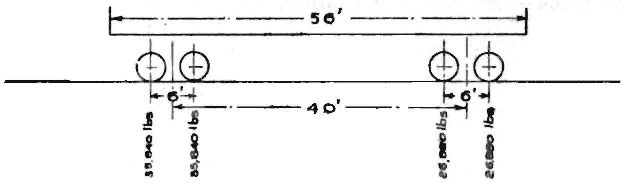
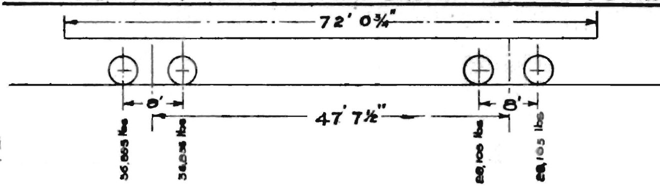
Plan No. 7.

No. 1. Sydney Harbour Bridge Conventional Load



No. 2. New York, Westchester and Boston Car with 78 Passengers.



No. 3. Heaviest Long Island Car with Crush Load.

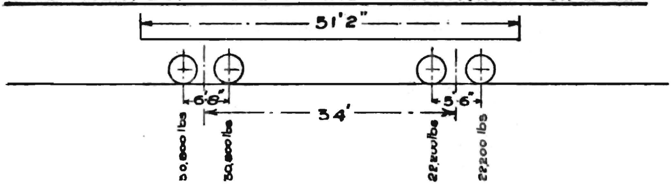


TABLE No. 9.

Comparsion of Stress Effects due to Electric Railway Cars.

Span of Stringers.	Bending Moment in Stringers.			Shear at End of Stringers.			Reaction at Cross Girder from two Stringer Spans.		
	New York, Westchester and Boston Railway Car.	Long Island Car.	Sydney Harbour Bridge Conventional Load.	New York, Westchester and Boston Railway Car.	Long Island Car.	Sydney Harbour Bridge Conventional Load.	New York, Westchester and Boston Railway Car.	Long Island Car.	Sydney Harbour Bridge Conventional Load.
	Foot tons	Foot tons	Foot tons	Tons	Tons	Tons	Tons	Tons	Tons
35	117	128	157	17.6	18.2	21.9	21.4	20.8	24.7
40	148	163	197	19.5	19.4	23.2	22.8	22.3	25.6
45	181	196	236	21.0	20.3	24.2	23.9	24.0	27.0
50	222	231	276	22.2	21.0	25.0	25.1	25.8	28.6
55	262	264	316	23.2	21.9	25.6	26.4	28.2	30.5

On examining the table it will be seen that the conventional load assumed for the Sydney Harbour bridge gives the greatest stresses. Owing to the lesser distance between wheels of adjoining cars, short cars can give worse stresses on certain spans than long cars of the same weight per foot run. For this reason a short car was adopted for conventional load.

Cars of equal weight driving on all four axles will give less stresses throughout than if arranged with motors at one end only, consequently the latter arrangement was adopted, and it is a type much used for suburban electric cars.

While it is to be admitted that there are in existence much heavier motor cars than those for which the suburban tracks of the bridge are designed (e.g., the 174,000lbs., 70ft. car of the Newhaven Railroad and the 84 ton, 76ft. car of the State Railways of France), still the suburban train adopted should be able to cope with any possible demands of the passenger traffic. The weight per foot run and the heavy axle loads demand a strength of bridge well in excess of present day requirements for similar traffic, and there is, as far as can be foreseen, an ample margin for future development.

Goods Traffic.—When North Sydney, Mosman, Manly and Pittwater are connected to the City by rail, a goods traffic will develop. The train load adopted for the suburban passenger traffic is heavy enough to enable goods traffic weighing about 2,240lbs. per foot run, hauled by electric locomotives weighing about 50 tons, to be taken over any of the railway tracks. Many such locomotives, each developing about 900 horse-power, are in general use for interurban goods and other traffic in Britain, Europe, and America. They are of a type having a bogie at each end, and all four axles driving.

Table No. 10 gives the bending moments and other stress effects in various parts of the deck produced by the conventional suburban cars adopted, and by the locomotives of the Brooklyn Rapid Transit Co., followed by fully loaded steel trucks, weighing about 1 ton per foot run. The 15-ton "S" trucks of N.S.W.R. were used in the calculations.

The type of locomotive used by the Brooklyn Rapid Transit Company is shown on Plan No. 5, Fig 16.

From an inspection of this table it is evident that light goods traffic, weighing 1 ton per foot, hauled by 50-ton locomotives, can safely be taken across the suburban railway tracks.

