The Assessment of VIPP (beam and slab PC bridges) in France

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The Beginnings of prestress in France

Experimental arch of the Veurdre bridge on Allier river

- built by Eugene Freyssinet in 1907 to study concrete creep
- supported on abutments linked by a tie prestressed by means of several hundreds of post-tensioned wires
- compressive force in the tie : between 25 and 30 MN

Experimental arch of the Veurdre bridge (1907)

Arch

Prestressed Tie

Opening of window in 1993…

Experimental arch of the Veurdre bridge on Allier river

Openings of windows operated in 1993:

- good behaviour of the tendons which were simply laid out in grooves filled with sand and sealed by a hydraulic mortar with care
- without any waterproofing on the surface of the tie and buried in soil for a long time

✂→ Experimental evidence that a prestressed structure may last more than 100 years…

Beginnings of the prestress in France

- **1928 :** official beginning of the prestress in France with the 2 patents taken out by Freyssinet
- **1939 :** real industrial beginning of prestress :

  -- with the supply of high-tensile steel by the steel industry

  -- with the development by Freyssinet of the anchoring by conical friction, and of the prestressing jack with double effect

construction of three bridges : The two slab bridges of Longroy and Elbeuf sur Andelle (1941), and the Luzancy bridge (1941-1946).

Luzancy Bridge over the Marne river (1941-1946)

Luzancy Bridge over the Marne river (1941-1946)

Prestressed concrete bridges of the 1946-1960 period : the rise of the VIPP (*)

(*) viaducts with simply supported spans made up of beams prestressed by post-tension

(beam and slab bridges)

Design of VIPP

- Beams precast on site and prestressed longitudinally (first stage)
- Beams assembled by a transversal prestress in the crossbeams, or in the slab, or in both
- Second stage of longitudinal prestress
- Spans : 30 to 50 m
- About -- 250 built between 1945 and 1957
  -- 450 built between 1957 and 1967

Many cast joints…

Main defects of VIPP

- Bad or no grouting of ducts
- Lack of waterproofing membrane (until 1965)
- Use of prestressing steel sensitive to SCC or to hydrogen embrittlement
- Unsufficient vertical stirrups near the end of the beams (to resist shear force)
- Low percentage of longitudinal reinforcement steel
- Lack of structural ductility before failure…

VIPP

Example of a VIPP

VIPP

Example of cracks along the tendons in the webs

VIPP

Active humidity in a crack on the toe of a beam…

VIPP

Crack with stalactite at the soffit of the toe of a beam

VIPP

Typical defect at the soffit of a toe due to concreting difficulties

VIPP

Example of the variability of corrosion

VIPP

General corrosion of tendons

VIPP

Example of broken wires due to SCC (KA system)

The problem of assessing VIPP

- Some VIPP present heavy deficits of prestressing due to corrosion or wires/strands failures
- These defects can not be detected by a visual inspection : no external signs …

- There is no NDT method to evaluate the global condition of prestressing tendons and the remaining load carrying capacity !…

- Then : How to assess those bridges ?

The Assessment Methodology

An assessment method in 5 steps

- Step 0 : Analysis of the bridge records
- Step 1: Detailed Inspection of the bridge

- Step 2: Investigation Level N1
- Step 3 : Investigation Level N2
- Step 4 : Investigation Level N3

1 - Analysis of the bridge record

Objective : preliminary analysis of the risk…

- General information :
  - Date of construction (before or after 1967…)
  - Design hypotheses (calculation rules, tension force, friction, relaxation, …)
- Construction information :
  - prestressing kit and type of steels
  - records on tension forces introduced
  - type of ducts and type of grout (mix used)
  - technique and period of grouting
  - incidents during construction
  - waterproofing membrane condition,…

2 – Detailed inspection

Objective : to pursue the preliminary analysis of the risk, especially the risk of corrosion of tendons…

- To detect the following disorders :
  - transversal cracks due to bending (vertical) or due to shearing force (inclined)
  - longitudinal cracks along the tendons in the webs or in the toes, with evidence of water circulating in the cracks
  - defects of anchorage sealings (long. and transv. tendons)
  - longitudinal or transversal cracks in the slab, with water passing through the slab at concrete joints…
  - vertical or inclined cracks in the crossbeams with water
  - abnormal longitudinal profile with one or more flexural cracks
  - corrosion stains on beam facings (especially in maritime environment

3 – Investigation level N1

Objective : to evaluate the quality of the grouting of the prestressing ducts…

- This evaluation is done by gammagraphy or radiography examinations which may detect :
  - the presence or the lack of grout
  - the conformity of the layout of the ducts (locations, crushed ducts, abnormal curvatures, …)
  - the possible presence of wire or strands failures (non systematic detection by these techniques…)
  - the conformity of the reinforcement.
- They do not allow to detect the presence of corrosion.

