Renovation and Transformation of the Pérolles Bridge in Fribourg

Rénovation et transformation du pont de Pérolles à Fribourg

Renovation und Nutzungsänderung der Pérollesbrücke in Freiburg

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SUMMARY

The rehabilitation work performed on the Pérolles Bridge in Fribourg, Switzerland, is more than a simple refurbishment. The renovation represents a comprehensive transformation. By retaining the infrastructure, it will be possible to modify and improve the use of the bridge. The width of the deck will increase from 10m to 17.5m, which gives an indication of the increased performance needed to satisfy the new service conditions. Adequate design and construction procedures, in particular the detailed structural analysis for better understanding of the behaviour of the spatial structure, and the use of a temporary bridge during construction, will increase the lifespan of the bridge by approximately 80 years.

RÉSUMÉ

Les travaux de réhabilitation du pont de Pérolles à Fribourg, Suisse, ne se limitent pas à la simple remise en état. La rénovation constitue l'occasion d'une transformation. Par la réutilisation de l'infrastructure, il est possible de modifier et d'améliorer les caractéristiques du pont. Le tablier passe d'une largeur utile de 10.0m à 17.5m, ce qui montre le gain de performance en vue de son nouveau service. Le concept et la mise en oeuvre de mesures adéquates, notamment la méthode de construction au moyen d'un pont provisoire, et l'analyse structurale avancée permettant de connaître le comportement de la structure spatiale, prolongeront la durée de vie de l'ouvrage d'environ 80 ans.

ZUSAMMENFASSUNG

Die Erneuerung der Pérollesbrücke in Freiburg, Schweiz, beschränkt sich nicht nur auf eine Wiederinstandsetzung, sondern dient gleichzeitig auch als Grundlage für eine Nutzungsänderung. Durch die Wiederverwendung der Infrastruktur ist es möglich, die Eigenschaften der Brücke zu verbessern. Die Fahrbahnplatte wird von 10.0 auf 17.5 Meter verbreitert, was eine Verbesserung der Benutzung mit sich führt. Das Konzept und die Ausführung der geeigneten Massnahmen, unter anderem das Bauverfahren mit Hilfe einer provisorischen Brücke, sowie die erweiterte Tragwerksanalyse, die es erlaubt, das Verhalten des räumlichen Tragwerks zu erfassen, führt zu einer Verlängerung der möglichen Nutzungsdauer von ungefähr 80 Jahren.

1 INTRODUCTION

In 1922, the Pérolles bridge, situated at the entrance to Fribourg was the longest bridge in Switzerland. It had a span of 554 m, a height of 70 m and consisted of 40,000 m^3 of concrete. Only the deck slab was reinforced concrete (Figure 1).

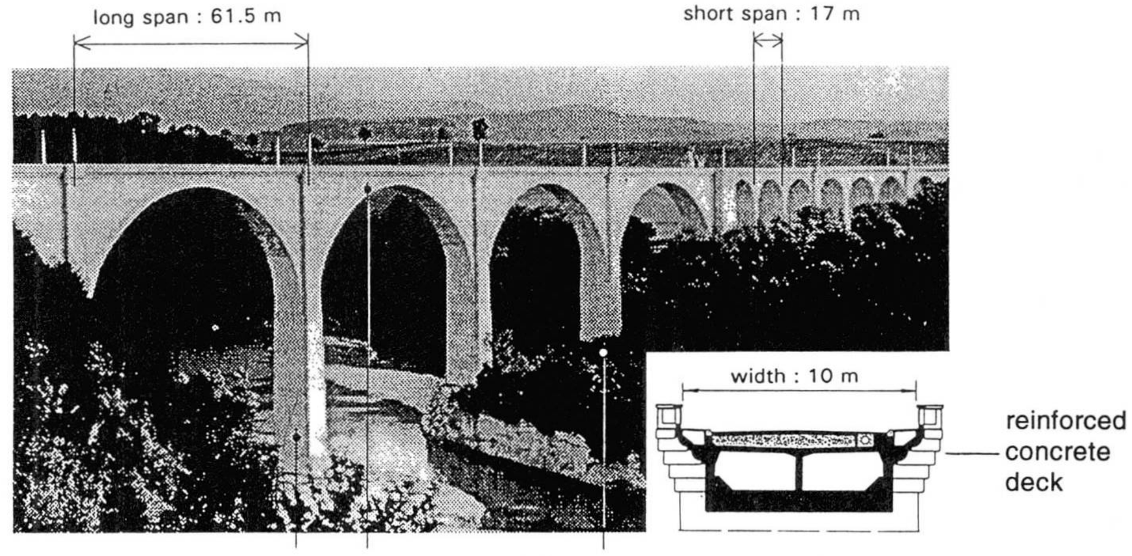

Figure 1 : Main features of old bridge

A detailed inspection of the bridge revealed severe degradation of the deck slab. The bridge had reached the end of its lifespan and consequently the deck slab had to be replaced.

