THE BRIDGE MANAGEMENT OF A TOLL MOTORWAY NETWORK RESULTS OF CURRENT DEVELOPMENTS AND IMPLEMENTATIONS

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SUMMARY

Abertis-Autopistas-España operates a highway network that is nearly 1500 km long. A "new generation" Bridge Management System centrally based and operated is being used for the management of the 3427 bridges of the road network.

This paper presents some results of the implementation of the system, mainly concerning most frequent damages observed on the inspected bridges depending on the type and location of each bridge, the degree of inspection and maintenance and the amount traffic.

The Bridge Management System implemented by Abertis-Autopistas-España is able to make an estimation of the expected cost for repairing the damages reported by the Principal Inspections considering the main properties of the observed damages, their location and the access of the damaged elements. Additionally, a priority ranking can be calculated. This paper also includes the results of the implementation of these criteria to the mentioned 3427 bridges and the improvements that Abertis-Autopistas-España has got when using the Bridge Management System.

As a result of the implementation of the system, some relevant damages produced mainly because of the usage of chlorides in winter time on certain bridges were found. Finally, some of the proposed rehabilitation works made for correcting the said problems are also presented on this paper.

1.- THE BRIDGES MANAGED BY ABERTIS AUTOPISTAS ESPAÑA

Abertis-Autopistas-España is responsible of a toll highway network 1527 km long, equivalent to the 59% of the total length of toll motorways in Spain; 3427 bridges can be found on the said motorways, being the average distance from one bridge to the next equal to 450 m, approximately. Most of the said motorways were built from 1970 to 1990. The construction value of abovementioned bridges is nearly 1200 million euros (equivalent to 1,6 billion USD)

Abertis Autopistas España owns some shares of some others toll motorways, including the new toll motorways near Madrid, that are managing some 229 km of toll roads

From the total 3427 structures which are more than 2.0 m span, 977 are bridges or viaducts, 880 are overpasses, 1552 are underpasses and the 18 that are left are pedestrian bridges crossing over the motorway.

Figure 1 – Toll motorway network managed by Abertis Autopistas España

A summary of the main characteristics of the structures (length, width, area of the deck) grouped depending on the typology (bridges or viaducts, overpasses, underpasses, pedestrian bridges) is presented in the following table.

Nearly all of the analyzed structures are concrete structures, except 14 of them that are composite bridges (hybrid concrete and structural steel); 7 of them are pedestrian bridges and the other 7 are overpasses. There are only 16 drainage underpasses that are circular hollow sections made of corrugated steel.

Table 1 – Main characteristics of the structures

TIPO DE OBRA	Total			Dimensiones medias		
	Número (m)	Longitud (m)	Superficie (m^2)	Longitud media (m)	Anchura media (m)	Superficie media (m^2)
Puentes y Viaductos	977	91 863	1 317 400	94.0	14.3	1 348.4
Pasos superiores	880	57 812	534 817	65.7	9.3	607.7
Pasos inferiores	1 552	78 386	463 759	50.5	5.9	298.8
Pasarelas	18	443	1 680	24.6	3.8	93.3
TOTAL	**3 427**	**228 504**	**2 317 656**	**66.7**	**10.1**	**676.3**

2.- THE BRIDGE MANAGEMENT SYSTEM

From 2008 to 2009 a “Bridge Management System” was implemented by Abertis Autopistas-España in order to efficiently operate the maintenance of the said structures. The following tasks were made on the said years, concerning the implementation of the system:

- Creation of a data base where all the data of all the structures will be stored.
- Creation of the required software for accessing the said database.
- Creation of an inventory to be stored in the database, including the main geometry of the structures. The drawings and some general photographs of the structures will also be included.
- Definition of the criteria for inspecting and evaluating the condition of the bridges based on visual inspections named “Principal Inspections” where no special

equipment is needed (movable scaffoldings, cranes, boats…) for making a detailed observation of all the elements of the bridge.
- Execution of the Principal Inspections of the 3427 bridges included into the database. Loading the results of the said inspections, including the photographs of the most significant observed damages.

The results of the inspections demonstrated that there were 89 bridges (3% of the total number, approximately) with some significant damages or that they need special inspection or some repairing works. In 2010 the required “Special Inspections” were made and the expertise engineers in charge of the said inspections proposed, in case it was necessary, some repairing works to rehabilitate the damaged bridges.

Additionally, the results of the Principal Inspections demonstrated that there were some elements of 101 bridges that could not be properly inspected because there were in a extremely powerful water flow, because there was no access to the bridge or because the height of some elements was so huge that it was not possible to be observed. On 2010 the Principal Inspection of all these bridges was completed using some special equipment.