3 – Investigation level N1

- GPR may be used to evaluate the conformity of the layout of the ducts and reinforcement, but it does not allow in any way to evaluate the presence or the absence of grout in metal ducts. It is a way to locate the gamma or radiographic pictures.
- The impact-echo method makes it possible to detect large grouting defects in metal sheaths, without being able, in the current state of the technique, to detect small voids.
- **According to the importance of the lack of grout detected for a given percentage of ducts, the LCPC guide leads to either a normal surveillance or to go to the level N2.**

4 – Investigation level N2

Objective : to evaluate qualitatively the prestress by opening windows in order to inspect the condition of tendons…

- It allows :
  - to examine the type of corrosion : simple rust, pits of corrosion, craters, generalized corrosion, stress corrosion,…
  - to take samples of grout, water, ducts, wires, strands, rust, etc… for the purpose of laboratory analysis
  - to practise the test known as «of the flat screwdriver» in order to detect a possible diminution of tension in the wires or strands.

4 – Investigation level N2

- If the results are satisfactory (absence of corrosion, lack of wire failures and water in the ducts,…), one moves towards a normal surveillance.

- If the results show stress corrosion, or a corrosion generalized on at least 5 to 10 % of the prestress, or if the analysis of the materials shows risks of corrosion, then it is recommended to go to the level N3.

5 – Investigation level N3

Objective : to assess the residual load carrying capacity of the bridge by practising various testing methods on the prestress and on the structure, in order to permit a recalculation of the bridge

- **The various testing methods are :**
  - The measurement of the residual tension of the prestressing steels by the crossbow method; it provides an invaluable average tension for the recalculation
  - The evaluation of the local longitudinal stresses by the stress release method : this method allows to estimate the stress gradient… 3 to 4 slots are necessary to obtain the normal force existing in a cross section of a VIPP beam (be careful with the non-linearity of the stress diagram)
  - The curvaturemetry : this method allows to detect non-linearities of curvatures under bending moment indicating the beginning of a cracking not yet visible in the central zone of a beam.

5 – Investigation level N3

- The acoustic monitoring can also be used to survey a VIPP and to listen to the elementary wires or strands failures. If it does not provide directly useable results to assess a load carrying capacity, it however allows to confirm the existence of a prestress damage by corrosion and to follow it with time.

- The final evaluation is done on the basis of recalculation integrating the results of the investigations and in particular the estimates of prestress losses. This recalculation can be done by traditional methods and if necessary on the basis of a reliability approach which requires to know the probabilistic distribution laws of certain calculation parameters (not easy !…)

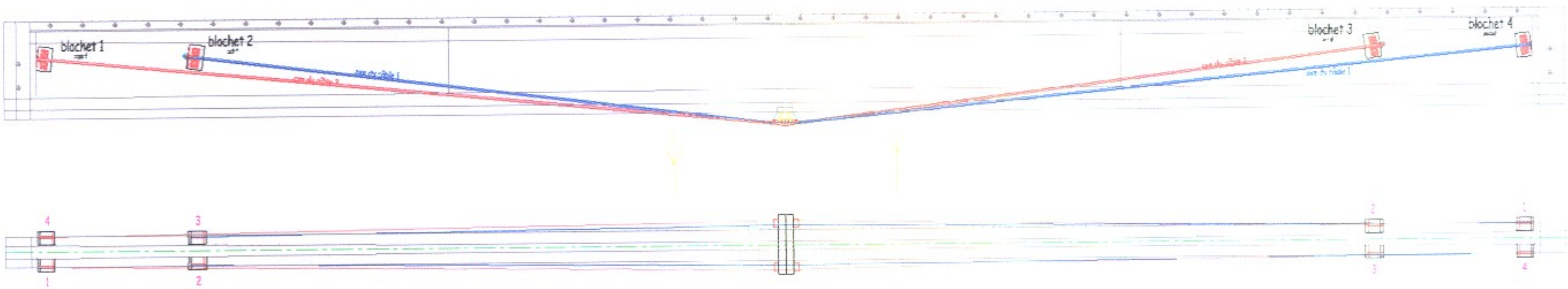
Finally…

According to the results of the recalculation and investigations of level N1, N2 and N3, various types of treatment are possible:

