 177 miles. This result had not been obtained without some increase to the capital, the Government aid had amounted to 406,500 dols., the municipal bonuses had been extended to 774,000 dols., but the amount raised on shares was not materially increased, and the total capital raised by the prospectus is returned at less than when at the Hamilton and Lake Erie the line in operation was 33 miles only in length.

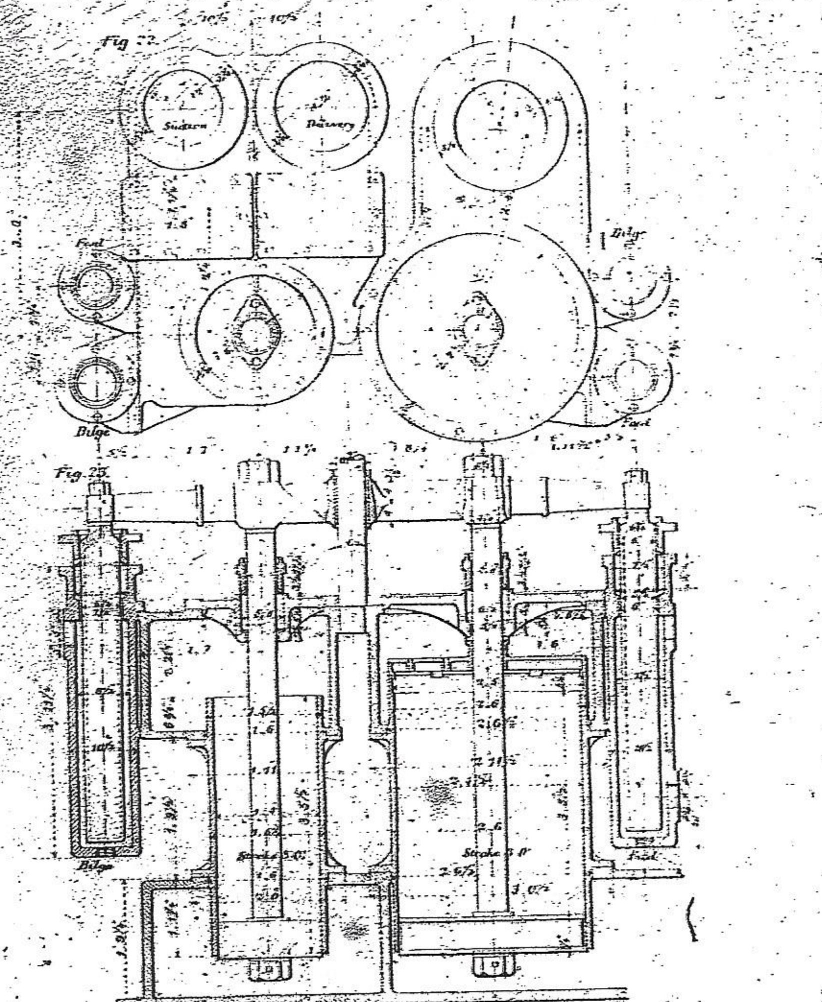
The line as then complete commences at the harbour of Port Dover on the north side of Lake Erie 40 miles west of the entrance to the Welland Canal and about 60 miles west of Buffalo, one of the best points for securing the heavy traffic of Lake Erie, and especially the coal business from the bituminous coalfields of Ohio and Indiana. The harbour lies in latitude 42 deg. 47 min., almost the most southernly point in Canada, and in a south-west direction from Toronto and Hamilton, the three places being almost in a straight line, and if the same course were continued across Lake Erie, it would strike the city of Cleveland, the outlet of the coal, iron, and oil productions of the Ohio valley, and one of the most important exporting and manufacturing centres of the West. From this and other places on Lake Erie, Port Dover is one of the best points to intercept the traffic to Canada or the St. Lawrence, and though rather wanting as a good harbour, it shares this discredit in common with almost every one of the Lake Erie ports; for none of the Canadian harbours on this inland sea are either very secure in stormy weather, or have naturally a sufficient depth of water. The harbour now belongs to the Stratford and Lake Huron Railway which also commences at this same point, both railways having equal access to the wharves, and the same terminal facilities, and both crossing in their diverging course north-east and north-west from the port all the great east and west lines that traverse the Canadian peninsula between the Great Lakes. At nine miles distance from the common terminus by the Hamilton line, and eight miles by the Stratford, they cross the "air line" of the Great Western at points 11 miles apart. At 19 miles from Lake Erie they cross the Canada Southern 26 miles apart. The Brantford extensions of the Grand Trunk and Great Western are each intersected by the two Port Dover roads at points 35 miles asunder, whilst the main line of the Great Western is crossed by both 48 miles apart and in 40 and 42 miles respectively from their common starting-point. Still further north again the Grand Trunk is intersected 77 and 63 miles from the southern terminus of both at Georgetown and Stratford, a distance apart of 59 miles.