Following there is a summary of the main inspection works and analysis made under the implementation of the system:

- 3.427 inspections of bridges
- 442 inspections of water flows
- 101 inspections using special equipments
- 103 special inspections
- 573 viaducts were inspected; the piers of 73 of them were taller than 20 m.
- The total length of the inspected decks was 228,5 km, equivalent to 2.500.000 m^2
- Average number of bridges per km of road = 2,7 structure/km
- 14.700 drawings stored into the database
- Size of the database = 70 Gb
- 10.900 photographs and 72.000 registers stored into the database.

A very expertise engineers were in charge of the implementation of the system, of the creation of the inventory and of the execution of the principal and special inspections. The delay for the execution of all these works was nearly 3 years. The total cost for making all the said tasks was, approximately, equal to 650- 700 euros per structure (equivalent to some 900-950 USD/bridge)

3.- PRINCIPAL INSPECTIONS

3.1.- Efficiency of the inspections

8 inspection teams, plus 2 other extra teams, were used for making the principal inspections of the 3427 bridges. Each team was integrated by one civil engineer and one technician. From August 2008 to April 2009 the 8 teams made the principal inspections, making 4 inspections per day.

Additionally 450 water flows were also inspected in order to evaluate the scour conditions of the substructures of the bridges that were crossing some rivers or water flows.

3.2.- Some results of the principal inspections

Following a summary of the main results of the principal inspections are presented:

- There was no structure having indications of having a lack of the load capacity due to some damages on the structural elements.
- The 44% of all the structures have some cracks on structural elements, but the size of the cracks was usually small (< 0,5 mm), and so the bearing capacity was not affected.
- There were less than the 20% of all the structures having cracks due to corrosion; this is because the concrete use to be very compacted and the weather atmosphere was not very aggressive.

Figure 2 – Some crack son piers, decks and front walls

- There were settlements of the foundation, tilting of some walls or other damages due to scour problems on 23 structures.

Figure 3 – Scour effect on the foundation of a pier

- There were 10000 m² of spalling on the concrete and some 26000 m² of reinforcing without cover and showing some indications of corrosion, but with no indications of structural affection.

Figure 4 – Loss of the cover and corroded reinforcing. Spalling of the concrete.

- There were some damages on the bearings of 263 bridges, that is nearly the 8% of the total structures.

Figure 5 – Blocked bearings o out of place

- The expansion joints of nearly 350 bridges, the 18% of all the bridges, were damaged.

Figure 6 – Damaged expansion joint . Non existing expansion joint

- The guardrails or the barriers of some 1300 structures were damaged, although nearly all of them will be repaired by the personnel in charge of the daily maintenance of the road.


Figure 7 – Damages on steel guardrails and barriers

3.3.- Priority ranking

The implemented software is sable to make a priority ranking of all the inspected structures considering the main properties of the observed damages but also considering the importance of the element (both from the resistant and from the serviceability point of view), the amount of traffic and the importance of the bridge

Using all the said parameters a mar was calculated to evaluate the actual condition of the bridge. Once a certain level of acceptance has been defined, the repairing works and the financing planning were defined. Considering the structural affection of the observed damages the results of the evaluation were as follows:

- 3320 structures (~97%) were under the level of acceptance. That means that the condition of these bridges is OK and so, they will be inspected again in 3-5 years.
- Nearly 100 structures (~3%) were around the level of acceptance- That means that the damages causing these conditions must be repaired or must be monitored to know how the damages are increasing.
- Only 11 structures (< 0.5%) were over the level of acceptance. In those cases it is necessary to make a detailed study of the observed damages and, in some cases, some repairing works are to be done.
- No bridge was required to be repaired urgently.

3.4.- Cost estimation of the repairing works

The sofware included into the Bridge Management System is also able to estimate the cost of the required repairing works to be done on a list of bridges that meets certain conditions. The cost estimation is made taking into account the results of the principal inspections. Considering different scenarios, the results of the said cost estimations were as follows:

- The cost for repairing the damages observed on the 111 bridges that were around or over the level of acceptance was some 2.2 million euros (equivalent to some 3 million USD). The resulting unit cost was 19400 euros/bridge (26500 USD/bridge, approximately). This estimated cost is around the 0.2% of the construction cost of all the bridges of the toll motorway network.
- There are 1315 bridges to be repaired, in case all the “moderate degree” damages are to be repaired. The estimated cost for repairing all these damages would be some 21.7 million euros (29.5 million USD, approximately), being the unit cost 16500 euros/bridge (22400 USD/bridge, approximately). The said total amount is equivalent to 1.8% of the construction cost of all the bridges of the toll motorway network.