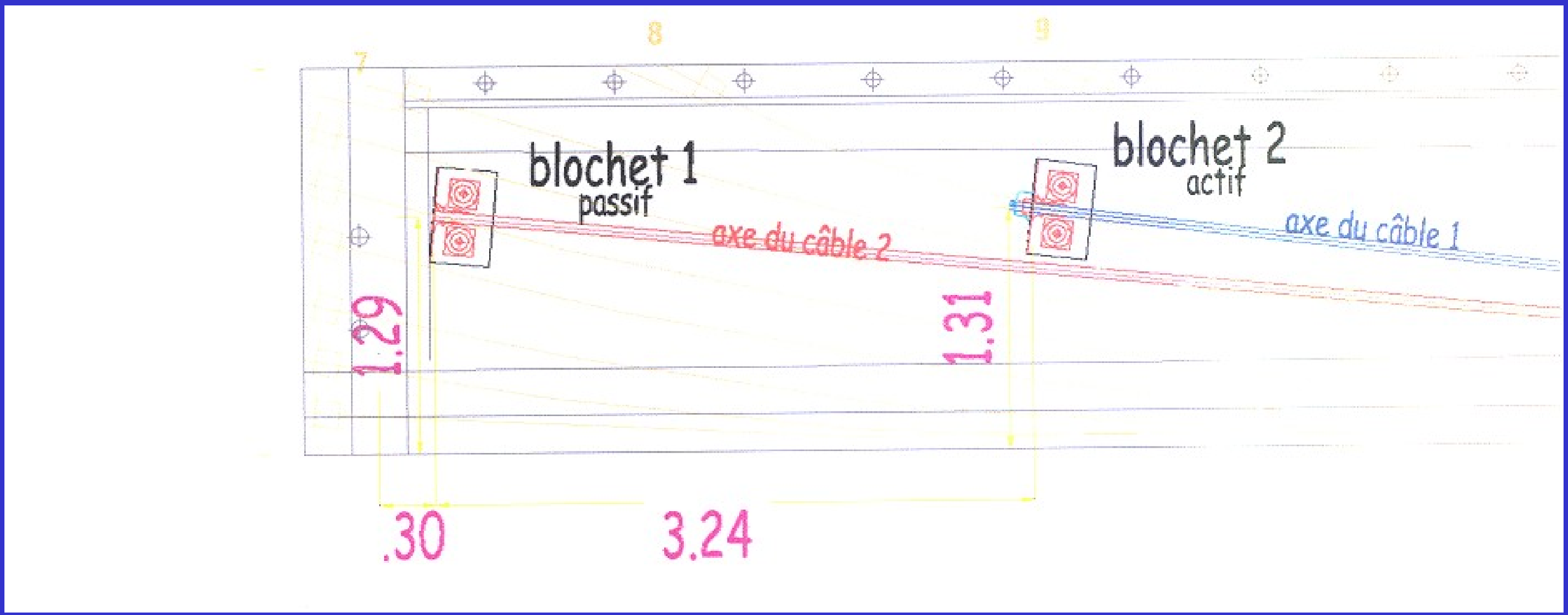
- a reinforcement by composites or by additional steels embedded in shotcrete, particularly for insufficiencies of shear capacity
- a strengthening by additional prestressing for insufficient resistance in bending and in shear close to the supports
- a reconstruction of the most damaged spans or beams
- an injection of grout in the empty ducts when that is possible (technique of the vacuum injection), or the injection of a corrosion inhibitor by powerful ultrasounds
- a repair of the waterproofing membrane, drainage, anchorage sealings, etc …