TABLE No 10.

Light Goods Traffic. Comparison of Stress Effects with Suburban Cars.

Span of Stringers.	Beading Moment.		End Shear.		Reaction to Cross Girder for Two Stringer Spans.	
	S.H.B. Conventional Suburban Cars.	Brooklyn R.T. Locos. and 15 ton Trucks.	S.H.B. Conventional Suburban Cars.	Brooklyn R.T. Locos. and 15 ton Trucks.	S.H.B. Conventional Suburban Cars.	Brooklyn R.T. Locos. and 15 ton Trucks.
30	118 foot tons.	94.4 foot tons.	20.2 tons.	16.1 tons.	23.5 tons.	21.7 tons.
40	197 ,,	162.0 ,,	23.2 ,,	19.5 ,,	25.6 ,,	26.2 ,,
50	276 ,,	239.0 ,,	25.0 ,,	22.8 ,,	28.6 ,,	30.1 ,,
60	355 ,,	355.0 ,,	26.5 ,,	25.5 ,,	33.1 ,,	34.2 ,,

The long distance tracks are designed for a heavier loading than the suburban, and thus any traffic that can be taken over the suburban tracks can also pass over the long distance tracks. Hence the conventional suburban trains and local goods traffic could be taken over any of the four railway tracks, but, of course, the heavy locomotives for which the long distance tracks are designed could not pass over the suburban tracks without greatly exceeding the limits of stress adopted.

Main Roadway.—The loading adopted is as follows:—

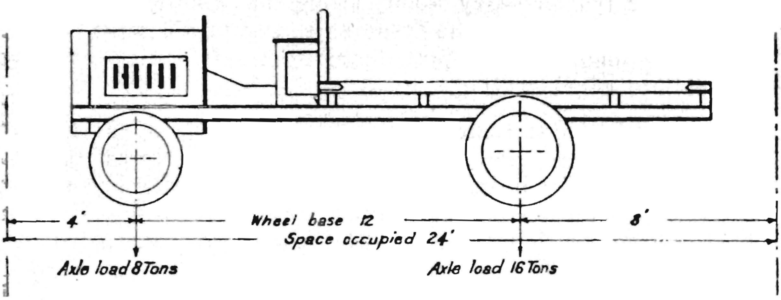
Cantilevers and Suspended Span.—A uniform load of 100lbs. per square foot so placed to give maxima stresses.

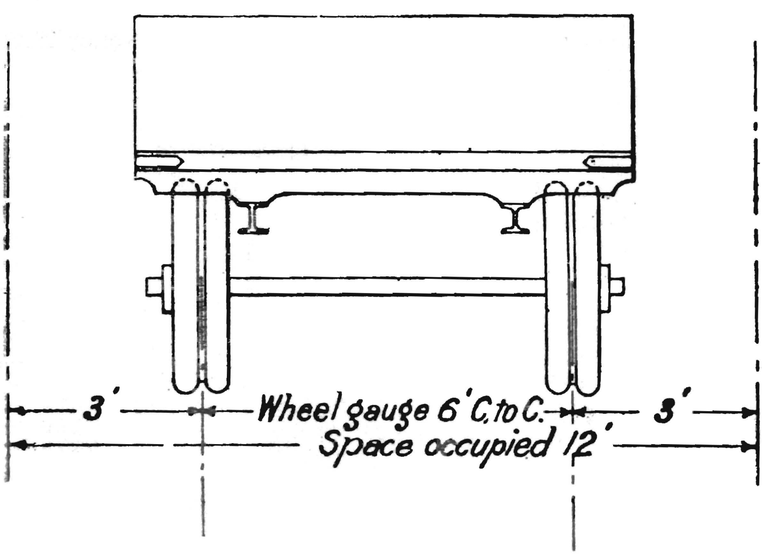
Deck System.—The concentrated loading shown on Plan No. 9 in any position to give maximum stresses, the remainder of floor to be covered with 100lbs. per square foot.

PLAN No. 8.

SYDNEY HARBOUR BRIDGE,

MAIN ROADWAY—CONCENTRATED LOADING.





For closely packed heavy vehicular traffic a distributed load of 100lbs. per square foot may obtain over the whole bridge. It is not considered possible that it can be exceeded. The average heavy traffic will be very much less. The high figure was adopted so that no restriction or regulation of the roadway traffic will ever be needed.