Based on the evaluation of the existing bridge and the implications of such a large project, another serious question was raised : would it be possible to augment the resistance of the bridge to meet new demands? [1]

This paper considers the overall concept and the implementation of appropriate measures during the renovation and transormation of the Pérolles bridge in Fribourg.

2 PLANNING AND ORGANISATION OF THE PROJECT

Before effecting important changes on a structure, it is imperative that special attention be given to the global aspect of the problem, starting with the maintenance records of the bridge from when it was just put into service, and finishing with its renovation (Figure 2) [2].

A reconstruction of the history of the bridge, an understanding of the real behaviour of the structure, and a diagnostic of the present state of the bridge contribute to the selection of a concept, and the measures to adopt, in order to improve the characteristics of the bridge.

The adaptability of the bridge depends on the choices made during the conceptual phase and the construction phase. These choices influence the reserve in capacity, and create flexibility in terms of the new needs.

Renovation and transformation gives the structure a superior conformance to the requirements of the the SIA (Swiss Association of Engineers and Architects) standards and the applicable rules of common practice [3].

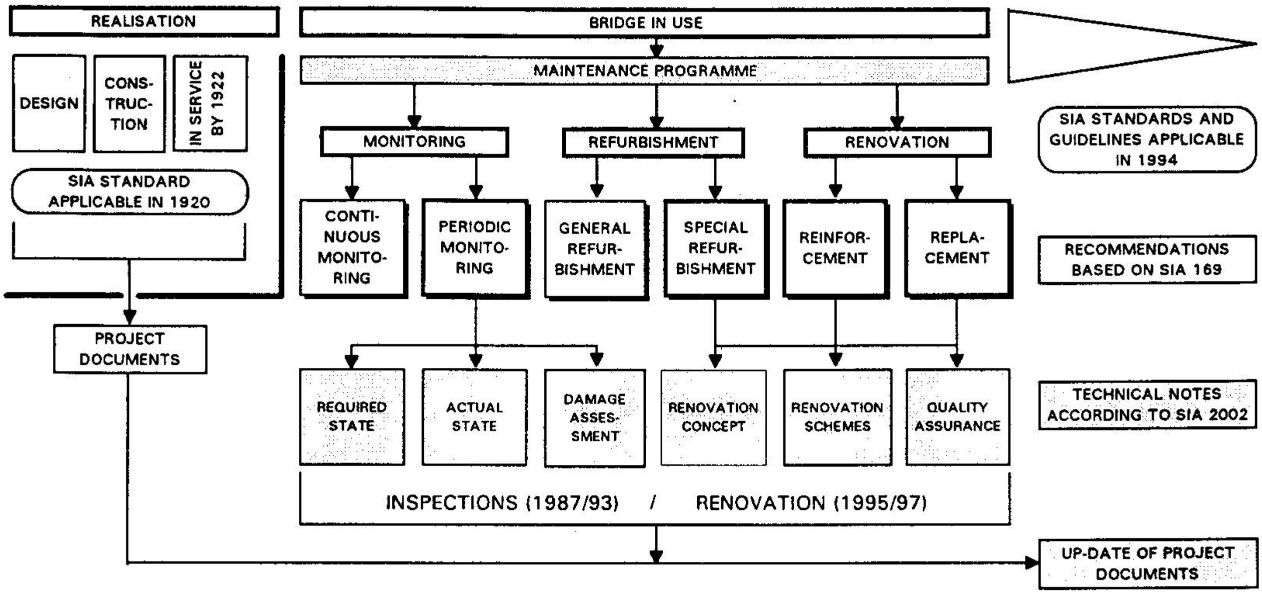

Figure 2 : Project organisation and planning

3 RENOVATION AND TRANSFORMATION

3.1 Concept

The general concept which influenced the renovation and transformation of the bridge is as follows :

- **optimise** use of existing structure as much as possible
- **satisfy** construction requirements through use of a temporary bridge
- **replace** the dammaged superstructure by one which is 70% larger
- **retain** the undamaged infrastructure but provide adequate reinforcement
- **preserve** the character of the bridge which is a part of Swiss heritage
- **ensure** high quality in terms of durability [4] [5]

Before the final concept was defined, another factor which needed consideration was the minimal disturbance to the existing structure.