Example of strengthening of a VIPP by prestress

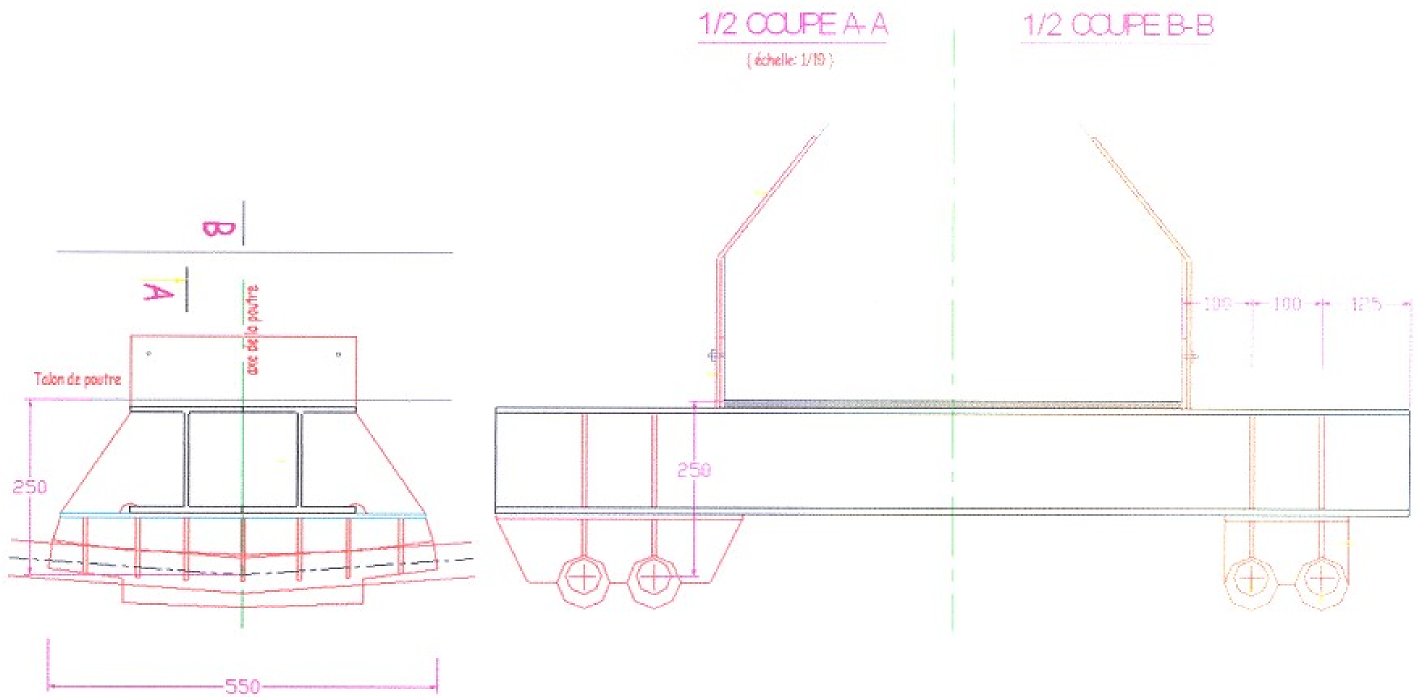
Example of strengthening by prestress



Dead and active anchorage…



Example of strengthening by prestress

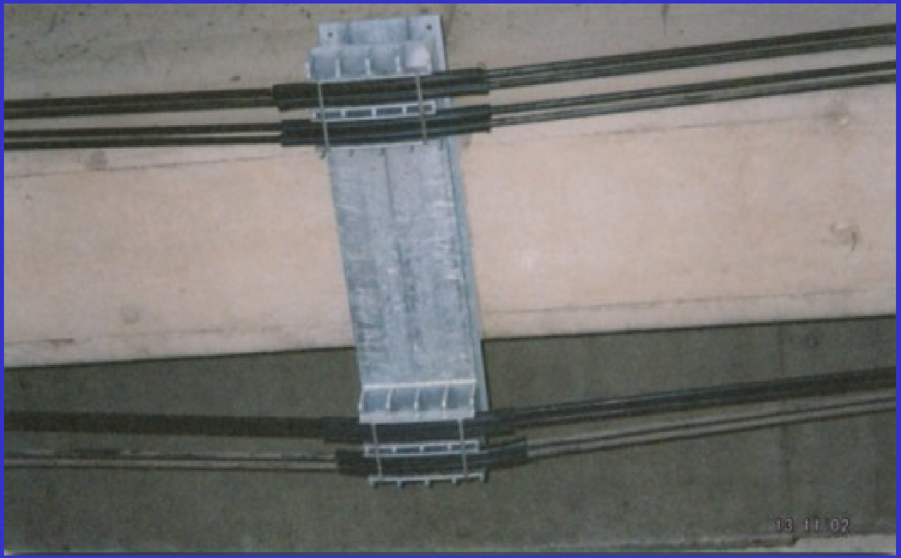


