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Safety Considerations for the Burlington Skyway Project

Aspects de sécurité dans le projet «Burlington Skyway»

Sicherheitsüberlegungen für die Burlington-Hochbrücke

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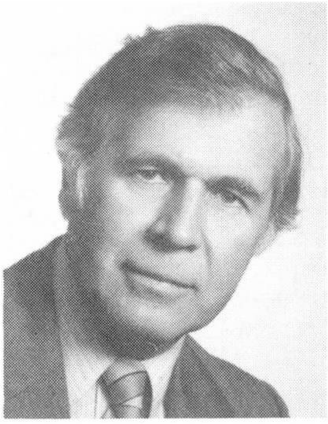

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SUMMARY

The Burlington Skyway twinning is the first application of cast in place segmental concrete bridge construction in Ontario. The special safety and quality assurance features applied on the project are described including the tendering method, design considerations, site organization and construction procedures. The bridge has steel box girder approach spans and a concrete main span of 151 m. The project was completed ahead of schedule and within budget with no sacrifice of normal quality or safety.

RÉSUMÉ

Le pont de «Burlington Skyway» est la première application d'une construction de pont en encorbellement coulé sur place en Ontario. L'article explique les caractéristiques assurant la sécurité et la qualité de la construction, notamment les appels d'offres, les points importants du projet, l'organisation du chantier et les procédés de construction. Les sections des extrémités sont des poutres-caisson en acier; la poutre principale du milieu est en béton et a une portée de 151 m. Le projet a été terminé avant les délais fixés et dans les limites du budget alloué, sans compromettre ni la qualité ni la sécurité.

ZUSAMMENFASSUNG

Die Burlington-Zwillings-Hochbrücke ist die erste nach dem Taktschiebeverfahren gebaute Hohlkasten-Konstruktion in Ontario. Die speziellen Sicherheits- und Qualitätssicherungsmassnahmen werden beschrieben, wie auch das Ausschreibungsverfahren, besondere Entwurfsüberlegungen, die Baustellenorganisation und die Bauverfahren. Die Brückenauffahrten bestehen aus einer Stahl-Hohlkasten-Konstruktion, während die Hauptspannweite von 151 m mit Beton überbrückt wird. Das Projekt wurde ohne Einbussen an Sicherheit und Qualität vorzeitig und ohne Mehrkosten fertiggestellt.

1. INTRODUCTION

The Burlington Skyway project, Figure 1, consists of a new 4 lane high level bridge parallel to the original 4 lane bridge, opened in 1958. The skyway crosses the shipping canal entrance to Hamilton Harbour, in Ontario, Canada. The new bridge, which is the subject of this paper, was opened to traffic in 1985, and renamed the Burlington Bay James N. Allan Skyway. The original structure was then closed for rehabilitation, including deck replacement, and the completed 8 lane, twin structure, facility is scheduled for full operation in 1988.

The new structure is the largest bridge project undertaken by the owner, the Ontario Ministry of Transportation and Communications (MTC) since the construction of the original Burlington Skyway nearly 30 years ago. As it was tendered as one contract, unlike the original structure, it represents by far the largest single contract ever let by MTC, with a value of $38.80 million. The overall length of the new structure is 2215 m, consisting of 24 steel box girder approach spans each approximately 64 m in length, and a 3 span cast in place segmental concrete central unit with spans of 83 m, 151 m, 91 m..

Although cast in place segmental concrete spans of this size are not unusual, from the international perspective, this form of construction had not been used before in Ontario, and the technology was thus new to both the designers and local contractors. This situation, coupled with the fact that it was the longest span and largest project undertaken by MTC, necessitated that particular attention be paid to questions of safety and quality assurance. These special considerations of safety and quality assurance for all phases of the project, including tendering, design, site organization and construction are covered in the following sections.

