rapidly until at about 2,000 ft. the weight of carbon steel required to carry the weight of such a span and of a moderate live load becomes infinite. For a span built of nickel steel the weight becomes infinite when the length reaches 2,700 ft. Simple spans much below those liimts, even if possible, would still be very uneconomical until we get down to spans 700 ft. or under.

CANTILEVER SPANS.—This leads us to cantilever spans. I mentioned two types of such spans—one without a suspended span and the other with a suspended span. A remarkable example of a cantilever bridge without a suspended span, which may be called a semi continuous structure, is the Blackwell's Island, or Queensboro bridge, in New York. There seems to be no advantage in omitting the suspended span; on the contrary, the structure differs from a true continuous bridge over several supports only by the introduction of a hinge at the centre of the main span which transmits shears but not moments. The vibrations and deflections of each segment are, therefore, transmitted through those hinges to all the other segments. Furthermore, since the stresses in such a structure depend on deflections, there is more or less uncertainty in the calculations. I do not wish to be understood as objecting to any type of structure seriously, because of the uncertainty of calculations. In any logical construction the calculations can always be made with sufficient accuracy for the safety of the work. It is only when everything else is equal that determinate stresses should be preferred.

Let us consider the usual type of cantilever bridges, the one in which two cantilever arms support a suspended span. We may assume that in bridges requiring the construction of a cantilever span the length of the main span is usually determined by local conditions. The general dimensions to be fixed by the designer are, therefore, the length of the suspended span, the length of the anchorage spans, when these are not determined by local conditions, the height of the trusses at various points and the relative distances and positions of trusses to one another. Let us discuss these various dimensions in connection with the new Quebec design. The Quebec bridge, with its longest span in the world, has justly attracted much attention among engineers and has naturally elicited comment and criticism. It is acknowledged that a discussion of a scientific subject by professional men is often of greater value than an elaborate paper on this same subject by one individual. If I refer to some of the criticisms, let it be considered as a friendly discussion which may be of value to the profession.

New Quebec Bridge.

The new Quebec bridge has been finally designed with two anchor arms 515 ft. long, a suspended span 640 ft. long, and two cantilever arms 580 ft. long. The moving loads finally adopted for the Quebec bridge are: On each track two Cooper's class E 60 engines, followed or preceded, or followed and preceded, by a train load of 5,000 lbs. per foot per track. In addition to the actual dead load of the structure, a load of 500 lbs. per lineal foot on suspended span and 800 lbs. on balance of bridge was allowed for snow.

THE WIND LOADS were taken as follows: A wind load normal to the bridge of 30 lbs. per sq. ft. of the exposed surface of two trusses and one and a half times the elevation of the floor (fixed load), and also 30 lbs. per square foot on travellers and falsework, etc., during erection.

A wind load on the exposed surface of the train of 300 lbs. per lineal foot applied 9 ft. above base of rail (moving load).

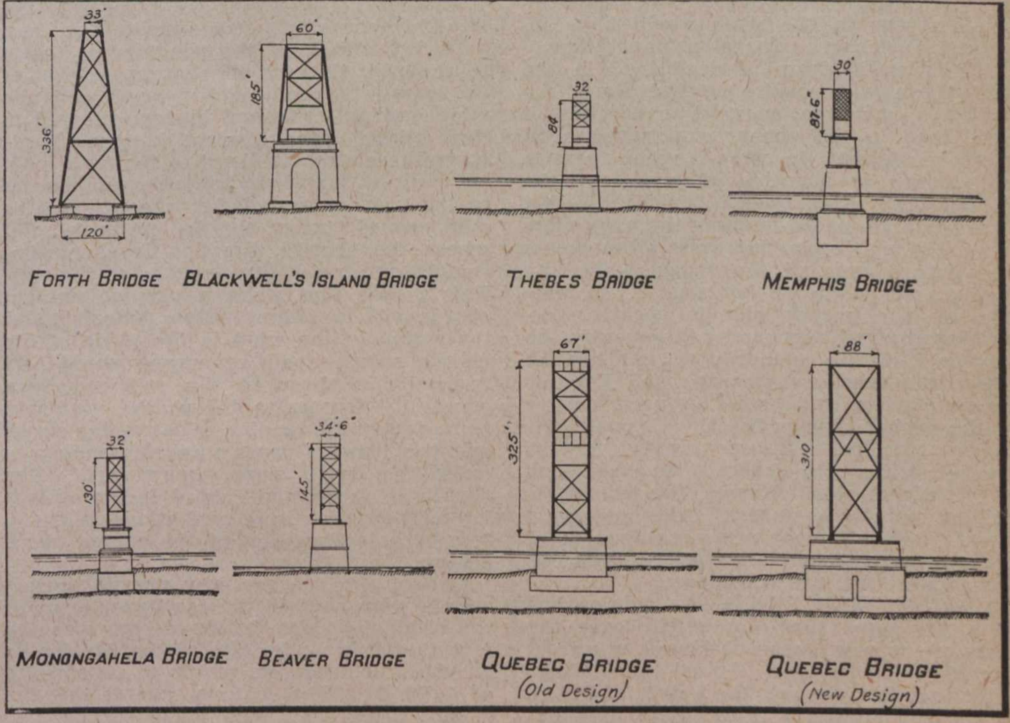
A wind load parallel with the bridge of 30 lbs. per sq. ft. acting on one half the area assumed for normal wind pressure.