The decks of the most recent long-span bridges across the East River, New York, were designed for 48,000lbs., equally distributed on 4 wheels, i.e., 12,000lbs. per wheel; wheel base, 10ft. x 5ft. wide. The motor lorry, however, renders it imperative to adopt a heavier loading. Motor lorries weighing about 34,000lbs. are in use in America, the distribution of weight on rear axle being about twice that on the front; thus there is a rear axle load of 10 tons (Engr. Record, Dec. 7th, 1912). The Department of Bridges, New York City, have increased their standard loading to four 15,000lb. wheel loads; wheel base, 12ft. x 8ft.; space occupied, 30ft. x 12ft.; total load, 60,000lbs., or 27 English tons.

Motor trucks carry about twice the weight on the rear axle that is carried on the front axle, and in deriving the conventional load, this unequal distribution of loading has been taken into consideration.

A load lighter than the standard adopted by the Department of Bridges, New York, gives greater stresses, particularly on the "I" beams, &c., of the deck, if there is uneven weight distribution over the axles. For the Sydney Harbour bridge a conventional load of 24 tons—8 tons carried on the front axle and 16 tons carried on the rear—has been adopted; wheel base, 12ft. x 6ft.; space occupied, 25ft. x 12ft.

To compare the stress effects of the conventional 24-ton load adopted with that of the New York standard—27-ton load —Table 11 has been prepared.

TABLE No. 11.

Comparison of Stress Effects from Sydney Harbour Bridge Conventional Load for Main Roadway, with 60,000 lbs. Conventional Load for New York City.

Span of Stringer.	Maximum bending moments in stringers, tons x feet		Maximum end shear in stringers, tons	
	S.H.B. Loading	N.Y. Loading	S.H B. Loading	N.Y. Loading
30	109	93	17.3	15.4
40	170	150	19.8	17.9
50	242	217	22.1	20.3
60	325	295	24.4	22.6

It will be seen that in every case the loading adopted for the Sydney Harbour bridge gives the greater stresses. In other words, the heavier load evenly distributed on 4 wheels recently adopted by the Department of Bridges, New York, could be carried by the Sydney Harbour bridge with less stresses in the deck than those given by the conventional load adopted.

Motor Roadway.—The loading adopted is as follows:—

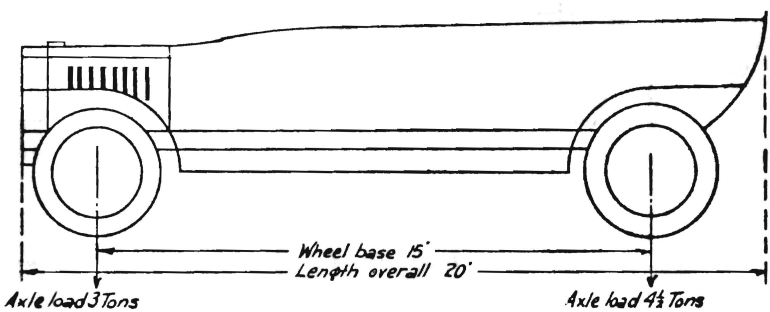
Cantilevers and Suspended Span.—A uniform load of 80lbs. per square foot so placed to give maxima stresses.

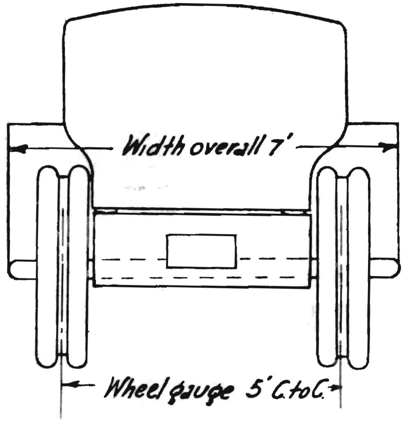
Deck System.—A uniform load of 100lbs. per square foot, or a number of conventional cars, as shown on Plan No. 9. When arranged in series, the end clearance is to be taken at 5 feet.

Plan No. 9.

SYDNEY HARBOUR BRIDGE,

Motor Roadway—Concentrated Loading.





The motor roadway will accommodate the heaviest passenger motor car and cycle traffic, but it is not intended to carry heavy lorries; these must traverse the roadway. The motor roadway may also accommodate crowds viewing a harbour spectacle, &c.

The heaviest tourist cars in Sydney at present do not weigh more than about 4 tons loaded.

The conventional car adopted weight 7½ tons, with an axle loading of 4½ tons. Thus provision is made for very greatly increased weights in motor cars.

With two cars abreast and a space of 3 feet between the cars, the distributed load, due to the heavy conventional motor car adopted is 80lbs. per square foot.

If, on special occasions, the motor roadway is used for pedestrian traffic, isolated crowds for small areas may reach 100lbs. per square foot, but over the whole area of the motor roadway the weight could not exceed 80lbs per square foot, consequently 80lbs. per square foot was adopted for the design of the cantilevers and suspended span, whilst the higher figure was adopted for the deck.