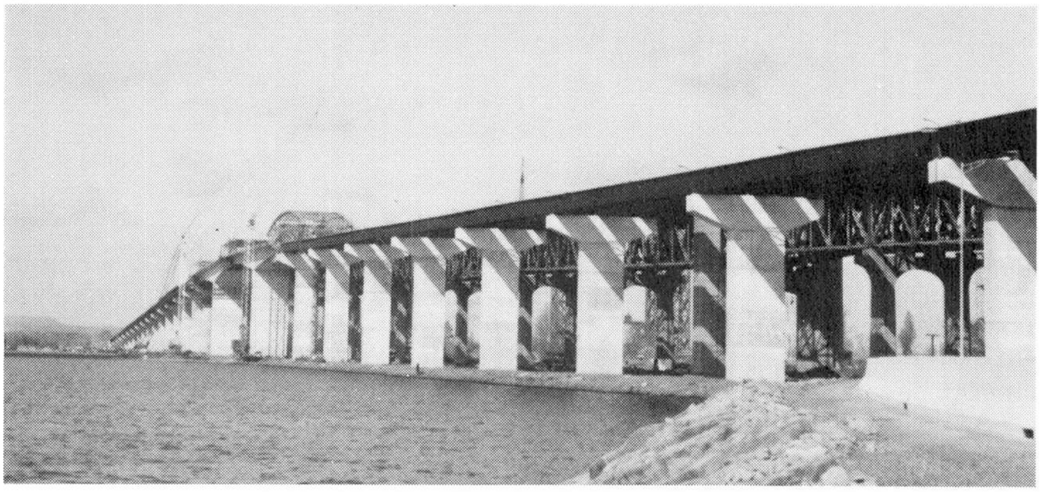

Fig. 1 Burlington Skyway under construction

2. BACKGROUND

In order that the Burlington Skyway project may be seen in the context of Ontario highway construction, the normal conditions and operations on MTC contracts will be briefly described.

The MTC has built and now has jurisdiction over nearly 3,000 highway bridges in the Province. They have generally been built by specialty highway contractors of medium size, and a $5 million contract would be considered large. These contractors usually have relatively small engineering back up, as they are rarely involved in design with the usual North American system of bidding on a single design package, fully detailed, with no alternative design opportunity. The contractors have extensive prestressed concrete experience, however, as cast in place post tensioned bridges have been the most common expressway interchange bridge type in Ontario for the last 20 years. There are well established pre-casting plants nearby, and a highly capable structural steel fabricating industry. General contractors manage contracts for a complete section of highway, including structures, and would normally sub-contract structural steel, reinforcing steel, prestressing and concrete supply for bridges.

The MTC Structural Office is responsible for the design of major structures, with 25% to 40% of the work in any year being carried out by consultants. The types of bridge structure normally used have become well established, with details standardized, so that contractors have become familiar with MTC projects. Similarly the specifications, quality assurance methods and contractural procedure are well established. MTC staff carry out on site inspection with a well trained body of inspectors and project supervisors, and the contractors submit shop drawings, falsework drawings and erection procedures for review before construction is authorized. This well established overall process minimizes surprises for the contractor, and has enabled a satisfactory level of quality and safety to be maintained, while encouraging competitive prices.

In moving away from the norm in both size and complexity for the Burlington Skyway project, it was decided that safety and quality would be best ensured by staying as close to the established MTC procedures as possible. Due to the unusual aspects of the project some additional procedures were required, as described, to make sure that the normal level of safety and quality was maintained or possibly improved.

3. TENDERING METHODS

Although the standard Canadian tendering method is to issue one design for contractors to bid, there is a growing tendency to issue alternative designs in different materials to increase competition and improve the chances of a lower bid. In Ontario the MTC practice is to have alternative designs prepared for bridges estimated to cost more than $3 million if preliminary designs do not indicate that one material has a clear advantage over another. The alternatives are fully detailed, and contractors are asked to bid on one or the other, with no provision for contractor redesigns. After a contract is signed the contractor may propose modifications, usually to the erection methods, provided the basic design is not altered. This is a limited application of the value engineering approach. This method does not compromise the usual level of safety or quality.

In North America some recent large projects have been called on the contractor design basis common in Europe. This approach has been slow to be adopted in North America as the contractors have not normally had the large design capability such as is present with major European contractors. Due to the size of the Burlington Skyway project, and the possible cost savings, this method of tendering was considered initially. It was rejected, however, as there was concern over a possible loss of design and contract administration control and hence a possible reduction in safety and quality. Another difficulty would be in establishing durability and serviceability criteria in a manner that would enable designs to be compared equitably. An additional factor was that the smaller Ontario contractors might be at a competitive disadvantage in a design-built tender compared to large American contractors. This was of particular concern as there was a construction recession in Canada at the time, and this large contract represented a significant portion of the MTC construction budget. The tendering method adopted was considered to give sufficient alternatives for competitive bidding, but at the same time maintain the usual level of control on design and contract administration. Complete designs and contract documents were prepared for a scheme with all steel superstructure, and another with all prestressed concrete superstructure. The main span lengths for both schemes were the same as they were controlled by site geometry requirements. The approach span lengths were varied, however, to suit the economic span for each material. These two designs enabled four bidding options to be offered, as follows:

A) All steel superstructure

B) All prestressed concrete superstructure

C) Steel approach spans and prestressed concrete main span

D) Prestressed concrete approach spans and steel main span.

