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Monitoring, Maintenance and Replacement Policies for a Stock of 100'000 Structures

Surveillance, maintenance et remplacement d'un parc de 100'000 ouvrages d'art

Ueberwachung, Instandhaltung und Erneuerung eines Baubestandes von 100'000 Bauwerken

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SUMMARY

French National Railroads (SNCF) manage a stock of 100'000 structures whose design, age and operating conditions present high variability. This paper describes the various arrangements (monitoring rules, weighting methods and maintenance strategies) which ensure safety, and more generally, the reliability of structures, and their use, a number of them being more than hundred years of age.

RÉSUMÉ

La SNCF gère un parc de 100'000 ouvrages d'art, dont le type de structure, l'âge et les conditions d'exploitation sont extrêmement diversifiés. Cet article décrit les différentes dispositions (règles de surveillance, méthodes de cotation des ouvrages et stratégies de maintenance) qui lui permettent d'assurer la sécurité, ou plus généralement la fiabilité, de l'exploitation d'ouvrages dont beaucoup sont aujourd'hui plus que centenaires.

ZUSAMMENFASSUNG

Die SNCF verwaltet einen Baubestand von 100'000 Bauwerken, deren Strukturtyp, Alter und Betriebsverhältnisse sehr vielfältig sind. Dieser Artikel beschreibt die verschiedenen Bestimmungen (Ueberwachungsregeln, Verfahren für die Kotierung der Bauwerke, Instandhaltungstrategien), die ihr ermöglichen, die Sicherheit -oder allgemeiner die Zuverlässigkeit- des Betriebes von Bauwerken zu gewährleisten, die heutzutage in grosser Anzahl mehr als hundertjährig sind.

1. DESCRIPTION OF THE STOCK OF STRUCTURES HELD BY FRENCH RAILROADS

The French Railroads'stock of structures consist of 80 000 bridges, 1500 tunnels and 8 million m2 of walls and stone pitching. The replacement cost of this stock is estimated at FFr 180 bn. This stock also presents a high geographic dispersion.

Most of the structures are very old and very few of them have been subject to renewals. Some of them date back to the dawn of the railroads' construction and are more than 150 years old. 75 % of masoned structures are over 100 years old, 45 % of steel bridges over 80 years old and 65 % of tunnels exceed one hundred years of age.

From the safety point of view, the structures requiring the sharpest scrutiny are the older steel bridges, the rail bridges in water environment and tunnels.

As a result of increased operating speeds and loadings, far in excess of their early design specifications, the steel bridges built between 1860 and 1920 have entered an irreversible fatigue process, which calls for a sustained and proactive policy in terms of monitoring, maintenance and replacement.

Since the average age of foundations in water-environment is 115 years, it is necessary to conduct a tighter monitoring and a specific strengthening due to the degradation of their condition, to the sudden changes in their land environment (lower river beds, remodeled banks), or to the risks that could be incurred in the event of the displacement of a bridge foundation.

After the Vierzy rail accident in 1974, French National Railroads have implemented over the last twenty years an organisation which provides an in-depth appraisal of the actual condition of tunnels and enables to plan repairs whenever necessary. Their current condition is therefore satisfactory, both in terms of safety and durability.

The past experience on these three types of structure has shown that their service life could be extended not only on the basis of initial structural capacity reserves but also with the adjustment of their monitoring and maintenance conditions. Performance standards have been enhanced in the process. A number of methods successful developed for tunnels, such as the weighting method described later on, have been extended to all types of structure. New monitoring and maintenance policies have been implemented as a result of the recent changes affecting the actual condition of the structures. These methods will be presented in this article.

2. PRINCIPLES GOVERNING THE MONITORING OF STRUCTURES ON FRENCH RAILROADS

The safety management of rail structures is first and foremost based on the reliability of visual examinations and is therefore conditioned by the competence of human operators and notably structure inspectors who have this fundamental duty to accomplish. There does not exist any mechanised means measuring and characterising their condition, contrary to some other rail infrastructure components, such as the right-of-way.

Monitoring starts with the analysis of the initial or reference situation. Subsequently, all the sections of a structure will have to be inspected in-depth, as part of detailed five-year inspections. These inspections appraise all the deteriorations existing on the structure. However, there is still the possibility of a rapid change. Therefore, detailed inspections have to be supplemented by annual inspections focusing more particularly on critical areas.