Footway.—The loading adopted is 100lbs. per square foot for deck system, reduced to 80lbs. per square foot for cantilevers and suspended span. The loading to be so placed to give maxima stresses.

Isolated crowds for small areas may reach 100lbs. per square foot, but over the whole area of the footway the weight could not exceed 80 lbs. per square foot.

TYPE OF BRIDGE.

The clear span of 1,600 feet between centres of main piers necessitates either a cantilever or a suspension bridge.

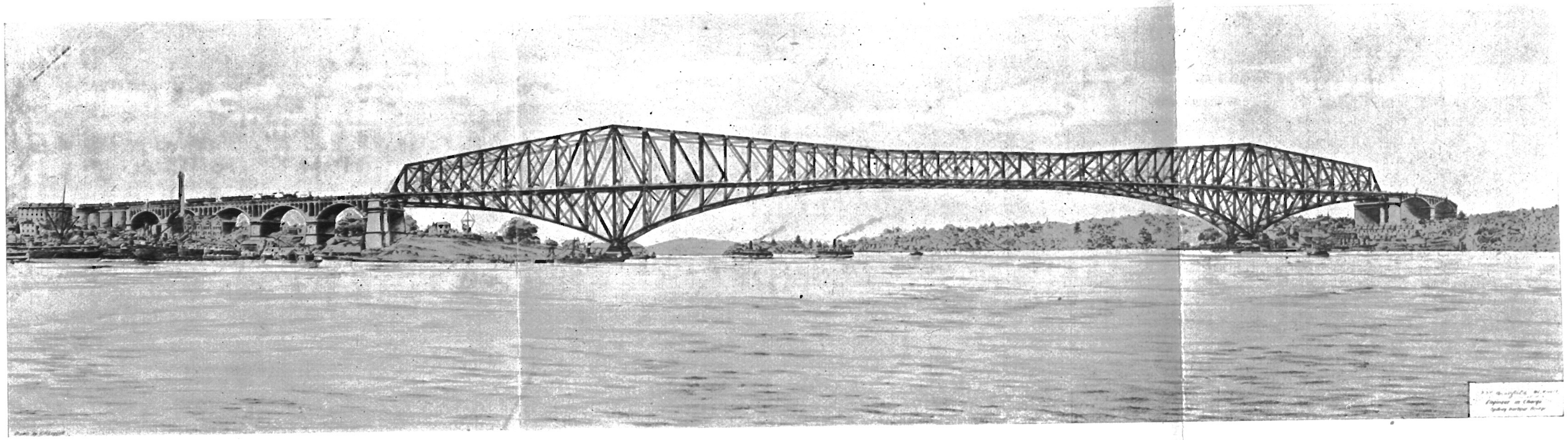
A suspension bridge would be more graceful than a cantilever bridge, but a cantilever bridge would be the more rigid.

Assuming that each bridge is manufactured outside the State, a suspension bridge would be slightly cheaper than a cantilever bridge, chiefly on account of the Federal tariff. All metal work manufactured in the United Kingdom is subject to an import duty of 25 per cent., elsewhere of 30 per cent., but the high grade steel wire forming the cables of the suspension bridge is exempt from duty.

A cantilever bridge is a rigid structure, and the stresses can be accurately determined; a suspension bridge is a flexible structure, and the stresses are more or less indeterminate. If, in addition to vehicular and pedestrian traffic, the bridge had to carry suburban electric railways or suburban railways and tramways, the suspension type would be as suitable as the cantilever type, but as the bridge must provide for heavy electric locomotive traffic, a cantilever bridge must be adopted.

