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The Canadian Engineer

A weekly paper for civil engineers and contractors

Sewage Disposal Works at London, Ontario

Two-Story, Non-Reversible Sedimentation Tanks and Enclosed Filters with Fixed Spraying Nozzles—History of London's Sewerage Problems Since 1891—Construction of Interceptors and Outfalls—Review of Work Done and Suggestions for Further Improvements

By WILLIS CHIPMAN
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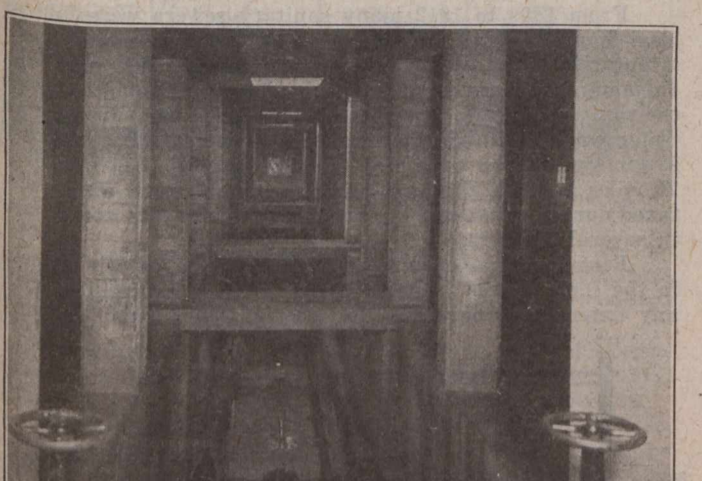
IN 1891 the population of the city of London was about 31,240. The central business section of the city was then provided with combined sewers, and in London South, a recently annexed suburb, many streets had also been provided with pipe sewers. One brick trunk sewer had been laid on Wellington St. with a tributary population of 3,000, a second on Richmond St. serving 2,000 people, and a third on King St. serving about 6,000; all discharging directly into the south branch of the Thames River. Each of these sewers was 36 ins. x 54 ins. Branches were laid on many streets to the limits of the drainage areas. These sewers were built without regard to future extensions, and in fact could not be extended owing to their high elevations. The south branch of the river was grossly polluted, and this pollution extended into the main stream below the forks. Some of the pipe sewers in London South, originally laid for cellar drainage and the removal of street water, were tapped for house sewage, which caused nuisances in certain water courses on private properties. Sewers were demanded throughout the city, but it was obvious that the former policy of building each sewer without reference to a general scheme could be no longer followed, and that the pollution of the rivers within the city limits should not only not be increased, but also that the existing pollution should be removed.



Distributing Gallery in Filters

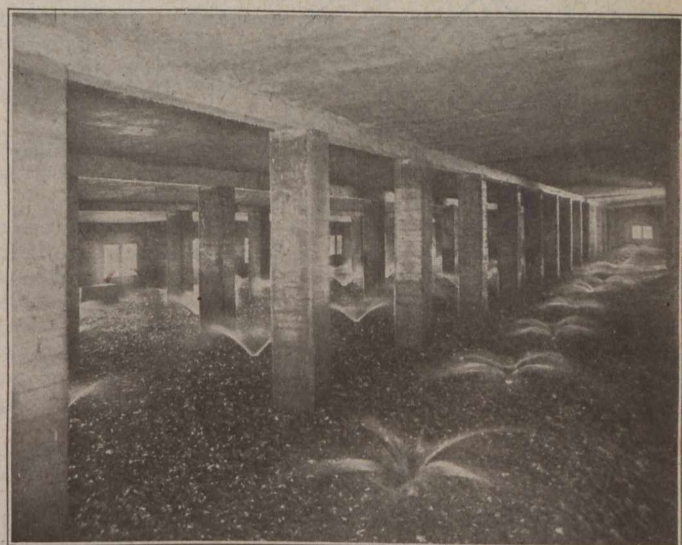
The writer was engaged to report upon the problem of a general sewerage system for the entire city and a method of sewage disposal.

The outstanding recommendations of that report were as follows:—

(1) That the separate system should be adopted for those sections of the city not yet sewered.

(2) That a main intercepting sewer should be constructed in the valley of Carling Creek to serve those sections to the north and to the east of the business section.

(3) That a second interceptor should be constructed for the southerly and south-easterly part of the city, its course roughly to parallel the north side of the south branch of the river.



Filter in Operation

(4) That a third interceptor should be constructed on Wharncliffe Road for London South.

(5) That a trunk sewer should be carried across the south branch of the river at King St., at grade, on a bridge to be constructed for the purpose, as an outlet for the two first mentioned interceptors, thence along Evergreen Avenue to a large chamber, the south London interceptor joining this trunk sewer at Wharncliffe Road.

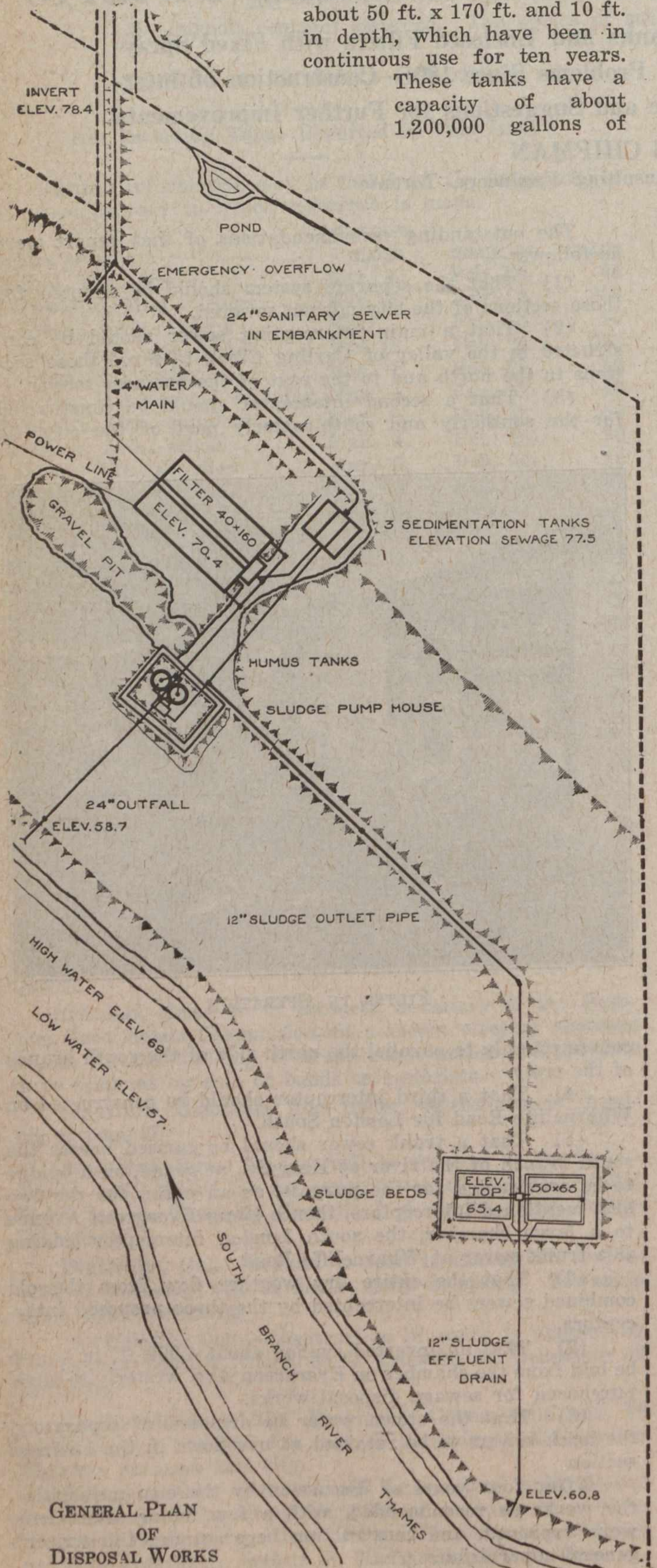
(6) That the entire dry weather flow from the old combined sewers be intercepted by the three proposed interceptors.

(7) That an inverted syphon about 4,000 ft. in length be laid from the chamber on Evergreen Ave. westerly to lands purchased for sewage disposal works.

(8) That the storm water be disposed of separately, the brick sewers to be retained as overflows in the business section.

After four years of discussion by the city authorities, the works as recommended, with a few minor alterations, were approved, and construction began under the writer's general supervision.

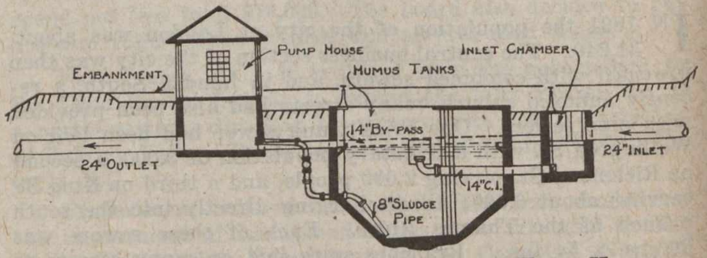
The interceptors, the main sewers, and the inverted syphon outfall were constructed in 1901 and designed to treat about 400,000 gallons per day if properly operated. The entire sewage flow, at that time two million gallons per twenty-four hours, was discharged on these beds and their efficiency was soon destroyed. The coke filling thereafter acted as a coarse strainer, until clogged with sludge. It is doubtful if these beds were ever operated in a scientific way, even experimentally. In 1908-1909 three sedimentation tanks were constructed, each about 50 ft. x 170 ft. and 10 ft. in depth, which have been in continuous use for ten years. These tanks have a capacity of about 1,200,000 gallons of sewage, the detention varying from twelve hours to six hours, depending upon the inflow and the amount of the sludge deposit. They are simply rectangular chambers provided with baffles, but with no proper provision for removing sludge. The effluent is generally darker in color than the crude sewage, and flows directly to the river. At times a part of the flow is diverted to the two small beds.



General Plan of Disposal Works

The main sewer and interceptors are now of ample capacity for the normal sewage flow, but the capacity of the inverted syphon is inadequate, as it will only take two-thirds of the flow, the remainder overflowing to the river at Evergreen Ave., without treatment. The laying of another inverted syphon has been recommended to council on several occasions and no doubt this much-needed outfall will be laid in the near future.

It was clearly pointed out when the separate system was under discussion in 1892-1896, and thoroughly understood by the city council and the city engineer, that all storm water was to be excluded from the sanitary sewers, and upon the completion of main sanitary sewers, the writer recommended that a storm sewer system should then be designed and constructed in advance of roadway improvements, but no action was taken.

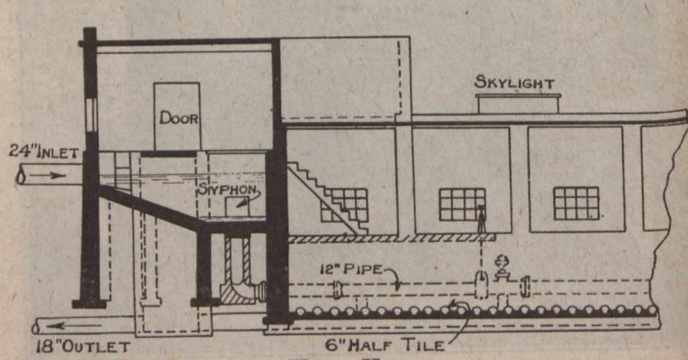


Cross-Section of Humus Tanks and Head House

Storm Sewer System

From 1899 to 1912 many sanitary sewers were laid as local improvements, discharging into the interceptors and tributaries thereto, and a few storm sewers were also laid. In many instances street catch basins were connected with the sanitary sewers, and generally speaking the surplus roof water was also discharged into these sewers. The sanitary sewer system had expanded from 22 miles in 1898 to over 70 miles in 1912, and as a result the interceptors were overtaxed during rains, causing flooding of basements and cellars in several districts.

Permanent pavements had been laid on certain streets in the central area prior to 1912. Before proceeding with any extensive programme for paving streets not provided with storm sewers, the city decided in 1913 to have a general plan of storm sewers prepared. A topographical survey was then directed to be made, a general plan prepared, and an estimate given of the cost.



Head House

Early in 1914 it was decided to proceed with construction, and contracts were awarded for five sections of the works. The enclosing of Carling Creek was included in the scheme, but not in the works contracted for in 1914. As the city had increased in population from 32,000 in 1892 to 48,000 in 1912, and an industrial district had developed in the north-east part of the city, it was decided early in 1914 to relieve the congestion in the intercepting sanitary sewers, and the flooding along Carling Creek, by constructing two intercepting sewers from the south branch of the river northerly along Egerton St. to Dundas St.

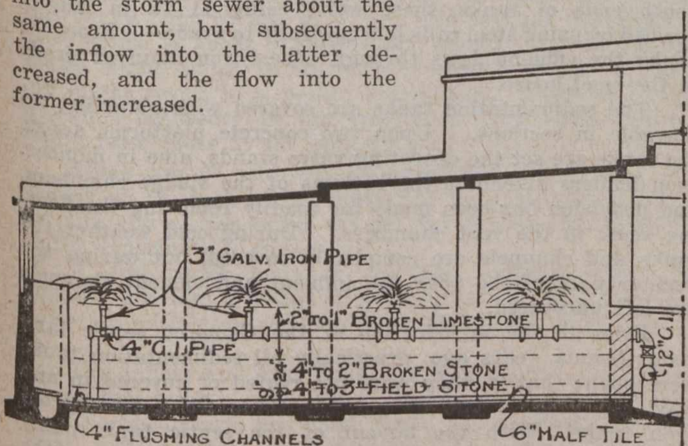
One sewer was designed to convey the domestic sewage, and a larger sewer laid alongside the sanitary was designed to take Carling Creek and the street water. In the design adopted, the cross section of the sanitary sewer is 2.7 sq. ft. and the storm sewer 13.7 sq. ft., laid on a grade of one in six hundred. The two were built together as a monolithic reinforced concrete structure.

The capacity of this sanitary sewer is about 7.7 cu. ft. per second, or about 2,600 gallons per minute, and of the storm sewer 90 cu. ft. per second. The sanitary sewer should be of sufficient capacity to serve a population of approximately 20,000, if the surface water be rigidly excluded.

The total length of the double sewer is 5,886 ft., the greater part of the excavation being in loose fine sand and gravel. For 4,350 ft. the bottom of the sewer was in sand or gravel, and for 1,500 ft. in clay. The average depth of excavation was 24 ft., and the maximum 29 ft. One short section, 93 ft. in length, under G.T.R. tracks, was tunnelled.

During construction the flow of water into the trench attained a maximum of 400 gallons per minute.

The maximum leakage in the 5,886 ft. of sanitary sewer after completion was about 50 gallons per minute, and into the storm sewer about the same amount, but subsequently the inflow into the latter decreased, and the flow into the former increased.



Half Cross-Section of Filter House

The leakage into the sanitary sewer cannot now be checked, as several tributaries that drain wet sandy areas have been connected with it, which has materially increased the inflow.

Construction on the Egerton St. double sewer was commenced on June 9th, 1914, and completed in March, 1917. The work was constructed under our general supervision.

At Beatrice Street the sanitary sewer was diverted easterly from Egerton to Price St., through a 22-in. tile sewer with a capacity of 7.9 cu. ft. per second, thence along Price St. southerly to the site acquired for sewage disposal works. The sewer on Pine Street was made 24 ins. in diameter, with a capacity of 9.7 cu. ft. per second, the size being increased to serve eventually several streets east of Egerton.