Special inspections may be decided when environmental conditions are likely to jeopardize safety : steel structures which are vulnerable to thermal loads (such as puddled iron) and subject to special inspections during very cold winter periods. Foundations in river environment are also inspected to detect any local scour after major floods.

These inspections are supplemented by examinations on foot on a weekly basis or over short cycles to investigate the track performance and by lineside audits determining the quality of monitoring and maintenance over a certain territory under one civil engineering authority.

3. PRESENTATION OF THE WEIGHTING METHOD FOR STRUCTURES DEVELOPED BY FRENCH RAILROADS

The weighting system serves the purposes that are described hereunder :

3.1 Possessing a reliability indicator for structures and measuring the condition and changes affecting the various stocks (broken into categories or geographical perimeters).

The weighting system for structures to be introduced this year is aimed at providing a better and more immediate comparative assessment of the various French Railroads regional stocks as well as pathologies affecting those structures and the changes they are likely to undergo. It is therefore a predictive tool which assists in the setting-up of preventive maintenance policies.

Naturally, the weighting of a structure taken in isolation has no absolute meaning. It has only a relative value and relevance is achieved if it is placed into the context of a statistical base encompassing the whole population of structures.

The weigthing system does not come in lieu of continuous and periodic monitoring steps. It is only an add-on to give an overall and synthetic assessment of the condition of structures. The weighting system is not meant to detect immediate risks in terms of performance and safety, since this is part of the local civil engineering authority to monitor those. So, this weighting system has to be understood as a "reliability" indicator for structures -and a predictor of their failures and therefore of their ultimate safety- rather than a measurement tool for immediate safety.

3.2 Obtaining ultimately statistical models of wear and tear per type of structure

Economists claim rightly that to be able to choose between two repair scenarios on a structure (for instance choosing between "protracted therapy" or replacement), it is necessary to make long-term net present values calculations so as to achieve the economic optimum.

This theory is thwarted today by the lack of scientific knowledge of engineers on the fatigue modes affecting structures. This is due to their very slow rate of change compared to other industrial equipment which are less of a durable nature (i.e. rails).

At the end of the day, the weighting system for structures will materialize in the form of major statistical data banks on the evolution of pathologies per type of structure. Models on ageing will be constructed as a function of their evolutionary factors (traffic, environment). In return it will be possible to predict a potential evolution of structures and their probable condition in the future.

3.3 Steering the national and regional maintenance policies

The weighting system will provide multiple indicators which will greatly improve maintenance policies as shown in the two previous experiments (weighting system for tunnels after the Vierzy accident), and weighting system to classify major iron structures of UIC International Union of Railroads) (groups 1 to 6).

It will be possible to justify more accurately the funding scenarios proposed for the maintenance and regeneration of structures.

As an illustration of financial targets :
- replacement every 10 years of all steel structures showing a weighting in excess of 60 points, which would mean a fatal fatigue failure in the next 10 years ;
- preventive treatment every 5 years on all masonry disjointings with a mark for disjointing in excess of 70.

From such objectives, it will be possible to establish the annual financial flows to be devoted to the various categories of structures thanks to the marks which will exceed the maximum threshold prescribed for a given pathology.

The assessment of average repair costs will be treatable statistically : from a homogeneous sample of structures of the same type and with the same mark, it will be possible to set simple economic rules applicable to a large family of comparable structures.

The weighting of a structure includes four chapters :

Chapter A - Condition of the structure
Chapter B - Evolutionary factors
Chapter C - Effects of this condition on operation and maintenance,
Chapter D - Strategic policy to be adopted on the structure.

The weighting of A and B is conducted as part of a detailed inspection by the inspector in charge (there are two types of inspectors : non-specialist and specialist inspectors, the latter handling special techniques.

Chapter A is a physical description of the pathologies affecting a structure. It includes a record of duly referenced failure codes. Each part of the structure is analysed and recorded : homogeneous segments or spans can be put together. The chapter A form is completed during detailed inspections which means that it is a five-year photograph of the condition of the structure.

Chapter B is a record (which is not evolving much from one inspection to the next) of the factors governing the evolution of the various pathologies.

