Long term monitoring of bridges

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Surveillance des ponts à long terme

Langzeitüberwachung von Brücken

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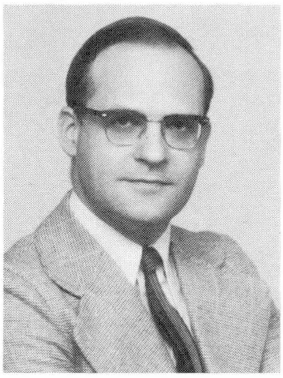

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SUMMARY
Resulting from a mandate of the Swiss Federal Department of Transport, a proposition on how to organize the monitoring of bridges is presented. In particular the evolution of cracking and long term deflections have to be observed during the whole life span and reported graphically.

RESUME
Suite à un mandat du département fédéral suisse des transports, une proposition concrète est présentée concernant la surveillance des ponts. En particulier, les évolutions de la fissuration et des flèches à long terme doivent être observées pendant toute la durée de vie et reportées graphiquement.

ZUSAMMENFASSUNG
Gemäss einem Auftrag des eidg. Verkehrsdepartements wurde ein konkreter Vorschlag für den Brückenunterhalt ausgearbeitet. Insbesondere wird die Aufnahme der Rissentwicklung und der Langzeitverformungen eingegangen, welche für die ganze Lebensdauer der Brücke in grafischer Form festgehalten werden.

1. INTRODUCTION

Although the maintenance of the highway bridges in Switzerland is carried out under the responsibility of each Canton where the bridge is situated, the Swiss federal department of transport has the task of coordinating the work. Therefore this department gave the mandate to our Institute to propose a methodology of long term monitoring of bridges in order to be able to make a sound diagnostic during all their life time. The report has just been published [4]. After defining a clear (french) terminology, it gives a survey on disorders and damages encountered in bridges. It describes the present methods of control and presentes in more detail the most suitable ones. Finally it gives a concrete propositon on how to organize the inspections and the maintenance.

2. TYPES OF INSPECTIONS

For the long term monitoring of a bridge, a correct medium should be drawn between the occasional visits and the placement of a permanent observation team. This surveillance must be exercised by means of meticulous control actions during specific inspections. It has thus been proposed to split bridge monitoring up into
- periodic inspections every 5 years
- routine inspections every 15 months
- special inspections according to needs.

So there are 3 routine inspections between two periodic inspections. With such a timetable, 20 % of all bridges are subjected every year to a periodic and 60 % to a routine inspection.

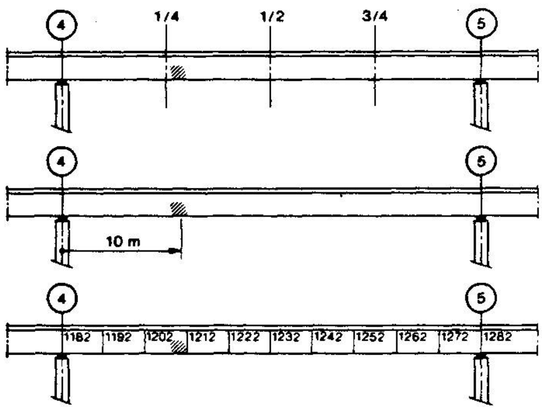

Fig. 1 Locating of observations

2.1 The routine inspections

The routine inspections should be done more or less every 15 months in order to get a change in season between two consecutive inspections, which may lead to the discovery of certain damages related to the climatic conditions.

The execution can be made by non specialised personnel of the highway department who have received an adequate training. The observations will be limited to a visual control of the bridge surface (cracks, humidity, corrosion) and of the equipment (bearings, joints, drainage).