The storm sewer was continued southerly on Egerton 633 ft. as a 54-in. circular section, thence continued as an open concrete flume to the river, an additional distance of 843 ft.

The storm sewers comprised in the 1913-1914 program were completed during 1914, 1915 and 1916 under our supervision, and certain extensions to the sanitary sewers and storm sewers have been laid by the city engineer between 1913 and 1919. The storm sewers constructed in 1914, 1915 and 1916 comprised 20 miles, varying in size from 38 sq. ft. rectangular cross section to small tile pipes.

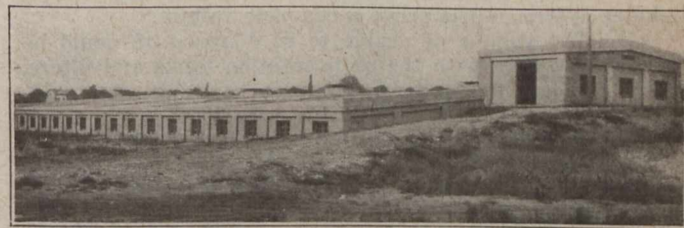
Sewage Disposal

The area tributary to the Egerton St. sewers comprises about 1,500 acres, of which 250 acres are now outside the city limits. The existing population within the area is less than 5,000, but owing to the erection of factories along Dundas St. East, this population will doubtless increase rapidly.

The following factories and plants are now erected and in operation in this area:—

(1) Grand Trunk shops, west side of Egerton;
(2) London Gas Power Co., machine shop;
(3) W. K. Kellogg Co., corn flake factory;
(4) Empire Manufacturing Co., plumbers' supplies;
(5) Middlesex Mills, dyeing work;
(6) Jones & Son, lithographing;
(7) McCormick Mfg. Co., confectionery;
(8) Hunt Milling Co., flour mill.

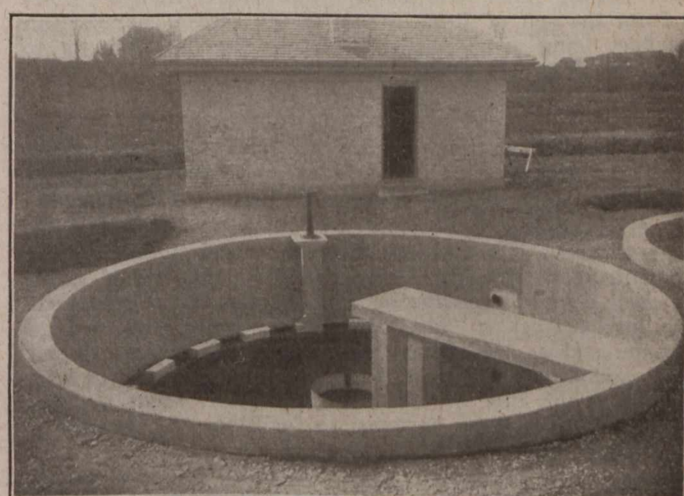
As the south branch of the river flows from east to west through a residential section of the city, and is crossed by half a dozen bridges, it was obvious that the discharge of any large volume of a crude sewage into the river would not be tolerated. Although the population of the area now draining to Price St. is less than 5,000, we decided to design the trunk sewer on Price St. for 30,000 population and the Egerton sanitary for 20,000 population.



General View of Filter Building and Head House

The sewage disposal works proper are, however, only designed for about 6,000 people, but extensions can be made without involving serious alterations.

In deciding upon the system to be adopted, it was considered essential that the effluent should be free from visible floating substances; also, that it should be stable; that is, it should not cause offensive deposits nor odors. It was also essential that the sewage disposal works should not be, nor cause, a nuisance within the vicinity where constructed. As the most troublesome problem in connection with sewage purification is the disposal of the sludge, it was necessary to secure a sufficient area of land.



Humus Tanks and Pump House

After considerable time had been expended in negotiations and in securing options on various plots of land along the river, about thirty acres of vacant land were acquired for sewage disposal works on the east side of Egerton Street and adjoining the river, and preliminary designs for proposed works were prepared in 1914, but the construction of the works was not authorized until 1916.

The site selected is admirably adapted for sewage disposal works, the soil being a sand underlaid by coarse gravel. It is unbuilt upon, comparatively remote, and can doubtless be utilized for sewage treatment when the tributary population has attained 25,000 people.

After inspecting the works at Baltimore, Fitchburg, Atlanta and Columbus, also the experimental plants at Cleveland and Milwaukee, the engineers decided that sedimentation followed by rapid filtration would prove more satisfactory than the activated sludge process, for the following reasons:—

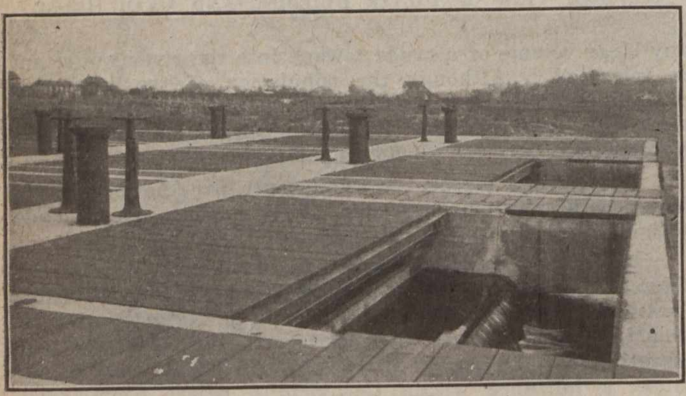
(1) The activated sludge process had not *then* passed the experimental stage.

(2) The costs of operation would be much higher in the latter system, and greater skill would be required in the attendants.

(3) Under ordinary municipal management the activated sludge system might prove a complete failure.

(4) The volume of sludge to be disposed of would be much greater than with the sedimentation tanks and filters, and its disposal would demand expert handling and treatment.

The works as designed and constructed comprise a small screen chamber, three sedimentation tanks, two dosing chambers, two percolating spraying filters with pipe gallery between, two humus tanks, one small pump house, and two



SEDIMENTATION TANKS—SECTION OF FLOORING REMOVED, SHOWING OPERATION

sludge-drying beds. The main sewer was continued easterly from the end of Price Street to the screen chamber, an overflow being provided for diverting the flow directly to the river if an emergency should arise.

Sedimentation Tanks

As the sewage contains practically no street water, it is free from sand or grit, and the rack or screen only prevents entrance to tanks of large floating cloths, pieces of wood, etc.

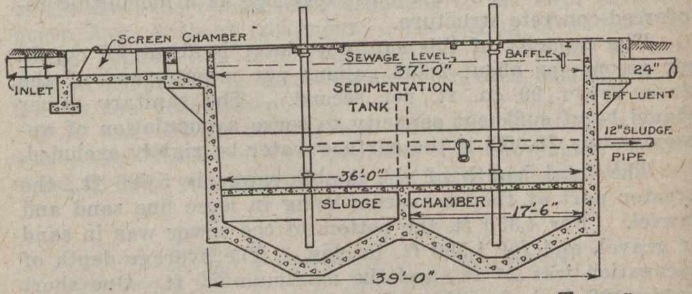
The sedimentation tanks are of the two-storied type, non-reversible. The sewage from the screen chambers flows first into a distributing channel at the north end of tanks, thence to a second distributing channel with submerged openings into the tanks. The tanks are provided with inclined bottoms and as the sewage flows slowly from end to end, the suspended solids drop to the sloping bottoms and slide through a slot into the sludge tanks below, which are also provided with sloping bottoms to facilitate the removal of the sludge.

Each sewage tank is 16½ ft. in width, 36 ft. in length, the depth of sewage above the top of sloping bottom being 7 ft. The maximum velocity of flow through the tanks will be about one-fourth of a foot per minute, giving one and three-fourths hours' detention. The average, however, will be over two hours' detention.

The combined capacity of the three sludge chambers is about 240 cu. yds.

Vent chambers of ample size between the sewage tanks permit the escape of gases and provide for scum or floating sludge. Baffle boards across the tanks near the outlet ends prevent floating scum, etc., from passing, deflect the flow downwards and promote settlement of suspended matter.

The sludge can be removed as desired by simply opening certain gate valves, the head of the sewage in the tanks being sufficient to cause a discharge. After standing stagnant through the winter months, it will probably be necessary to agitate the sludge in the outlet pipes and in the sludge chambers at the base of these outlet pipes before the sludge will flow by gravity.



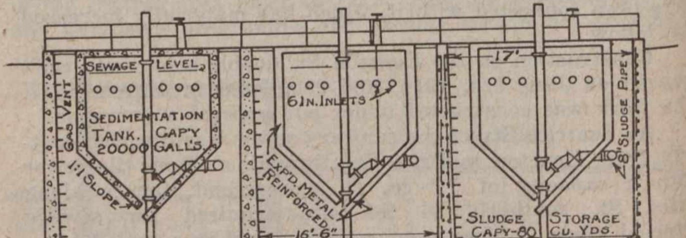
LONGITUDINAL SECTION OF SEDIMENTATION TANKS

Another set of valves permits the discharge of sewage through the sludge pipe.

The effluent from the tanks flows over weirs at the south ends of tanks, these weirs being 11 ft. in length, formed by using steel rails laid carefully to grade. From the tanks the effluent flows through a cast-iron main at grade to the head house.

The sedimentation tanks are covered with planking, removable in sections. Upon two concrete platforms across the tanks are set the operating valve stands, nine in number. Iron ladders extend to the bottoms of the sludge chambers, and provision has been made for readily removing the floating scum in the vent chambers. During cold weather the tanks and channels are completely covered, but during the greater part of the year the influent and effluent channels are left uncovered.

Prior to the introduction of the Cameron septic tank about twenty years ago, practically all sedimentation tanks were open; that is, they were not roofed or covered in any way. In Ontario two or possibly three cities constructed open tanks. With the advent of the septic tank, many cities and some towns constructed enclosed tanks, upon the assumption that the exclusion of light and air would, by the propagation of the growth of anaerobic bacteria, digest the solids in the sewage. It is probable that some of the



CROSS-SECTION OF SEDIMENTATION TANKS

reported improvements in results over open tanks were due to the concrete roof protecting the sewage from frost, also to a bottling up of foul gases.

When the two-storied tanks were introduced, those in Great Britain, Europe and the United States were open, but in this Canadian climate there can be no doubt that they should be covered or closed in the winter months.

Filters

Within the head house, at east end of filter house, which is entirely enclosed, are an inlet chamber, two dosing chambers, and an overflow chamber. The inflow into dosers can be determined almost instantly by noting the depth of flow over sharp-crested weirs set in inlet openings. An automatic syphon in each of the dosing chambers discharges the sewage through cast-iron pipes to the filters; one syphon for each filter. The content of each dosing tank is 3,400 gallons, which volume is discharged in six minutes with no inflow. The basement beneath the head house permits inspection of tank bottoms, which are perfectly water tight.

From the dosers the sewage flows through two cast-iron mains to the filters, these mains being laid in a gallery between the filters.

Each filter is 160 ft. in length and 40 ft. in width. The floors of filters are of concrete, sloping down from the pipe gallery towards the outer walls. Troughs were formed in the concrete floor for drainage, 15 ins. apart c. to c., each covered with a half-round glazed tile. Over the drains, field stone 3 to 4 ins. diameter were hand laid to a depth of nine inches. The next layer consisted of two feet of crushed limestone 2 to 4 ins., then about 4 ft. of crushed stone 2 ins. to 1 in. The total depth of media varied from 6½ ft. to 7 ft.

The effluent from the subdrains flows to two longitudinal collecting channels that discharge into two manholes to the east of the head house.

After careful consideration we decided that fixed spraying nozzles would prove more satisfactory than revolving sprinklers or travelling distributors, owing to their simplicity. The nozzles are spaced ten feet apart in each direction. The transverse main distributors are of 6-in. cast iron pipe, and the branches of 3-in. galvanized pipe. The static head on nozzles varies from 65 ins. to 22 ins., and average discharge of each nozzle is about 9 gallons per minute. It is possible that a slight change in the form of sprayer or size of opening might result in a better distribution. There is no appreciable difference in the sprays at head house end of filters from those at the opposite end.

There are 64 sprayers on each filter, subdivided into groups of 16, each group controlled by gate valves, which permits any section being cut out for repairs, for renewals or for experimental purposes.

A 4-in. water main in the pipe gallery under city pressure provides a means of flushing out the subdrains and collecting drains, or washing down the walls, gallery floor, etc.

The gallery and head house are well lighted by windows and electric lights.

The head house and filter house are of monolithic concrete, with concrete roof supported by columns at 10-ft. centres. "Hyrib" steel reinforcing material was used in the roof. The heat from the sprayed sewage prevents freezing within the building and the capacity of the filters in the winter months will not therefore be seriously reduced. Where uncovered filters have been adopted in the northern part of the United States, east of the Pacific Slope, more than half the surface area of the filter may become a mass of ice which the spraying increases in thickness, and if a nozzle becomes clogged, freezing of pipes follows. It would be impossible to operate open percolating filters satisfactorily in this climate.

Humus Tanks

The effluent from the filters flows through a 24-in. main to a chamber, subdivided into four compartments,—one inlet, one overflow and two outlet compartments. Two outlets, each provided with gate valves, control the flow to the humus tanks. Each of these two tanks is circular in plan, 22½ ft. interior diameter, with vertical sides 12 ft. in height, and conical bottom, the total depth of liquid being 12¼ ft. The inlet pipe discharges upward, into a cylinder 36 ins. in diameter, 42 ins. in height, submerged 15 ins., which diverts the flow downwards, thence radially to the circumference where the liquid discharges over 20 steel plate weirs, very accurately set, into a concrete channel, thence through a chamber in pump house basement.

Each humus tank contains about 23,000 gallons, or 16,000 gallons of clear effluent and 36 cu. yds. of storage for sludge in the cone-sloped bottom.

The sludge which collects in these tanks is removed periodically by a small pump set in the basement of pump house, the pump being operated by an electric motor on ground floor. The humus sludge is pumped into the main sludge pipe from the sedimentation tanks.

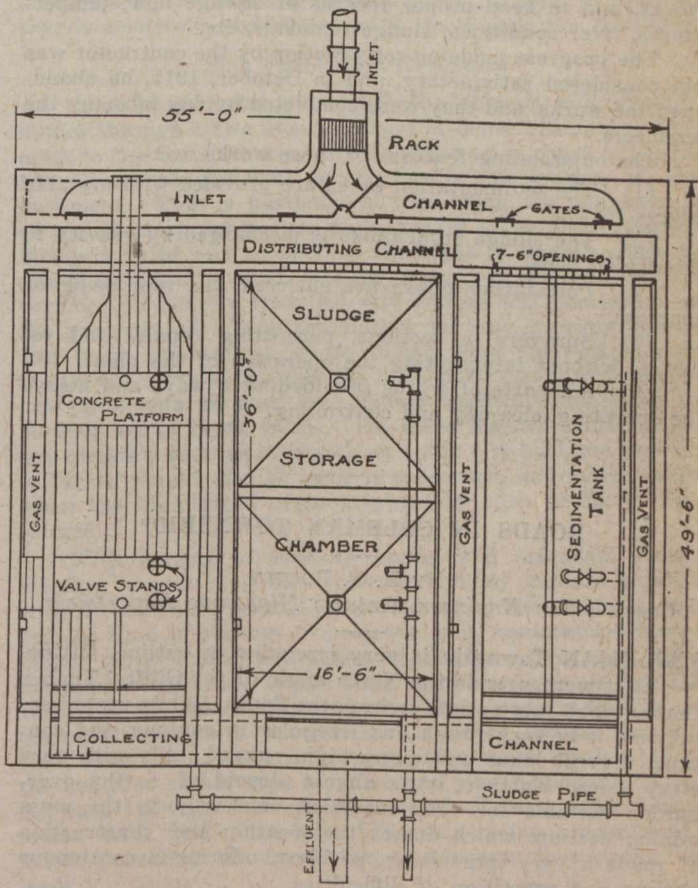
This sludge pump can also be used to flush out the main sludge pipe by pumping clarified sewage through it.