It is from chapter A that it is possible to know the condition and therefore the reliability of the various stocks in French Railroads, at the regional or local level, and to monitor the evolution of their condition every five years so as to possess ultimately statistical models on wear and tear per type of structure (identification of cases where deterioration thresholds are exceeded).

With chapter A and B, the purpose is to predict the future over a ten-year horizon without any repair on the structure and therefore to predict the aggravation of defects over time.

The record on the consequences of the condition over operation and maintenance (Chapter C) is a quality indicator to be monitored in real time as opposed to the condition weighting which only takes place every five years. It records the safety steps taken such as strengthened monitoring, operating restrictions, track repair or temporary reinforcement which all reflect insufficient monitoring or maintenance.

The strategic policy (chapter D) is determined for each structure. Chapter D provides a strategic repair criterion irrespective of the condition of this structure. It depends on the tracks which are intersected or supported and on the repercussions for third parties and the environment.

Assessments contained in chapter B, C and D are special selection criteria between structures having the same condition mark. B, C and D can be used concurrently with other (mainly financial) criteria, so as to prioritize repairs.

Details concerning the determination method for the condition mark A :

A tunnel, a wall, a stone pitching can be broken down into segments with a homogeneous condition.

A bridge can be broken down into elementary parts (mechanically speaking) : foundations, bearings, deck, arch, membrane,...

As for the whole structure, the parts or segments receive a mark over 100 (maximum mark). For each part of the structure, Ci coefficients are introduced so as to be able to reconstitute the total mark for the whole structure from the individual marks allocated to each part.

The weighting formula adopted is the following :
N = sum (Ci x sum (Nij),
where Ci is the coefficient of the structure related to part i and Nij is the condition mark reflecting damage j of part i.

For bridges, the structural coefficient are 0.9 for deck and 0.1 for bearings and, for foundations in water environment, 0.5 for foundations and 0.5 for the superstructure.

There are two ways to query from the system :

- the first way is to outline the most serious defects requiring an immediate repair : in that case, the question is on those cases where the predetermined severity threshold for each basic pathology are exceeded ;

- the second one is to identify the general condition of a structure or part of structure in order to assess economic requirements. In that case, the question is on most cases where a certain mark on the condition of the structure or part of the structure are exceeded.

4. DEVELOPMENT OF MAINTENANCE STRATEGIES

To define the financial flows required for maintenance and renewal of structures, three methods have been selected for cross-examination purposes :

4.1 Method using the weighting of structures : case of steel structures

SNCF has surveyed in 1993 the steel structures in excess of 30 meters over high density lines and constructed before 1900. A hundred structures have been identified by a team of specialists and have received a mark on a very detailed grade, validated over a few examples. The marks were given between 40 and 280. The most critical decks (mark in excess of 120) must be exchanged within 15 years, so as not to be safety critical. This experimental approach has been extrapolated to the whole population of older structures. It was possible to predict that 130 000 tons of steel will have to be replaced by 2010 ; this amount corresponds to a total budget of 5300 MF.

4.2 Using next repair periods : example of foundations

The average age of the 480 foundations in water environment was 124 years at the time they were treated (some of them have been treated under an emergency). Knowing the age of foundations and the average repair cost per foundation (1.6 MF per bearing), it is possible to quantify an annual financial flow of 150 MF until 2010 to be able to put in place a true preventive policy in lieu of the emergency exchanges (the average age for foundations to be treated should be around 130 years so as not to be safety critical).

4.3 The use of global management ratios

The use of global ratios of the OECD type is not the most reliable method since the level of ratios recommended depends on the actual design and condition of structures. However, comparing the results of this method with the existing ones has enabled SNCF to make sure that the expenses predicted for maintenance and regeneration of structures were correct.

SNCF has a backlog of work to catch up to ensure the durability of its stock of structures, and more particularly its steel structures and foundations in water environment. French Railroads should spread evenly their operating costs and investments so as not to penalize the accounts of the company or its train operations. Such penalties would be unacceptable for the company.

Therefore, an average financial flow of about 0.5 % of the value as new of its stock over 15 years (0.7 % for bridges, 3.5 % for steel bridges, and 0.2 % for tunnels), excluding all the ancillary costs related to signalling and protection work (speed restrictions and train diversions) (i.e. the sole civil engineering cost).

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