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# Rehabilitation of the Beauharnois Suspension Bridge

## Remise en état du pont suspendu de Beauharnois

## Instandsetzung der Hängerbrücke von Beauharnois

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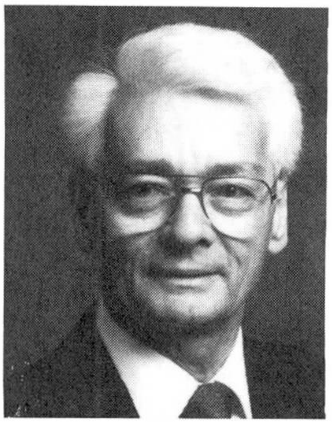

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## SUMMARY
Under certain constraints, the rehabilitation of a structure may leave the Engineer with no alternative but to resort to rarely-used mixed repair techniques. Provided that a thorough scrutiny of the whole design procedure is conducted, the born-again structure may become a perfectly safe and viable solution. Not only will the exercise always be beneficial to the designer but such a structure will often provide unexpected additional bonuses.

## RÉSUMÉ
En raison de certaines contraintes, la remise en état d'une structure force souvent l'ingénieur à recourir à des principes structuraux mixtes, peu usuels. La remise en question de chaque phase de la conception et de chaque détail de construction s'impose pour que la viabilité et la sécurité de l'ouvrage soient assurées. Non seulement l'exercice est-il enrichissant pour le concepteur mais le résultat technique offre souvent pour l'ouvrage, des avantages additionnels inattendus.

## ZUSAMMENFASSUNG
In gewissen Zwangslagen muss der Ingenieur bei der Instandsetzung von Brückenbauten auf verschiedene selten benützte Verfahren zurückgreifen. Bei äusserst genauer Überprüfung jeder Konstruktionphase und jedes technischen Details kann die Widerstandsfähigkeit und Sicherheit des erneuerten Bauwerks garantiert werden. Diese Aufgabe stellt für den Konstruktionsingenieur nicht nur eine bereichernde Erfahrung dar, das technische Resultat selbst kann auch oft unerwartete Vorteile bringen.

## 1. INTRODUCTION

Ladies and gentlemen, I am pleased to report this experience in the rehabilitation of a bridge. As happens in most projects, one element often becomes a determining factor in the solution that is to be chosen. Here, had a larger amount of reinforcement or all of the suspension cables required replacement, then a totally different approach would have had to be adopted, leading to certain increases in costs and in delays.

The Beauharnois suspension bridge spans one of the numerous spillways of the HYDRO-QUEBEC power plant, which is located on the St. Lawrence river, 40 km South-West of Montreal. This facility is a modest 2-lane, 177 m conventional suspended structure. The deck is composed of 2 built-up I-beam stiffening girders, supporting transverse floor beams and longitudinal stringers. The roadway is concrete-filled grating, with an asphalt overlay.

Designed and built by a local bridge construction company in 1947, the bridge structure was submitted to ever increasing heavy traffic loading and to chemical attack by polluted air and generous salt sprayings over the roadway during periods of up to 6 months, every year. As all too often, insufficient maintenance budgets allowed the structure to deteriorate - in spite of some occasional strengthening efforts -, to a point where in 1987, traffic had to be reduced to one lane only and lower speed limits had to be posted.

## 2. INVESTIGATIONS

A number of condition surveys had shown the extent of the deterioration that prevailed and recommendations were made that appropriate corrective measures be taken to prevent further damage or to allow a protentially dangerous situation to develop. DESSAU was mandated to draw up complete rehabilitation documents, based on retrofitting the suspension system and on replacing the entire deck structure, while the original foundations and anchor blocks should remain.

The main cables had already suffered some corrosion and a number of wires were known to be broken. Thus, the main load-carrying members were in a deficient condition. Additionally, recent highway codes were calling for higher truck loadings, so that coming up with a solution to compensate for an overall cable deficit estimated to be about 20%, could prove to be quite difficult.

The road profile was to be maintained and the existing suspenders were to be reused, as required by the Client. Various deck configurations were analysed and checked for stiffness, weight and cost. The increased live loads led to larger deck weights and therefore, to still larger cable strenght deficits.

## 3. SOLUTION

For a viable solution to be implemented, major changes had to be considered. The task was to find a way to increase the carring capacity of the catenary cables and at the same time, to provide a deck that is stronger and lighter.

DECK STRUCTURE: it is well known that a torsionally rigid ORTHOTROPIC deck can be designed to be both stronger and lighter than conventional structures. By adding extensions to the suspenders, the entire structure could then be built under the deck level, allowing full torsion capacity to be developed. Still, the stiffening trusses had to be made more resistant to satisfy the controlling quarter-point moments.