From the pump house basement the effluent flows through a 24-in. outfall, 240 ft. in length to the river.

Disinfection of the effluent may be demanded ultimately, in which case the chemical solution may be applied in the west chamber of pump house basement. Another small building will then be required for storing the chemicals for tanks and for necessary pipes and apparatus.

Sludge Beds

The sludge from the sedimentation tanks is conveyed by gravity through a 12-in. pipe, 1,487 ft. in length, to the



PLAN OF SEDIMENTATION TANKS

sludge beds, which were built at as great a distance as possible from Egerton Street.

The sludge from the two humus tanks is forced by pump through 80 ft. of 8 in. pipe into the 12 in. gravity pipe. If a stoppage should occur in this gravity line, either humus sludge or clarified sewage may be pumped into the main to remove it. The small capacity of this sludge pump, which is only 40 gallons per minute, has been adversely commented upon. It operates quite satisfactorily, however, and about 24 hours pumping in a month will remove the sludge from humus tanks.

The sludge beds are two in number, each 50 ft. x 65 ft. Upon the graded excavation, tile pipes with open joints were laid, these being covered with river shingle. Upon the shingle were laid 9 ins. of broken stone followed by 27 ins. of gravel. It is possible that additional beds will be required in the near future for sludge drying.

The dried sludge may be disposed of by filling low places on the site, but there is a probability that a large percentage will be sold or given to truck gardeners and another large percentage can be used on the sandy portions of the grounds around the tanks.

The normal low-water elevation of the river at the works is 57 above city datum, or 4 feet below the basement floor of pump house. During heavy rains, which may occur three or four times per year, the river may rise to 61 or even 62, which will not affect the operation of the works.

When the ice breaks up in the early spring the water may rise to 69, as it did in February, 1918, the highest on record. In 1917 the highest elevation was 65. The water stood above the elevation of the basement of the pump house for about a month in 1918, and for four or five days was above the floor of the filters.

The discharge of untreated or partially treated sewage into the river during floods cannot be objected to.

Embankments have been constructed around the pump house and humus tanks, also around the sludge beds, to protect them from floating ice and debris.

One attendant is employed to supervise and operate the works, and to keep proper records of sewage flow, temperatures, river conditions, sludge removals, etc.

The progress made on construction by the contractor was not considered satisfactory, and in October, 1917, he abandoned the works, and they were completed by day labor by the engineers.

The outstanding features of these works are:—

(1) The sedimentation tanks are provided with movable covers.

(2) The sludge from tanks is discharged by gravity to the drying beds.

(3) Percolating filters are enclosed, the roof being of concrete.

(4) Sprayers in sections, permitting repairs and renewals without interrupting the operation of the plant.

(5) All parts of works provided with ways and means for operating, cleaning and controlling.

ROADS IN COLEMAN TOWNSHIP*

By H. T. Routly,
Construction Engineer, Ontario Highways Department

COLEMAN Township is very irregular in outline, sitting, as it were, astride the North angle of the Gillies' Timber Berth, which juts up into it from the South. While not mountainous, it is very rough and irregular in contour, and contains several lakes and many high, rugged hills with very steep sides. Further, it is almost devoid of earthy overburden suitable for road material, especially in the main mining section, which makes the location and construction of roads a very interesting problem, offering a continuous variety and repetition of difficulties.

Work on the roads of Coleman Township was commenced in 1907 under the township foreman, and so continued through that and the following season. Commencing with the season of 1909, however, it was soon recognized by council that their system was entirely too inefficient, and the writer was retained to supervise the work, arranging to supply all necessary assistants and taking entire charge on a percentage basis.

Locations Were Fixed

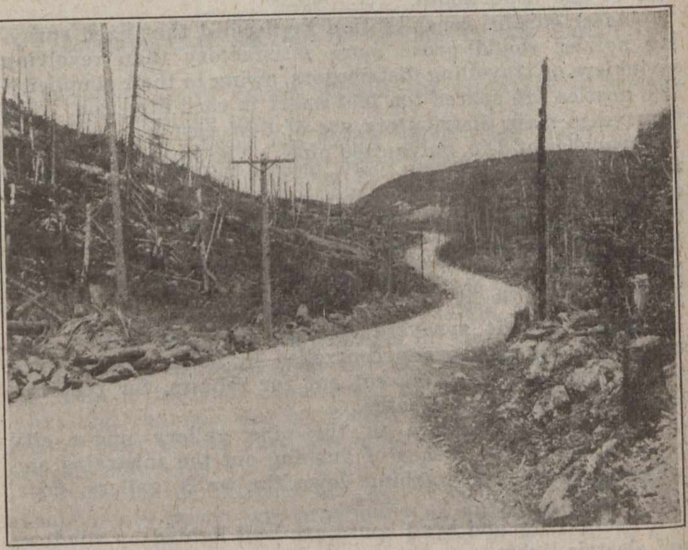
Finding about 100 men on the payroll working on definite locations into properties in urgent need of immediate transportation facilities, little change could be made during the first few months in either location or methods of construction. Much of the location of that and the previous two seasons had to be revised when heavier construction was undertaken later on.

During the latter portion of the first season, however, any new roads opened were on fairly well examined locations. Strong recommendations were made for the purchase of a regular road-construction plant. This was refused at first, but ordered by council in the spring of 1910, and from then the real road history of Coleman Township begins.

There are no road allowances along original survey lines, but 5 per cent. of all the land is reserved for roads, which may be located where desired except in very special cases. Theory was not allowed to limit grades or restrict curves. The only limitations on location were the termini. Between the mine or prospect at one end, and the railway or some other section of constructed road at the other end, the new road or trail wound and sloped, seeking always to get through (with the funds available) to the objective, but having always in view the possibility of further development and ever seeking to find the best location.

Haste and Erratic Development

That the best location was not always obtained is admitted, and can be laid largely to the fact that much of the general location was made, and considerable sums expended thereon, prior to the employment of an engineer; partly to the great difficulty of examining in detail so rough a country, covered largely by timber; and partly to the haste required and the more or less erratic development of the camp.



Macadam Built in 1910 in Coleman Township
(Photo 1910)

A grant for a certain section made in April might be cancelled in August because of the cessation of work at the particular mine to be served, and the funds diverted to some entirely new prospect which had developed in the meantime and was pressing urgently for a road.

To reiterate,—location, alignment and grade were fixed solely by the termini and the natural obstructions. Some grades in the first instance were as high as 15 per cent., or even 20 per cent., and there were curves that a wagon would just turn. But the first trail opened was always such that teams could get through with fair loads, and was the best to be had for the money immediately available, having due consideration for future development. We never exhausted a grant and built a road only part way. The grant was always expended over the entire section, leaving future grants to be spent likewise, and so developing the location generally, and, as far as possible, uniformly.

Relocations and Improvements

After a year or so, when the whole road had been improved to a fair standard earth road, and before any macadamizing was attempted, a special grant might be set aside to relocate or otherwise improve a particularly steep or difficult section. No road was given a macadam surface until the sharper curves and steep grades of the first location were thoroughly revised. While the finished roads are quite winding, there are only two hills with grades over 6%.

From the foregoing you will see that the first point in the determination of a new location was generally the de-

(Continued on page 286)

*Read February 19th, 1919, at the annual meeting of the Association of Ontario Land Surveyors.

EFFICIENCY OF BITUMINOUS SURFACES AND PAVEMENTS UNDER MOTOR TRUCK TRAFFIC*

By Prevost Hubbard,
Chemical Engineer, U. S. Bureau of Public Roads

THE title of this paper covers a subject upon which a great deal of thought has been spent by progressive highway engineers as applied to pre-war traffic conditions and its progressive normal development. Many engineers had, at least in their own minds, classified the various types of pavements with relation to their efficiency under ordinary variations in traffic encountered on county, state and municipal highways and their ideas were fairly well fixed on the subject as evidenced by more or less consistent practice in their choice of types when reconstruction or new construction became necessary. Just where the dividing line should be drawn, so far as traffic is concerned, between different types of pavements has always been a matter of individual opinion, but in general with increases in volume and weight of traffic the increasing efficiency of the bituminous types has been rated as follows:—

1 Bituminous surfaces.
2 Bituminous macadam.
3 Bituminous concrete.
4 Sheet asphalt and asphalt block.

Suddenly and with little opportunity for anticipation, a very large mileage of our important state highways and many of our local county and municipal pavements were subjected to a tremendous increase in traffic. This increase was not only in volume, which would have presented a comparatively simple problem to solve, but in the weight and load carrying capacity of the individual vehicle. This, coupled with an unusually severe winter and immediately followed by war restrictions upon the use of many road materials, labor shortage, excessive costs, and loss of members of highway engineering organizations, created a situation during the year 1918 which was abnormally serious and complicated. With comparatively few exceptions, new construction ceased and maintenance was so handicapped as to became inadequate.

Foundations or Subgrades Failed

Hundreds of miles of roads failed under the heavy motor truck traffic within a comparatively few weeks or months. Roads with bituminous surfaces, bituminous macadam roads and bituminous concrete roads all failed alike, together with other types used in state and county work. These failures were not only sudden but complete and almost over night an excellent surface might become impassable. Such rapid and complete failures in municipal pavements were of less common occurrence and as sheet asphalt and asphalt block have always been largely confined to municipal work, failures of these types have not been noted to the same extent as the other types mentioned.

In the haste and confusion of war activities little opportunity has existed for a systematic and comprehensive study of the problem suddenly thrust upon highway engineers. Reports from all parts of the country have, however, established one outstanding fact which has a most important bearing upon any consideration of the efficiency of bituminous surfaces and bituminous pavements. A very large proportion of the failures have been characterized by an almost simultaneous destruction of the entire road structure, and not merely the disintegration of the wearing course or pavement proper. No type of pavement will be efficient unless provided with a foundation which will hold up the pavement until it is worn out. When, therefore, the entire structure fails suddenly, inadequate subgrade or foundation conditions are primarily responsible and but little basis exists for placing an efficiency valuation upon the wearing course.

Inevitably coupled with subgrade and drainage conditions, foundation failures occurring as previously described may be due to one of two causes, lack of thickness, or inability of the foundation structure to sustain the loads without appreciable internal movement. So far as bituminous surfaces or bituminous pavements are concerned, remedy of the first cause does not affect the general type of construction. If, however, present heavy motor truck traffic is to continue and possibly increase in weight as well as volume the second cause may have a direct bearing upon possible modifications in design and in the ultimate determination of the efficiency of certain classes of bituminous work. Most subgrades have a much lower carrying capacity in the spring than at other periods of the year. As there is practically no slab effect produced by the structure of a broken stone or gravel foundation, a load applied to any overlying bituminous surface is transmitted quite directly to the subgrade. In other words, the intensity of load under its point of application is relatively high throughout the foundation thickness.

Slab Foundation Necessary

Under heavy motor truck traffic the intensity of load transmitted through a two inch thickness of dense bituminous concrete to the foundation may be so great as to cause an internal movement sufficient to produce disintegration of the pavement. This is particularly true when the subgrade is of a soft or clayey nature and appears to be quite possible irrespective of any economical thickness of broken stone or gravel foundation which may be used. In general, the experience on heavily travelled city streets has demonstrated the necessity of a slab foundation for any wearing course and there appears to be no reason why such experience should not serve as a guide for new construction of bituminous pavements on state and county highways subjected to modern heavy truck traffic. On these highways the traffic has certainly been as severe as on many city business streets, so far as weight of unit loads is concerned, and more severe when the high speed often attained by such traffic is considered.

With respect to existing gravel and macadam roads, whether or not they have been previously surface treated with bituminous material, it would seem far safer at the present time to attempt to preserve such roads under heavy motor truck traffic by means of surface treatment with bituminous materials rather than to utilize them as foundations for the construction of new bituminous macadam or bituminous concrete pavements. In other words, for the time being such treatments may prove more efficient than the use of a higher type of pavement placed upon the existing road although it is clearly recognized that, under heavy motor truck traffic, the bituminous pavements are more efficient providing the foundation is adequate to support the loads.

Gravel Roads and Frost

Under the same conditions of traffic bituminous surfaces are most efficient in localities where frost action is either absent or not severe. Such treatments used in connection with gravel roads adjacent to army cantonments in the far south have given reasonable satisfaction even under heavy motor truck traffic. North of the frost line and particularly in connection with the treatment of clayey gravel roads which become soft during the spring months, bituminous surfaces are apt to completely disappear. If, however, the gravel road is maintained by dragging and at the end of the thawing out period is reshaped, thoroughly compacted and again treated with bituminous material, it may be kept in a reasonably satisfactory condition. Under very heavy motor truck traffic, however, maintenance costs may be extremely high so that if a continuation of such traffic is to be expected the construction of a new road may be necessary. Thus, during a period of 120 days on a clay gravel road leading from Alexandria to Camp Humphreys, Virginia, which was subjected to an average daily traffic of some 230 heavy motor trucks, the cost for maintenance amounted to approximately $10,000 per mile. Because of this enormous expense the construction of a new type of road became necessary.

In connection with this road it is of interest to note that prior to its maintenance as a gravel road, it had served as

*Presented at the sixteenth annual convention of The American Road Builders' Association, February 25th, 1919.

a six-inch foundation for a dense bituminous concrete pavement two inches thick. This pavement had successfully passed a year of ordinary country and pleasure traffic carrying a large number of touring cars between Washington and Mt. Vernon. In the spring of 1918, it was suddenly subjected to an average traffic of over 200 heavy motor trucks a day and within a comparatively few weeks was absolutely ruined, due to failure of the foundation during the thawing out period. An extension of this road in the city of Alexandria consists of a number of sections of very carefully constructed bituminous macadam laid some years ago upon a concrete base. Although subjected to the same heavy traffic, the bituminous macadam, ordinarily considered less efficient than bituminous concrete, did not fail except in a few places where failure of the concrete base could be held responsible owing to exceptionally poor subgrade conditions.

Bituminous surfaces on properly constructed macadam roads subjected to heavy motor truck traffic may, as a rule, be maintained in localities north of the frost line with less expense and better results than on gravel roads under the same conditions. Such surfaces, under heavy motor truck traffic, cannot be considered as economical from the ordinary standpoint but may prove the most efficient temporary method of preserving the existing road until money is available for reconstruction. It is believed, however, that under these conditions bituminous surfaces will not even prove efficient unless constantly maintained by a patrol system operating throughout the year.

Maintenance by the Bureau of Public Roads of experimental bituminous surfaces on the Rockville Pike, Maryland, which is a macadam road, have demonstrated that such surfaces constructed with suitable tar and oil products are efficient under reasonably heavy traffic, provided the patrol system of maintenance is followed. If such a system had not been in use during the past year when from 28 traffic counts an average of 135 motor drays, 816 motor pleasure vehicles, and 61 horse drawn vehicles per day passed over the road, it would from all indications have been completely destroyed.

Bituminous Macadam

With regard to the efficiency of bituminous macadam under heavy motor truck traffic, there are a number of points to be considered. In general, bituminous macadam has not been thought to be efficient for such traffic but, on the other hand, it has almost invariably been placed upon a broken stone or gravel base. Results obtained in the city of Alexandria, which have previously been mentioned, indicate that if properly constructed and laid upon a concrete base, the bituminous macadam may prove quite satisfactory.

