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EXPERIMENTATION OF A BRIDGE WIM SYSTEM IN FRANCE AND POTENTIAL APPLICATIONS FOR BRIDGE MONITORING AND OVERLOAD DETECTION



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Abstract

B-WIM is experimented in France for 15 years now, and several publications have been written about this. But generally no real attention is given to the element »bridge«, that is what we try to do here. Indeed, this paper gives some elements about the issues and the structures to be chosen to carry out B-WIM tests. It also highlights the importance of the position of the sensors and the whole instrumentation system to obtain accurate results. To do this, it summarizes several B-WIM tests carried out in France by IFSTTAR (former LCPC) on reinforced concrete bridges and metal bridges. The issue of their structural behavior is addressed. Then, bridge builders and managers explain their interests in B-WIM, by reviewing the type of usual bridges in France and their health. A way to maintain their level of service needs to be found.

Keywords: B-WIM, reinforced concrete bridges, metal bridges, orthotropic deck, trucks.

Résumé

Le pesage par pont instrumenté est testé en France depuis 15 ans, and plusieurs communications ont été écrites à ce sujet. Mais généralement, peu d'attention est accordée à l'élément « pont », ce que nous essayons de faire ici. En effet, cet article donne quelques éléments sur les sur les problématiques et les structures qui doivent être étudiées pour réaliser des tests de pesage par pont instrumenté. Il met ainsi en valeur l'importance de la position des capteurs et de tout le système d'instrumentation pour obtenir des résultats corrects. Pour faire ceci, nous allons décrire quelques tests de B-WIM réalisés en France par IFSTTAR (précédemment appelé LCPC) sur des ponts béton armé et des ponts métalliques. L'importance de la connaissance de leur comportement structurel est abordée. Ensuite, nous donnons la parole à des constructeurs et des gestionnaires d'ouvrages d'art qui nous expliquent leur intérêt pour le B-WIM, vu la qualité actuelle des infrastructures du réseau français. En effet, une manière de les maintenir en état de service doit être trouvée.

Mots-clés: Pesage par pont instrumenté, pont béton armé, pont métallique, dalle orthotrope, poids lourds.

1. Introduction

In France, engineers do have a quite good knowledge of the structural health of the bridges: Indeed, since 1195, the procedure called “IQA”, which is the short form of “Image Qualité des Ouvrages d’Art” (this means “image of the quality of the structures”) is mandatory in order to assess the health of the structures of the national road system owned by the French government [F. Thierry2010]. Each year, this procedure is applied to one third of all bridges, so theoretically all bridges should be inspected in 3 years, and each two years a general report on the structural health of state-owned bridges is published.

For example, in 2010 the number of inspected bridges was 11930, with a total deck surface of 55657494 m². Between one quarter and one third of the total surface (1477 structures) is located in the Parisian region.

Most of these bridges are reinforced concrete bridges (5771 out of a total of 11930, with a surface of 1549629m²). The second most represented sort of bridges is the prestressed bridges: their number is about 2218, with a surface equal to 2634104m². This is quite ordinary, since the prestressed technology is generally reserved to long span bridges, which are quite rare.

We did not realize B-WIM tests on prestressed concrete bridges because their spans are long with not so short influence lines, which means that multiple presence events would be difficult, or even impossible, to manage. But we did realize several experimentations on reinforced concrete bridges, especially rigid frame bridge (frames and bents). In France, there are 2550 frame bridges (440000m²) and 1754 bents (604000m²), which explains why they are of special interest for us.

The quality of the inspected bridges is classified in 5 classes: the bridges in class 1 are bridges in good visible health, needing only routine maintenance. Class 2 corresponds to bridges in good visible structural health but with equipments or protection elements with defaults or bridges with small defaults needing a specialized treatment without urgency. Class 2E corresponds to the same kind of bridges as class 2, but needing an urgent treatment. Class 3 corresponds to bridges with structural defaults and needing non-urgent repairing. Class 3 U is the worst class and regroups bridges whose structure presents important defaults and which need urgent repair works. IN 2010, most bridges were listed in class 2, see Table 1.

Table 1: Assessed health of French bridges (see [F. Thierry2010])

Class	1	2	2E	3	3U	Non assessed
Percentage	11%	47.4%	22.5%	5%	1.1%	13%

Generally, the defaults do not concern the equipments, but are localized on the bearings or the structure.

This assessment demonstrates the need for preserving these structures, by monitoring the loads applied to them and their behavior. Of course, in this paper, we are interested in the loads due to traffic.