In the Forth bridge the enormous wind load of 56 lbs. per sq. ft. was assumed. This load was imposed on the designers by the Board of Trade soon after the Tay bridge disaster. The Tay bridge was not designed to withstand even a 30 lbs. pressure. This assumption of a 56 lbs. wind in the Forth bridge results in a very large addition of metal in the bottom chords through which the wind stresses are transmitted to the piers. The material in those members is distributed as follows:

	Gross tons
Dead load	2282
Live load	1022
Wind load	2920
Total	6224

The metal here provided for the wind is nearly three times that provided for the live load, and is about 47% of the total required. In the new Quebec bridge design the wind pressure is equivalent to about 35% of the uniform live load near the piers and to about 20% of the live load near the ends of the cantilever arms.

A pressure of 30 lbs., according to German experiments with electric cars, would correspond to a wind of a velocity of over 100 miles an hour. Other experiments made at various times on small surfaces show that a velocity of 85 miles would correspond to a pressure of about 30 lbs.



Comparative Height Over Piers of Various Bridges.

The following formula for wind pressures is generally used: $P=kv2$, in which $P=$ pressure per square foot, $v=$velocity in miles per hour, and $k=$a coefficient.

Eiffel's 200 or more experiments show this coefficient to vary from 0.0026 to 0.0032, and the average is 0.0030, which he recommends. Trautwine makes $k=0.0050$, which seems too high. But, even using the latter, a pressure of 32 lbs. would correspond to a "hurricane" of a velocity of 80 miles. The German experiments agree with Eiffel's. Making $k=0.0030$, a pressure of 30 lbs. would correspond to a velocity of 100 miles an hour, which, according to Trautwine, is a violent hurricane uprooting "large trees."

With a wind of this velocity there would be no traffic on the bridge—empty freight cars or even light passenger cars would be overturned. Velocities of more than 85 miles may occur in cyclones and tornadoes over restricted areas. Such storms are very rare in Canada; but even should such an extraordinary disturbance happen, causing a wind pressure of as much as 60 lbs. to be applied to the entire Quebec bridge as now designed—the stresses in the truss members would be less than with the maximum live load and a 30 lbs. wind—and although the stresses in the laterals would be increased above the specification limits, they would still remain within the elastic limit of the members.

LENGTH OF SUSPENDED SPAN.—The length of the suspended span does not depend merely upon the most economical distribution of material required for carrying the live loads and the dead load of the bridge after it is completed. Where there are no other considerations beyond the actual working stresses in the finished structure, the most economical length of the suspended span for a total span of 1,800 ft. would be in the neighborhood of 1,000 ft. But to erect a simple span of such unprecedented length, either by floating or by cantilever method, would be impracticable. Furthermore, the cantilever method of erecting a suspended span of even a moderate length always requires additional material, both in the cantilever arms and in the suspended span, to take care of the erection stresses.

The longer the suspended span in relation to the total main span, the greater will be the required addition—so that whether it be contemplated to erect the suspended span by cantilever method or by floating into position, the length of the suspended span finds itself limited not by mere economic considerations of the finished bridge, but by either the excess of material required during erection by cantilever method, and difficulties arising therefrom, or by the difficulties attending the floating of a very long and heavy span into position. These difficulties increase very rapidly with the length of the span to be floated. In the new design the suspended span is the longest which the board considered safe to float, and it fits the entire design very well.

Erection by Floating.

The erection of this span by floating made it possible to design it with the view to greatest economy. Its various members will