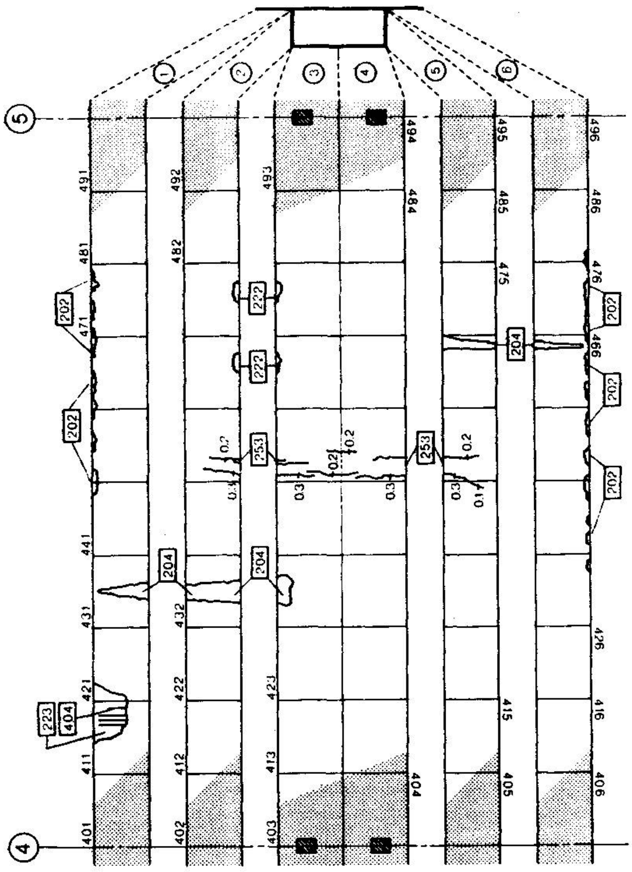

Fig. 2 Observations on the external surfaces plotted in a drawing provided with a numbered net

2.2 The periodic inspections

They have to give an image as complete as possible of the condition of the bridge and of its evolution. Cracks for instance are not necessarily a sign of disorder but their variation in time has to be known in order to be able to have a sound judgment. All areas of the structure must be controled. This means the necessity of putting the bridge out of service, either totally or partially, temporarily of for the whole duration of the inspection. The execution of the inspection requires specially trained personnel with sufficient access means (mobile foot bridges, nacelles etc.) : it should be possible to reach all points of the structure. Each periodic inspection should include :

- detailed visual control of the surface
- statement of the cracking patterns and their opening widths
- detailed control of the equipments

- measurement of :
  deck deflection
  displacements of the supports
  movements of foundations
- measurement of :
  E-modulus (sclerometer)
  depth of carbonatation
  presence of chlorides
  corrosion of reinforcement
- check for leaks of the watertightness.

A good deal of these observations should be noted in drawings (fig. 1). Cracks, water infiltration, traces of corrosion, bursting of concrete etc. have to be carried back conscientiously in the drawings in order to get a general survey of the disorders. For that purpose, the drawing of each span should be divided in equal parts, creating a regular wide-mesh net (maillage) which has also to be reported on the bridge itself. In fact, it proves difficult to situate an observation only by means of a distance, for instance 10 m from pier 4 as shown in Fig. 1. These drawings have to be utilized during all the life time of the bridge, so that with time a lot of indications will have to be plotted, with many specifications as crack length, crack width, date of appearance, evolution observed from the last inspection etc.

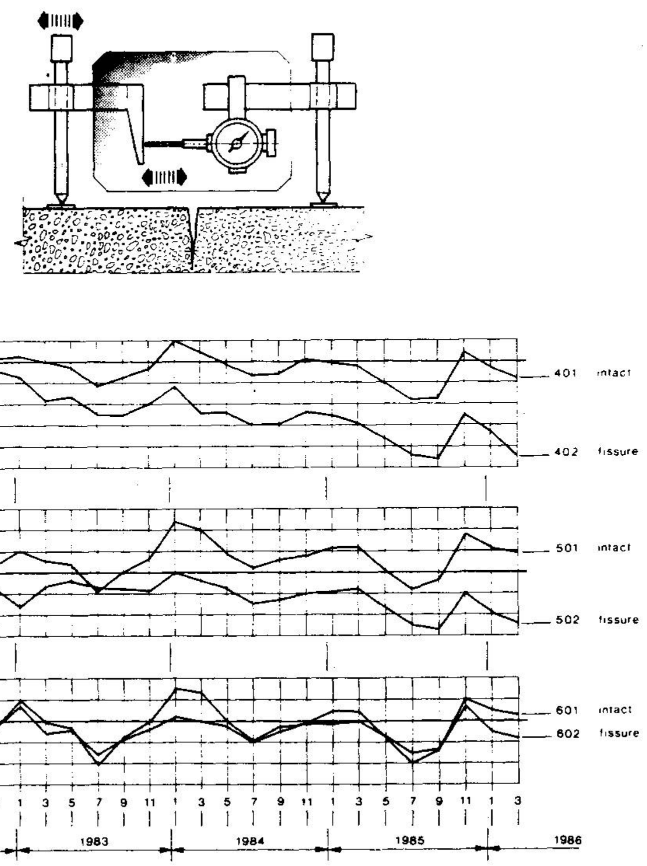

Fig. 3 Evolution of crack-openings

As a result one obtains drawings as shown in Fig. 2 where all visible parts of the bridge have to be treated.

