RENOVATION OF LIONS' GATE BRIDGE NORTH VIADUCT

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This paper is concerned with the deck replacement of the 670 m (2200 ft) long approach viaduct to Lions' Gate Suspension Bridge in Vancouver, Canada, which was carried out during night closures without affecting peak daytime commuter traffic flows. The structure was built in 1938 and comprised a series of steel plate girder spans supported on steel bents and with a 0.18 m (7 in.) reinforced concrete deck without wearing surface. Under the cumulative effects of road salt and traffic for 35 years, the deck was cracked through in places and the rebar was heavily corroded, resulting in surface spalling and potholes. The support steel had suffered some section loss from corrosion and also corrosion buckling in thin cover plates over long rivet spacings. A solution was required which would reduce the load in the support steel, cut down the corrosion rate, permit wider lanes and a wearing surface, all under the constraint of maintaining the bridge open for daily commuter traffic. This paper discusses the unusual design concepts adopted to satisfy these requirements and explains how they were realized in practice by careful attention to detail in every aspect of the job. Methods used to alert the bridge users to closures and estimated opening times are discussed together with emergency plans in the event of failure to complete a section on time.

Original Structure

Lions' Gate Bridge was built in 1937-8 to the design of Monsarrat and Pratley of Montreal. The structure is divided into two parts, the 670 m (2200 ft.) North Viaduct, and the suspension bridge itself. This project was concerned with renovation of the former structure. This comprised a 8.8 m (29') wide by 178 mm (7 in.) thick concrete road slab plus two 1.2 m (4') wide sidewalks supported by steel WF crossbeams resting on rivetted plate girders. The girder flanges were built up from 8 mm (5/16") plate with rivet spacings considerably in excess of sealing pitch. The concrete deck had no wearing surface and run off drained directly onto the support steel below. The application of deicing salts, coupled with the use of studded tires by most of the bridge traffic, had caused severe distress in the concrete deck. Wear in places was below the top steel and cores showed micro-cracks extending through full slab depth. The deck was essentially failed and breaking up at an increasing rate. The exposed support girders and bents beneath the deck also suffered corrosion losses from deicing salts. The accumulation of corrosion products under the flange cover plates caused buckling of up to 12 mm (1/2 in.) between the widely spaced rivets.

Requirements for Renovation

By 1972 the deterioration of the North Viaduct deck had reached the point where the B.C. Department of Highways felt it was essential to commence planning of renovations. The problems, in order of importance, appeared to be the break-up of the viaduct deck and the continuing corrosion of the support steelwork, also the traffic lanes at 2.9 m (9'8") were too narrow and should be widened if possible. In July 1972 Buckland and Taylor Ltd. were commissioned to study the problem. A detailed examination of the bridge was carried out and it was concluded further that the bridge lighting and electrical system was in need of renewal and that the heavy traffic density made a high grade replaceable wearing surface essential.

Neither the nature of the renovation work, nor the pattern of daily traffic were suited to progressive lane by lane renovation. Therefore, short total bridge closures were planned for the major work. Daytime traffic flows could not tolerate more than a single lane closure and peak rush hour traffic must have use of all three lanes. This meant that the portion of the work requiring total closures of the bridge would have to be carried out between midnight and 6 a.m. with single lane closures at other off peak times.

Constraints on the Design

The requirements to remove a section of bridge and replace it with a new one ready for traffic in six hours was the largest constraint on the scheme and the one which provided much of its difficulty and fascination. The structural constraints were a little more complex. Heavier modern traffic loads on a wider deck, acting at larger eccentricities

from the girders and riding on a wearing surface which didn't previously exist, all tended to increase the forces on the existing support steel. Conversely, corrosion losses in the existing steel required that the total effective load be reduced for safety. These opposing structural constraints had to be constantly borne in mind as the design of structural renovations evolved.