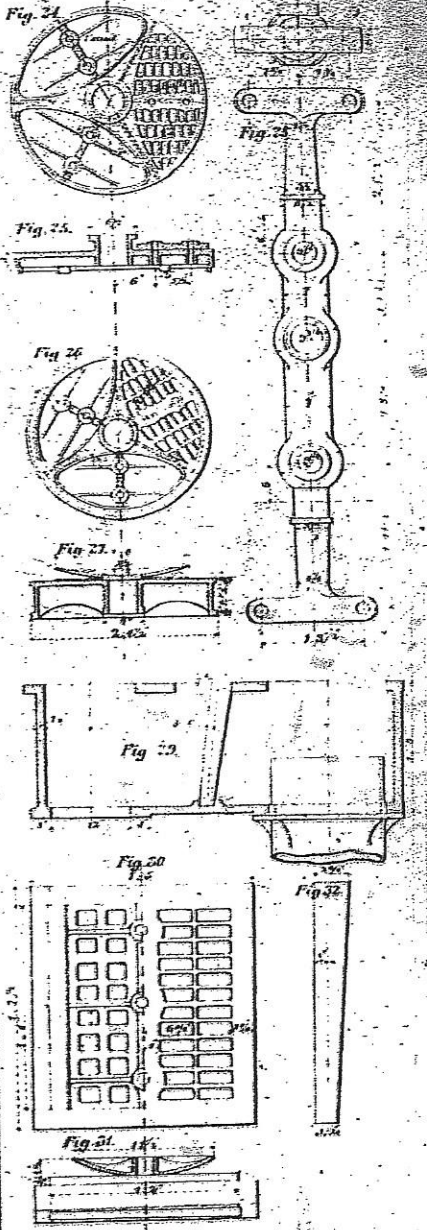
The Hamilton and North-Western, after leaving Port Dover, runs across a rich agricultural and level country to the village of Caledonia, 26 miles from the terminus, crossing in this distance the air line of the Western, the Canada Southern, and the Buffalo division of the Grand Trunk all on the level, and with a junction siding with each for the interchange of traffic. At each of these places is a thriving village, and at Caledonia especially a very considerable interchange of traffic at one time took place with the Grand Trunk, which made this temporarily its freight and express passenger route between Toronto and Buffalo. The distance between these two cities by the Grand Trunk, passing over an acute angle at Stratford, is 203 miles; by using the 51 miles of the Hamilton and North-Western between Georgetown and Caledonia, this was reduced to 139 miles, and a very heavy coal and general traffic was for some time run by the Grand Trunk between these important points over the Hamilton and North-Western line. Circumstances have, however, interfered to prevent this accommodation between the two companies, and the locomotive coal for Toronto and general freight is now dragged round by Stratford, 203 miles, at the same rates that the Great Western charge for the 104 miles which their line makes between the same points. At Caledonia, the railway crosses the Grand River, the most important river on the whole route, and immediately north of the river the Grand Trunk Railway at a union station for both roads, the village itself being on both sides of the river, which runs through its centre, and which is here crossed by the main street of the town on a magnificent iron bridge, which was erected in 1875. It is not a very ancient place, and thirty years since it was only struggling into existence on a very modest scale. In 1835 the Grand River Navigation Company laid out the original building site on the west side of the river in the township of Oneida, the plot containing only 16 acres, which they named after the township. A year or two afterwards the same company laid off another village on the opposite side of the then unbridged river in the township of Seneca, again naming it after the old Indian tribe whose reservation this had once been. In 1843 the Government laid out a new village, Caledonia covering both sites, and the immense water power of the Grand River commenced to be utilised for manufacturing purposes, and has drawn a healthy business population round what is now an important railway junction. From this point

ENGINES OF THE S.S. "ASSYRIAN MONARCH;" AIR AND CIRCULATING PUMPS.