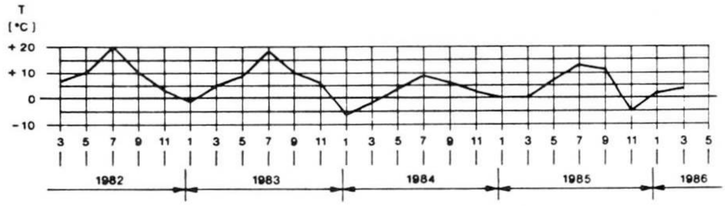

Fig. 4 Evolution of temperature in concrete

It is evident that it will be necessary to observe certain disorders in shorter intervals, for instance every two months (Fig. 3). From this figure, it can be seen that, in spite of temperature effects, crack Nº 602 seems to be stabilized whereas crack Nº 402 continues to open. In Fig. 4, the corresponding temperature in the neighbouring concrete is shown.

3. LONG TERM DEFORMATIONS

A most important and instructive assessment of the behaviour of a bridge will be obtained by monitoring the long term deformations. The most usual way will consist of optical or hydraulic levelling. The old known hydraulic levelling method by use of communicating vessels often fits especially well with the necessity of a regularly repeated observation during the whole life span of a structure.

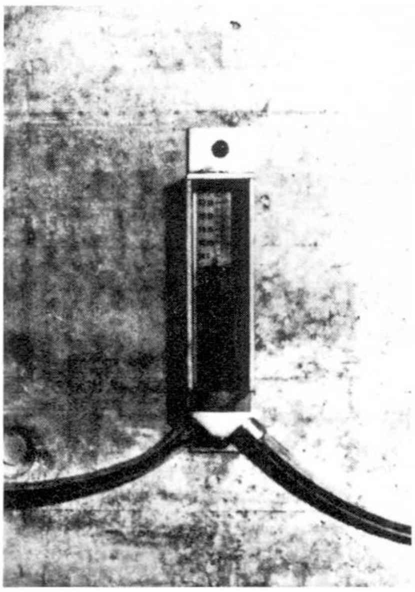

Fig. 5 Vessel for hydraulic levelling

Our Institute has been charged to install such communicating vessels in 10 bridges (Fig. 5 and 6). Having once installed these vessels, the cost for the observation of the displacements are very low so that it is recommended to install them in all important bridges, as far as the accessibility is provided.
A reference point has to be choosen, an abutment for instance. As a minimum, communicating vessels are placed on the supports and at mid-span, but also quarterly along the significant spans. In order to notably reduce the thermal effects, the measurements should be carried out in similar conditions, that is late autumn or winter. They therefore rarely coincide with the periodic inspections, at least at the beginning. They should be carried out every year for the first five, then every other year for the following four years and then every five years during the remaining life span. Thus the evolution tendancy can be better estimated.