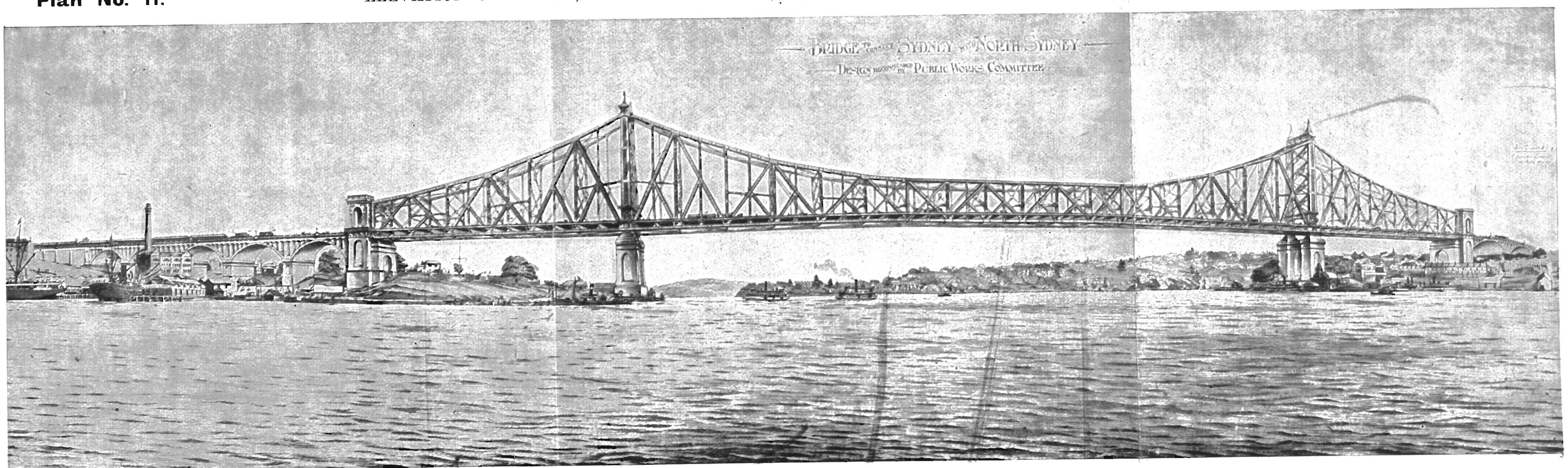
Plan No. 10.

ELEVATION OF BRIDGE, WITH LOW PIERS.



Plan No. 11.

ELEVATION OF BRIDGE, WITH HIGH PIERS (Bridge recommended by the Public Works Committee, 1913)



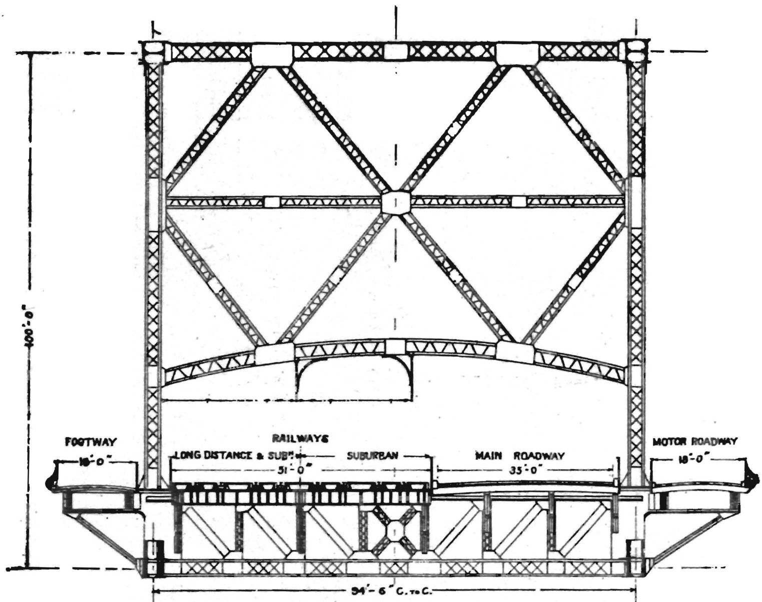
Two proposals with estimates for cantilever bridges were submitted by the author to the Parliamentary Standing Committee on Public Works, viz.: a cantilever bridge, with the lower chord curved and the top chord almost horizontal, as shown on Plan No. 10; and a cantilever bridge, with the lower chord horizontal and the top chord curved, as shown on Plan No. 11, each providing for 4 lines of railway, a main roadway 35ft. wide, a motor roadway 18ft. wide, and a footway 15ft. wide. A bridge of the first type, with a headway of 170ft. over the central 600ft., reducing to 60ft. at the piers, was estimat to cost £2,600,000, whilst a bridge of the second type, with a headway of 170ft. over the central 600ft., and a headway not less than 156ft. over the whole fairway, was estimated to cost £2,750,000.

As the latter design, Plan No. 11, gave better facilities for shipping, and was generally considered to have the better appearance, the Public Works Committee recommended its adoption.

Plan No. 12.

SYDNEY HARBOUR BRIDGE, DAWES' POINT TO MILSON'S POINT.

Design Recommended by Public Works Committee, 1913.



CROSS SECTION AT CENTRE

SYDNEY HARBOUR BRIDGE, DAWES' POINT TO MILSON'S POINT.

PLAN No. 12.

DESIGN RECOMMENDED BY PUBLIC WORKS COMMITTEE, 1913.