For 15 years now, IFSTTAR (former LCPC) experiments bridge Weigh-in-motion on different kinds of bridges, by buying and using a SiWIM system of the Slovenian company CESTELS. This paper has the purpose to make a short summary of these experiments and to give voice to other participants of the civil engineering domain: Claude Servant, technical director of the construction company Eiffage who contributed to the building of the viaduct de Millau, and Yves Marchadour who has been for several years the responsible for traffic and their impact on bridges at the French Ministry for Transportation.

So we begin first by a technical summary of these experiments, then we share the points of view of bridge builders and transportation managers.

2. Different kind of bridges and installations

This second chapter summarizes the main experimentations of B-WIM carried out in France by the IFSTTAR, for more information see [Mohamed Bouteldja2003]. These can be divided in two sorts depending on the sort of bridge: reinforced concrete bridges and metal bridges.

2.1 Concrete bridges

Frame bridges

The institute investigated B-WIM on several frame bridges, where the most known ones are the experiments on the national roads RN19 and RN4.

The RN19 (which should now be called RD19, since several parts of this road have been given up by the state and given to the departments) goes from Paris to the Swiss border and is 170km long. The heavy traffic is about 1500 trucks/day. The studied structure is near the city Nogent-sur-Seine (kilometer 102) and carries 2 lanes, one in each direction. It is a standard frame bridge, with a span of 10 m (the width is about 11m), see Figure 1 with a photograph of this bridge and the position of the sensors. The thickness of the deck is 60 cm, which is ideal for measuring correctly the deformations.

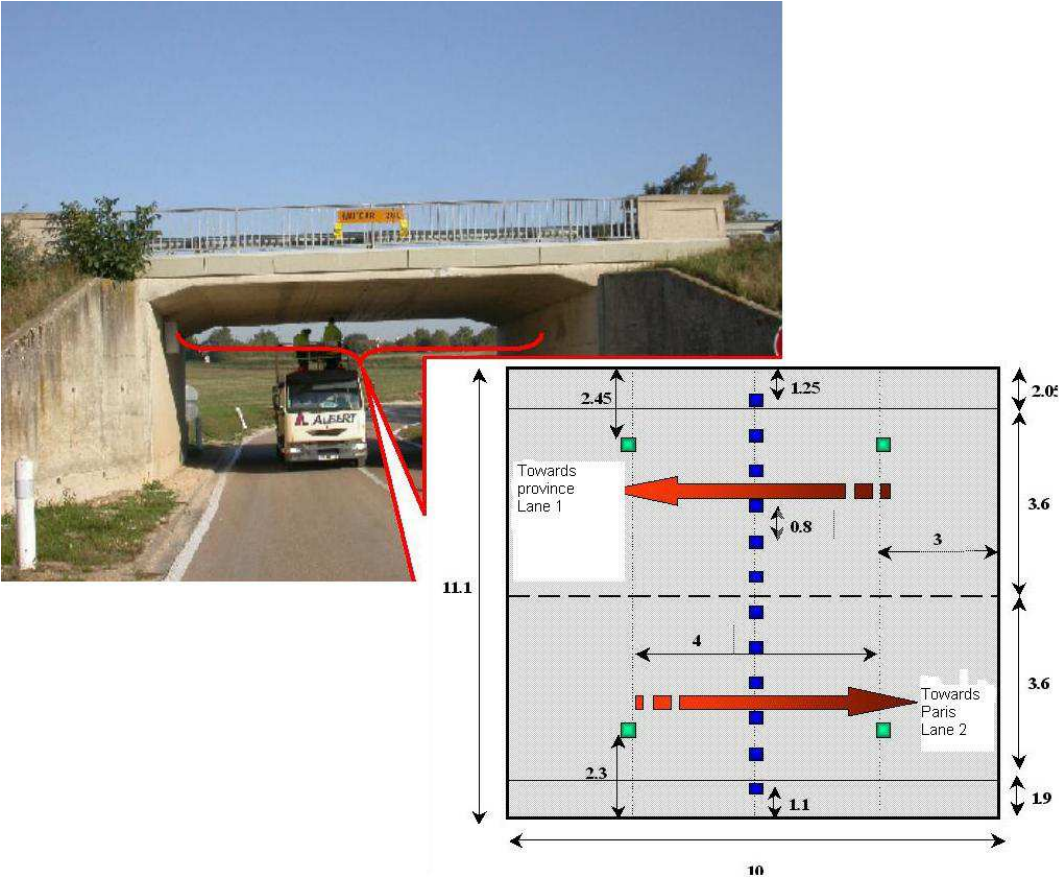


Figure 1: Frame bridge near Nogent sur Seine, and instrumentation used for the B-WIM.

