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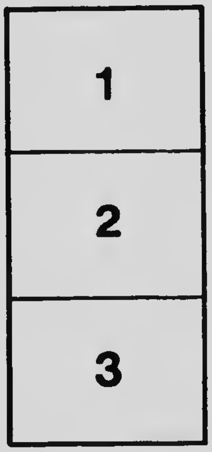
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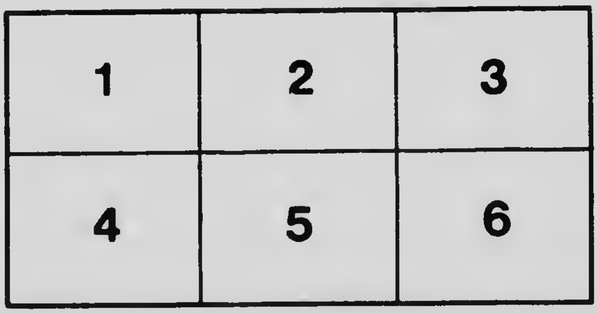
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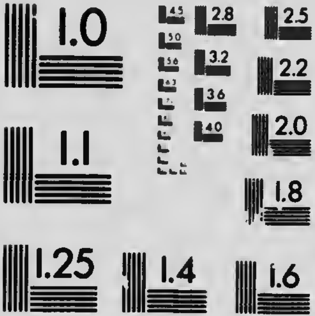

MODERN HIGHWAY BRIDGES

BARBER & YOUNG

RIDGE AND STRUCTURAL ENGINEERS

TORONTO

TYPES OF

MODERN HIGHWAY BRIDGES

BARBER & YOUNG

BRIDGE AND STRUCTURAL ENGINEERS

57 ADELAIDE STREET EAST

TORONTO

Reprinted from The Canadian Engineer,
February 18, 1910.

INTRODUCTION.

IN THE FOLLOWING PAGES are given illustrations and short descriptions of a number of typical modern highway bridges designed by us, built under our supervision, and opened to traffic during the year 1909. Each example represents a permanent structure conforming to the best modern practice, as much care having been exercised to secure efficiency, economy and pleasing appearance in the lighter and less expensive bridges as in those subjected to the heavy, constant traffic of important highways.

The problems of bridge engineering are gradually becoming recognized by those in authority as of sufficient importance, even in apparently simple cases, to warrant the retention of specialists in this work if the people's money is to be expended economically and effectively. Instances are only too numerous of insecure foundations and the gross and dangerous misuse of material in structures designed and built under the direction of those unacquainted with the distinctive problems of bridge construction. If immediate disaster does not attend misguided efforts of this kind, and the files of the technical press bear witness to the frequency with which it does, a very few years of service suffices to wear out the structure and render replacement necessary. The system of adopting a design from a number submitted by competing bridge companies without careful scrutiny by an experienced bridge engineer is scarcely less pernicious. Once freed of the restraint of a properly drawn and rigidly enforced specification considerations of excellence in design and of graceful appearance are thrown to the winds in the efforts of competitors to underbid each other and secure the contract. An illustration of the evil effects of such a system is afforded by the absence of practically any improvement during the last fifteen years in the design or construction of Pony Warren Truss spans turned out by the average bridge company when not forced to conform closely to a good and complete specification and proper inspection in shop and field. The flimsy T-chord, rod laterals, excessively light sections in latticed hand-rails, corroded material, a large percentage of defective field rivets and poor materials and workmanship in painting are some of the consequences of entrusting the work entirely to the contracting bridge company without the check of adequate supervision by an engineer of experience in bridge design and construction. Fortunately this is being remedied by the growing disposition of municipalities to employ competent bridge engineers to prepare the designs and specifications, require proper inspection in shop and field, and give personal supervision to the work throughout its progress.