In order to take advantage of these options it was necessary to tender the whole bridge as one contract, and each bidder could put in a tender price on only one of the options. As each of the options was equally acceptable to the owner, the award was based on low bid alone. No contractor design alternatives were permitted in accordance with normal MTC procedures.

In order to make sure the tendering process was fully understood, all contractors were obliged to attend a pre-bid meeting to pre-qualify as a bidder. They also had to name their major sub contractors in their bid, and name the prestressing specialist they would engage. This specialist had to be selected from a list approved by the MTC, of people with established experience in cast in place segmental construction. This requirement ensured that all contractor teams had the required expertise even if the general contractor had no direct experience of this form of construction.

A total of nine tenders were submitted, the lowest three all being for Option "C". Options "A" and "B" were also bid, but not "D". The contract was awarded to the low bidder, Pigott Investments Ltd., Hamilton, Ontario for a price of $38.8 million which was a few percent lower than the MTC in-house estimate. The winning option has a cast in place segmental concrete main span, Figure 2, and steel box girder approach spans with reinforced concrete deck, Figure 3.

Fig. 2 Main Span

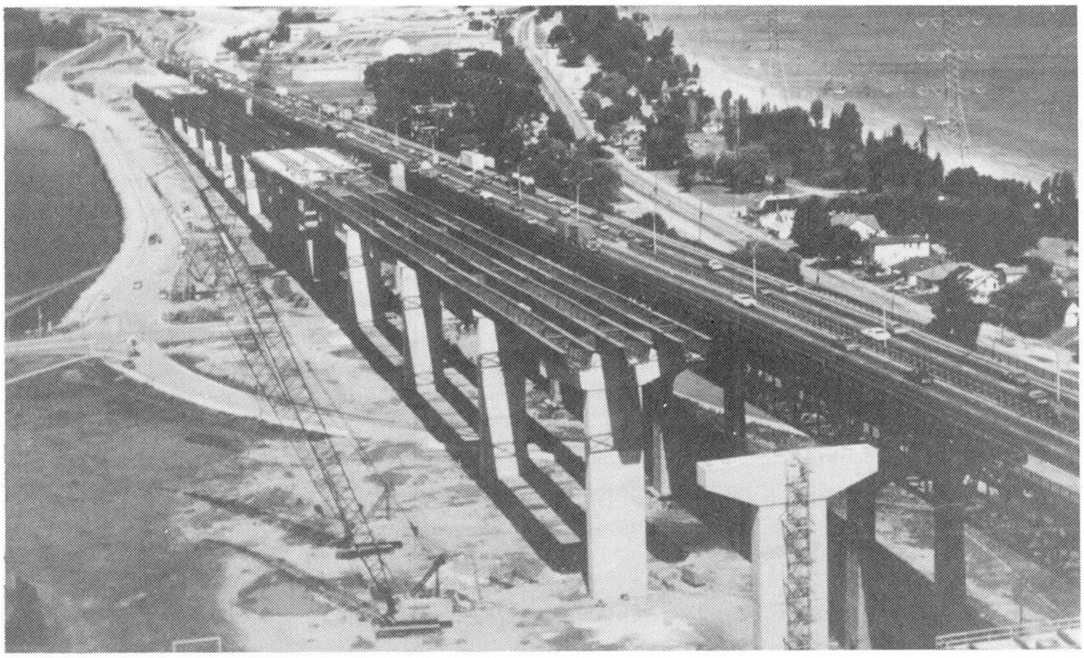

Fig. 3 Approach Spans

4. DESIGN CONSIDERATIONS

For the adopted tendering method, whereby full alternative designs were to be prepared, it was essential that the designs in both materials be competitive, economical, and as far as possible to be equally durable. It was decided that these criteria could best be met by preparing all designs in the MTC Structural Office. This office was large enough, with a staff of 80, to have expertise in all materials and design types, and had the equal confidence of the concrete and steel industries. The design code to be used was the newly developed Ontario Highway Bridge Design Code [1]. This was the largest project and longest span to which the code had been applied. The new code represented a major change from the working stress and load factor design approach of AASHTO [2] previously used in Ontario, to a fully limit states design approach calibrated to a prescribed safety level [3] . As several of the MTC Structural Office engineers had been active in the development and writing of the new code, this central office was the most logical location to carry out the design of this project.