The events of multiple presences had to be removed manually, and then the results are quite acceptable, see Table 2. We observe a better result in lane 1 than in lane 2. This could be explained by bump being on the surface of the pavement of lane 2.

Table 2: B-WIM results on the frame type bridge of Nogent sur Seine, the classes are calculated following [(chairman)1998].

Lane 1	GVW	B(10)	B(10)
	Axle groups	B+(7)	
	Single axles	B(10)	
	Axles in groups	B+(7)	
Lane 2	GVW	C(15)	C(15)
	Axle groups	B(10)	
	Single axles	B(10)	
	Axles in groups	B(10)	

The position of the sensors is explained by the diagram of moment of this kind of structure, see Figure2. Indeed, the maximum of deformation will be observed at mid-span. There is a need to avoid a node and the best results would be obtained near an antinode, see [Ieng2011]. Some other frame bridges have been tested for the use of B-WIm, especillay one bridge on the national road RN4, near Rozay en Brie. Here again, the accuracy of the system has been C(15), which is not sufficient for automatic detection. In this case n the reason for these quite poor results is the design of the bridge: it is skewed. This highlights one again the importance of the position of the sensors, related to the structure and its behavior.

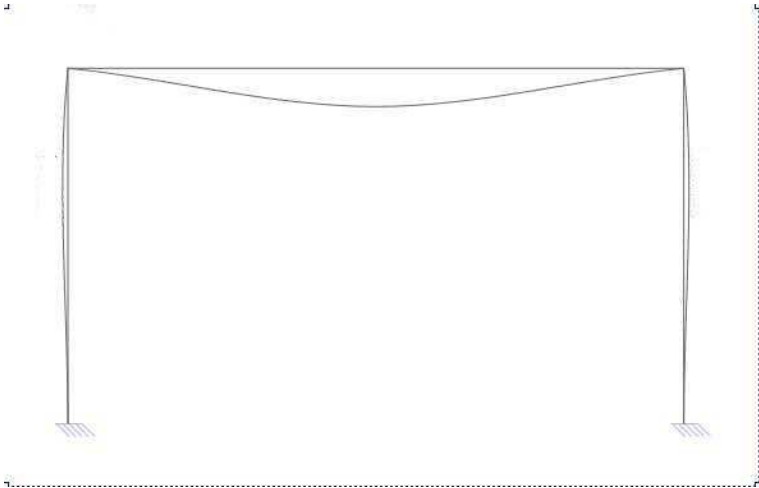
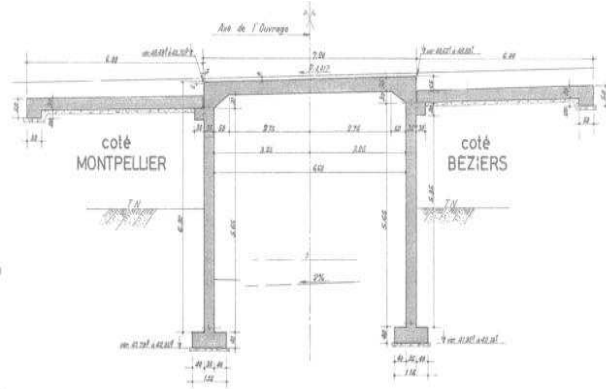


Figure 2: Diagram of moents for a frame type bridge. The bearings are fixed.

Bent bridges

Bents in reinforced concrete are very frequent bridges on French roads. A simple bent is composed of a bridge sleeper fixed on the abutments, which lie on a spread footing or deep foundations. So, contrary to frames, bents are hyperstatic structures, with various degrees from 1 to 3, depending on the way the structure is linked to the foundation and the soil.

We experimented B-WIM on a bent bridge on the highway A9, near Montpellier, see Figure 3. It is a bent with hinges at the bearings. The behavior is then very similar to that of frame bridges, like represented in Figure 2. The rotation at the bearings is more important.



(b)

Figure 3: Bent bridge used for B-WIM experiments near Montpellier. (a) Photograph of the bridge, (b) Sketch of the structure.

This bridge and its dynamic behavior has been studied extensively by UCD. We just studied the accuracy of B-WIM on this bridge. The results are given in Table 3, the class obtained is D+(20). Here the reasons for these poor reasons could be more simple: indeed, there is suspicion that there have been bad links done between B-WIM signals and the corresponding static weight.

