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LIFE-CYCLE ANALYSIS OF ROADWAY BRIDGES

José Carlos Almeida*; Paulo J. S. Cruz**
*ISISE, Instituto Politécnico da Guarda – Unidade Técnico Cientifica de Engenharia e Tecnologia
**ISISE, School of Architecture, University of Minho
E-mail:jcalmeida73@gmail.com

In all the second half of the past century in Portugal, and in the most part of the developed countries, we have been witness of a heavily investment in new road infrastructures. The aging of the stock of bridges will require the redirection of the investment for the maintenance, of the existing bridges, instead of buildings new bridges.

The bridges are very singular constructions of the roadways. For that reason the restraining of the utilization of a bridge, or imposing load limits in a bridge, causes always a great disturb of the normal flow of traffic, even when the rupture of the bridge is not taken in consideration. These reasons, motivated in most developed countries, the intensification of the measures for the preservation policies of the bridges.
The roadway bridges are the principal asset in the management of the roadway heritage, it represents around half of the total value of the roadways. In the last decades we have assist of a huge growth in the investment in the maintenance of the roadway bridges. The main reasons are the growth of the stock of existing bridges, the continuum increase of the requirements of those type of structures (e.g. load increase) and also because of the outsourcing of the maintenance works to private companies (Dekker e Scarf, 1998).

The magnitude of the problem can be observed in the document FHWA (2006a). In the United Estates of America, who as a stock of around 600,000 bridges, 25% as a deficiency, 52% of those bridges are classified as functional obsolete. That document shows also that 47% of the bridges are more than 40 years old. In that group 75% of the bridges as at leats one kind of deficiency.
If doesn't exist a long-term vision, and a correct maintenance policy, the degradation of the stock of bridges is unstoppable. At long-term the magnitude of the deterioration is going to be so high that all the investment is imperatively applied in urgent tasks with the direct consequence of the increase of the risk of collapse in all the stock of bridges.

In 2004 the total investment in the highway network in the United Estates of Americas was around 70 Trillion dollars of this amount of money only 27.5 Trillion was applied in building new highways. This values illustrates that is crucial, for the sustainability of the countries, the optimization of the funds assigned to the maintenance of the infrastructures of the roads (FHWA, 2006b)

Over the last decades, the study of the life-cycle behaviour of bridges and the life-cycle cost consideration are issues with a growing concern. The choice of the structural type, of a bridge, must be realized considering the long-term behaviour and also the costs involved in all the life-time (FHWA, 2003b).
The choice of the type of material of the bridge of study in this thesis is concrete built bridges. The main reason results of the observation of Figure 1. It shows that in the last decades a huge decrease in the number of bridges built in steel instead of the concrete material (TRB, 2000).

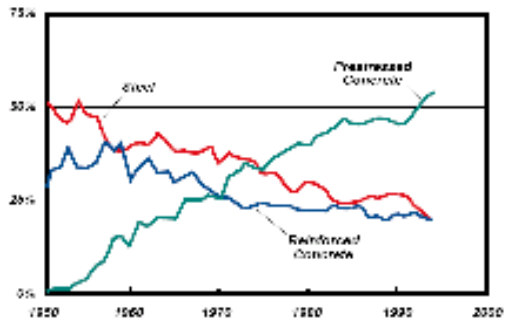

Figure 1 – Distribution of the three main materials of construction materials between 1950 e 1994 (TRB, 2000).

The design of bridges is increasingly aimed at the long term operation. This new approach requires the appraisal of a growing number of parameters beyond the structural functioning

The aim of this PhD thesis is life-cycle cost evaluation of different maintenance strategies in concrete bridges.
The life-time, and consequently the costs, of a bridge can be subdivided in tree major chapters: construction, use and replacement. The life-cycle costs of a bridge can be quantified utilizing the equation (1) (Cruz, 2003):

$$CCV = CP + CC + CM + CR + CV + CU - VR \quad (1)$$

Were:
CCV – life-cycle costs; *CP* – design costs; *CM* – Maintenance costs; *CR* – rehabilitation costs; *CV* – vulnerability costs; *CU* – use costs and *VR* – residual value.

As it can be observed in equation (1) all the costs are relevant for the analysis, however the choice of the best option must be fulfilled in the design stages.
In the design stages is very important having in consideration of the durability of the elements that have a inferior life-time than the bridge, for example the of the expansion joints (Lima e Brito, 2006). The main objective is the early definition of the indicators of deterioration and stipulate the periods of substitution of all the elements.

The tool in each step of the decision process must be the economic analysis. The principal benefits of the life-cycle cost analysis are (FHWA, 2003): the exact design and construction cost quantification; determination of the best economic return policy; better understanding of complex projects and documentation of the decision process.
The reliability of a bridge is a time variable parameter. This variation can result from natural causes (loads and material resistance), deterioration (carbonated concrete or chloride-induced corrosion) or other factor like the increase of the legal limit of loading (**Error! Reference source not found.**, 1996).

The deterioration phenomenon in bridges is a stochastic phenomenon depending on a huge amount of factors that are very difficult to predict for example: the freeze-thaw cycles or the effects of the previous maintenance operations (Christofas and Karlaftis, 2006).
Due to the difficulty of the establishment of a correlation between the degradation of the individual components with the overall condition of a bridge it is necessary the utilization of stochastic methods like the chain of Markov (Zhang *et al.*, 2003).
In this work it is intended to perform a detailed analysis of the uncertainty of the values of some parameters, with regard to cost and time of implementation of some actions. For achieving this propose it will be carry out some analysis using methods which estimate the variation over time, such as the Markov Method and Monte Carlo simulation. For this end it will be studied different scenarios for determining the interaction between all the parameters.

Branco and Brito (2004) have referred that the subsystem of decision rehabilitation/substitution of bridges needs, due to the large amount of money involved and due to the complexity of the analysis the different parameters, a practical and rational method for quantifying the life-cycle costs.
With the main objective of comparing the different monetary values invested along the life-time of the bridge for the different proposed solutions it will be realized a study with the net present values of all costs involved. For achieving this propose it will be developed a deterioration model for the concrete structures, it will be established a relation with the different anomalies of the bridges and the rehabilitation methods that can be applied with the aim of defining the best rehabilitation strategies. This method is going to be applied in different case studies of existing bridges.

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