CONSTRUCTED BY EARLE'S SHIPBUILDING AND ENGINEERING COMPANY, LIMITED, HULL.

(*For Notice, see Page* 585.)





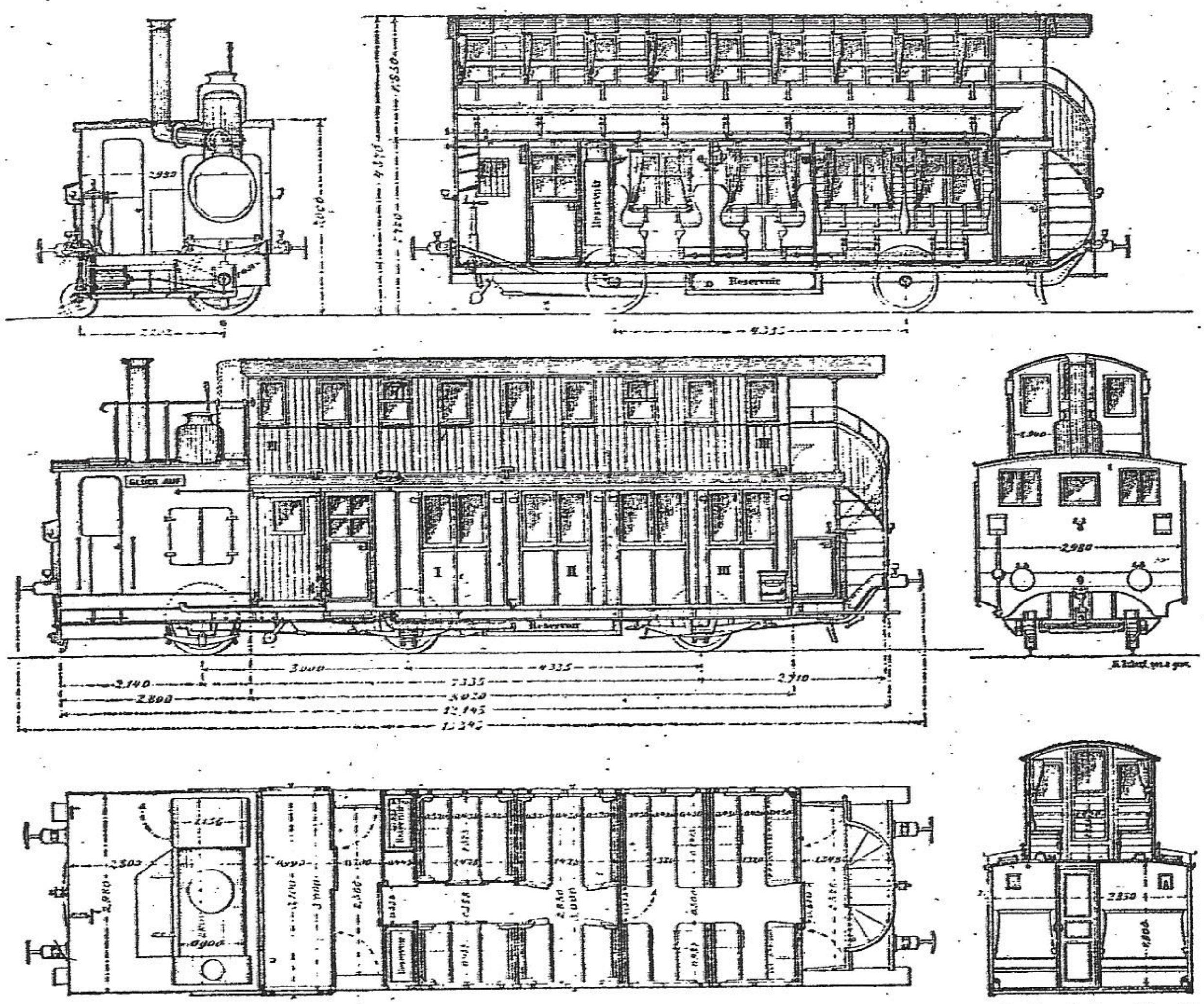
the Hamilton line rises over the watershed of the Lake Erie river system, and then descends nearly 500 ft. in the last ten miles to Hamilton. For nearly two miles through Hamilton the railway is carried on a level with and through the streets of the city in what appears to be a most exposed and dangerous manner, and not far from the business centre of the city is the covered waiting-room and platform that is dignified by the title of Hamilton Station, a most modest and unsatisfactory arrangement for a city of its size and importance, and which prides itself upon the possession of some of the handsomest buildings on the continent. There is such a thing as being too niggardly in the outlay that is classed as non-productive on a railway, and in no particular is this more provokingly apparent than in the utter want of appearance and convenience of the stations in towns that seem to be deserving of better accommodation. Of late years something has been done to remove the discreditable shanties, and to build more appropriate depôts in most of the large Canadian cities, and at Hamilton the Great Western Station is a model of neatness and convenience, whilst the head-quarters of the North-Western, and the principal station on the line, is simply ridiculous.