Table 3: B-WIM results on the bent type bridge on the highway A9, near Montpellier

	Number	Mean	Standard deviation	Class	General class
GVW	94	94	2.61	C(15)	D+(20)
Axle groups	91	3.77	9.59	D+(20)	
Single axles	188	1.21	6.74	B(10)	
Axles of groups	273	4.06	12.26	D+(20)	

To finish this paragraph on reinforced concrete bridges (frame and bent), there is a need to underline the fact that this type of bridge is really convenient for B-WIM: indeed, there is a great number of these structures on French roads, their behavior is easy to understand, it is generally easy to access to the underside of the deck, multiple presences are infrequent.

But, for a bridge and structure engineer, these structures are not the most interesting ones, that is why we experimented B-WIM on some long-span metal bridges.

2.2 Steel bridges

The first metal bridge to be instrumented with the SiWIM system was the Autreville bridge on the highway A31. It is a metal bridge with an orthotropic deck, see Figure 4. In this case, we had some problems to install the sensors: indeed, the system generally distributed by CESTELS uses sensors adapted to concrete bridges, but not metal bridges. A new way to fix the sensors on the underside of the metallic deck had to be found, with the help of CESTELS. But this experimentation made it possible for us to recognize the suitability of these bridges for B-WIM.

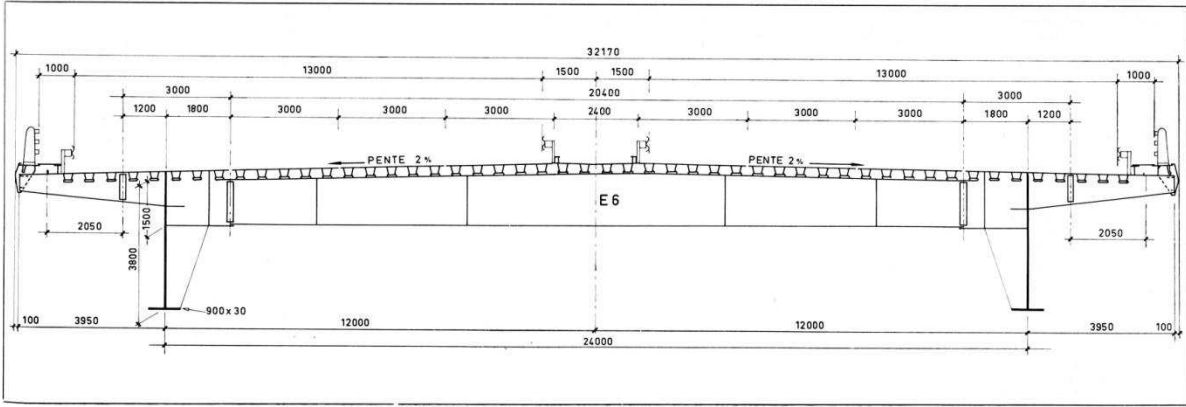


Figure 4: Sketch of the deck of the Autreville bridge.

Indeed, these bridges have short influence lines, because of the transverse stiffeners (all 7-8 meters), which means that multiple presences are no real issue. Moreover, the particular transverse design of these bridges makes it possible to detect the lateral position of the wheels. But one »drawback« would be that these structures need a more sophisticated algorithm to weigh correctly through B-WIM, see [Jacob2012] or [Zhou2012].

So, several B-Wim tests were carried out on the viaduct of Millau, see Figures 5, in 2009 and 2010. The viaduct is a bridge with guying, which is 2460 meters long. It goes over the valley of the Tarn, with height of 270m over the level of the river. Its decks is 32 meters large, and carries a highway of twice two lanes (so two lanes in each direction) and an espace lane in each direction. There are 7 piers, whose heights are between 77m and 245m and which are extended by pylons with a height of 87m and 11 pairs of stays.



Figure 5: (a) Picture of the viaduct of Millau, with its 7 piers and pylon. The pier number 2, is the highest in the world with 245m. (b) Picture of the inside of the caisson with two extensometers used in the case of B-WIM adapted to metal bridges.

The decks is a caisson, and each wall of this caisson is orthotropic. Two types of steel have been used for this deck: S355 for the slab of the lateral caissons and S460 for the caissons linking the piers, the decks and the pylons and the slab of the central caissons. The general design of the caissons and the dimensions are given in Figure 6.