4.- SPECIAL INSPECTIONS

It has been mentioned before that, as a result of the Principal Inspections, there were 89 structures that need some detailed investigations because some observed damages could have some consequences on the serviceability or on the load capacity of the bridge. Then some Special Inspections were recommended. These investigations were made by very expertise civil engineers.

The main reasons for making these detailed investigations are summarised as follows:

- 45 bridges have a lot of cracks due to bending moments on the decks.
- 10 bridges have lot of vertical cracks on the piers.
- 7 underpasses have a lot of horizontal cracks on the top slab
- The deck of 4 bridges has been hit by a over gauged traffic
- 6 bridges seems to have some kind of chemical attack on the concrete
- 10 structures were affected by some scour problems
- 7 structures have some other kind of concrete damages (spalling, corroded reinforcing,…)

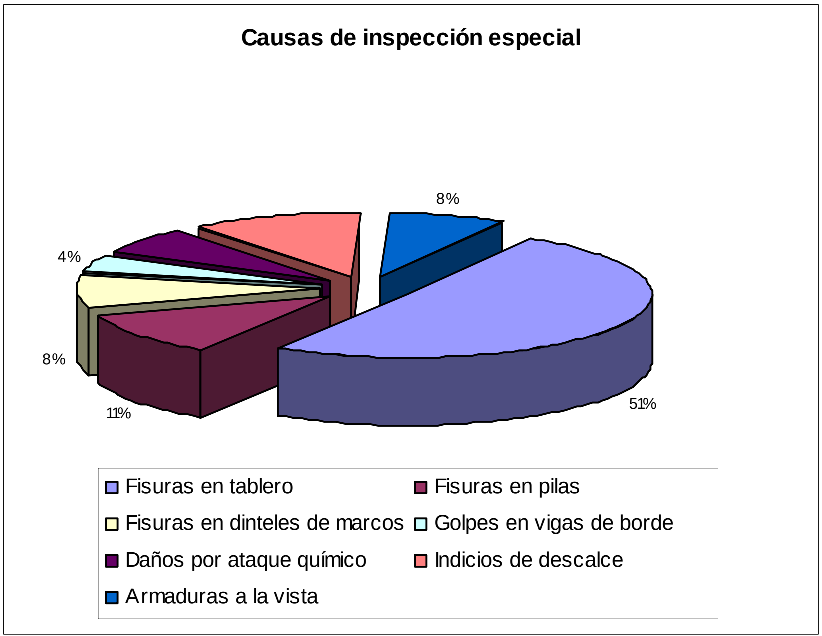

Figure 8 – Special Inspections. Origin of the required detailed investigations.

Following the main conclusions of the 89 Special Inspections are presented:

- 34 structures are recommended to be repaired in a short period of time
- 21 structures are recommended to be repaired in a not very long period of time
- 26 structures are recommended to be monitored in order to follow the evolution of the observed damages.
- The bearings of 2 structures are recommended to be substituted
- 16 structures were in good conditions and the observed damages were not dangerous.
- The observed damages of 8 structures were harmless.
- It was necessary to use special access equipment for investigating 2 structures, because the piers were very high.

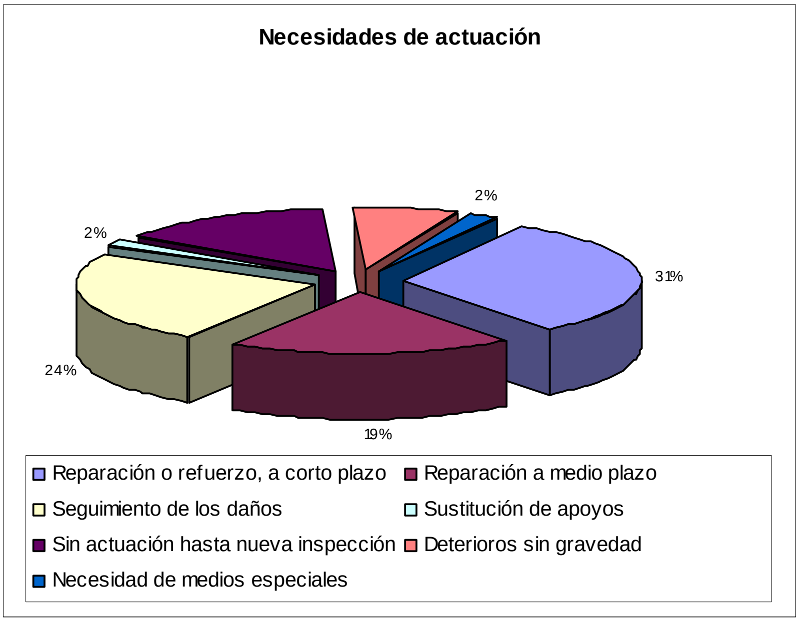

Figure 9 – Results of the Special Inspections

5.- VISUAL INSPECTIONS USING SPECIAL ACCESS EQUIPMENT

As a result of the Principal Inspection there were 101 bridges where the access was limited and so special equipment for accessing was recommended because the access to the bridge was hard, because the bridge crosses over wide water flows or because here were some elements that were high enough for not being possible to be inspected without using special equipment. In any case, the principal inspection could not be completed because some of the said circumstances.