Aside from character of foundation, it is believed that sufficient attention has not in general been paid to the important details of bituminous macadam construction so as to obtain best results. Too frequently the coarse stone is not sufficiently compacted before the first application of bituminous material is made and later uniform compaction is extremely difficult, if not impossible, to secure. Rutting the road with certain types of distributors just prior to application of the material is a common cause of lack of uniformity in compaction, and a strong tendency to distribute faster than the road can be satisfactorily compacted and finished by a single roller is another. Best results from this type of road which have come under the writer's notice have been secured by the hand pouring method, although this method is considered antiquated by many engineers. Where the first application upon the thoroughly compacted coarse stone is made diagonally across the centre line of the road and the second pouring or seal coat is made in a direction diagonally across the first, with proper attention to uniformity of distribution it is possible to secure a very excellent pavement, as has been repeatedly demonstrated by E. C. Dunn, city engineer of Alexandria, Va.

The efficiency of bituminous concrete, sheet asphalt and asphalt block pavements under city traffic is so well understood as to require little comment in this paper. If laid upon suitable concrete foundations there is no reason to suppose that the results given by these pavements in city construction will not be duplicated on county and state highways subjected to heavy motor truck traffic. If the foundation is inadequate to support the load, the pavement is bound to fail but, as previously pointed out, failure cannot then be considered a measure of efficiency of the pavement proper.

With regard to materials of construction a few comments may not be out of place, as the efficiency of a bituminous surface or bituminous pavement depends not only upon its method of construction but of what materials it is composed.

Bituminous Carpets or Traffic Mats

In general, the author's observation and experience has been that the most efficient bituminous carpets are constructed with the heaviest grade of bituminous material which it is possible to apply and make adhere uniformly to the road surface. For cold surface treatment this will demand either a cut-back asphalt, a heavy asphaltic oil with specific viscosity of 80 to 120 at 25°C. containing an appreciable amount of volatile material that will evaporate after application and leave practically an asphalt mat residue, or the most viscous refined tar product that can be applied cold. For the latter a specific viscosity as high as 25 to 35 at 40°C. should be used if climatic conditions will permit. While on old macadam roads it is advisable to keep the thickness of carpet under ½ inch, on certain types of soft gravel it may be of greater thickness provided a hard and tough coarse aggregate cover of sufficient size to force into the old gravel surface by rolling is used. For clay-gravel or sand-clay-gravel roads north of the frost line it is believed that for maintenance under heavy truck traffic light superficial treatment with bituminous materials applied cold will prove more efficient than the construction of a bituminous carpet although neither will be adequate to carry the road through winter.

With regard to bituminous macadam and coarse aggregate bituminous concrete, there is little to suggest in connection with the grades of bituminous materials ordinarily used. It is believed however, that even in the northern U. S., the use of an asphalt cement softer than 120 penetration or a refined tar of less than 120 seconds float test at 50°C. for bituminous macadam is inadvisable if modern heavy motor traffic is to be sustained. It is also believed that more attention should be given to specifying and securing a uniform size, and grading within reasonable limits, of coarse stone for bituminous macadam in order to promote uniformity in the penetration of the bituminous material as it is applied and to produce a surface that will wear as uniformly as possible. Such specifications should be based upon tests made with laboratory screens and should at least cover the permissible percentage retained on the maximum and passing the minimum diameter of screens selected, as well as the percentage limits required to pass or be retained upon an intermediate screen.

Aggregate Grading Needs Attention

In connection with sheet asphalt and the fine aggregate bituminous concretes the tendency to use harder grades of asphalt cement than heretofore used may prove advisable for very heavy traffic conditions. It is quite possible, however, that better results may be secured by a reduction in the compacted thickness of such pavements with a corresponding increase in thickness of binder course where one is commonly used. For fine aggregate bituminous concretes which are commonly laid without a binder course, the introduction of such a course not less than 1½ inches thick may prove advisable with a reduction in thickness of wearing course to not more than 1½ inches. Provided the binder course is properly constructed such practice should tend to produce a pavement less susceptible to displacement under heavy motor truck traffic. In any event, it is believed that even more attention should be paid to aggregate grading than heretofore in order to produce most satisfactory results.

The resistance to displacement of compacted bituminous aggregates, containing particles from one half inch in diameter down and consisting largely of sand, is mainly dependent upon grading of the mineral aggregate and hardness of the bituminous cement. When, however, the particles become very small and possess absorptive or colloidal properties neither grading nor consistency of the cementing medium are such important considerations. Very large surface contact and high frictional resistance then become the prime factors. Thus, a fine mastic composed of limestone dust or clay and a very soft asphalt cement may exhibit even greater resistance to displacement than a graded sand aggregate mixed with a much harder asphalt cement. The former type is exemplified by certain finely pulverized bituminous limestones. Use of the latter has but recently passed the experimental stage. It is quite possible, however, that future developments will establish such extremely fine bituminous aggregates as being highly efficient under heavy motor truck traffic for both the sheet and block type of construction.

CAN SETTLE IMPORT DISPUTES

OFFICIAL notice has been received by the Senior British Trade Commissioner in Canada (G. T. Milne, 367 Beaver Hall Square, Montreal) that he is empowered to appoint an expert to examine and report upon consignments of goods from the United Kingdom, in respect of which a dispute has arisen, and to certify the signature of such experts as authentic. The commissioner will intervene only when requested to do so by both parties to the dispute.

The kind of disputes in which the commissioner may intervene are those regarding goods which are alleged to be not up to sample, or which have arrived in a damaged condition owing to faulty packing. The commissioner is not authorized to deal with claims under insurance policies for goods damaged during the voyage.

As the official trade representative of the Indian Government, the commissioner is also authorized to act in regard to disputes relative to shipments from India.

The remuneration of experts appointed by the commissioner is a matter for the parties to the dispute. No fee will be charged for the commissioner's services.

The trade commissioner at Toronto (F. W. Field, Confederation Life Bldg., Toronto) is empowered to act in disputes arising out of shipments to Ontario.

DR. JEWETT ADDRESSES HAMILTON ENGINEERS

"INDUSTRIAL and Scientific Research" was the title of an address delivered last month by Dr. F. B. Jewett, chief engineer of the Western Electric Co., New York, and vice-president of the American Institute of Electrical Engineers, at an open meeting of the Hamilton Branch of the Engineering Institute of Canada, held in the Royal Connaught Hotel.

One of the greatest difficulties encountered in research work is the lack of thoroughly trained, scientific investigators, said Dr. Jewett. Although a firm believer in the great results to be obtained from properly conducted research, he issued a warning against attempts to build up research organizations without thoroughly educated and experienced research workers. He stated that research organizations should not be built up too rapidly, but should have a normal rate of growth, and he also gave warning against taking from the universities the men who are training the future investigators.

Dr. Jewett showed an interesting collection of slides, illustrating the results of the work of his organization. The long-distance telephone line from New York to San Francisco; the multiplex telephone; the wireless telephone, as used on war ships, destroyers and aeroplanes; and other remarkable developments in telephone work, were described.

Earlier in the day Dr. Jewett had addressed the Hamilton Branch of the Canadian Manufacturers' Association upon the same subject, and the previous week he had delivered the same lecture in Toronto before the Royal Canadian Institute. He also gave a more informal talk, on wireless telephony, at a meeting of the Electric Club of Toronto.

RAILWAY RIGHT-OF-WAY SURVEYS AND DESCRIPTIONS*

By Edward Thompson Wilkie
Formerly Chief Engineer, Toronto Suburban Railway

SO far as the surveys and descriptions for right-of-way are concerned, there is practically no difference between steam and electric railways, although the electrics sometimes use sharper or shorter curves and narrower right-of-way than the steam roads, which makes more difficult work in preparing the descriptions, particularly on sharp curves, through a subdivision of small town lots, when the remainder of the lot is not acquired as a severance.

One method of making right-of-way surveys is to take the line chainage, as located by the engineers, and plot it by latitudes and departures on strong drawing paper to the scale required, 1 in. to 200 ft. being very suitable, across one township, showing curves, if any, with their radii and chainages of beginnings and ends, and chainage of as many location hubs as possible, but nothing more.

Location Chainage Must be Checked

The surveyor takes this plan into the field and picks up the several lines crossed, whether lot, concession or boundary lines, noting the location chainage of the crossing and measuring the angle with the centre line of the railway and distances to nearest corner posts; or better, to one on either side of the railway line; and treating similarly all forced roads or other peculiar features encountered.

The surveyor must not neglect to check the location chainage, as it is always difficult to get careful chaining done on location surveys. The chainmen will not use anything but the chain stakes and generally do their work carelessly with them. Also the bearing of the tangents should be checked and given astronomically.

Extra widths are frequently required for high fills or deep cuttings. When the requirements for these can be obtained, they should be shown on the survey, but if they can not be obtained while on the ground, they can generally be fixed up in the office.

It frequently happens that as the construction work proceeds it becomes necessary to obtain extra width of right-of-way in certain places. This, of course, necessitates additional surveys, which are mostly made by the engineering-construction force. When the plan is completed for the township, showing (according to ownership) all lots or parts of lots that are crossed, small plans are made from it, showing what is required from each individual, whether it be a one-acre or smaller parcel, or one or several township lots.

It is not necessary to show the whole township lot. The portion taken and the ties to the nearest corner post will be sufficient, but must be enough to show clearly the land taken in relation to the whole lot or lots.

Another method is for the surveyor to make his surveys as above described and put his information on the engineer's location plans, making corrections where necessary, these being usually made to a scale of 1 in. to 400 ft., which is very suitable where individuals own large tracts of land, but the 200 ft. scale plan is better where the parcels are small.

Plans Must Fold Conveniently

On the last railway work with which the writer was connected, he used plans of 400 ft. scale for farm lands and 200 ft. scale for villages; and in some places where peculiarities were encountered, a scale of 1 in. to 100 ft. was used, so as to be able to show short distances clearly.

But it must be remembered that all these plans have to accompany deeds which are written on paper about 8 by 13 13 ins. in size, so the plans should either be within that size or of some dimension that folds conveniently to that size; and as they are again folded into four, if the plans are large, they make a bulky document.

In writing the descriptions, the commonest method is to describe the centre line of the railway. The description

*Read February 19th, 1919, at the annual meeting of the Association of Ontario Land Surveyors.

starts out by saying: "A piece of land 100 ft., or 66 ft., or whatever is to be taken, in width across lot (the designation of which is given) being (half) of the width required on either side of the centre line."

In the west, the form most generally used is: "Lying between two lines parallel with and . . . feet perpendicularly distant from the centre line of railway which is described as follows:—

"Commencing on the northerly (or as may be) side of the said lot, distant (the measured distance) from the nearest corner of the lot (or some well defined point) measured on a bearing, (the actual bearing), and along that side of the lot from the post or point to the centre line."

Thence, give actual bearing of the centre line. If it is a tangent or straight line all across the lot, give actual measured distance to opposite side, stating which side, and it is always well to say "more or less." And then if it can be done, give actual bearing and distance along that side from nearest corner or well defined point on the side, preferably on the same side of the railway line as the starting point.

Description of Curve

If there is a curve in the line in the property being described, the description is started as before, and bearing and distance given to the beginning of the curve. Then if it is a simple curve, say, northerly or as the case may be, following a curve to the right or left, as may be, having a radius of (give length of radius), to which the last course is tangent.

This phrase is important, as it fixes the position of the curve the same as a bearing fixes the position of a line.

Give distance to edge of property being dealt with, if it is still on curve, and finish as before, but if edge of property is not reached on the curve, give distance to end of curve, and thence give bearing of next tangent, and being tangent to last described curve. (This is not absolutely necessary, but if it is inserted it gives a check on the curve) then distance to edge of property.

If spirals or transitions are used on the curves, as they are now in modern railway location practice on all curves sharper than one degree (and some roads use spirals on them), the description is a little more complicated.

The description is started as before and continued to the beginning of the spiral, thence following a spiral curve to the right or left, as may be.

Give number, chords of, length of chord used, feet in length (the number depending on the degree of curvature to be attained), increasing in curvature when going from tangent to curve (but not forgetting "to which the last course is tangent.")

Give total length of spiral, which is a multiple of the number of chords by the length of chord used. It is well to give either the total angle in the spiral or the bearing of the tangent to the curve at starting point of the simple curve. Then continue on the curve, as before stated, to edge of property; or if not reached on the curve, continue describing the spiral in opposite or decreasing-in-curvature direction.

There are so many forms of spirals in use that it is almost necessary to state the formulæ used, which further complicates the matter. If the description commences on a curve it is necessary to give the bearing of the tangent to the curve at the point of commencement.

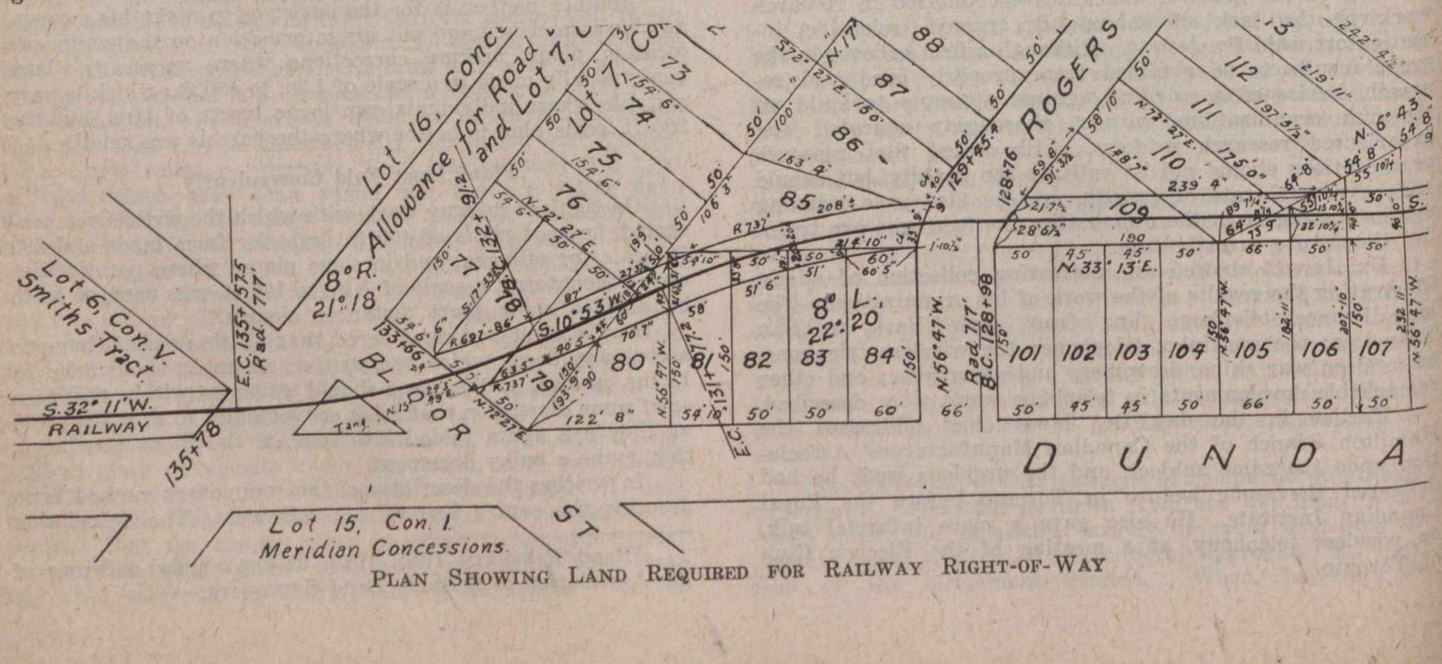
Many descriptions have been written by the centre line method, describing the curves as simple curves, when they have been actually built with spirals, the result being that if the right-of-way were to be accurately marked out according to the description, the railway would not be exactly in the centre. The distance off centre is not of vital importance on the easier curves, but on sharper curves, when long chords are used on the spirals, the distance may amount to several feet, in which case the simple curve method must be avoided. One reason for the simple curve method being used is that the right-of-way is usually purchased from descriptions prepared from the first location plans, when spirals are not always shown but are afterwards put in when construction commences.