Since our attention is devoted almost exclusively to reporting upon, designing and supervising the construction of steel and reinforced concrete bridges and buildings, in which we have a very large practice, we are particularly well qualified to render efficient service to municipalities in the connection outlined above. As we are not engaged in the contracting business and have no interest in one material, system of reinforcement or type of bridge over another, accurate comparative estimates from an unbiased point of view are always submitted to the purchaser in order that he may decide upon the most suitable kind of bridge for the situation. Our familiarity with the methods of securing unyielding foundations and equal experience with steel and reinforced concrete as materials of construction enable us to serve a municipality much better than the engineering department of a contracting company, which is interested only in selling one particular commodity or in erecting one particular type of bridge. Apart from the contractor's lack of interest or experience with the work as a whole, it is self-evident that engineering advice paid for in the price of the bridge is worthless. Such advice, to be of any value, must be paid for directly by the purchaser, and the engineer should be his representative, and not an official in the pay of the contracting company.

Believing that the advice of specialists in bridge engineering will be welcomed by many municipal corporations in Canada, as it has long been in the United States and Europe, we invite correspondence with respect to projected work or any bridge or structural problem. No better guarantee of the character of our work is required than the fact that in none of our bridges has a case of failure, crack or flaw occurred.

Barber & Young,
Bridge and Structural Engineers,
57 Adelaide Street East,
Toronto.

January 27th, 1910.

STEEL HIGHWAY BRIDGES.

THE UNIFORM EXCELLENCE of structural steel with the increasing price and poor quality of timber has resulted in the practical abandonment of the latter as a material for bridge construction except in parts of the country where timber is cheap and plentiful. In the more populous districts it is now no longer used for floors, steel stringers and reinforced concrete floor slabs having been found much more economical in the end on account of the frequent renewals necessitated by rapid wear and decay. Even in the sparsely settled regions of New Ontario, the use of timber floors in bridges built by the Provincial Government is regarded as a temporary expedient, provision being made in designing for the substitution of concrete floors when the traffic becomes heavy and timber becomes scarce and poor.

While great progress has been made toward permanent bridge construction by the extensive employment of steel, neither excellence of design nor the valuable properties of the material remove the necessity for care in fabrication and erection. Thorough inspection in shop and field by experienced inspectors is the only method of ensuring that the plans and specifications of the designing engineer are executed with absolute fidelity. Without it the temptation on the part of the contracting bridge company to unload corroded and pitted material upon the municipality is often too great, and steel which has suffered, through rusting in the stock piles, a loss greater than ten years of service would entail, frequently finds its way into the work. The laxity which makes this possible is likely to result in field painting of a character no better than that of the steel supplied. In all our work the necessity for rigid inspection is recognized, both during fabrication in the shops and erection at the bridge site.

As a result of inadequate inspection during construction and infrequent and careless painting while in service, it is difficult to predict the life of many steel bridges without careful examination by an expert. If properly designed, constructed and maintained, a steel bridge should last at least fifty years, but so little care has been exercised in connection with a great number of highway bridges that they cannot last half of that time. The careless or incompetent builder responsible for such structures will defend himself on the ground that fifteen or twenty years ago the art of bridge building was far less advanced than it is to-day. While this is true, it is no reason why bridges built at that time should not be in excellent condition now, for the famous Britannia and Conway tubular bridges, built sixty years ago, are in service to-day, and are carrying some of the heaviest railway traffic in the British Isles.

It is to be regretted that so little attention has been given in the past to the appearance of steel highway bridges in Canada. Frequently careful re-designing will greatly improve a structure from the aesthetic point of view at no increase in cost, and in very many cases the expenditure of a small additional amount in order to employ a curved top chord or to substitute a latticed hand-rail for one of gas pipe will result in a most gratifying improvement of appearance. Fortunately, there is an increasing willingness on the part of municipal councils to approve of a slight additional expenditure for this purpose where the bridge is situated in a populous district on a much-travelled road.

SRIGLEY STREET BRIDGE, NEWMARKET, ONT.