The office had experience of precast segmental concrete construction, but not cast in place balanced cantilever construction. For this reason, DRC Consultants of New York were engaged to provide advice on this form of construction and the selection of the structural form. The DRC segmental construction computer program was used for the longitudinal design, and a MTC design engineer was assigned to New York during the running of the program. Direct input from the construction industry was obtained during the design phase. Existing liaison committees with the steel industry and prestressed concrete industry were used for advice on construction aspects during design development and in the selection of the most economical structural forms.

There were four basic designs developed for the bidding options: main span concrete, main span steel, approach spans concrete, and approach spans steel. Instead of having the design check carried out in-house, in the usual way, it was decided to use the expertise of local consultants and engage four different firms. Each firm carried out a completely independent check of one of the four basic designs. This approach was an extra safety precaution deemed advisable considering the size of the project and the fact that a relatively new design code was being applied. In addition, during the initial design, aspects of the

AASHTO Code were used as a check against the Ontario Code. This was done to identify, and subsequently obtain a satisfactory explanation of any significant variations between the two codes. This was thought to be advisable as the Ontario Code had not previously been applied to spans as long as the 151 m main span, and this span is at the limit of the prescribed applicability of this code.

The design was carried out with construction simplicity, and repetition of operations in mind, as an important way of reducing cost, but also the best way to obtain good construction quality and on-site safety. For the approaches, the span lengths are the same, 63.75 m, and only two pier sizes were used. The pier form selected was a very simple shaft with hammerhead cap, Figure 3, allowing maximum reuse of forms. The structural steel box girders were detailed to be shipped by road, and the maximum weight of 59 tonnes for any unit meant they could be readily handled by available equipment. For the segmental concrete main span the piers were designed to be integral with the superstructure, Figure 2, thus eliminating the need for any temporary supports during segment erection. The piers were designed to resist the unbalanced moment during segment construction, which was considered the safest approach, and enabled the design to be completed and detailed knowing the construction method. The twin cell box superstructure was kept simple with equal segment lengths, vertical webs, and straight rather than draped longitudinal strands.

The Ontario Code was calibrated to a target safety index of $\beta=3.5$ at the ultimate limit state. The question of safety during balanced cantilever erection of segmental concrete bridges has been addressed in the second edition, and the same safety level has been prescribed as for the completed bridge [4]. The consequences of failure during construction are normally considered less severe than for a bridge in service. However, for balanced cantilever construction loss of stability leads to total collapse and this was considered justification for calibrating to $\beta=3.5$. The construction condition is illustrated in Figure 4, along with possible applied loads. At the ultimate limit state the moment to be resisted by the pier is given by the following equation, which also shows the load factor applied to each load:

$$M_O = 1.05D_O + 1.10C_O + 1.25W_O + 1.05L_O + 1.10F_O + 1.10E_O - 1.00D_S - 0.90C_S - 0.75W_S - 0.90F_S$$

where subscripts "O" designate overturning moments and "S" stabilizing moments, and D = dead load, C = construction load, W = wind uplift, L = weight of last segment, F = weight of formwork, and E = edge load.

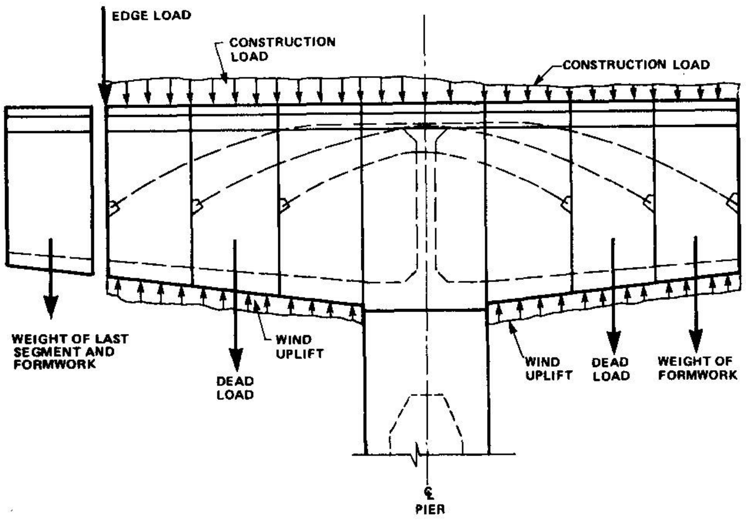

Fig. 4 Segmental Construction Loads

The Ontario Code also has been calibrated to prescribed safety levels at the various serviceability limit states, the values being less than $\beta = 3.5$. Although quality assurance is generally considered a function of construction control, long term quality can only be satisfied by considering suitably calibrated serviceability limit states and addressing durability aspects at the design stage. The Burlington Skyway is subject to winter salting of the roadway, and protection against this aggressive environment was of prime concern. The approach spans are in 6 span continuous units to minimize deck joints and their inherent leakage problem, deck drain pipes extend below the girder soffit, epoxy coated bars are used in the deck and piers, and extra thickness was used on the steel box girder webs adjacent to the original bridge to allow for brine splash. In addition, steel box girders were selected rather than plate girders, possibly at a cost premium, in order to minimize the steel surfaces exposed to the corrosive conditions.