A better method of writing descriptions is to go round the parcel by metes and bounds, just as describing any irregular piece of land. But where there are sharp curves, such a description becomes rather complicated and is especially so on spiral curves. So the simpler method of describing by the centre line is adopted, and as the railway usually fences the land it gets, any small inaccuracies are in a short time obliterated by the possession; but this must not be relied upon to cover errors in the descriptions.

A Line as a Right-of-Way!

The writer had one case come under his observation in which the right-of-way was described by the centre line method, where in transcribing the description to the deed, the width of the right-of-way and the width on either side of the centre line was omitted, and the omission was not discovered until after the deed was registered, when it was found that the deed only gave the railway the centre line. In the meantime the party who gave the deed to the railway had sold the remainder of his property and there was a lot of trouble getting it corrected.

So far as the writer knows, there is no provision in the Railway Act nor in the Ontario Statutes requiring railway rights-of-way to be posted in Ontario, and he has seldom seen it done. He understands that Manitoba, Saskatchewan, Alberta and British Columbia have such provisions, and that the British Columbia Act has given the railways a great deal of trouble, as sometimes one side of the right-of-way would be in a river and the other side on an almost inaccessible mountain point.



PLAN SHOWING LAND REQUIRED FOR RAILWAY RIGHT-OF-WAY

The writer had just finished preparing the above notes when he received a copy of the report of the eighth annual meeting of the Saskatchewan Land Surveyors, in which he found a paper by Edgar C. Brown on "The Railroad Spiral in Relation to Land Surveys," in which Mr. Brown says that for several years the Land Titles Office had received descriptions of railway rights-of-way described by the centre line method, using the spirals as located in the railway, but that when the Surveys Act for Saskatchewan and Alberta came in force requiring "iron reference posts to be planted to mark every change in direction of the right-of-way limit, and at the beginning and end of every curve of constant radius." Some change became necessary to meet the altered conditions, as a spiral was obviously not a curve of constant radius.

The matter was finally settled by devising a simple curve that would nearest cover the spiral, and substituting it for the spiral in the description. This gave, instead of the original curve and spirals, a three-centred compound curve with circular parts.

An Actual Problem

As an example of some of the problems the writer was faced with recently in some of his right-of-way work:—

The accompanying plan shows how a railway went through a certain subdivision. When the location was made, a plan of the subdivision was prepared, and the railway line (showing the right-of-way, which was 40 ft. wide) was superimposed upon it. This plan was given to the agents to purchase the right-of-way required by the railway.

The plan did not give much detail as to what was required from individual lots. But little progress could be made, and expropriation for nearly the whole subdivision had to be resorted to, but was finally settled, without going to arbitration, sometime after the railway was in operation.

For the final settlement the accompanying plan was made, showing the exact amounts required from each owner, and three copies of it were given to the solicitors with each description, one copy being bound with each copy of the deeds. The plan, of which only a portion is shown by the accompanying drawing, covered the whole subdivision, and the particular lot, or lots, dealt with were colored pink and the number of the lot or lots, name of owner and area were filled in the blanks in the title; and if the measurements on that particular parcel were not clear, they were gone over with a pen.

All through this subdivision the descriptions were written by metes and bounds going round the outlines without any reference to the centre line of the railway. This was necessary in all but 6 of 34 lots out of which something was required for right-of-way. Most of the parcels were simple enough, but lots 78 and 79, which fortunately were both owned by one party, gave a lot of trouble.

The calculations were checked by a latitude-and-departure table and even then it did not check to within an inch, but the writer has to admit that he neglected to follow Bro. Ransom's advice and state the probable error.

The Description

The description given for these lots was as follows:—

"......containing by admeasurement five thousand nine hundred and thirty-six (5936) square feet, be the same more or less, being part of lots numbers seventy-eight (78) and seventy-nine (79) as shown on registered plan — — — . . ., described as follows:—

"Commencing at the north-easterly angle of said lot No. 79, thence south seventy-two degrees and twenty-seven minutes west, along the northerly limit of said lot, thirteen (13) feet; thence south ten degrees and fifty-three minutes west, eight-seven (87) feet; thence southerly following a curve to the right having a radius of six hundred and ninety-seven (697) feet, to which the last course is tangent, for eighty-six (86) feet, more or less, to the westerly limit of lot No. 78; thence south seventeen degrees and thirty-three minutes east, along the said westerly limit, six (6) inches, to the southerly limit of said lot No. 78; thence north seventy-two degrees and twenty-seven minutes east, along the said southerly limit, forty-eight (48) feet and three (3) inches; thence northerly following a curve to the left having a radius of seven hundred and thirty-seven (737) feet, whose tangent at point of commencement has a bearing north fifteen degrees and forty-nine minutes east, for sixty-three (63) feet and five (5) inches; thence north ten degrees and fifty-three minutes east, tangent to last mentioned curve, forty (40) feet and five (5) inches, more or less, to the easterly limit of said lot No. 79; thence north seventeen degrees and thirty-three minutes west, along said easterly limit, sixty (60) feet, to the place of commencement, the said parcel being shown colored pink on the attached plan. All the above bearings are the bearings shown on the said registered plan or are calculated from them."

PUBLICATIONS RECEIVED

RECOMMENDATIONS to Inspectors, Clerks of Works and Foremen Concerning the Execution of Reinforced Concrete Works.—16 page booklet, 4 by 6½ ins., published by the Concrete Institute, 296 Vauxhall Bridge Road, London, S. W., 1, England. Price 6d.

DIXON'S GRAPHITE PRODUCTS is the title of a new book catalogue issued by the Joseph Dixon Crucible Co., Jersey City, N.J. While not so complete as the large general catalogue, it furnishes a good idea of the variety of products made by this concern, including lubricants, paints and pencils.

CALCULATION OF FLOW IN OPEN CHANNELS.—By Ivan E. Houk. Published as Part 4 of the "Technical Reports" of the Miami Conservancy District, Dayton, Ohio; 6 by 9¼ ins.; 284 pages and cover; numerous illustrations, diagrams, etc. The summary and conclusions of this report were published in *The Canadian Engineer* for December 26th, 1918.

JEFFREY IMPROVED CARRIER.—Catalogue No. 210 issued by the Jeffrey Manufacturing Co., Columbus, Ohio, on the latest type of pivoted bucket conveyor for handling coal, ashes, clinker, etc. The 96 pages of the catalogue are divided equally between illustrated details of the carrier, views of power plant equipment and reproductions of dimension blueprints of the various sizes of carrier equipment.

SPECIAL WATER POWER INVESTIGATION, STATE OF MAINE.—General report of the Public Utilities Commission, covering water powers and water storage schemes within the state. The report is divided into three parts, covering the legal, engineering and administrative phases of water power developments. In the engineering report, data are given regarding the various power sites, storages, etc. The administration report deals with the unit costs of power, rates and schedules, factors effecting costs, cost of transmission, cost of storage, etc. 420 pages and paper cover, 5¾ by 9 ins., with large map of the state, showing location of storage reservoirs, power sites and transmission lines.

The Canadian waterfront along the Detroit River may be placed under the jurisdiction of a harbor commission.

A bill providing for the licensing of architects and engineers is about to be introduced in the Ohio legislature by the Ohio Association of Technical Societies. Copies of the bill may be obtained from E. G. Bradbury, president of the Engineers' Club, Columbus, Ohio. Engineers in Michigan are also about to introduce a bill in that state, copies of which can be obtained from Gardner S. Williams, Ann Arbor, Mich.

In a recent issue of *The Canadian Engineer* it was stated upon what was thought to be excellent authority that the John Ver Mehr Engineering Co., Ltd., had received contracts in Belgium, and that William Storrie of their firm was engaged in rebuilding the mole at Zeebrugge. Owing to the source of the information, the accuracy of it was not doubted, but it now appears that there was no truth whatever in the report.

REINFORCED CONCRETE SLAB BRIDGE DESIGN BASED ON TESTS OF FULL SIZE SLABS*

By A. T. Goldbeck,
Engineer of Tests, U. S. Bureau of Public Roads

In all of the slab tests at the Bureau of Public Roads, the method of procedure was to apply known concentrated loads on the slag specimens, which rested on two suports. The deformation of the steel reinforcing and concrete, and also the deflection were measured. These deformations or changes in length in the slab were always taken at the "dangerous section," where they were greatest. In a few cases, deformations were also measured over the entire area of the slab. A strain gag capable of measuring changes of 0.0002 of an inch was used in all of the tests, and in addition, the vertical deflections of the slab were obtained, generally by means of a micrometer head reading to 0.001 of an inch.

Theory of Application of Results of Tests.—Consider first a wide slab supporting a single load concentrated at its centre. The maximum deformation occurs under the load, and as the sides of the slab are approached, the deformation becomes smaller.

This curve of deformation is the same in shape for both the steel and concrete. The resisting moment of any slab is directly proportional to the area of the curve of unit deformation. Two similar slabs stressed to have the same area of unit deformation, even though their unit deformation curves are dissimilar in shape, exert equal resisting moments. The effective width of the slab is the width which may be considered as carrying the entire concentrated load. When the value for this width as determined by test is substituted in the common formulas for narrow rectangular beams, these formulas may be directly applied to the design of wide slabs.

A number of slabs have been tested as outlined above, and their effective widths have been obtained from the deformation curves, first, by getting the areas included between these curves and their base lines, then dividing these areas by their maximum ordinates. When the load is placed in the centres of the slab and the width of the slab is more than about twice the span length, the effective width may be considered as equal to seven-tenths of the span length of the slab.

A number of slabs have been tested with a central load and having width equal to twice their span lengths. Table I gives data on the slabs tested at the Bureau of Public Roads during the past 5 years.

Slabs Having Widths Less than Twice Their Span.—The foregoing discussion treats of slabs having widths equal to twice the span length, in which case the sides of the slabs are not stressed appreciably. When the width is less than this, however, stress does reach the sides, and the narrower the slab, the more are the sides put under stress. It will be recognized that the width of the slab plays an important part in influencing the effective width. The amount of this influence has been quite fully investigated by a number of slab tests, in which the width of the specimen has been decreased after each load application, the sides of the slab having been spilt off by means of plugs and feathers. It has been possible to obtain from these investigations the values for effective width given in Table III. These values also are plotted in Fig. 1.

*From "Public Roads."

Table II—Effective Widths Under Central Loads

Center Load.	Slab 835: 10½ in. Effective Depth.	Slab 930: 8½ in. Effective Depth	Slab 934: 6 in. Effective Depth
15,000............	....	11'.4=71.6 per cent span.	12'.7=79.5 per cent span.
20,000............	11'.6=72.3 per cent span.	13'.0=81.2 per cent span.	17'.5=109.3 per cent span.
25,000............	11'.5=71.9 per cent span.	12'.9=81.1 per cent span.	....
32,500............	12'.1=75.7 per cent span.	....	....
35,000............	....	14'.5=90.7 per cent span.	....
Failure...........	119,000 lb.	80,000 lb.	40,000 lb.

Two Loads on the Slab.—When the span is such that a single axle load will control the maximum bending moment, the slab is subjected to two wheel concentrations, and the most dangerous condition exists when these wheels are midway between the supports. In order to investigate this condition, tests were made on slabs with two loads spaced 5 ft. apart on the centre line of the slab.

Table III—Values for Effective Widths

Total Width ÷ Span	Effective Width ÷ Span	Total Width ÷ Span	Effective Width ÷ Span
0.1	0.1	1.1	0.67
0.2	0.2	1.2	0.68
0.3	0.28	1.3	0.70
0.4	0.37	1.4	0.71
0.5	0.44	1.5	0.72
0.6	0.50	1.6	0.72
0.7	0.55	1.7	0.72
0.8	0.58	1.8	0.72
0.9	0.62	1.9	0.72
1.0	0.65	2.0	0.72

The above values may be used for spans up to 16 ft. at least, and probably for longer spans.

Note the fact that directly under the load the deformations are greatest, and are even slightly greater than the deformation at the centre of the slab. This stress distribution does not hold, however, for every thickness of slab, for a few of the tests show the deformation to be greatest at the centre. The effective width of slabs loaded in this way may, in general, be assumed as equal to the effective width due to a single load plus 4 ft.

Eccentrically Loaded Slab.—When a heavy load traverses a slab bridge it may not remain at the centre line, but may travel over the bridge near one side. Again there are often occasions where a heavy traction engine will stop at the side of a bridge spanning a stream, in order to replenish its sup-

Table I—Data on Slab Tests of Bureau of Public Roads

Slab No.	Dimensions: Span Feet.	Dimensions: Breadth Feet.	Depth: Total In.	Depth: Effective In.	Steel Percentage: Longitudinal.	Steel Percentage: Transverse.	Central Load Effective width ÷Span.	Failure: Span.	Failure: Central Load.
679	11.5	6	7	6	0.77	....	...	11.5	21,500
705	6	7	5	4	.91	....	0.9	..	......
706	3	7	5	4	.91	0.41	...	3	42,800
730	5	7	6	5	.91	....	1.1	6	24,700
	6	..	..	..	...	....	.96	..	......
736	6	7	4	3	.60	....	...	6	7,560
737	5	7	7	6	.75	.33	1.2	6	34,200
	6	..	..	..	...	....	1.2	..	......
835	16	32	12	10½	.75	....	*	16	119,000
930	16	32	10	8½	.75	....	*	16	80,000
934	16	32	7	6	.75	....	*	16	40,000

*See next table.

ply of water. On such occasions heavy load concentrations are supported on the side of the bridge as eccentric loads, and this is a much more severe condition than that of the centrally applied load.

For the investigation of this case a slab specimen 16 ft. in span, 32 ft. in width and 13 in. effective depth was made up. The original width was decreased after each test by cutting strips off of one side. The load applied in the centre of the original 32-ft. width became an eccentric load as the side of the slab was gradually removed. Referring to Fig. 2, the strips ij, hi, gh, fg, ab, bc, cd, and de, were split off in the order named. The load was always applied to the same spot and thus its eccentricity varied as the slab width was decreased. Without going into the details of the test, the results are shown in the curve in Fig. 2. The dash line curve is merely a duplication of that in Fig. 1, and applies to wide slabs under a central load. The solid curve is based on the tests of the eccentrically loaded slab. About 10 ft. were split off the sides of the slab before the effective width began to differ from that of the centrally loaded slab. The load was then 6 ft. from the side of the slab, and when its distance to the side became less than this, the effective width became much less than that of the same slab centrally loaded. This is shown by the deviation of the solid line from the dash line. The dotted line is plotted to represent the effective width of an eccentrically loaded slab with values for this effective width assumed to be equal to $\frac{b_c}{2} + D$, where b_c = the effective width of the slab under central load. D = distance of load to nearest side of slab.

This curve follows the curve of test results very closely and it may be quite safely stated as a general proposition that when a slab is eccentrically loaded, the effective width to be used in design may be calculated in the following manner:

(1) When the distance of the load from the nearest side is more than half of the effective width of the centrally loaded slab (Table III) use the effective width for central loads.

