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International Doctorate in Civil and Environmental Engineering

LIFE-CYCLE COST-BASED OPTIMAL DESIGN OF ROAD BRIDGES EQUIPPED WITH SHM SYSTEMS

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Abstract

Road bridges are subjected during their life-cycle to loads of different nature and intensity. Unlike buildings for which the most serious condition is often represented by the seismic action, in the case of bridges, several are the potential causes of damage or failure: fatigue, subsidence of the ground, decay of mechanical properties due to age or to exposure to adverse environmental conditions, transit of exceptional vehicles, earthquake or design and execution errors. Several dramatic collapses occurred to bridges of the Italian road network in the last five years highlighting that a large part of the existing infrastructures need strengthening and repair. This situation is mainly attributable to the lack, protracted for many years, of a planned maintenance, which has caused the acceleration of the natural phenomena of aging of the public works.

The described scenario highlights the need to carry out activities to maintain and repair these strategic and non-replaceable constructions and Structural Health Monitoring (SHM) is a valid and efficient tool to prioritize inspection and interventions and therefore optimally distributing public funds.

The main advantages of installing a monitoring system on a new structure are the following: ease of installation, greater control of the phases of construction, increase of knowledge of the real behaviour of the structure, identification and location of damages and consequent increase of safety and optimization of maintenance operations. On the other hand, the cost of realization that an instrumented structure with SHM implies is quite high. Nevertheless, the installation of a monitoring system and a change of maintenance strategy can lead to a significant reduction in the interventions, as they are targeted, therefore of the cost as well as the inconvenience to circulation.

The research project proposes to develop a general methodology for computing the life cycle cost of road bridges equipped with an SHM system, so as to evaluate and prove the benefits in the economic terms and in terms of structural reliability given by the SHM system

itself, and then apply it to real case studies. The procedure will be focused on the most common technologies of bridges currently used, such as steel-concrete composite girder bridges with reinforced concrete piers and/or pre-stressed reinforced concrete bridges.
For the development of the cost model to apply to the bridges, it is necessary in the first step of work to carry on an extensive literature review about the state of the art of the several topics addressed: i) main issues and risk sources of the analysed bridge technologies regarding their life cycle and the main parameters which characterise the behaviour of bridge; ii) advances in the sensors and monitoring methodologies, in particular continuous monitoring, to detect the current value of the specific quantities investigated; iii) signal analysis and processing techniques to purify the sensor responses from the possible sources of environmental noise in order to detect and locate the damage; iv) evolution of normative requirements about planning of inspection and management of bridges; v) existing life cycle cost procedure developed for civil infrastructural and SHM system.
In the second phase of work the reliability analysis of the investigated structures will be carried out in order to define the limit states: for permanent and progressive phenomena will be defined the extent of the damage after which maintenance is expected; for random exciters a probabilistic assessment is necessary, i.e. definition of parameter of damage; determination of the extent of the damage, and therefore quantification of the state of damage, then definition levels of damage, or performance, and the probability of overcoming the useful life of the work.
The third step consists of the development of a procedure for the evaluation of the life cycle cost of monitoring systems and to apply existing cost models to the bridge equipped with a monitoring system.
The last step consists of the development of the methodology for the optimal design of the bridge-system-monitoring complex based on the minimization of the total life cycle cost of the system. In the first analysis, it can be assumed that, following the achievement of the established level of performance, and reported by the monitoring system, the recovery operations are such as to bring the work back to its initial conditions. Subsequently, the model will be enriched taking into account the damage accumulated in the time interval between the exceeding of the limit state and the repair.