Hamilton is one of the finest cities in Canada, and stretching along the beautiful Burlington Bay for over two miles, runs back to the base of the perpendicular escarpment, which is an extension of the Niagara outcrop, and marks the watershed between the drainage of the Lakes Erie and Ontario. At the point where the city is built this rocky escarpment comes within a mile and a half of the waters of the lower lake, forming a natural barrier to the growth of the city in this direction, which it will be a long time before it overreaches. The site of the city was, within the memory of some still alive, covered with a dense growth of low and almost impenetrable bush, with here and there a tall water elm. Interspersed amongst this were ravines strewed with fallen trees, and patches of swamp, the favourite haunts of rattlesnakes, frogs, and squirrels. On the spot now occupied by the market square was a particularly dense thicket, which was the rendezvous of numerous wolves, whilst up the steep and over the mountain where the water works reservoir now stands, was an Indian trail which connected the Grand River with Burlington Bay. The aborigines were not partial to the uninviting locality and seldom made any stay here, but where Emerald-street now approaches the water they had a burial-ground far from human observation, and in the deepest solitude. The first settler was Robert Land, who, originally from the banks of the Delaware, had fought on the British side through the Revolutionary War, and in 1778 was rewarded with a grant of land of 300 acres, covering the greater part of the eastern half of the present city. In 1796 and 1812 other settlers arrived, and by the latter year all the land facing the bay had been granted. In 1813 a portion of Land's grant was laid out in village lots by George Hamilton, at that time member of Parliament for the district, after whom the "ambitious city" is named, and who in 1815 held here no less than 1416 acres, of which, however, only one-tenth was cleared. In 1823 the town of Hamilton was incorporated. In that year and 1826 charters had been obtained for the construction of the Burlington Bay and the Desjardins Canal, the first of which gave it access to Lake Ontario and the latter opened up the convenient water power of Dundas, and both contributed to the wealth and population of the town of Hamilton. In 1846 it was created a city, the Great Western having made this their head-quarters, and employing not far from 1000 men in their workshops and on the line tributary to this place. Since then its progress has been very marked, and in 1879 the population was 34,268, and the valuation of the property 15,431,780 dols., an increase during the previous year of 757 in population. Hamilton possesses an admirable system of water works and drainage. The water for the

STEAM TRAMCAR FOR LOCAL TRAFFIC AND BRANCH LINES.

CONSTRUCTED BY MR. G. THOMAS, ENGINEER, MAYENCE, GERMANY.

(For Description, see Page 585.)



former is taken from a distance of 3½ miles into the bay, and forced into a reservoir on the brow of the mountain, which holds 9,000,000 gallons, and permits a high-pressure service over the whole town below sufficient for all purposes. Along this same mountain brow and commanding a magnificent prospect is the insane asylum, a spacious and beautiful structure of red brick, which is a great ornament to the city. It was first occupied in 1876, and in two years had 320 patients. Another handsome building is the new court-house built in 1878 for the county of Wentworth as well as for the city, and which is one of the finest edifices in the Dominion. It fronts on Prince's-square, 168 ft. in length, the main building being 74 ft. deep and the wings 64 ft., built of the beautiful magnesian limestone of the Niagara outcrop, and quarried within two or three miles of the city. Leaving the "station" at Hamilton, the railway traverses a street for the next half-mile, and then descending on a steep grade passes underneath the Great Western Railway, and follows for some distance the southern margin of Burlington Bay, a fine sheet of water about six miles across in its widest part, and nearly triangular in shape with its vertex at the opening of the Desjardins Canal just north of Hamilton. The base of this triangle is a long sandy beach about 300 ft. in breadth, and six miles long, which separates the waters of Burlington Bay from those of Lake Ontario. The bay inside has a depth of 25 ft., and an area of about 10,000 acres. Through this sand bar the Burlington Bay Canal was constructed and opened in 1832. The railway skirts the southern shore of this bay, and then crosses the bar which separates it from Lake Ontario, crossing the canal by a very handsome iron drawbridge, built by the Hamilton Tool and Bridge Company, which has turned out some very fine specimens of bridgework, of which this probably is their best. The bridge rests on a central pier just back of the northern wall of the canal, showing when in place two clear spans of 135 ft., one on each side of the central pier. This bridge is opened and closed by a small engine, which is attached to its side near the centre, and works a small pinion on the bridge, which engages the cogs of a fixed spur-wheel bolted in segments on the circular central pier.