(2) When the distance of the load from the side of the slab is less than half the effective width under central loads (Table III) the effective width is to be taken equal to $\frac{b_c}{2} + D$. In order to make a slab bridge eccentrically loaded equal in strength to one centrally loaded, it will be necessary to supply extra strength at the sides by means

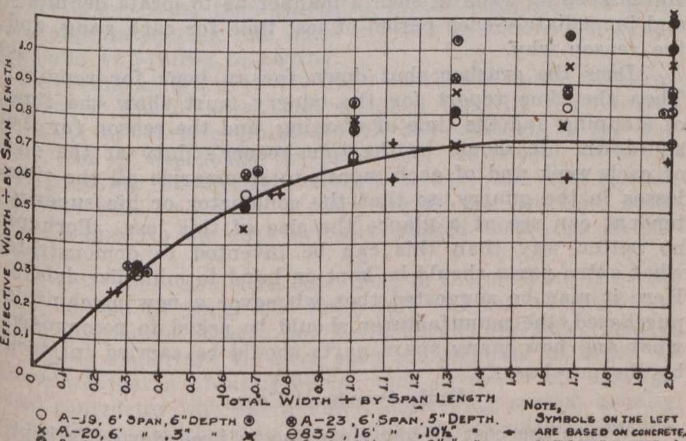


Fig. 1—Influence of Total Width on Effective Width of Reinforced Concrete Slabs Subjected to Concentrated Loading

of a parapet wall, and the following procedure for the design will give safe results:

(1) Use the formulas for narrow rectangular beams substituting for the breadth b the value obtained from Table III, (2) determine the loss in effective width due to the assumed eccentricity of the load, (3) supply the deficiency by designing the curb of the parapet to provide a resisting moment equal to that of the slab width lost due to eccentricity. Allowance will have to be made, however, for the stiffness of the section under the parapet. An unfinished test thus far indicates that this method of design is safe at least.

To illustrate the above method. Assume the slab 16 ft. in span length and 20 ft. in width, designed to carry a concentrated load to be applied 3 ft. from one edge, then the

$$\frac{\text{Total width}}{\text{span}} = \frac{20}{16} = 1.25.$$

From the table for central concentrated loadng (Table III), the effective width = 0.69×16 ft. = 11.04 ft. = b_c. Consider the load to be carried by a width of 11.04 ft., use the ordinary

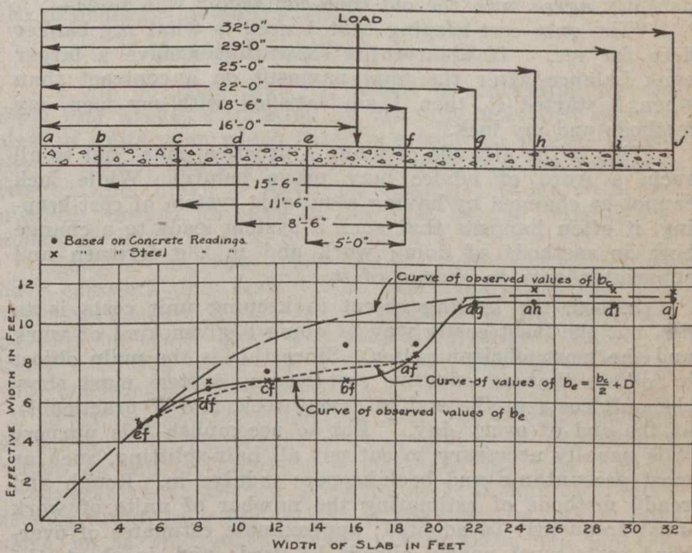


Fig. 2—Showing Effective Width vs. Width of Slab

formulas for rectangular beam design, and determine the effective depth of the slab and the area of the steel required. Next determine, by the relation indicated above, the effective width with the load placed 3 ft. from the side.

$$b_e = \frac{11.04}{2} + 3 \text{ ft.} = 8.52 \text{ ft.} = \text{effective width for eccentric load.}$$

The difference between the values of b_c and b_e is 11.04 − 8.52 = 2.52 ft. The curb of the parapet should, therefore, be designed so that it will have a resisting moment equal to that of a slab of width 2.52 ft.

Although there are several other conditions which may arise in the investigation of bridge slabs, the few above considered are most important, as they generally control the design.

During the 1918 harvest in Great Britain some remarkable results were obtained from "electrified seeds." H. E. Fry, an electrical engineer of Dorset, Eng., has developed a process of stimulating seeds so that they yield healthier and more prolific crops. The process consists of soaking the seeds in a solution of common salt, sending a current of electricity through the solution, and subsequently drying the seeds. Trials have been made with electrified wheat, barley, and oats in comparison with non-electrified seeds from the same sack and sown on adjoining ground. The electrified seeds threw up more straws, which were so much stronger than the normal that they withstood storms which laid the non-electrified harvest low. The gain in yield per acre varied in different parts of the country from 5 to nearly 20 bushels per acre for oats, and from about 5 to 7 bushels for wheat. Barley showed an increase of 16 bushels in another recorded case. Twenty-seven farmers in South Devon realized an average gain per acre of about $23 after deducting the cost of treatment, which is only about $1 per sack. The latest British contribution to the promising science of electroculture is being investigated by a sub-committee of the Board of Agriculture of Great Britain.

COST-KEEPING FOR HIGHWAY CONTRACTORS*

By Halbert P. Gillette

Last September the Office of Public Roads, Washington, D.C., published a 52-page pamphlet entitled "Highway Cost-Keeping," by Tobin and Losh, engineer-economists. This pamphlet can be had for 10 cents, and as it should be secured by every highway contractor and engineer, it will be unnecessary to repeat in this paper anything given in that pamphlet.

Although several books and a great number of articles on cost-keeping have been published during the last ten or twelve years, there still exist many contractors who apparently agree with the old time contractor who said:—

"The only cost-keeping that I need is what my banker does for me. If his records show that I have a larger bank balance after the final payment on a contract than when I started it, then I am satisfied with my men, my methods and my luck."

This is the attitude of many a practical man; but to all such, a word of advice may prove helpful. While luck cannot be changed by having a suitable system of cost-keeping, it often happens that such a system leads to a change both in methods of doing work and in the foremen and superintendents in charge of it.

Indeed, the leading object in keeping unit costs is to find out the least costly way of doing a given kind of work and the most efficient bosses. Since this is the main object it follows that an effective cost-keeping system must show the unit costs at the end of every week, and if practicable, at the end of every day. But to accomplish this purpose it is usually necessary to cut out all hair-splitting, such as most accountants and book-keepers indulge in. Rough and ready methods of estimating the number of units of work must frequently be adopted; approximate estimates of overhead costs must nearly always be used; and, in short, the aim must be to get at the unit costs within a few per cent. —say 5 per cent.—rather than "to the last red cent." It is that "last red cent" ideal of the book-keeper that is accountable for the practical failure of many a cost-keeping system.

Estimating Excavation Yardage Daily

As an illustration, take almost any dirt-digging job and try to apply the usual book-keeping methods to it. The time-keeper may report each day the day's labor cost of excavating, but he does not ordinarily ascertain the yardage of earth moved that day. Perhaps the engineer can give a rough estimate of the yardage, but his estimate may be 25 per cent. off, for he usually makes his guess merely by looking at the map profile or at the cut and fill marks on the slope stakes and then looking at the partly graded roadbed.

Since the engineer seldom makes a careful quantity estimate oftener than once a month—and it is not always careful then—it follows that there are very few grading contracts on which the cost per cubic yard of earth excavated is known within 10 or 15 per cent. at the end of each week. As for knowing the earth yardage cost for each day, how many members of this association have ever seen a contractor who did know it?

For a long time the author regarded it as impracticable to estimate earth yardage costs with reasonable accuracy oftener than at the end of each week. Several years ago the author's brother, W. A. Gillette, devised a method of estimating earth yardage on grading jobs every day. The method consists in mounting a time-keeper on a horse and having him ride from gang to gang all day long, stopping 20 to 30 minutes at each gang. If a gang is excavating with fresno scrapers, for example, the time-keeper counts the number of fresno loads taken out by the gang in, say 20 minutes; and he records the count for that gang. Then he rides on to the next gang which, let us say, is loading earth by hand into wagons. This gang is timed for, say, 30 minutes, and the wagon loads are counted.

In the course of the day, each gang is thus visited and its output counted several times. If, for example, gang No. 1 has been visited 3 times and during a total time of one hour it has turned out 50 fresno loads, it is then estimated that it would turn out 400 loads in 8 hours. An estimate is made of the average size of a load, and the total yardage output of gang No. 1 for that day is estimated. Similarly with the other grading gangs. At the end of the month the totals thus estimated are compared with a careful monthly estimate based on cross-sections. After a little experience it is possible thus to estimate within 5 per cent. of the actual yardage moved.

Of course this intermittent count method can not be expected to give satisfactory results unless good judgment is used in its application. But it has been shown to the author's satisfaction that the method is sufficiently reliable when properly supervised. That it is simple is self-evident.

The two greatest obstacles to the successful use of any cost-keeping system are, first, a fairly accurate measurement of the number of payment units of work done each day; and second, a correct ascertainment of the total time lost or wasted by each gang. By "payment units" is meant the units of work for which a contract price is paid, as, the cubic yard of earth excavation, the square yard of pavement, etc.

Recording Lost Time Daily

All costs should be finally reduced to so and so many cents or dollars per payment unit, so that the contractor can compare them with his contract prices. Fortunately the highway contractor has a relatively simple task in devising methods of measuring most of the payment units every day. Excavation measurements are the most difficult to secure daily, but a suggestion as to how this may be done has just been given. The yardage of pavement laid daily is readily ascertained. Since excavation and paving usually constitute the bulk of the cost of a road, it is evident that if a contractor can keep these two items of cost within his bid prices, he can usually "win out" on the entire job.

Lost time is the bottomless pit into which more money has been dumped by road contractors than can be estimated. The author has seen, and has himself experienced, the bitterest disappointment resulting from time lost while wages were going on. It is not an uncommon thing to lay twice as much yardage of concrete on a day entirely free from delays as is laid on the average day. In other words, it seems practicable to do twice as much work daily as actually is averaged. How is this ideal to be attained, or at least approximated? Only by system, and system involves keeping costs in such a manner as to locate definitely and immediately each period of lost time for each gang, and the reason why.

Does the crusher shut down for an hour for repairs? Then the time report for the quarry must show the time of stopping and the time of starting, and the reason for the shutdown. It should be the time-keeper's duty at the end of each week and of each month to summarize all the time losses in the quarry, so that the contractor or his superintendent can see at a glance the size of this loss. Perhaps no better way than this can be invented to demonstrate what extra parts should be kept on hand to minimize delays. Here it may be suggested that whenever a new machine is purchased, the manufacturer should be asked to recommend what and how many spare parts should be carried in stock by the purchaser.

Daily Overhead Costs

Where the cost of lost time due to breakdowns is kept, it frequently becomes evident that it is economic not merely to have spare parts on hand, but to have entire spare machines. Take a pump, for example, that is delivering water to a concrete mixer and for sprinkling, etc. Upon the service of that one pump will depend the progress of the pavement. Yet to save an investment of $500 to $1,000 in a spare pump, many a road contractor loses several-fold that sum each year. Such losses result from failure to keep records that show the cost of lost time.

Closely associated with the question of lost time is the question of overhead costs. Among "overheads" should be

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*Read last week at the annual convention of The American Road Builders' Association, New York City.

included superintendence, office expense, interest and depreciation on plant. Superintendence should include some compensation for the contractor's own time. To the author it seems desirable to divide the contractor's compensation into two parts, (1) salary and (2) profit.

The salary should be only as large as would be paid to a skilled superintendent. The profit should cover both compensation for the contractor's skill as an organizer and financier, plus insurance against all risks for which an insurance policy can not be secured.

Working Days or Days Worked?

A common mistake in estimating "overheads" consists in dividing the annual overhead cost by the number of working days in a year, instead of dividing by the average number of days actually worked. In our northern climates, the number of days actually worked by a given organization on road construction usually averages about 125, but there are 300 working days in a year; hence a highway contractor and his plant are usually idle nearly 60 per cent. of the working days of the year. If a contractor's annual salary as a superintendent be added to the annual salaries of his permanent employees, and if this salary total be divided by 125, instead of by 300, the salary "overheads" per day worked will be ascertained for all practical purposes. Similarly as to plant "overheads" and office rental "overheads."

The total "overheads" per day actually worked must be apportioned among the units of work done. Both highway contractors and engineers who have not been accustomed to prorate overhead costs in this manner will get some surprises. Failure to do this is largely accountable for the fact that so many road contractors "go broke," and it also throws light upon the fact that a good many engineers think that road construction can be done more cheaply by day labor than by contract.

Having estimated the overhead costs per "day worked" (not per working day), some of these daily overheads can be assigned directly to a given class of work. Thus, the daily interest, depreciation and repairs on a concrete mixer can be assigned to the pavement. But certain of the daily overhead costs must be prorated to the different classes of work.

There are several theories of prorating joint costs, which the author has discussed at some length in the "Handbook of Mechanical and Electrical Cost Data." Usually it suffices on construction work to prorate overhead salary costs in proportion to direct labor costs. Thus, if the direct labor cost of grading is $50 a day and the direct labor cost of paving is $100 a day, and there are no other direct labor costs, then one-third of the daily cost of general superintendence and office expense is assigned to grading, and two-thirds to paving.

Having assigned all the daily overheads to the different classes of work, divide each assigned total by the number of units of work performed each day worked, to get the unit cost of overheads for each day. It should be noted that by using this method there are no overhead costs for the days on which no work is done, for all the overhead costs are assigned to the days actually worked each year on the average.

While there are some objections to this method, it is the only method by which the total unit cost can be estimated with any degree of accuracy for each day worked. And it is highly important to have such an estimate in order to know whether a profit is being made or not. The average road contractor who has a unit cost-keeping system usually is deceived into thinking he is making money, because the daily overheads are either not known or are not properly allocated to the various classes of work.

Cost of Installing and Shifting Plant

There is another source of error in estimating daily or weekly or monthly profits, which arises from failure to segregate the cost of installing, shifting and removing the various plant units, together with miscellaneous costs of getting ready to do work. It is rare that any contractor is able to state what these "preparatory costs" have been on any given job, and this holds true even where the contractor has a cost-keeping system. No argument is needed to prove that unless the "preparatory costs" are known, there is grave danger of under-estimating the total unit costs.

Having so kept the daily records as to show the actual cost of moving and installing a crushing plant, for example, to this should be added the estimated cost of shifting it (where shifting will be necessary) and the cost of dismantling and shipping it home. Then this total should be divided by the total number of cubic yards of stone to be crushed on the given job, to get "the unit preparatory and shifting cost" of crushed stone.

This unit cost should be added each day to the "unit overhead cost" and the "unit direct cost" for that day. The resulting total will then be really significant as to what the pavement is actually costing.

Importance of Daily Unit Costs

It will be noted that the author is contending for the daily and weekly estimating of the total unit cost of each class of units upon which there is a contract price. Unless this is done it almost invariably happens that the road contractor who thinks he has been making a profit on a job, awakens toward its close to find that he has actually lost money on it.

Now, he may lose money on the job even if he does have complete unit costs before him every day, for it is very common to bid so low a price that no profit can possibly be made. But it is surprising what a difference there is in the energy of a desperate man as contrasted with one who is well satisfied.