The cross-section of the renovated and transformed bridge illustrates the modifications and improvements to the existing structure (Figure 3).

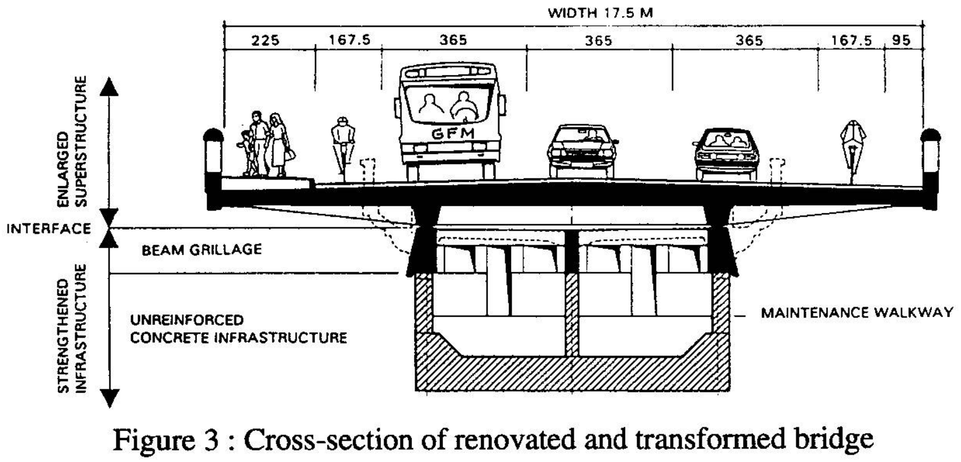

Figure 3 : Cross-section of renovated and transformed bridge

3.2 Course of action

Amongst the appropriate measures for prolonging the lifespan of the bridge, the choices of the construction conditions and method, and of the structural analysis approach were essential in order to satisfy requirements concerning respect of the environment, quality, cost and deadlines.

3.2.1 Conditions and construction method

The use of a temporary bridge provides optimal construction conditions by creating an independent site.

The construction method is based on the following criteria :

- **satisfy** safety requirements
- **ensure** concurrence and reliability of operations
- **maximise** use of repetition
- **reduce** complexity of procedures and introduction of new materials
- **monitor** quality-control, running costs and site schedule

Project management involves six construction phases as illustrated in Figure 4.