Burlington Beach claims to be one of the most fashionable summer resorts in Canada, and an excellent hotel admirably placed on the railway and near to the canal, equally accessible by the steamers passing through the one, and the numerous local trains which run to Hamilton on the other, makes this a most convenient resort either from Toronto or from the west, and a popular watering place from which Niagara, St. Catharine's, and a hundred other "show places" are easily reached. At the north end of the beach where it joins the north shore of Lake Ontario was one of the first, if not the very earliest settlement in Upper Canada, exclusive of military forts, and the little villages surrounding them, and which as Wellington Square grew to be a largish fishing locality long before either Toronto or Hamilton was inhabited. Here the railway leaves the beach, and rising from the Lake Shore, at a distance of nine miles from Hamilton by this railway and eight miles by the Great Western, crosses that railway's Toronto branch at a place called Burlington Village, and thence proceeds north-east and north to Milton, the capital of Hatton county, 24 miles from Hamilton and 66 from the terminus on Lake Erie, where it crosses the Credit Valley Railway, and with it forms a second route between Hamilton and Toronto. Still trending north, in eleven miles it crosses over the main line of the Grand Trunk at Georgetown, a side track diverging from the railway half a mile from the crossing joining the other road on the level at the Grand Trunk Station, and serving the connexion between the two lines, which at one time seemed of so much importance to both. Seven miles from this, still trending north, the Hamilton line comes nearly alongside the Orangeville branch of the Credit Valley, the river only being between the two railways for nearly three miles, when the latter railway crosses the river and the North-Western line at a little hamlet called Sligo, after which the two railways rapidly diverge, the Hamilton line keeping due north, whilst the course of the Credit Valley at this point is nearly west. The next six miles is on a steep ascent, the railway rising to the height of land flanked by the Caledon Mountains, and in six miles from Sligo or 93 miles from Port Dover passes underneath the

Toronto, Grey, and Bruce. This is near the high tableland which forms the watershed between the rivers running north and south, and 17 miles further Beeton Junction is reached, where the two branches of the railway to Collingwood on the north-west and to Barrie on the north-east diverge. To this point the Hamilton and North-Western has crossed no less than nine different railways, of which six are on a level, the country through which the road passes, excepting for the first 30 miles from Port Dover, is not equal to the average of Ontario, and for the whole distance from Hamilton to the Mono crossing of the Toronto, Grey, and Bruce it must necessarily compete with the other railways which are closely parallel, and which as a rule follow the direction of the traffic, whilst the North-Western scarcely runs in the right course for any trade excepting that going to Hamilton.

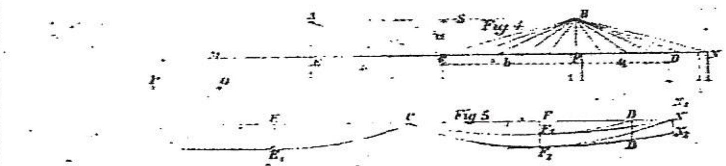
STRAIGHT-LINK SUSPENSION BRIDGES.—No. III.

By T. Claxton Fidler.