The more often used special equipment was a special 6 axle lorry supporting a self-supported structure that could move itself using a hydraulic mechanism. Aerial platforms, boats and cranes were also used.

Figure 10 – General view of the self supported platform used for some inspections

Using the said self supported platform, some 7 to 10 spans could be inspected per day, depending on the length of the spans and on the cross section of the deck. The operation for opening the platform takes 10 to 15 minutes, approximately. When using this kind of equipment the right lane must be temporary closed to the traffic.

The results of the inspections made using special equipments showed some bearings out of place, the bad condition of the covering of some bearings or the lack of cover of a prestressed tendon; some cracks, not visible without using special accessing equipment, were also detected.

Figure 11 – An eladtomeric bearing out of place, and a lack of cover of a prestressed tendon.

The average estimated cost for repairing the damages observed using special equipment were some 55000 euros per bridge, that is nearly 15 euros per m^2 of deck; this is a clear indication of the good condition of the inspected bridges.

6.- CONCLUSIONS

The objective of implementing the Bridge Management System is optimizing the available funds, that are always not enough, for the maintenance of the structures of a road network. In doing so, the funds have been used for repairing the bridges according to a certain technical priority ranking

Additionally, the extensive and detailed inspections made have been used for defining some requirements that are needed to be considered to really manage the maintenance of the bridges in an effective way. The main conclusions from the results of the said inspections are:

- The elastomeric bearings are also a weak element for the maintenance of a bridge, because their remaining life is always smaller than the remaining life of the structure itself. But, generally, the condition of a lot of the inspected bearings, that they were 30-35 years old, was quite good.
- A lot of expansion joints have been substituted by expansion joints type “embedded elastomeric joint covered by an asphalt mastic”. These joints are very comfortable for the user; these type of joints are really waterproof. The usage of these joints is recommended when the expected movements are not very big, as it is in a lot of the inspected bridges that are not very long and were the movements due to the remaining shrinkage and creeping are very small.
- When winter snow is usual using, spreading some chlorides on the platform as a preventive operation has been widely used. The use of this very aggressive component, the bad waterproofing layer of some decks (in some cases there were no waterproofing layer at all) and the bad condition of the drainage system of the deck is the reason of having found some concrete decks severely attacked by the chlorides. Some decks were to be demolish because of the importance of the damages.

7.- REPAIRING WORKS

Finally, sometimes some repairing works are made when some other important works are proposed, such as the addition of one lane to certain sections of the toll motorway. This kind of repairing works are made in addition to the programmed works included into the annual funding plannings, such as the substitution of the pavements, the substitution of some expansion joints or the repairing works concerning the improving of the cover of certain elements made of concrete.

For example, now the enlargement of the platform, from 2 lanes to 3 lanes on each direction, of the section San Rafael-Villacastin (Segovia) of the toll motorway AP-6 is undergoing. Taking advantage of this situation, some repairing works, in addition to the enlargement and improving of some structures, are also being made such as the substitution of the bearings of the Viaduct of La Jarosa, the repairing works of some underpasses and the demolition of the deck of three existing bridges that were in very bad conditions due to the chloride attack.

Figure 12 – General views of the repairing works of some bridges of the AP-6

The Viaducts of San Rafael were seriously damaged and so it was proposed demolishing the compression slab of the deck end constructing a new one. Hydro demolition techniques have been used for demolishing the existing reinforced concrete slab of the deck. Special environmental measures have been followed while making such operations, particularly avoiding the dumping the waste of the demolition operations to the surroundings of the bridge.

Moreover, the outer beams of the existing decks were severely damaged because of the use of chlorides in winter time, so it was proposed picking up the damaged beams and substituting them by some new ones. As it have been mentioned before, in some particular cases all the beams of the deck were substituted, because it was more effective changing all the beams, because of the poor condition of the beams.

Figura 13 –Repairing works of the top slab of the deck of the Viaduct of San Rafael (AP-6)

The piers and the piers cap were also repaired because they were also suffering Chemicals attacks due to the use of chlorides in winter time. The repairing works of the substructure have been made with no temporary diversion of the traffic over the deck.

Figure 14 –Repairing works of the piers of a bridge of the AP-6