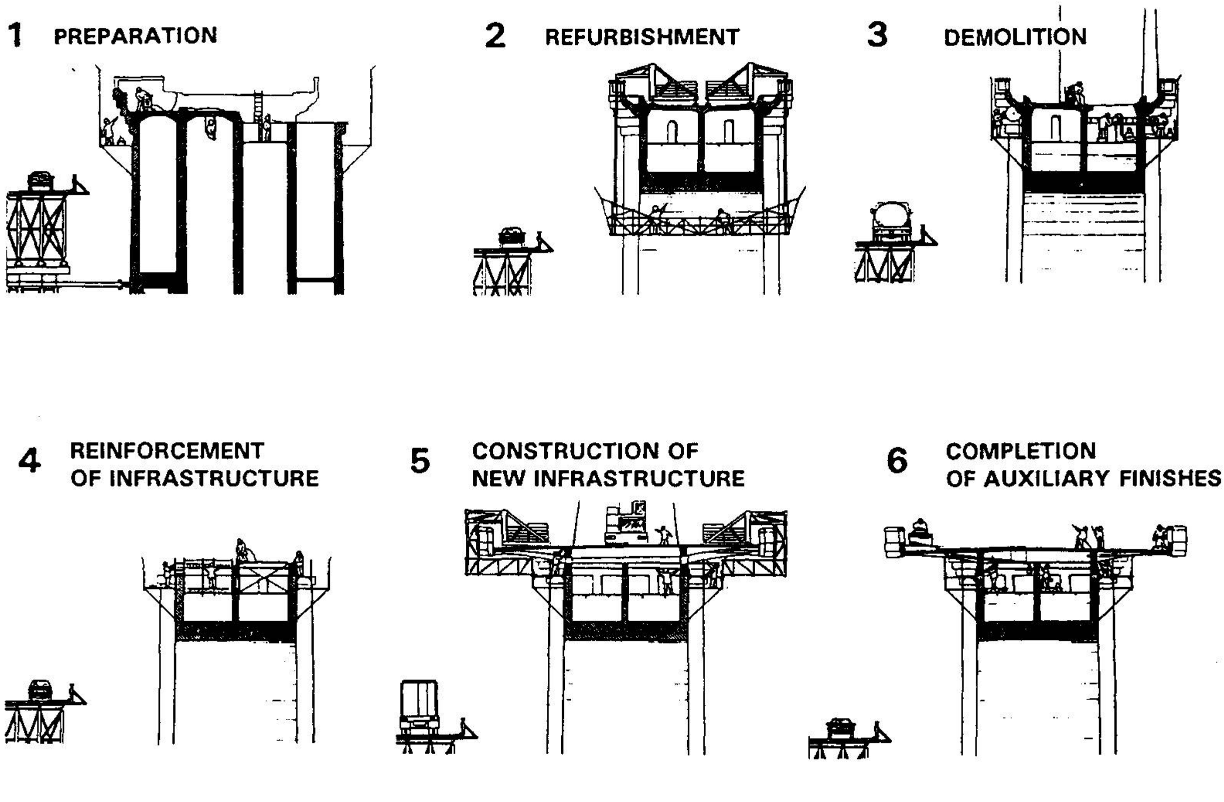

Figure 4 : Six construction phases

Interestingly, the construction method involves phases which require different loading conditions from those to which the completed bridge will be subjected.

3.3 Structural analysis

3.3.1 Evaluation of structural capacity

The construction of the vaults governs the design of the structure for the renovation of the bridge. The static model adopted at the time was a fully-connected arch, loaded by the fresh concrete of the walls and of the superstructure. The evaluation of the effective structural capacity, which fortunately had sufficient reserve, lead to the space frame analysis involving "arch, walls and deck-slab". Only the finite element method, through use of a precise model of the structure during the construction phases, provided a global approach to the problem by localising the critical zones. The MAPS computer program was retained for the comparative analyses performed by IBAP/EPFL (Figure 5).

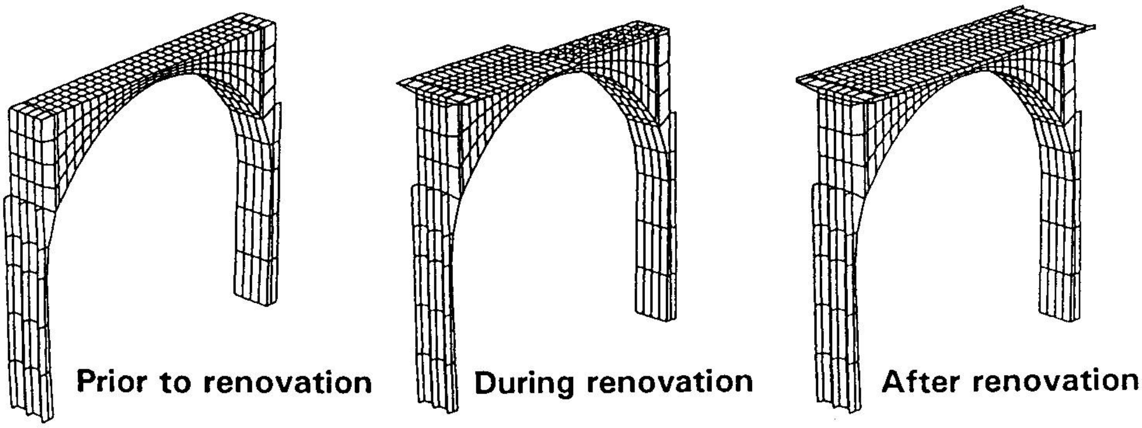

Figure 5 : Evolving structural models for a 60.5 m span according to the state of renovation

A parametric finite element analysis opened new avenues and lead to an optimal design of the structure. Measurements *in situ* contributed to a better understanding of the real behaviour of the structure and helped validate the reliability of the model (Figure 6).

3.3.2 Calibration of the model

The calibration was based on a large set of simultaneous temperature and deformation measurements of the structure. Comparison with the model helped to refine the material properties and the structural model (Figure 6).