11. The alterations of stress which accompany change of temperature, when the roadway girder is abutted between immovable piers, may be more perfectly annulled by carrying the girder on at each end as a strut to the horizontal stress of the backstay, whose vertical lifting force may be resisted by holding-down bolts or a vertical anchorage, so arranged as to allow the girder with the backstay attached to move freely upon the abutment. Thus, in Fig. 4, let the roadway girder be continued through the pier E to M, where the backstay A M is attached to it, and where it is also held down by a vertical anchorage M O, but left free to move horizontally on the abutment at M. The direct pull of the backstay A M will thus be resolved into a horizontal compression in M E, and a vertical tension in M O. Now if the member A E is of iron (no matter whether it be a plate pillar in one with the upper and lower members of the cantilever, or whether it be an iron tower fixed to the pier E and allowing the saddle at A to move along the top of it upon rollers), it is evident that any expansion by heat, affecting all the ironwork alike, will not alter the proportions of the triangle A M C, so that its only effect will be a horizontal motion of the girder and stays as a whole: there will be no deflection of the roadway, and no alteration in the stress of any member. In this respect the present plan has an advantage over any that we have hitherto considered—for the sake of brevity we have not stopped to consider all the effects of change of form by heat or strain in the previous examples, but it will be evident that in all cases a deflection of the roadway girder will ensue from any lengthening of the inclined stays and backstay, just as it does in the case of a common suspension bridge from the extension of the chains, and unless the girder is hinged in the centre it will be liable to a bending stress from this cause; but so far as a regular expansion by heat is concerned, the present example is freed from any effect of that kind by the movement of the point M, which exactly takes up the expansion of the inclined stays and backstay. The bridge will evidently carry its load as a pair of cantilevers: the stress in the lower member will be proportional at different points to the ordinates above the parabola in Fig. 5, and its maximum value at E will be $E E_1 = (p+q)\frac{s^2}{8d}$; this will also be the horizontal component of the stresses in A M and M E. The theoretic mass of the bridge between the piers will, therefore, be the same as that of the pair of divided cantilevers considered under paragraph 5. In that example we found, as explained in paragraph 6, that the lower member might be relieved of a good deal of stress by coupling the longest pair of stays, and supporting a portion of the roadway in the centre upon the suspension principle; but in the present example it is clear that if the backstay A M is to take the horizontal stress of *all* the inclined stays, the stress of the longest pair *must* in any case be sent through the whole length of the girder. If we wish to have a bit of suspension bridge in the middle, it must form a distinct system—the stay A C must have its own independent backstay, not attached to the roadway girder but anchored horizontally as well as vertically at M. This would, of course, upset the temperature compensation before adverted to; thus, starting the expansion from M, the point C would now drop vertically while the points at the ends of the penultimate stays would only advance horizontally; there would, therefore, be a short and rather severe bending of the girder at C, and if it is not sufficiently flexible to accommodate itself to this deflection without much resistance, the middle pair of stays would be slack and would not give their proper quota of support, and consequently the next pair would have to carry more than their proper share; conversely, a fall of temperature would lift the point C, and if the roadway girder were a stiff one, the middle pair of stays would have a great deal more than their proper load.

The stress in the vertical anchorage M O will, of course, depend upon how much of the span is really cantilever: if we revert to the first arrangement, which is much the simplest, and so make it all cantilever, the load upon E C will exert a lifting force at $M = (p+q)\frac{s}{2}\cdot\frac{EC}{2ME}$; and if there is no load upon M E, this will be the stress in the anchorage M O.

With regard to the economy of this plan, as compared with that of previous examples, it may be observed that the backstay A M is common to all: the combined mass of M E and M O will perhaps, in some cases, be not very much heavier than that of the direct anchorage M P which would be required by other methods; and against the difference, whatever it may be, we have to set the saving in masonry which is effected in this system by the vertical anchorage.



12. If we employ the extra length of roadway girder beyond the towers to carry the load over a pair of side openings, and thus convert the structure into a three-span bridge, as shown on the right-hand side of Fig. 4, we shall not only cover a greater width between abutments with about the same weight of superstructure, but the anchorage will be relieved of a great part of the vertical lifting stress. There will arise, however, some new points to claim our attention.