STEEL BEAM BRIDGES, consisting of I-beams supported laterally by channel cross-braces, are economical up to spans of 35 feet. They are more permanent than steel truss spans, since the thickness of metal in the beams is greater than in many members of truss bridges, and on this account will not so quickly deteriorate by rust.

The bridge illustrated is on Srigley Street, Newmarket, and was designed for a 15-ton roller.

Span, 30 ft. clear.
Roadway, 16 ft., with 4-ft. sidewalk.
Floor, 6 in. reinforced concrete.
Contractor, E. C. Lewis, Toronto.
Cost of abutments and superstructure, $1,511.

SRIGLEY STREET BRIDGE, NEWMARKET, ONT.

BRIDGE OVER HIGHLAND CREEK, TOWNSHIP OF SCARBORO'.

DECK TRUSS BRIDGES, in which the trusses are underneath the floor, should always be used in preference to through spans where the height of the roadway above the stream will permit. By reason of the much smaller distance required between the trusses and between the bridge seats and the water, a considerable saving in both steel and abutment masonry is effected over the through type of structure. In ability to resist wind pressure and vibration deck spans are much superior to pony or low truss designs, which are necessarily without top lateral bracing.

Some data relating to the typical deck span illustrated on the opposite page are given below:—

Span, 42 ft., centre to centre of bearings.
Height of roadway from ordinary low water, 17 ft. 6 in.
Distance centre to centre of trusses, 10 ft.
Floor, 6 in. reinforced concrete.
Cost of abutments, superstructure and filling, $2,857.

BRIDGE OVER HIGHLAND CREEK, TOWNSHIP OF SCARBORO'.

WESTON ROAD BRIDGE OVER BLACK CREEK, TOWNSHIP OF YORK.

PONY TRUSS BRIDGES, which are not high enough to permit an overhead lateral bracing, are used for short spans where there is not sufficient height above the water for deck structures. The best practice does not sanction the use of pony truss designs for spans over 90 feet on account of the difficulty of providing satisfactory lateral support to the top chord. This member should be of box section, that is, built up of two angles and a cover plate, or two channels and a cover plate in the form of a box with open bottom. The T-chord consisting merely of two angles placed back to back, although still used to a considerable extent in some places, is objectionable because of its lack of lateral stiffness.

The illustration shows a typical pony truss bridge, with box chords and latticed hand-rail.

Span, 44 ft., centre to centre of bearings.
Roadway, 20 ft., with 5-ft. sidewalk.
Floor, 10 in. reinforced concrete and paving brick.
Height of floor from low water, 13 ft.
Cost of steel, $1,787; cost of concrete abutments and floor, $1,627.

WESTON ROAD BRIDGE OVER BLACK CREEK, TOWNSHIP OF YORK.

GRUBBE'S BRIDGE, TOWNSHIP OF ETOBICOKE.

THROUGH TRUSS BRIDGES differ from pony truss structures in being of sufficient depth to make the use of top lateral bracing possible, and, as already mentioned, supplant the latter type for spans of over 90 feet. The double-intersection Warren truss with eight panels employed for Grubbe's Bridge (illustrated opposite) possesses the advantage of requiring the same section from end to end of the bottom chord, and the same is true of the top chord. The cost of this bridge was considerably enhanced by the treacherous nature of the foundation-bed. Owing to the strong scouring effect of the rapid current upon the soft soil at this point and the tendency of the bank to creep towards the stream bed, unusually extensive piling on each abutment was required, in one case involving the use of a row of anchor piles in the rear, to which the abutment piles were connected by steel rods.

Span, 92 ft. 6 in., centre to centre of bearings.
Width of roadway, 16 ft. clear.
Height of floor above water, 12 ft. 8 in.
Floor, 6 in. reinforced concrete.
Cost of piling, abutments, steel superstructure and filling, $6,593.

GRUBBE'S BRIDGE, TOWNSHIP OF ETOBICOKE.