More complete data on the design aspects of the project have been previously documented [5] .

5. SITE ORGANIZATION

The contractor, Pigott Investments Ltd., had no experience of segmental concrete construction, and had not been active in bridge building for many years. The contractor is one of the largest in Ontario, however, with considerable construction management capability developed on many large projects in the building and heavy construction fields. Pigott's site office was adjacent to the MTC site office, and the two offices collaborated closely on drawing approvals and held regular site meetings, so that all operations were planned and agreed in advance.

The specialist sub-contractor for cast in place segmental work was BBR Canada. The MTC site engineering staff, in addition to the Project Manager, was augmented by two engineers who had been involved with the design in the Structural Office. They carried out most of the shop drawing checking on site, so that differences could be discussed directly with little delay. All erection calculations, including cantilever deflections could similarly be agreed to on site, with the back up of head office staff when needed. In fact, there were few modifications required as the design contract documents gave full details such as reinforcing bar lists, prestressing details and segment deflections.

The contractor was very safety conscious, having safety movies shown, monthly safety meetings for all workers, and seminars given three times by the Construction Safety Association. This attention paid off with the accident frequency for the project being only 15% of the industry average, and there were no fatalities.

6. CONSTRUCTION PROCEDURES

The pier footing concrete was required to be placed in the dry, and due to the high water table in the filled land on which the piers were located, dewatering of the excavations was necessary. There was concern about settlement of the spread footings of the adjacent existing bridge as the water table was lowered, hence dewatering proceeded at a controlled rate as pier settlements and possible rotations were monitored. The maximum measured settlement of 17 mm was on the main span footing, and was considered an acceptable value. The only quality problem on the substructure occurred on the main span footing, where some thermal cracking took place near the surface. The size of the pour was such that concrete cooling provisions should have been included.

On the approach spans, a number of procedures were adopted that were not only cost effective but reduced the risk of accident. All the reinforcing steel for the hammerhead pier caps was prefabricated into cages on the ground, then lifted by crane into the forms, thus minimizing the work at high level. The steel box girders, supplied by Frankel Steel Ltd., were shipped to the site on the day of erection, pairs were bolted together and then erected. This operation minimized girder rehandling, as there was no site storage, and enabled half the field bolting to be done at ground level, in safety. For the reinforced concrete deck construction, stay-in-place metal forms inside the boxes gave an immediate and safe platform to work from. The wooden slab forms between boxes were large reusable custom built forms, which could be lowered from the deck slab level.

The main span segmental travelling forms were first assembled on the ground to fully check their operation before erection. A one-week turn around rate was achieved for the segment forms. The cantilever deflections were monitored on a weekly basis, at the same time of day to reduce thermal effects, and were always within 15 mm of the theoretical elevation. This was well within the allowable tolerance. The specified slump of 50 mm could have caused concrete placement and compaction problems, and the contractor opted to use a superplasticizer to increase the slump to 150 mm, with fully satisfactory results.

It was imperative that the segmental span be completed in one construction season, as a winter shut down would void the assumed schedule for cantilever construction and deflection control. This required completion close to the onset of winter, and thermocouples were installed to monitor temperatures after mid-October. When the temperature fell below $5^{o}C$ warm air was introduced inside the boxes before cable grouting, and temperatures measured to ensure the thermal gradient in the girder did not exceed the design value. A contingency plan was established for possible winter concreting, but insulation and internal heaters were the only needs, as concreting and grouting were completed in November.

7. CONCLUDING REMARKS

The project was completed ahead of schedule, on budget, and with no extra claims. The contractor's safety record was excellent, and the quality of workmanship above average. The special safety and quality controls employed, as described, were a contributing factor to the overall success of the project, but of perhaps equal importance was the real concern by the contractor for the safety of his staff and the quality of the product.

All operations were well planned and detailed and there was good communication and co-operation on site between participants. This was helped by the clear delineation of responsibilities in the contract documents, and the following of normal MTC practices whenever possible. The resulting lack of serious problems, on the largest project ever undertaken by MTC, is perhaps best exemplified by the title of a paper given this year by the MTC Project Manager, "The Burlington Skyway, Another Routine Project".

8. ACKNOWLEDGEMENTS

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