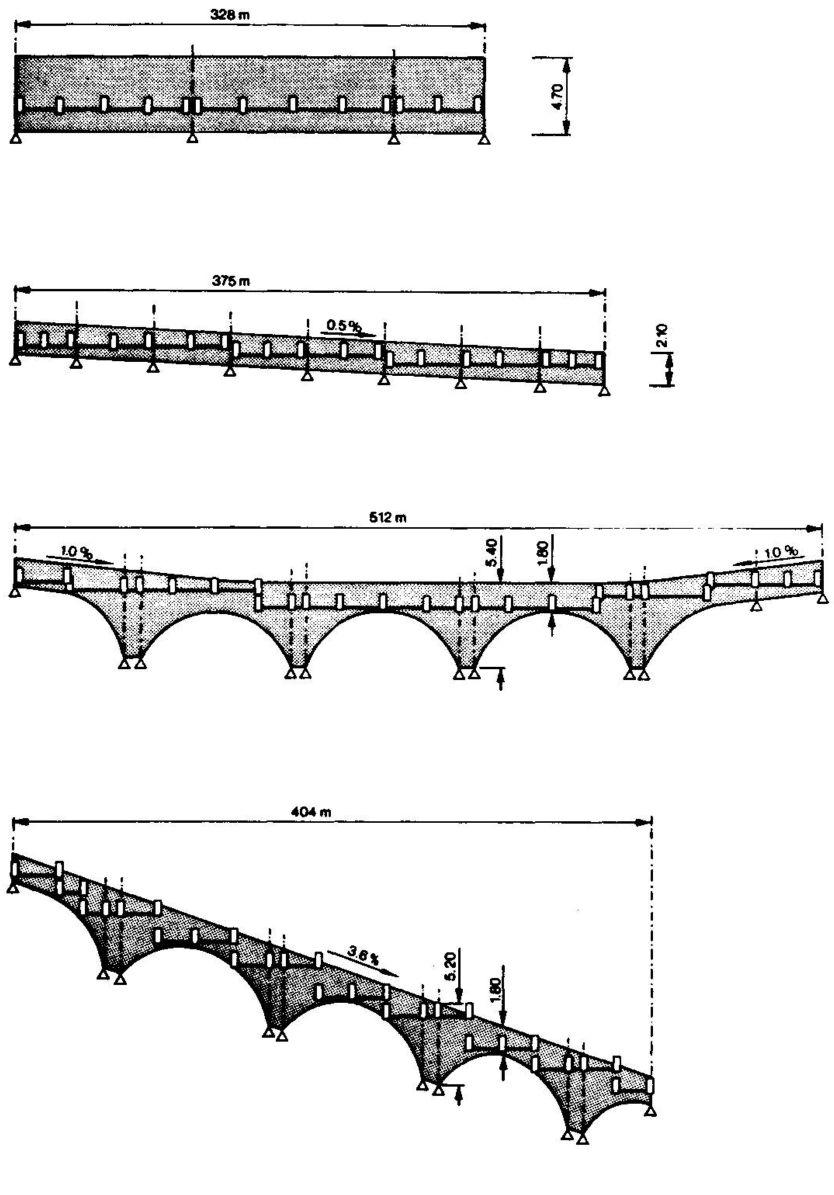

Fig. 6 Examples of installed communicating vessels

The results are interpreted under the following two aspects :
- affinity or not with elastic deformations
- size of the deformations compared with the predicted ones.

If the long term deflection curve has no good affinity with the calculated elastic curve, it may be the sign of a local weakness (Fig. 7). In the weak zone the increase of curvature cannot only be the result of creep but must be due to other effects, such as cracking, loss of prestressing force, bad concrete, bad continuity due to joints during execution etc.

Fig. 7 Elastic and long term deflection curves without affinity

If the long term deformations are bigger than the predicted ones (Fig. 8), the reasons have to be investigated very thoroughly. One has to be aware of the fact that there is a real lack of knowledge concerning the prediction of long term deflections.