BRIDGE OVER HOLLAND RIVER, NEAR BRADFORD, SIMCOE COUNTY, ONT.

THE HOLLAND RIVER at this point is very sluggish, never rising above the level of Lake Simcoe, and is 14 feet deep and 200 feet wide. On one side hard pan lies nearly 70 feet below the surface of the water, and the intervening soil is much too soft to give proper lateral support to piles. For this reason, after the piles were all driven to refusal and capped, stone was placed inside and around the piling to the surface of the water. Upon these foundations the concrete was built.

A double-span Pratt truss bridge, with centre pier, was adopted as being somewhat cheaper than a single span. Here a centre pier could be built for about $500 less than one for the Scarlett bridge, described on a subsequent page, on account of the smaller distance from water to bridge floor. Moreover, no harm to the centre pier was anticipated from undermining or ice on account of the nearly dead water.

Each span, 100 ft. centre to centre of bearings.
Roadway, 16 ft. clear of hand-rails.
Floor, concrete and paving brick.
Contractors for substructure, Barrett & Scott, Lambton Mills, Ont.
Contractors for superstructure, Dickson Bridge Works Co., Campbellford, Ont
Total cost, $18,000.

BRIDGE OVER HOLLAND RIVER, NEAR BRADFORD, ONT.

BALTIMORE TRUSS BRIDGE OVER THE HUMBER RIVER ON SCARLETT ROAD, YORK COUNTY.

THE SCARLETT BRIDGE spans the Humber River about a mile south of Weston. The stream is 200 feet wide at this point, and the bottom shale rock. The traffic carried is heavy.

In the layout of the bridge one question to be decided was the relative merits of a single-span bridge or one of two spans, with a centre pier. Estimates for each plan follow:—

	(1) Single Span.	(2) Double Span.
Steel superstructure with concrete floor	$10,700 00	$8,300 00
(1) Abutments; (2) Abutments and pier	4,450 00	6,750 00
Filling approaches	300 00	300 00
Temporary bridge and removal of old bridge	250 00	250 00
	$15,700 00	$15,600 00

The cost being nearly the same for either method, the single span was adopted for the following reasons: first, because of the undermining effect of freshets on piers and the abrasion of ice, centre piers should be avoided when possible; secondly, the waterway is better without a centre pier, even when the distance between abutments is decreased according to the width of the pier; thirdly, the much heavier steel structure required for a single span would be more permanent than lighter structures on account of the greater thickness of metal.

Span, 203 ft., centre to centre of bearings.

Roadway, 10 ft. clear.

Height of trusses, 20 ft.

Contractors for substructure and floor, O. L. Hicks & Son, Humber Bay, Ont.

Contractors for steel superstructure, Ontario Bridge Co., Toronto, Ont.

Reinforcement for floor, "No. 10, heavy" expanded metal, manufactured by the Expanded Metal and Fireproofing Co., Toronto.

Mill and shop inspection, Canadian Inspection Co., Montreal and Toronto.

Bridge Commissioners, Warden Geo. S. Henry, W. D. Annis, and J. E. Harris.

This bridge is one of the longest single-span highway bridges with a concrete floor in Canada.

BRIDGE OVER THE HUMBER RIVER ON THE SCARLETT ROAD, YORK COUNTY.

REINFORCED CONCRETE BRIDGES.

CONCRETE IS NOT a new or experimental building material, but is one of the oldest of which we have record, and the recent device of reinforcing concrete with steel has added greatly to its safety and economy. A well-designed and well-constructed concrete arch is one of the safest, most durable and most beautiful forms of bridge, and where the situation is favorable it is often cheaper than a steel bridge with a concrete floor.

However, the durability, and even the safety of a concrete arch depends entirely upon the design, the selection and proportioning of materials, and the care taken in construction. On the one hand, because of excellent design and workmanship, we have concrete arches built by the ancient Romans which remain to the present day, and numberless concrete arches built in the last fifteen years which have stood the severest tests without showing crack or flaw, and have grown harder and better with age. On the other hand, many concrete arches built in recent years, even with the advantage of steel reinforcement, have already partially or wholly failed on account of poor design or ignorance or carelessness in workmanship.