Let us first suppose the side span F N to be equal to F C or half the centre span, and the roadway girder F N to be supported by inclined stays at short intervals in the same way at F C, stay for stay. Then, under the uniform load, the whole thing will be balanced upon the pier F, and there will be neither pressure nor any upward pull upon the abutment N. Thus, the last stay B N, which we may still call the backstay, will have no stress, or at least no more than the stay B C, the vertical component in each being merely equal to half the load on the last bay of roadway girder. The load upon the centre span will produce exactly the same stresses in the members of the centre span that it did in the last example: the maximum horizontal compression at F or tension at B will be $(p+q)\frac{s^2}{8d}$, and to the right of F each successive stay will annihilate the increment of stress brought by the corresponding stay to the left; thus the stresses in the roadway girder will be as the ordinates below the straight line C F N in Fig. 5, measured to the parabola C F_1 N for dead load only, and to the parabola C F_2 N when the bridge is uniformly covered with the rolling load; F F_1 being $= p\frac{s^2}{8d}$ and $F_1 F_2 = q\frac{s^2}{8d}$. Now when the rolling load covers the centre span, but not the side span, there will be an excess of horizontal tension at B and of compression at F, equal to $q\frac{s^2}{8d}$, and unbalanced by the stays upon F N; or again there will be an excess of weight upon the arm F C unbalanced by the weight upon the arm F N, and exerting a lifting force at N equal to $\frac{qs}{4}$, which must be borne by the anchorage, and requires a compression in N F and tension in N B whose horizontal component is $\frac{qs^2}{8d}$. The diagram of stresses will now be C F_2 N_2 in Fig. 5, F_2 N_2 being a parabola parallel to F_1 N, so that N $N_2 = F_1 F_2 = \frac{qs^2}{8d}$ = the horizontal force at N (tension in the backstay, compression in the girder). Again, when the rolling load covers the side span but not the centre span, the excess of weight on the right-hand side will require to be supported at N, where it will exert a downward pressure upon the abutment of $\frac{qs}{4}$, and unless we rely upon the transverse strength of the roadway girder to carry the rolling load, this downward pressure upon the abutment at N can only be brought by a compressive thrust in the backstay B N, and a tension in the member F N, the horizontal component of both being $\frac{qs^2}{8d}$. Thus the diagram of stresses in the lower member will be the curve C F_1 N_1 in Fig. 5, in which F_1 N_1 is a parabola parallel to F_2 N, so that N $N_1 = F_2 F_1 = F - \frac{qs^2}{8d}$ = the horizontal force at N (compression in the backstay and tension in the girder). If the backstay is incapable of resisting compressive strain, the roadway girder must carry the irregular load as a continuous girder; the determination of its bending stress and deflection, as affecting and reciprocally affected by the action of the inclined stays, will in that case form a complex problem which we do not now propose to enter upon.

13. The backstay may be saved from the infliction of compressive strain by modifying the proportion of side span to centre span. Let the bridge, Fig. 4, be terminated at D instead of at N, so that the side span is considerably less than half the centre span: if the proportions are such that the dead and live load together upon the short arm F D do not more than counterbalance the dead load alone upon the long arm F C, there will, of course, be no downward pressure upon the abutment at D, and, consequently, no compression in the backstay B D. To find the greatest length of side span that can be had without throwing the backstay into compression let

a = the side span F D
b = F C, or half the centre span.

The dead load to the left of F will exert a moment $\frac{pb^2}{2}$, and to the right a contrary moment of $\frac{pa^2}{2}$; the lifting force at D will be, for dead load alone $\frac{pb^2 - pa^2}{2a}$, and when the rolling load covers the side span it will be $\frac{pb^2 - a^2(p+q)}{2a}$. When the loads exactly balance and the lifting force is 0 we have $a = b\sqrt{\frac{p}{p+q}}$.

The point D is then located at the intersection of the parabola F_1 N_1 with the straight line F N in Fig. 5. For example, if the intensity of rolling load is equal to that of the dead load, or $p=q$, we have $a = \frac{b}{\sqrt{2}}$.

In the fine example of this class at Chelsea, designed by Mr. Ordish, the centre span is 400 ft., and the side spans 155 ft. The greatest lifting force at D, or stress in the vertical anchorage, will occur when the rolling load covers the centre span, but not the side span, and will be $\frac{(p+q)b^2 - pa^2}{2a}$. The horizontal component of the greatest tension in the backstay B D, and compression in the roadway girder at D will then be D D_2, Fig. 5 $= \frac{(p+q)b^2 - pa^2}{2d}$.

The diagram of maximum stresses will be the curve C F_2 D_2 Fig. 5, and for minimum stresses the curve C F_1 D.

We have now glanced very superficially at about