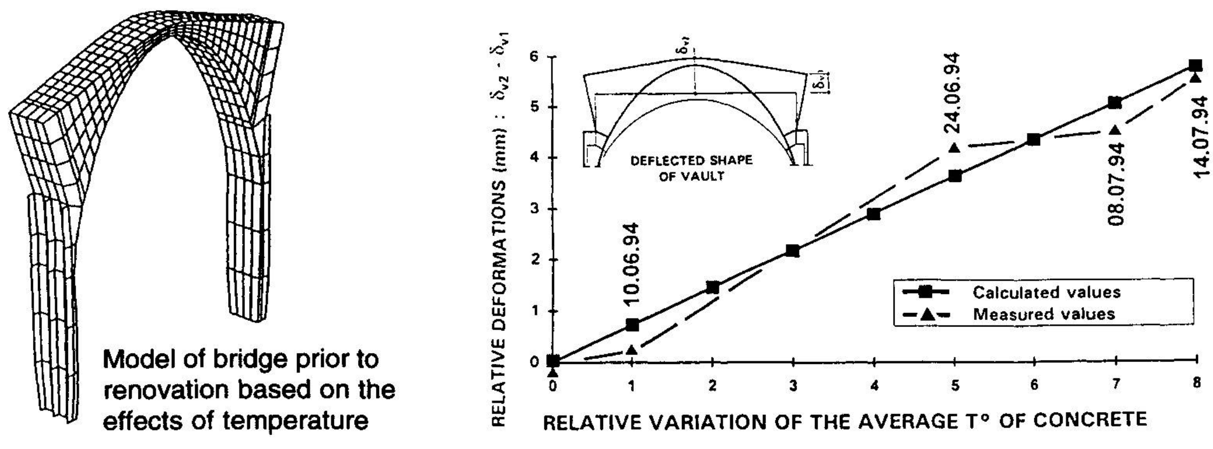

Figure 6 : Calibration of the model based on the effects of temperature

3.3.3 Identification of critical stress zones

The actual stress distribution in the infrastructure serves as a reference. The structural concept creates a minimum of disturbance to the unreinforced concrete elements. The evolution of the stresses during the renovation process was simulated in order to identify critical zones vulnerable to dammage. The set of tests performed by the LMC/EPFL laboratory, and the observations of the behaviour of the unreinforced concrete structure served as the basis for fixing a design value for the biaxial stress resistance in the vault, taking into account the discontinuous surface conditions of the concrete (Figure 7). The beam grillage is the only critical zone. It represents the only area reinforced concrete elements are used for strengthening the infrastructure. The non-linear analysis helped verify the cracking resulting from the imposed deformation restraints [6].

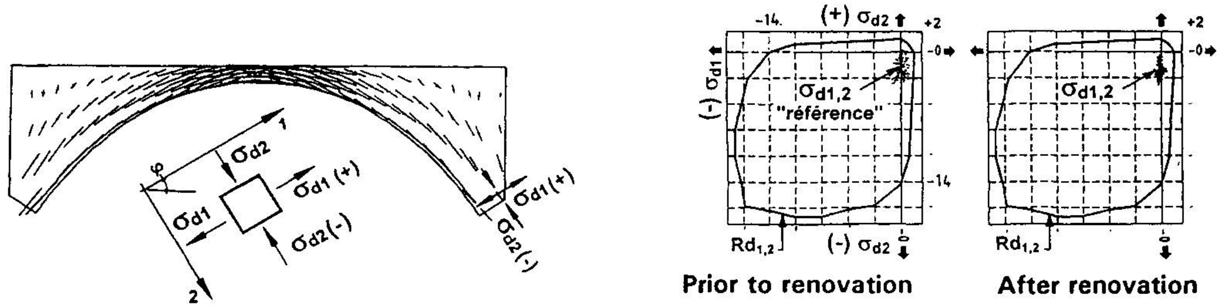

Figure 7 : Principal stress distribution in the vault prior to and after renovation, biaxial stress resistance (R_d) and normal stresses (σ_d)

4 CONCLUSIONS

For the renovation and transformation of the Pérolles Bridge in Fribourg, the selection of the concept and the appropriate construction measures, notably the method of construction using a temporary bridge and the advanced structural analysis procedure, helped optimise a set of criteria. These are : respect for the environment, aesthetics, reliability, durability, safety, deadlines and costs. The rehabilitation work will increase the lifespan of the bridge by 80 years.

5 PARTICIPANTS

Owner :	Direction of Public Works, Bridge Division, Canton of Fribourg
Design/Build team :	Consortium
• Renovation	Bongard & Zwick Consultants
• Temporary bridge	C. von der Weid Consultants
Expert :	H.-U. Frey, Ing. dipl. EPFL/SIA, Frey & Associates, Lausanne.

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