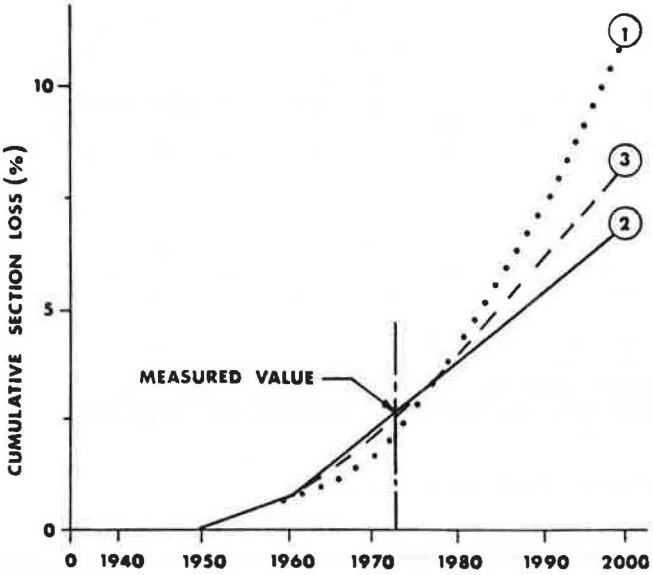
Evolution of the Design

Consideration of the constraints led to two conclusions. Firstly, the new deck must have a much lower dead weight than the original and secondly, a very high degree of prefabrication was necessary in order to permit installation within the limited time available. Several materials and many schemes were examined and compared. A 14.3 m (47') wide orthotropic steel deck with a 38 mm (1.5") wearing surface of epoxy asphalt was finally selected because it best met all the demands and constraints and when connected by shear diaphragms to the existing weakened girders, provided increased strength by composite action under live load.

Corrosion of Support Steelwork

Many approaches were considered for inhibiting the corrosion attack on the viaduct support steel. These ranged from encasing the structure in concrete to the use of sophisticated non corrosive deicing compounds. A study was made of the extent of existing corrosion and then three future section loss curves were projected, see Figure 1. Curve 1 shows a continuation of the existing corrosion rate, Curve 2 shows a reduced rate and Curve 3 an intermediate situation.

Figure 1. Estimated cumulative section losses due to corrosion.



It was concluded that a moderate reduction in the existing corrosion rate would leave adequate structural reserves for four or five more decades of bridge life at present live load levels. It was therefore decided to seal the deck and to take steps to duct the deicing solutions down to ground level away from the support steelwork and to carry out blast cleaning and repainting of this steelwork to bring it to a common level of protective coating. It was considered impractical to attempt to seal all existing corrosion cells in the bridge.