Deviator in the middle of the beam

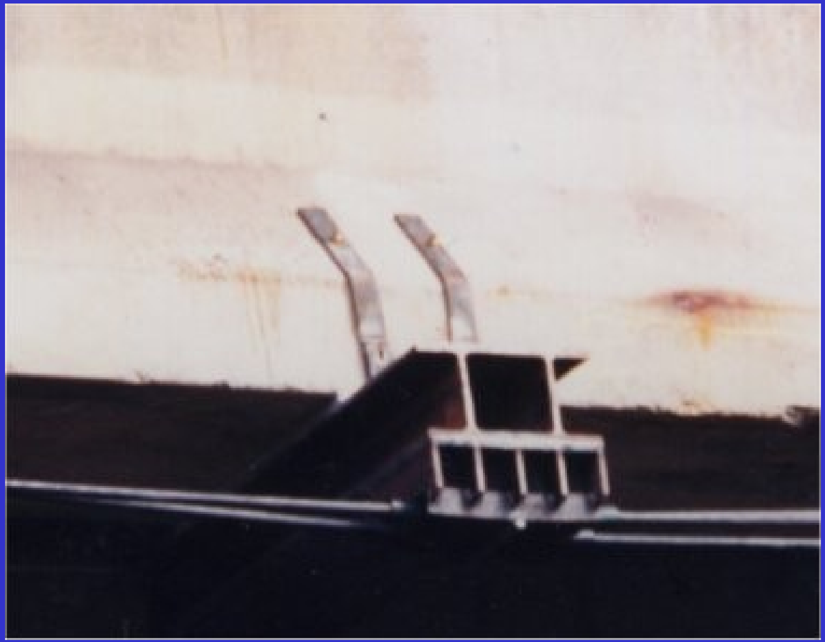
Anchorings blocks

Precast on site

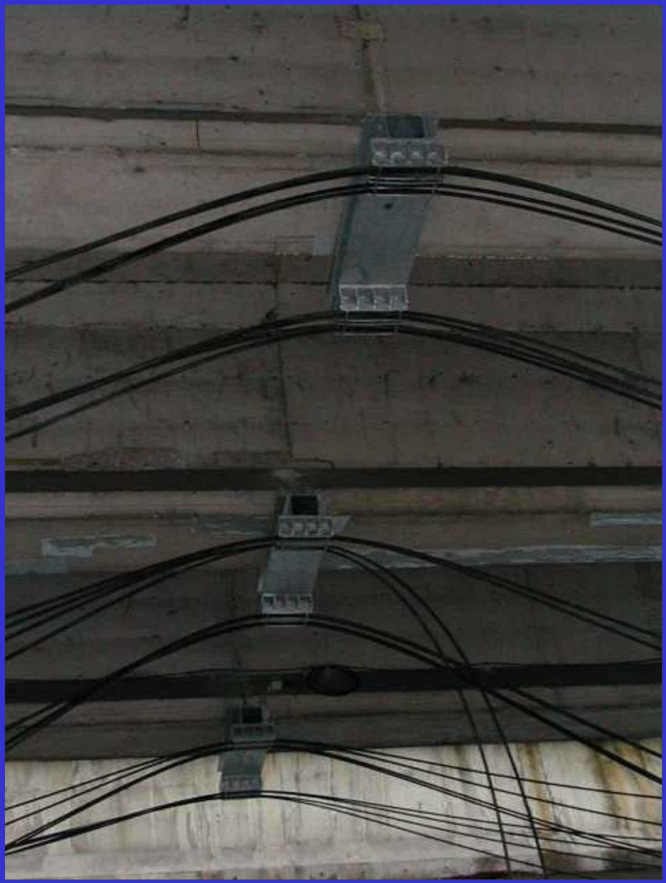
Steel
Deviators



Prefabricated
anchor blocks



Installation of tendons



Installation of tendons