SUSPENSION SYSTEM: no ready-made example could be found, despite a long search through printed records and theoretical publications on suspension bridges. Supplementing catenary cable deficit by the addition of diagonal cable stays seemed to provide a logical solution, but to our knowledge, the two systems have not been used on the same structure on many occasions. Very few accounts of actual applications were available to provide guidelines.

Numerous computer runs where all indicative of the perfect compatibility of the two systems applied to the same structure. Therefore, diagonal stays were dimensioned to compensate for the load-carrying deficit that was found in the catenary cables.

Since the two systems were found to behave similarly, not much horizontal resistance could be developed to reduce cable-to-deck displacements, which occur under unbalanced loadings. The critical quarter-point moments were not substantially reduced either. If anything could be done to reduce the large reversals of stress and geometry in the main cables, at the clamp level, it would help in preventing the condition of distress that was found to exist at that location, to develop further.

HORIZONTAL ANCHOR: by transferring the longitudinal force, which is generated by unbalanced loading on the bridge, directly into the abutment instead of into the main cables, an attempt was made to eliminate the mid-span cable clamp. This might be possible because of shallow foundations which are resting on competent bedrock. Indeed, this single feature would achieve more than expected. The reduction in the horizontal displacements between the deck and the cables allows dispensing completely with the mid-span deck-to-cable clamp. Moreover, calculations show a considerable reduction in the quarter-points moments.

Thus, the overall solution to the deficient suspension system was possible by providing à TORSIONALLY RIGID ORTHOTROPIC DECK, by incorporating DIAGONAL CABLE STAYS and by ANCHORING the deck to the foundation at one end of the bridge. These three features also favor greater lateral distribution of eccentric loads, thereby reducing values in the design moments and forces. Very real reductions in the weight of structural steel were possible, which in turn, further reduced cable reinforcement requirements.

## 4. DESIGN CONSIDERATIONS

After a feasible solution was found, the creation of a mathematical model was undertaken. The sizing of the diagonal cables was done by basic, preliminary calculations - the cables having been assumed to carry about 15% of the total uniform loads -. A house-developed computer program was used, first, to calculate stresses and moments in a two-dimension beam-elements model. The same program was used to treat a two-dimension truss-elements model and, finally to analyse the far more complicated three-dimension truss-elements structure.

Envelopes for stresses were generated for each individual member, by developing influence lines to determine the exact maximum loading conditions, and then by running a complete computer analysis to determine the resulting loads in the member under observation. The model was then revised according to the final construction details and, new computer runs where made to verify that the maximum stresses were not exceeded.

For fatigue evaluations, the magnitude of stress reversals needed to be evaluated. The Canadian National Building Code sets very rigid rules to determine the maximum allowable stresses in welded bridges. For the expected life of this structure,the 500 000 cycle category was used.

## 5. CONSTRUCTION

In the summer of 1988, rehabilitation work was undertaken by the owner, on the concrete anchor blocks, where drilled anchors and surface treatment has been specified, as part of the program.

Rehabilitation of the catenary cables started in the fall of the same year, by THE JANIN CONSTRUCTION COMPANY, with the assistance of STEINMAN of New York.

Fabrication of the steel deck structure was sub-contracted to LES ATELIERS PONCIN of Belgium who provided top notch workmanship, in complete agreement the very demanding specification clauses. SECO of Brussels, lent assistance with Quality Assurance in shop practices.

LES LABORATOIRES VILLE MARIE (DESSAU-owned), conducted all shop and field inspections for the project.

Welded sub-assemblies of deck and truss components were prepared in Belgium and shipped to the Beauharnois dock site. Larger, full-width assemblies, corresponding to bridge sections between field splices, were erected on a construction barge, and then floated into position. The first section was raised on June 15$^{th}$ 1989. As each section of the old bridge was dimantled and towed to shore heading for the scrap yard, its newly-assembled replacement was erected in the vacant space. Working progressively from the center of the river towards the abutments, nine such sections were floated in, raised on hydraulic jacks and connected to the existing bridge suspenders.

The Contractor, under the very able guidance provided by its own Consultant, managed to pre-measure all suspender links and to erect the whole bridge to a near-perfect match of the theoretically specified geometry. The results were excellent considering that the old bridge showed all kinds of imperfections, ranging from uneven oblique towers, erratic cable profiles, a twisting distorted road deck, etc. After all sections of the bridge had been erected and assembled into a rigid continuous structure, the cable stays were tensioned to pre-set values which were adjusted to the prevailing temperature.

With less than half of the underside of the bridge left without its final coat of paint, the job was stopped in November 1989, to be completed in the following spring.

OWNER and CONSULTANT were proud to point out that the completed bridge was opened to traffic, in October 1989, as scheduled.

## 6. NOTICE

This paper (conference) is presented for information and discussion purposes only and its content should not be construed as giving guidance for application to any other structure, without express written consent.