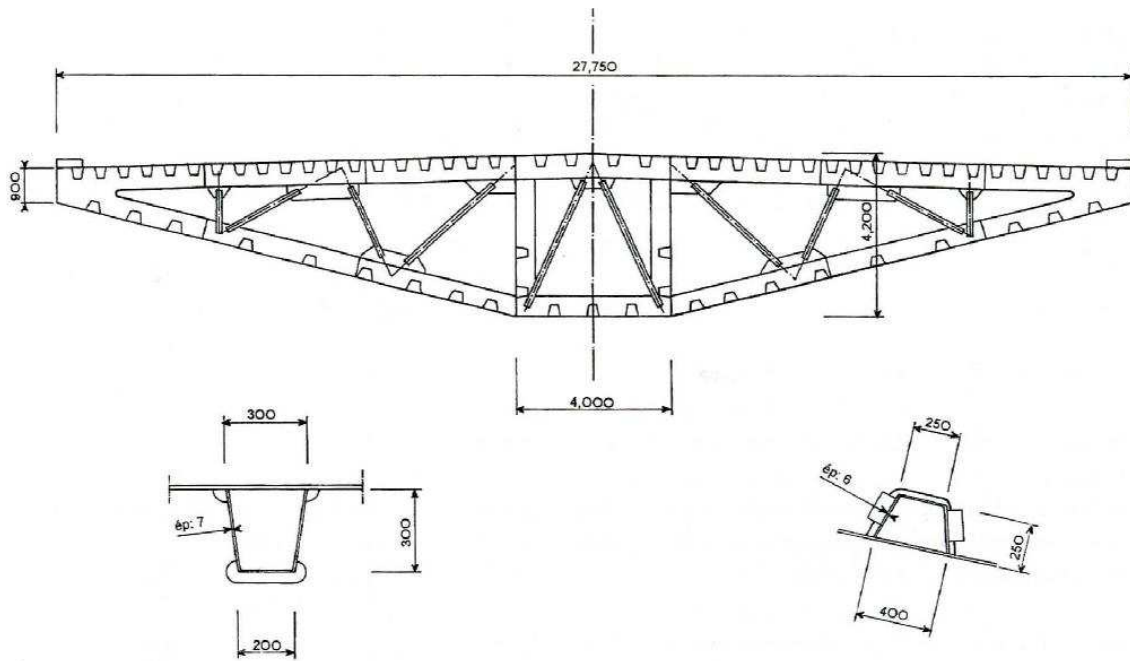


Figure 6: General design of the deck of the viaduct of Millau.

Some results of these tests are given in Table 4, or [Romboni2011]. Two reasons for these poor results can be found: the first one is that there are numerous tanks driving on this bridge and these vehicles are well known to be badly weighted by B-Wim (because of the movement of the fluids). The second reason is that this kind of structures needs adapted algorithms to treat the signals [Jacob2012], algorithms which are different from those incorporated in the SiWIM system.

Table 4: Some results obtained while testing B-WIM on the viaduct de Millau.

	Mean	Standard deviation	Class
GVW	-2.36	6.67	D(25)
Single axles	1.14	7.91	

This first (long) part is aimed to highlight the importance of the structure in the B-WIM system. In the next part, we explain why, as a contributor in the management of infrastructure in France, we are interested in B-WIM.

3. Point of view of an infrastructure manager

The French infrastructure network is ageing: indeed, numerous structures were built quickly after the destructions of World War 2. These are not of critic age.

Indeed, the structures built after 1995 are in good shape: if we use again the classification explained in the introduction, quite no structure is in class 3U. Most of them are in class 2. For each period of construction, the general health is known, see Table 5.

Table 5: Classification of the structures according to their period of construction

Class	<1850	1850-1900	1901-1950	1951-1975	1976-1995	>1995
1	6.6%	6.3%	7.8%	4.7%	10.3%	24.6%
2	69%	73.2%	62.8%	66.4%	73.8%	63.7%

3	11.6%	7.3%	10.8%	8.3%	3.4%	1.3%
3U	3.5%	3.4%	3.1%	1.8%	0.5%	0.1%

With decreasing public funding, these structures need to be maintained, and so the ereparation prioritised. To do that correctly, realistic information about the sollicitations (traffic in this case) and the behavior of the structure is needed. B-WIM is able to provide all this as it calculates the weights and dimensions of the trucks passing over the system and it records the strains in the structure. Thus, we have access to the real sollicitations and the real strains, which makes it possible with reliability and probabilistic methods to calculate probabilities of failure and prioritize the intervention of the public person (reparation, law on the weight and dimensions of the trucks, specific regulations on some structures or some roads...).

4. Conclusion

In this short summary paper, we wanted to recall the experiments of B-WIM done in France and their physical and structural explanations. We wanted also to introduce the works done on these structures newly used in B-WIM which are the structures non constant transversely like the orthotropic decks. These works are presented in two other communications oat these conferences [Jacob2012] and [Zhou2012].

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