Amongst the common sources of danger may be mentioned, first, attempting to measure cement loose in wide barrows; secondly, using pit-run gravel without such additional aggregate as may be required, or without even testing its fitness, though it may contain an excess of sand, which is the usual case, or not enough sand, which sometimes happens. Again, some are deceived by the apparent simplicity of the outlines of an arch into supposing that the designing is so simple that it may be undertaken by one who has given the matter no special study, and who would not attempt to design a steel bridge. Nothing could be farther from the truth. Reuterdahl says in his work on arches: "Of all the problems of bridge engineering, the analysis of the arch is by far the most difficult."

All our arches are designed and analysed in accordance with the theory of elasticity.

Where there is not sufficient height for an arch from water to roadway, or where the foundations would require too expensive treatment to enable them to resist the great horizontal thrust of an arch which tends to spread the abutments apart, or where it is desired to build a new superstructure upon old abutments and piers, a reinforced concrete girder or truss bridge may be constructed for about the same price generally as a good steel bridge.

Examples of the several types mentioned above, with some remarks as to the special features of each, are given in the succeeding pages.

BRIDGE ON TOWNLINE BETWEEN KING AND VAUGHAN TOWNSHIPS, COUNTY OF YORK.

A FLAT ARCH should not be constructed in a situation where piling is required without exceptional care in designing the foundations, for if the abutments spread even slightly the arch will crack—sometimes to a dangerous extent.

The bridge illustrated is an example of one method of treating a quicksand bed. Here several rows of piles, 20 feet long, driven to refusal, formed the foundation on each side. The concrete abutments were tied together by steel rods embedded in a 6-inch concrete slab, three feet below the surface of low water, which may be described as an invert or apron, forming the bed of the stream.

Clear span, 45 ft.
Roadway, 14 ft.
Rise of arch, 5 ft. 6 in.
Distance from roadway to low water, 8 ft. 6 in.
Contractor, John A. Watson, Laskay, Ont.
Cost, complete, $2,802.

BRIDGE ON TOWNLINE BETWEEN KING AND VAUGHAN TOWNSHIPS, COUNTY OF YORK.

ARCH AT KLEINBERG, ONT.

THIS IS AN example of a rather high arch on a grade of 6 per cent., which necessitated an average of two feet greater depth of filling, or about 240 pounds per square foot greater weight, on one side of the arch than on the other. If the design had not been specially prepared to meet this condition this would have imposed a much greater additional strain upon the arch than the heaviest live load that it would ever have to bear. There are two methods by which such unsymmetrical loading may be provided for. One is to distort the curvature of the arch in accordance with computation so that it may properly resist the unequal loads, and the other is to correctly balance the loads on either side of the arch by using lighter filling material on one side than on the other. In the Kleinberg arch recourse was had to both methods. The curvature was only slightly changed from the symmetrical so as not to be very noticeable to the eye, and in addition to this cinders were used for a considerable proportion of the filling on one side of the arch and boulders on the other.

It may be mentioned that in general the height of roadway from river bed affects the price of an arch (or, indeed, of any kind of bridge) much more than the span. As an example, the Kleinberg arch contains nearly double the quantity of concrete of the Vaughan arch (shown on the preceding page), although the span is only five feet greater.

Clear span of arch, 50 ft.
Roadway, 16 ft.
Height of floor from low water at crown of arch, 17 feet.
Rise of arch, 13 ft. 6 in.
Cost of arch and filling, $3,535.

ARCH AT KLEINBERG, ONT.

ARCH OVER HOLLAND RIVER, NEWMARKET, ONT.