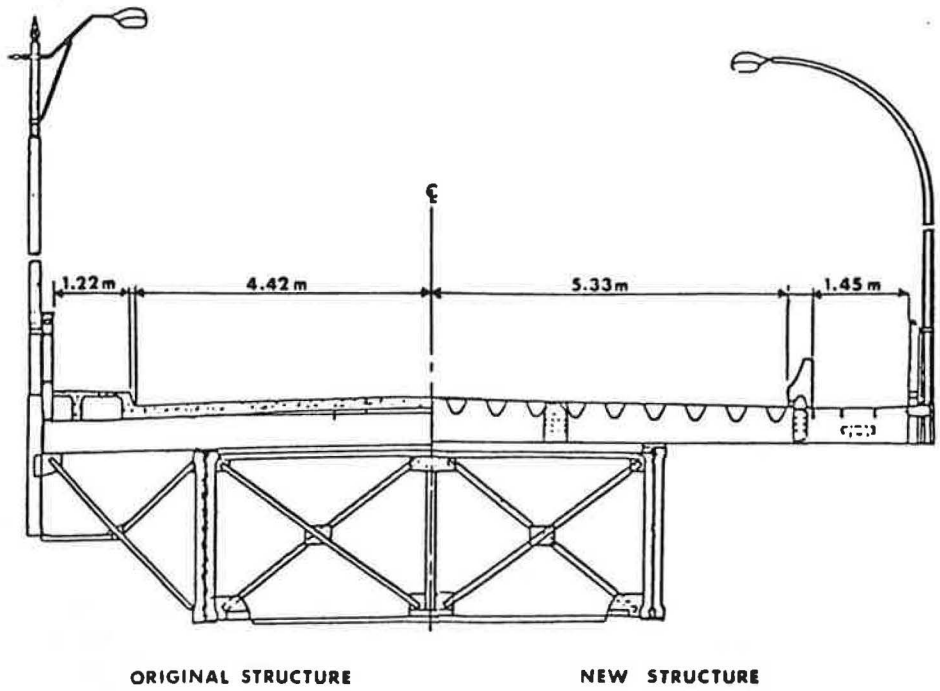
Traffic Loading

In order to arrive at a rational design load for the viaduct and suspension bridge, a traffic study was carried out using stop frame cine cameras to record the size and spacing of vehicles. Statistical methods were used to derive load probability curves for the bridge. This work was later extended to the general situation of traffic loading on long span bridges, culminating in a paper on the subject presented to this Conference. The traffic studies indicated that some control of loads was necessary and a permanent 12,684 kg (28,000 lb) G.V.W. load limit was instituted.

Details of Design

One key to success in this project was the careful design of the numerous new deck to existing girder connections. They were required to be of adequate strength and stiffness, but also simple to connect and tolerant of misalignments in any planar or rotational direction. In order to provide realistic tolerances for the connection of new steel to existing, the new cross beams are attached by field welding to oversize shims which in turn are connected by countersunk bolts through existing rivet holes in the main girders. As mentioned earlier, extra reserve strength was attained by making the new deck composite for live load. The necessary shear connections at the end of each span were obtained by inserting 3 or 4 panels of plate diaphragms between the cross beams and aligned over the main girders. The steel orthotropic deck used was the conventional arrangement of U troughs. Concresive® epoxy asphalt was selected after testing due to its outstanding abrasion resistance under studded tires. Other improvements incorporated in the new deck scheme included traffic barriers protecting the widened sidewalks, maintenance catwalks and gantries, telephone trunk cable trays, and a new electrical power distribution system, lighting system, overhead traffic sign bridges and stand-by generator. Half sections of the original and new design are shown in Figure 2.

Figure 2. Half sections of original and new structure.



Construction

Due to the critical structural nature and time restraints on the work, all aspects of construction were under 24 hour supervision by the Consulting Engineer. Prior to erection, the deck units were spliced on a carefully prepared paving site and paved. Then they were taken apart and transported to the bridge. Preliminary work on the bridge involved successively removing all the floorbeam connection rivets and replacing them with HS bolts for speedy dismantling. The thin girder cover plates were subject to local buckling failure after removal of the rivets and precautionary stabilization by welding was required by specification. Removal of the original deck and installation of the new was handled by a Manitowoc Ringer crane.

Emergency Precautions and Public Information

One major concern during renovation was the possibility of equipment breakdown occurring while a gap existed in the roadway. Therefore, the Contractor was required to hold light emergency deck components on trucks at each end of the bridge. By careful planning and co-ordination, the 58 new deck sections were installed with delay to the public by late opening on only 4 occasions.

The need for public information and confidence was recognized early by both ourselves and the client and a most successful three pronged information system was set up. This consisted firstly of media advertisements giving a full explanation of what was going to be done and defining the extent of traffic closures. This was followed up by mailings to local businesses containing calendars of bridge closures. Finally, morning bulletins were supplied to local radio stations at 15 minute intervals until the bridge was open to traffic.

Suspended Spans

The next task to be tackled is the renovation of the suspension bridge part of the crossing. After investigation, it was discovered that the main cables had stretched, causing the centre of the bridge to drop 1 m (3.3 ft) and the towers to move out of plumb. Aerodynamically, the bridge was found to be stable only if reliance was placed on the natural turbulence of the wind. Accordingly, full model tests were conducted in turbulent wind in the N.R.C. 9 m (30 ft) wind tunnel in Ottawa.

Tenders will be called shortly for the replacement of the entire suspended structure - stiffening trusses and deck - to be replaced with a wider, lighter orthotropic deck with welded rectangular tubular stiffening trusses. It is believed that this is the first time that the entire suspended structure of a bridge has been replaced. Reconstruction will take place one section at a time during weekend closures and the bridge will remain open 24 hours per day Monday to Friday.