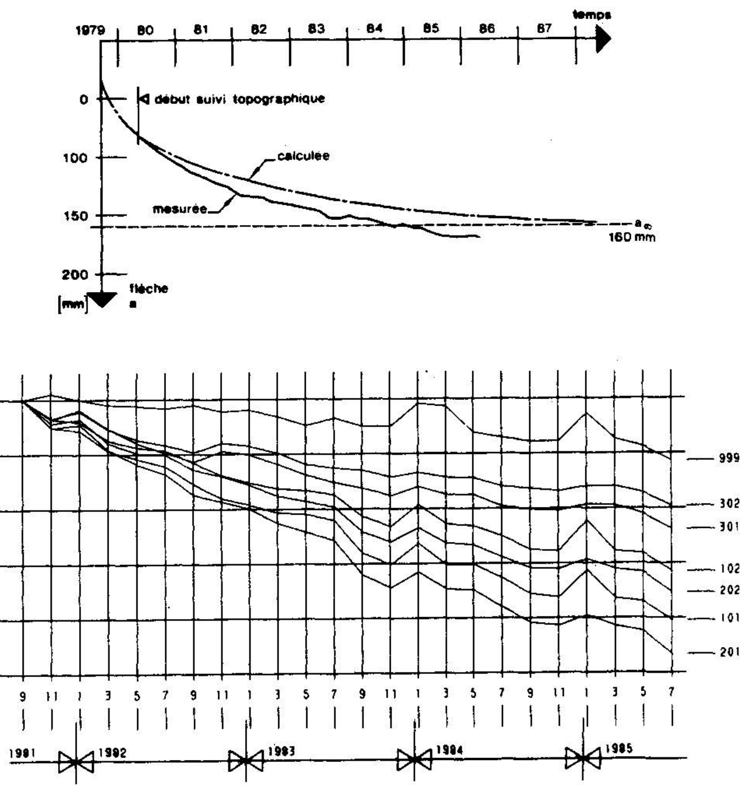

Fig. 8 Two examples of long term deflections greater than predicted

The real creep of the concrete in situ, the real prestressing forces, the moment redistribution due to asymetric reinforcement bars are difficult to be known with sufficient accuracy, so that even in the uncracked state I the prediction is not easy. But due to loads and especially thermal effects, some zones of the bridge may sometimes be cracked. That means that sometimes the curvatures and therefore the deflections will increase. When these effects have disappeared, the possibility of a certain irreversible amount of the deformations has to be considered. Tentative moment-curvature relationships for instantaneous reloading and unloading in the cases of simple bending and bending with normal forces are given in Fig. 9. These laws are given without any creep effect because they assume that the cracks are due to instantaneous effects.

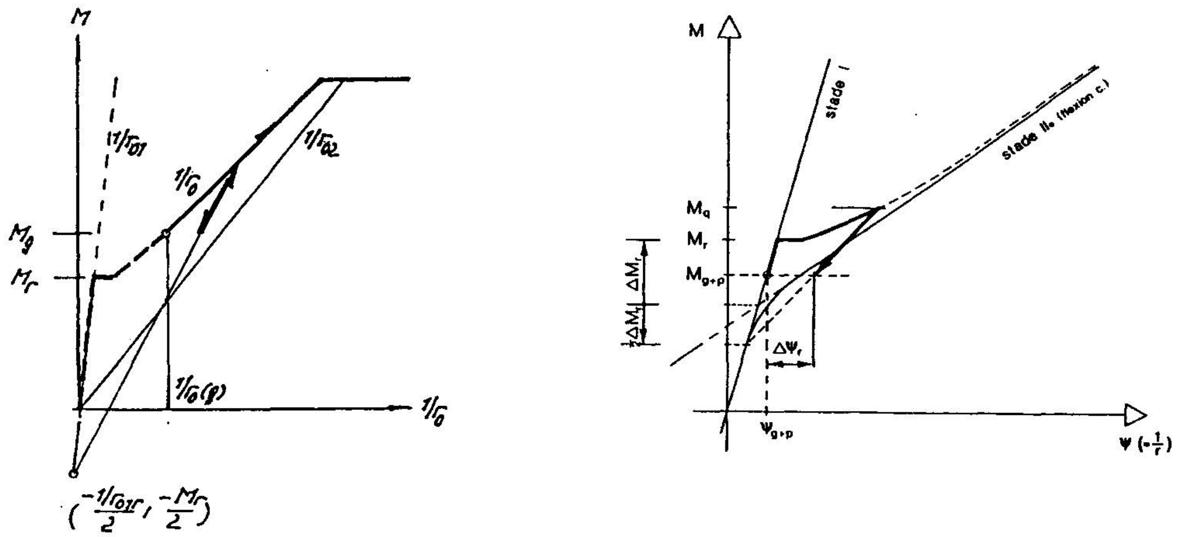

Fig. 9 Moment-curvature relationship for instantaneous reloading/unloading
a) simple bending
b) bending with normal force

The total deflections are given by the sum of long term deflections plus an irreversible part of often repeated instantaneous actions. It is absolutely necessary to increase our knowledge in that domain. In particular partially prestressed concrete bridges may suffer from these irreversible phenomena if they are frequently cracked due to thermal effects or large traffic loads.

CONCLUSION

This contribution shows a possible way of how to organize the long term monitoring of bridges through well defined systematic inspections. In order to have a complete view of the state of a bridge, it is necessary to have drawings in which the main observations are reported. Only with such a document an engineer will have a global information on the state of a bridge. The long term deflections are also of great importance but more information is needed on the real behaviour that should be expected. The big advantage of steel bridges are their elastic behaviour. Therefore it is absolutely indispensable to compensate the disadvantage of an unelastic long term behaviour in concrete bridges by better comprehension and forecast of their irreversible deformations.

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