THIS ARCH IS not a highway bridge, but was designed by us for the Metropolitan Division of the Toronto and York Radial Railway, and is introduced here as a type of structure which might well be used for highway bridges approached by very high embankments. Here the depth of fill would have necessitated very expensive wing walls if the more usual kind of arch had been adopted. This design resulted in a saving of about 18 per cent. over an arch with wing walls, and brought the first cost somewhat below that for a steel bridge with concrete abutments and wing walls.

To adapt this bridge to highway traffic it would only be necessary to place a fence on either side at the top of the fill.

Clear span of arch, 50 ft.
Rise of arch, 23 ft.
Height of roadway from water, 27 ft.
Width of abutments at the springing line, 94 ft.
Width across arch at crown, 21 ft.
Earth fill over crown, 2 ft. 6 in.
Thickness of arch at crown, 1 ft. 6 in.
Designed for a load of 5,000 pounds per lineal foot.
Contractors, O. L. Hicks & Son, Humber Bay, Ont.

ARCH OVER HOLLAND RIVER, NEWMARKET, ONT.

THE HOLLY BRIDGE, CONCESSION 5, YORK TOWNSHIP.

CONCRETE GIRDER BRIDGES are suitable for short spans in situations where the distance from floor to low water will not permit of an arch. Even where this distance is sufficient for a low arch the girder bridge is generally more economical if the foundations require piling. We have designed girder bridges for spans up to 50 feet, but for greater spans than this the concrete truss bridge described on the following page is preferable.

Span, 30 ft. clear.
Distance from floor to low water, 8 ft.
Roadway, 16 ft.
Weight of superstructure, 60 tons.
Contractors, McLennan & Alexander.
Cost of abutments and superstructure, $1,299.

THE HOLLY BRIDGE, CONCESSION 5, YORK TOWNSHIP.

MIDDLE ROAD BRIDGE OVER THE ETOBICOKE RIVER, BETWEEN THE COUNTIES OF YORK AND PEEL.

REINFORCED CONCRETE TRUSS BRIDGES combine the permanence of concrete construction with the graceful lines of trusses with curved top chords at a cost practically the same as that of good steel structures with concrete floors. In situations where yielding foundations or insufficient rise render the employment of an arch impracticable, or, as in the present case, where a new superstructure is required on the old abutments, an equally artistic result may be secured at no greater cost and with no attendant structural uncertainty by the use of a reinforced concrete truss span.

The Middle Road bridge, the first structure of its kind to be built in Canada and one of the first in America, was officially opened in October, 1909. During construction and since completion it has excited a great deal of interest among engineers and municipal officers from its novel character and the possibilities suggested by its successful completion and operation. The severest load for a highway bridge, consisting of a densely packed herd of rearing, trampling cattle, which weighed not less than 35 tons, was applied on opening day, and failed to produce more than a tremor. The contention was thus justified that in a massive concrete structure the impact effect of teams trotting down the grade of 5 per cent., which was necessitated at this point, would be very small.

MIDDLE ROAD BRIDGE.

The commissioners for whom the bridge was built were Warden Geo. S. Henry, W. D. Annis and J. E. Harris, of York, and Warden Jackson and T. L. Kennedy, of Peel. The contractors were O. L. Hicks & Son, of Humber Bay, Ont.

The steel reinforcement used was principally plain round rods for the trusses, beams and hand-rail, and for the floor slab it was expanded metal, manufactured by the Expanded Metal and Fireproofing Co., of Toronto.

We shall be pleased to send on application to municipal officers or others who may be interested a booklet describing this bridge more fully.

Span, 82 ft., centre to centre of bearings.

Roadway, 15 ft. 2 in.

Height of floor above water, 14 ft. at one end and 18 ft. at the other.

Weight of superstructure, 200 tons.

Cost of superstructure, $3,100.

MIDDLE ROAD BRIDGE.

FRANK BARBER,
YORK COUNTY ENGINEER

C. R. YOUNG, B.A.SC.,
A.M. CAN. SOC. C.E.

BARBER & YOUNG

Bridge and Structural Engineers

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