When a contractor realizes that he is daily sinking deeper into the quicksands of bankruptcy, he will usually "camp on his job" night and day, and his wits will be steadily at work; whereas if he thinks he is making a satisfactory profit, he is apt to take things easy, let well enough alone, go off on frequent pleasure excursions, and the like.

Incidentally it may be remarked that one of the reasons why day labor so frequently exceeds the cost by contract lies in the psychological fact that the engineers and superintendents in charge of the work have no pecuniary stake in the cost of the work.

Summary

Summing up, a road contractor can use his brains to no better advantage than in finding ways of securing daily reports that show the total unit cost of every item on which he has bid a unit price. To do this it is frequently necessary to invent methods of securing approximately correct estimates of the number of units of work done, and it often pays to employ an engineer for no other purpose than to measure up daily the number of units.

Lost time should be reported daily and its cost estimated.

Overhead costs should be estimated per average day worked, not per working day, and unit overhead costs estimated every day.

Plant, preparatory and shifting costs should be kept apportioned to each class of work, and reduced to unit costs.

If these methods are adopted, profits will be increased or losses decreased. If engineers in charge of contract work will follow the same method, they will usually discover that there is little or no profit to the average road contractor. Indeed, unless engineers give adequate study to the costs of lost time, overheads, plant installations, etc., and unless they devise ways of enabling competent contractors to secure adequate prices, it will be only a matter of a few years before there will be no competent contractors in the road-building business.

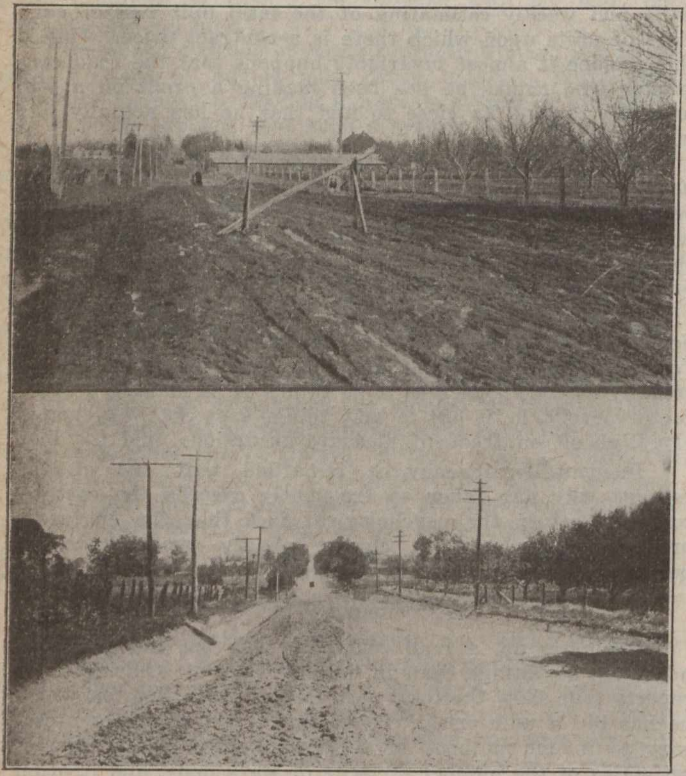
A. H. Harkness, chairman of the Toronto branch of the Engineering Institute of Canada, has announced that W. J. Francis and Arthur Surveyer, members of the council of the institute, will address the Toronto branch about March 20th, in order to give "inside information" regarding what the institute is doing for engineers.

ROAD FOUNDATIONS, DRAINAGE AND CULVERTS

By George Hogarth
Chief Engineer, Ontario Highways Department

IN highway construction it is essential that careful attention be given to the foundation and drainage of the roadway in order to provide the surfacing material with that firm and uniform support so necessary to its life. A dry earth subgrade, when properly drained and compacted, is the real foundation of the road, and such subgrade, by its strong and permanent support, materially lessens the need for thick and expensive road surfacings.

In many instances this ideal condition of the subgrade may be attained by one or several of the many layouts of tile drainage; and any expenditure made to drain away water and render the subgrade unyielding, will al-



Above—Road Before Ditching
Below—After Placing 10 to 12 ins. of Gravel and Ditching at Sides

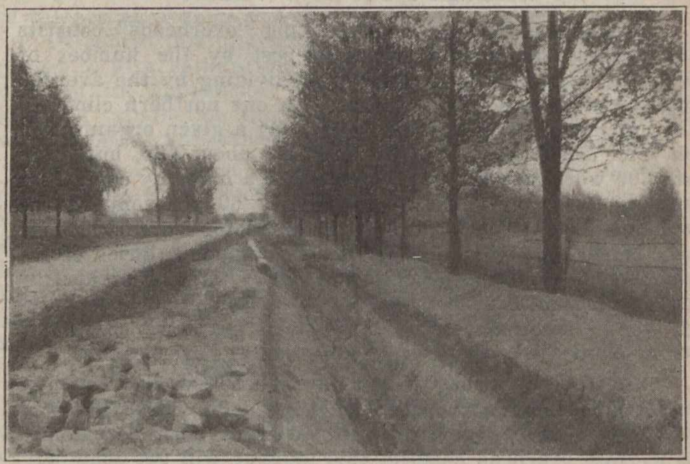
ways give a splendid return in reduced maintenance charges. A comparatively small expenditure for tile drains and open side ditches will very often produce a hard, natural soil roadway, upon which a gravel or macadam surface or pavement may be placed; and under such circumstances, less gravel or stone will be required to produce a good surface for travel.

While the earth subgrade in a dry state will carry all the loads passing over the highway, it will be found that certain natural conditions render it impossible to maintain this condition; and wet weather requires that some other means must be provided for distributing the concentrated wheel loads over the subgrade. To properly distribute the wheel loads, a base or foundation course is used in the construction of highways. The importance of this foundation course to the highway is such that a foundation failure will cause the surface above it to fail.

The foundation course may be gravel, field stone, oversize crushed stone, quarry stone, telford, or any existing pavement. The lower course of a macadam road, when built in two courses, is the foundation for the upper or wearing surface. Under ordinary circumstances, this lower course is about 6 ins. in depth after rolling. Where the subsoil is poor, or it is desired to aid the subdrainage of the roadway, the lower course may be increased in thickness.

A telford foundation may be constructed and usually consists of stone 6 to 8 ins. deep, 3 to 8 ins. wide and 6 to 15 ins. long, laid on edge and with the longest dimensions across the road. The spaces between the stones are filled with spawls and screenings, after which the entire surface is thoroughly rolled.

Concrete as a foundation is used for city pavements and consists of crushed stone, sand and cement in the pro-



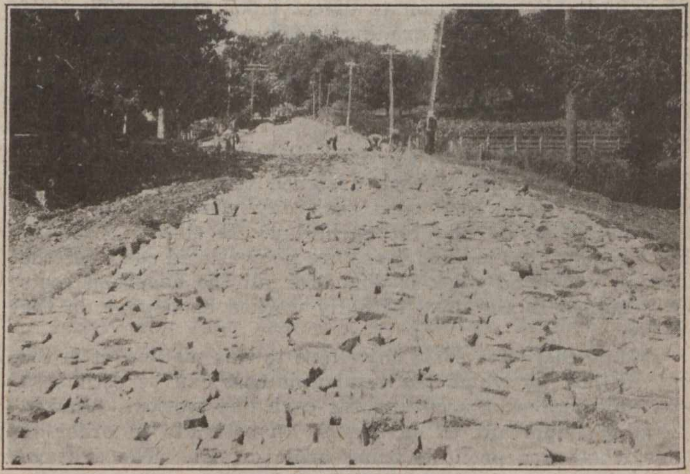
Placing Tile Drain Under Bottom of Side Ditches

portions of 1 part cement to 2 parts sand to 5 parts crushed stone.

Old macadam pavements may be cleaned and swept and used as foundations for bituminous surfaces and very good results are frequently secured.

Drainage

For road drainage, porous tile or vitrified pipe may be used, and a diameter of not less than 4 ins. usually gives good results. A properly graded trench, in which to lay the tile, is first prepared, and after placing the tile and covering or filling the joints, the trench should be back-

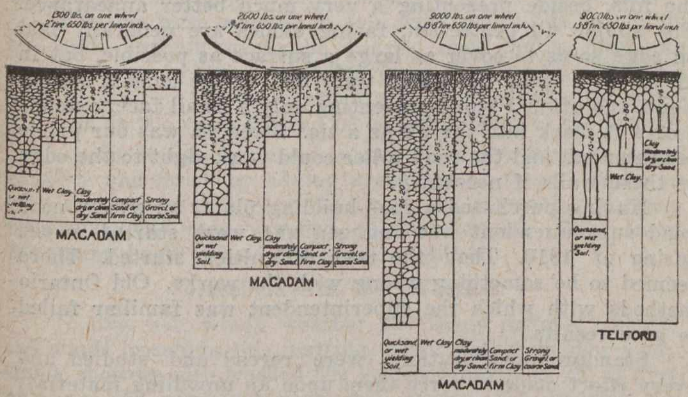


Telford Foundation, 18 ft. Wide, Built in 1918

filled with porous material such as gravel or crushed stone. The entire purpose of such tile is to intercept the flow of ground water before it reaches and softens the subgrade; and in wet and boggy soils, such treatment will produce excellent results. This particularly applies to a road on a hillside or a road at the foot of a slope. The flow of ground water naturally tends to break out at the side of such a road and, unless checked, will produce such a boggy condition that no road can be maintained. Tile drains may be placed in the bottom of the side ditches of the road, or in the shoulder of the road, or in some cases under the centre of the road; and in all instances, the trench should be at least 3 ft. deep.

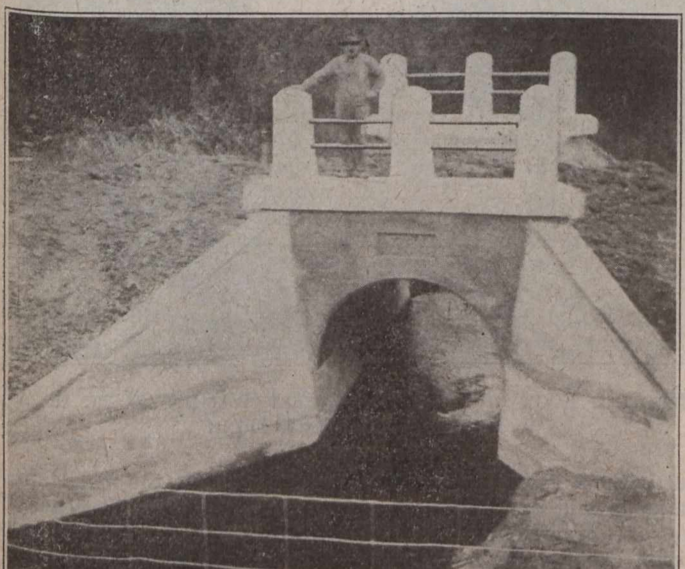
Adequate tile drainage prevents the heaving action of frost by removing the water before damage can occur. A road on a wet undrained bottom will always be troublesome and expensive to maintain, and it will be economical in the long run to go to considerable expense to make the drainage of the subsoil as perfect as possible.

The objects of underdrainage are to lower the water level in the soil and keep it away from the road foundations. The sun and wind will dry the surface of the road but a soft foundation will soon result in the road becoming a mass of mud. Underdrainage also assists in drying the ground rapidly when the frost first comes out of the ground in the



DEPTHS OF FOUNDATION REQUIRED FOR VARIOUS WHEEL LOADS ON DIFFERENT SOILS

spring. A good system of tile drainage as stated above will also remove the underflow of ground water so that ground which is comparatively dry in the fall will remain so and not become waterlogged in the spring. Water is frequently found to be forced to the surface of the ground by pressure from water in higher places, and if this water is not drawn off by underdrainage it saturates the soil and rises as the frost goes out. Underdrainage not only re-



ARCH CULVERT FOR TRUNK ROAD

moves the water, but also prevents or reduces the destructive effects of frost.

Open side ditches or gutters are necessary in order to receive and carry away all water from the surface of the travelled roadway and the surrounding land. Side ditches should be of adequate depth and should have as great a fall as possible to a free and clear outlet. Crowning the roadway gives the transverse slope which sheds the water to the side ditches. On earth roads a slope of one inch per foot will be found satisfactory; while for the macadam roadway and the higher types of pavements, a flatter slope of from ⅜ to ¼ inch per foot is ample. For ease in construction, a side ditch cross-section having a bottom width the same as a drag scraper, is economical, as giving a size which is readily constructed and easily maintained.

Culverts

Culverts should be constructed of permanent materials, should be large enough to take the maximum flow of water, should be graded so as to be self-cleaning, and should be long enough to take the normal width of the roadway section between parapets.

The size of opening necessary may be determined usually by a close examination on the ground and after making enquiries as to the greatest flow of water to be expected. In using pipe for culverts, it is not advisable to use a smaller diameter than 12 (or, better, 18 ins.) because of the likelihood of the smaller-sized pipes choking up quickly.

Culverts are required to support the weight of the materials covering them and also the weight of any superimposed loads. Water freezing in the culverts may cause heavy expansive forces tending to burst or crack the walls of the culvert.

The usual materials used for pipe culverts are vitrified clay, reinforced concrete, corrugated iron, or cast iron. All pipes should be laid on a firm bedding and the backfilling carefully tamped around and over the pipe.

Headwalls at each end of the pipe should be constructed in every case to prevent the scouring action of the water washing away the supporting soil. Frost action may affect the headwall, and for that reason the foundation should go to a sufficient depth to reach below the usual depth to which frost penetrates. Headwalls should also be long enough to prevent the earth falling around their ends and blocking the channel to the pipes.

Culvert Location Requires Judgment

Culverts having an opening of 2 ft. and upwards in width are usually built of reinforced concrete and may be of the box, or bridge, or arch type, depending on the span.

Spans of 2 ft. to 16 or 18 ft. may have a flat-slab top, with vertical sidewalls, as the forms for such construction are readily framed at small expense. The reinforcing of the slab may be composed of any of the usual forms of concrete-reinforcing steel, such as bars, rods, expanded metal or wire.

Where the span is over 18 ft., it is advisable that reinforced concrete beams, or steel beams, be used to support the reinforced concrete roadway slab. The roadway slab, where not carrying a fill, is usually constructed from 6½ to 7½ ins. in thickness, depending upon the spacing of the supports, and a richer mix of concrete is used to give a greater resistance to wear.

The location of culverts is a matter requiring careful judgment, and it is often found that they are built and maintained where unnecessary. To secure proper benefit from a culvert, the water carried across the road should be carried from the end of the culvert directly away from the road. Water may be carried along a road wherever the volume is not sufficient to cause washing and scour.

Frank Barber, consulting engineer, Toronto, this evening will give an illustrated lecture before the Toronto branch of the Engineering Institute of Canada, on reinforced concrete bridges in Canada.

In Parliament recently Hon. Frank Carvell, Minister of Public Works, announced that the government will spend $20,000,000 on highways improvements, to be extended over a period of five years from April 1st, 1919. Mr. Carvell also said that the government is spending a large sum on shipbuilding,—about $20,000,000 or $25,000,000 this year and about $30,000,000 during the coming fiscal year.

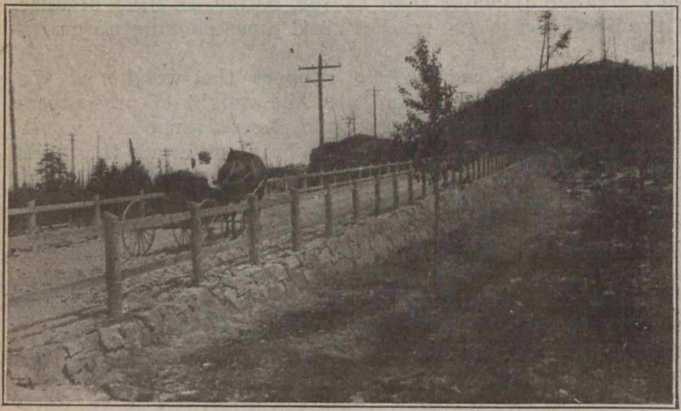
ROADS IN COLEMAN TOWNSHIP

(Continued from page 274)

velopment of a new mine or prospect; second, a small money grant by council to open a trail passable for teams with 800 or 1,000 lbs. wagon load. Then, if continued development justified the expense, a thorough grade reduction and re-alignment where necessary, widening and macadamizing were successively undertaken.

The materials of construction were principally rock; in outlying districts, generally boulders; in the central mining sections, waste rock from the mines.

In most of the township there is very little overburden of soil available of suitable quality. The waste mine rock was given willingly in most cases. Rock running as high as 40 ounces of silver to the ton was at one time considered waste. The limit was rapidly lowered to 20 ounces on the introduction of concentrating mills, then to 10 ounces when cyaniding was found to work successfully, and now—owing to the increased value of silver and the introduction of oil flotation methods of recovery—mine managers would probably hesitate to give away rock running over 5 ounces of silver per ton. I have no doubt that some of the original rock fills will eventually be removed and milled. The question of ownership of this rock may then become quite a live issue. Many fine pieces of high-grade silver were found in the rock piles by the workmen.



DRY-ROCK RETAINING WALL FOR GRADE REDUCTION FROM 18% TO 5%

On the question of alignment you will have gathered that it was usually a case of getting around or through, using the best location available, knowing little and caring less what the degree of curvature might be. There were no automobiles there then. The first roads were built for one-track team traffic to get supplies into the mines and ore out. Consequently, these roads, which are now used very largely by autos, provide many thrills, and are in some places quite dangerous.

Excavation Provides Thrills

Rock excavation and dry rock retaining walls were two very interesting portions of the work. Owing to high cost, extensive rock excavation was avoided where possible. It was cheaper to make fills from mine dumps than by excavation. When we did have rock excavation, it was generally in some very restricted quarter where great care had to be exercised to avoid damage. One of the accompanying illustrations gives some indication of the cramped quarters in which we sometimes worked. The fact that no serious damage ever occurred, and slight damages very infrequently, can be attributed to the skilled miners obtainable and to constant watchfulness and insistence on "safety first." Carelessness in these conditions meant instant dismissal. And it is truly remarkable how little damage is really necessary, even in such close quarters.

Considerable rock work was done in the town of Cobalt on Cobalt St. and Prospect Ave., and along the Haileybury road at mileage 105. Dynamite was also in constant daily use by several gangs throughout the township for removing boulders, stumps and small rock outcrops.

The first dry rock retaining walls were built loosely, perpendicularly, and with little care, and after the purchase of a road roller many of these had to be rebuilt. They were not laid by regular masons, but by ordinary workmen who showed capabilities along this line, and who were trained and assisted for a short time and then paid a little extra over regular workmen's pay. They were not only lower-priced men, but would lay nearly double as much as regular masons.

Profitable Retaining Walls

These well-built dry walls paid for their construction several times over in the saving of material necessary for the fills, beside presenting a very much better appearance. For simple fill protection, facing stones are generally laid on edge so as to cover as large a surface as possible, but in all of these walls the stones were laid on the longest dimensions, and often a stone presenting only a small face, extends 3 or 4 ft. back into the fill as a tie. Strength was our prime requirement, and the road roller could work right to the edge of these walls if necessary.

Having purchased a road-building plant, an experienced road superintendent was engaged and work started in the spring of 1910. Then the real difficulties started. There seemed to be something wrong with the works. Old Ontario methods with which the superintendent was familiar failed to give results.

Standard specifications were reread and studied and every effort made to force them upon an unwilling material; but without avail. Specifications say that when the macadam stone is laid and spread it shall be rolled until "it ceases weaving or creeping ahead of the roller wheels." This condition could never be obtained. Stones refused to bind, but rolled around loose, no matter how much rolling was given.

BLASTING ROCK ON A COBALT STREET WITHIN 20 FT. OF A HOUSE—NO DAMAGE DONE

Again, the specifications say that when the screenings are added, brushed in and sprinkled, there shall be formed a wave of mud or slurry ahead of the roller wheels. Failure number two; no such condition was ever obtainable.

Such refusals on the part of our refractory material were very disconcerting to the engineer in charge, and for a time caused a vast deal of worry.

Then again, one section of road would "make up" quite readily and satisfactorily, while adjoining sections would remain loose and open for days, despite continued applications of screenings and repeated sprinkling. Opening both outlets of the sprinkler full force would fail to flush the road, the water going straight through as if the road surface were a sieve. Then quite suddenly this condition would cease, and the road refuse to absorb any more water, which would run off the sides in floods. We then knew that the road was finished, but it was some time before the process was thoroughly understood.

The explanation, of course, was that the water and fines continued to run down into the coarse rock foundation until all voids were filled. In some cases, where there was three or four feet of rock fill, this took days, whereas adjoining sections, where the fill was lighter, filled more quickly. The explanation was so obvious after once being determined, that it seemed inexcusable to have missed it for so long a time.

Methods were adopted to deal with heavy fills by adding an earth cushion over the coarse rock before applying macadam, or by using suitable loam or gravelly clay as a first application on the crushed rock, which had a tendency to block up the voids instead of washing down to the bottom.

Again, it was found necessary to depart from standard practice and finish by adding a surface of from 1 to 2 ins. of screenings over the crushed rock, as a wearing surface. Otherwise the road ravelled quickly, because there is no cementing bond to hold the stones together.

Excellent—In Wet Weather

In dry, hot, windy weather the roads suffered greatly, the winds loosening this matting, which rolled or blew away. Quick showers also washed the loosened particles off at first, but once the surface became well wetted, the deterioration ceased, and as long as wet weather continued the macadamized road remained in excellent condition. One could drive over the whole macadamized portion during or following a heavy rain and find no mud to soil a buggy.

While wet weather lasted, no other preservative was necessary.

These roads were well crowned so that no water was allowed to lie on the surface to form puddles. This absence of any mud would not apply to unmacadamized surfaces, though even there we kept the surface well rounded, and mud holes of any moment were practically unknown in the road after the second season's work.

A grant of $2,000 was made annually for maintenance work. This amount was always more then sufficient, because the roads once constructed were never allowed to get into bad condition but were taken in hand as soon as a weakness developed. This is the very cheapest of maintenance and the most efficiently expended money ever put upon a road. This is one of the first great lessons for all road supervisiors to recognize.

Of course, in time, the matting of screenings wore off and had to be renewed. Also a rapid development of automobile traffic brought new problems and aggravated old ones. Trap rock roads, bound with trap rock screenings, are ill-adapted to withstand the rubbing, sucking, tugging action of pneumatic tires, and some other binder had to be found. Experiments were quietly carried on with various grades and densities of oils, but with unsatisfactory results. The problem was finally met and fairly well cared for by surface treatment with Tarvia.

Bituminous Binder Needed

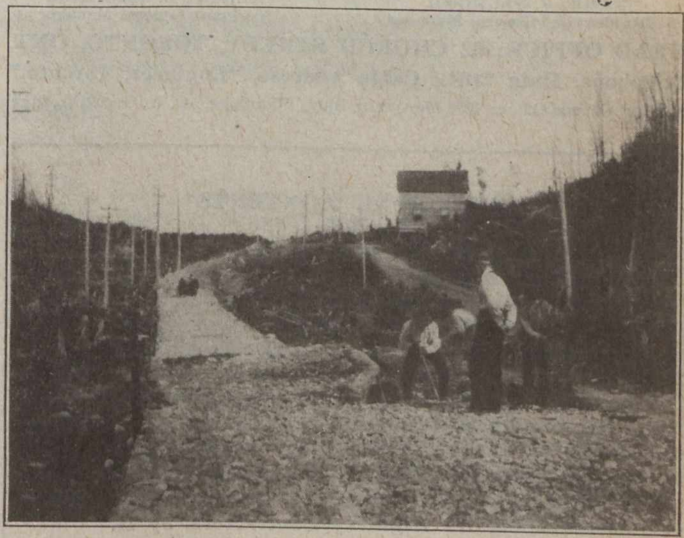
However, this material did not give entire satisfaction with the above type of construction, as it had a tendency to lift off this surface mat in large cakes, not being able to penetrate and bind the screenings to the coarser stone beneath. Special care was required to bring the Tarvia into direct contact with the coarse crushed rock after the same has been well set in place.

Where Tarvia surface treatment is contemplated, much less screenings should be applied as a wearing course, and these should be all removed just before application of the Tarvia.

The best results however, would be obtained by using bituminous binder, tar or asphalt, for the top layer of macadam.

My connection with the work terminated shortly after the application of the first tank of Tarvia, in June, 1913, and of the subsequent methods used and results obtained I have little personal knowledge. They must have been quite beneficial, as several tank cars have since been used.

You may have noted and criticized the lack of technical and statistical details given regarding this work. This is for two reasons: First, the conditions were so different from what is ordinarily met in road construction that methods and results, I felt, would be more interesting; conditions also varied so much in different parts of this small system, that one mile might cost quite double, or more, than the next mile



Typical Road Revision in Coleman Township

built to the same width and standard. Approximate average costs, however, would run about as follows:—

Type 1—For opening the first narrow single track trail, per mile, $500 to $1,000.

Type 2—For widening to 10 or 12 ft., improving grade and surfacing the track with fine waste rock or other available material, about $1,000.

Type 3—For widening for double track road, bringing to finished grade and making necessary rock cuts and dry rock retaining walls, varied largely in different locations but averaged about $2,000.

Type 4—For macadamizing the surface, $1,800 to $2,000.

Type 5—For Tarvia surface treatment, per mile, $350 to $500.

Rock excavation in open country (very little of this) $1 to $1.25.

Rock excavation in restricted locations, $1.25 to $2.00.

Dry rock retaining walls with roughly hand-laid backing of 2 to 5 ft., per sq. yd. surface $1.50 to $1.65.

By June, 1913, we had in the system about 15 miles of trails,—15 miles of type 2, 5 miles of type 3, and 10 miles of macadamized road (of which about 3½ miles had been given a treatment of Tarvia B).

We also had laid in June, 1911, 990 sq. yds. of Rocmac on Cobalt Square at a cost of 93c. per sq. yd. Sample stretches of this material had been laid in Woodstock and Niagara Falls in the fall of 1910, but I believe Cobalt Square to have been about the first laid on a regular, commercial basis. It is also one of the best of the Rocmac roads and is still giving excellent satisfaction after carrying for 8 years the traffic of the busiest spot in Northern Ontario.

Personnel

Arthur Ferland, of Haileybury, was reeve of Coleman continuously from 1907 to 1918. During those years there was no election for reeve or councillors, the council changing somewhat in personnel but always being elected by acclamation.

Assistant engineers in direct charge of the road work were Thomas Strachan in 1909, A. E. Jupp in 1910, and G. C. Godard in 1911, 1912 and 1913.

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PRINCIPAL CONTENTS

TORONTO ENGINEERS DISCUSS SALARIES

"WHAT the Institute Can Do," was the subject of four papers read last Friday evening before the Toronto branch of the Engineering Institute of Canada. The papers were by E. M. Proctor, H. A. Goldman, J. C. N. B. Krumm and Geo. Phelps. A. H. Harkness, chairman of the branch, presided. About fifty were present.

Mr. Proctor stated the fundamental aims of the institute and suggested visits to engineering works, the visits to be preceded the day before by a technical paper describing the works. He also urged that debates on engineering questions should be held by the branches, choosing subjects such as the following:—

Is the building of the Georgian Bay canal advisable?

Should municipalities own and operate all public utilities?

Are deeper and wider canals on the St. Lawrence Canal advisable and economical?

Mr. Proctor also suggested that the engineers organize in such a manner that they can insist upon being paid a respectable sum, so as to cause people to have some respect for their opinions. He favored the preparation of a schedule of salaries. He also urged the appointment of at least one capable engineer on every commission dealing with engineering matters, and advocated the encouragement by manufacturers of research work.

Mr. Goldman said that it is no secret that the small financial returns for engineering services have contributed more than anything else to the degradation of the engineering profession. "It is idle and useless," he claimed, "to blame the public for not giving the engineer the proper recognition.

"We must not forget that the public at large knows nothing of the amount of training that one has to go through to qualify himself for an engineer. The public has no idea of the nature of the problems that daily confront the engineer, and the sound judgment and skill that he must exercise in order to solve these problems. The public knows nothing of these things and therefore cannot appreciate the importance of the engineer in terms of these attainments.

"The public has but one method whereby to determine the value and importance of any commodity, or any class of people whose services the community requires, and that method is by means of the usual medium of exchange, dollars and cents. The standing, importance and prestige of any class in the community is in direct proportion to the value of the services of the members of that class. If, then, the engineers themselves establish a low rate of pay for their services, the public can only take them at their own valuation and can only place them in a class and in a position to which such valuation entitles them.

"It must be evident, then, that never will the engineers as a class occupy the same position in the community as the doctors or lawyers, until they raise the value of their services to the same extent as that of the men of other professions.

"When speaking of the services of the engineer to the community, W. H. Finley suggests that the engineer, because of the nature of his education and training, would be the best qualified to solve the difficulties between labor and capital. It is surprising that such suggestion should be made at all, for what class of labor is there that has sufficient confidence in the engineers, as a class, to entrust them with their financial interests, when as a matter of fact, under the present economic condition, organized labor considers the engineers inferior to themselves. More than that, they consider the engineer as a hopeless economic failure.

"It is realized, of course, that the adoption of Dominion-wide standards of salaries would at first entail some difficulties in the enforcement of same. But on the other hand we must not forget that the question of pay is not an issue between the engineer and the public. As a matter of fact it is only a family affair, requiring just a little adjustment among the engineers themselves; because in nearly all cases the pay and salary of one engineer is usually entrusted to the hands and to the judgment of another engineer, and if that second engineer could have a guide as to what is actually the value of such services as he requires from his applicant, and since such a schedule would serve as a guide, there should be no difficulty in getting a square deal.

"Furthermore, the mistake must not be made that the demand for a square deal is confined merely to the younger men, as some seem to be inclined to think. The truth of the matter is that the profession is underpaid all the way up the line; that many men in full charge of departments, with great responsibilities, are just as much underpaid as their subordinates."

Mr. Krumm urged that a close corporation be formed along lines similar to those enjoyed by physicians, lawyers, dentists, druggists, etc. He suggested a standard schedule of minimum fees to be charged by consulting engineers and urged that municipal engineers be supported to a greater extent by the institute.

Mr. Phelps suggested that a committee be appointed to prepare a list of the municipal engineering staffs in Canada, and to secure full information regarding their salaries, for the purpose of preparing a standard schedule of salaries from the chief engineer to the lowest paid assistant.

R. O. Wynne-Roberts advocated the establishment of an employment bureau. He declared that he is against the idea of close corporation, but at the same time is in favor of being closely united and of ostracizing any engineer who does not live up to the ethics of the profession and the schedule of fees and salaries.

He introduced a resolution calling upon the executive committee of the branch to appoint a committee of five members to discuss how best to organize an employment bureau and to report on same for further discussion at a future meeting. The resolution was adopted.

Mr. Goldman moved that a salary committee be appointed by the branch to study the question thoroughly, and prepare a schedule of minimum salaries and fees for engineering services. This motion was adopted.