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Tanks criticality assessment by the dependability method. Case study

Hocine Hammoum *, Karima Bouzelha, Hacene Ait Aider, Naceur Eddine Hannachi

Département de génie civil, Université Mouloud Mammeri, 15000 Tizi Ouzou, Algeria

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ABSTRACT

In industry, performing dependability evaluation along with other analyses allows anticipating and making trade-offs. This field has then gained its current distinguished standing, mainly during the last half-century, in areas such as defense, aeronautics, space, and nuclear. It is now absolutely crucial and critical for all sectors of industry, particularly in civil engineering. However, dependability is able to include, explicitly, the failures, uncertainties, hazards, etc. as far as their corresponding knowledge. It also highlights the absence of the dependability process as the awareness of the studied system does not exist. With this approach, "concrete tank" system study has been conducted in terms of functions to be fulfilled and designed to understand the way it works. The FMECA (Failure Modes their Effects and Criticality Analysis) method, to be discussed in the present work, consider systematically and successively each component of the tank and its failure modes analysis. Furthermore, a failure mode corresponds to the state in which the considered tank will not fulfill its major function: each unachieved, or badly achieved, function is matched up into a given a failure mode. These failure modes have been quantified according to different parameters, and prioritized by a causal graph. Finally this method will evaluate the criticality of the failure of each function component before proceeding to the evaluation of the overall criticality of the tank failure.

As a practical application (case study), we illustrate the method of dependability in a water storage tank, placed on the ground of a 2000 m^3 capacity and located in a coastal town in Algeria, in order to be investigated. This structure, we studied here, was built in 1987 and has been then examined and analyzed 20 years later.

1. Introduction

In the field of civil engineering, concrete tanks are considered as hydraulic structures. They take a special place among the constructions, given their social importance, by the role they play in the daily life of the country. These tanks are sensitive to public opinion, as the closing of a tank even temporarily, for maintenance or repair, results in strong reactions from the subscribers, ready to denounce the laxity or negligence of public services. The manager of these tanks needs to have a global view of the structures park he is in charge; in terms of objectives and constraints, in order to keep a continuous assessment of their state in a dynamic operating context. To accomplish this task, the general idea is to maintain a continuous intervention priorities based on the risks assessment of the tanks. The manager shall ensure that the structure performs its functions at the best cost, within the projected operating. For this objective, he needs to refer to a reliable evidence allowing him to take decisions concerning the maintenance, or reparation, of the tank. Many structures park managers have developed

* Corresponding author. Tel.: +213 555 92 85 41; fax: +213 (0)26211306.
E-mail address: hammoum_hoc@yahoo.fr (H. Hammoum).

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different methods to evaluate the civil engineering structures for diagnosis, risk analysis and scheduling of maintenance actions, such as dependability techniques defined as failures science. The tank dependability analysis is based on the prediction of the failure evolution related to the environment and the stresses to which it is subjected.

Among the techniques of dependability we cite the FMEA and FMECA. These methods appeared during the sixties in the American aviation industry. After that, they have taken their flight in Europe during the seventies in automotive, chemical and nuclear industries [13]. Besides, they are recently introduced in the civil engineering sector, particularly in the field of dams [6,7], embankments against flooding [8], in the field of maritime structures [1] and in the field of concrete tanks [3,4]. These techniques represent powerful approaches for diagnosis and risk analysis. They highlight, aging scenarios for a given tank, and the most dangerous structures at the scale of tank parc.

Peyras [6,7], was interested in the dams under the control of the French Ministry of Environment. His investigations, at the research unit of the hydraulic structures Cemagref (Aix en Provence, France), suggests methods for the diagnosis and risk analysis through an approach by expertise. The first result concerns the modeling of aging scenarios. This work included the construction of the dams functional analysis and the adaptation of FMEA to the context of the dams, and then proposed a model of scenarios representation using directed graphs. This model connects failure functional sequences and organize information linked to aging around three variables: symptoms, function and phenomenon.

Serre [8–12] was interested in the embankments against floods under the control of the French Ministry of Environment. His work, at the research unit of the hydraulic structures Cemagref (Aix en Provence, France), develops tools for the management of embankments, allowing established priorities in maintenance actions throughout the linear park. His study provides a summary of failure mechanisms of the French earthen embankments park. It presents a complete collection of failure mechanisms and then proposes a model of failure embankment. Serre [8] details then the functional analysis and the FMEA method, adapted to the particular context of embankments. The method he developed has been integrated into a Geographic Information System (GIS).

Boéro et al. [1] have implemented a methodology for risk analysis in order to optimize the management of port structures. Managers are required to schedule maintenance operations (monitoring and maintenance) on a heterogeneous heritage and having a large number of structures with various functions. Corrective maintenance is generally very expensive in direct costs such as indirect consequences (shutdowns), consequently, the use of a methodology for early warning and prioritization is of primary importance. However, the approach is to identify and prioritize failure modes according to their criticality (Qualitative Risk Analysis). Besides, a Quantitative Risk Analysis determines, in a finer way, the probability of the most critical failure modes.

Hammoum [3,4], as part of a PhD thesis of Science in Civil Engineering, has conducted research and led to propose a method for evaluating a concrete reservoir taking into account the mechanisms of aging by the FMECA method. After a functional analysis, we obtain a precise description of a tank, its components and links between components each other and with their environment, that is what we have called the functional block. All these informations, from the functional analysis, will be used as basis into the application of the FMEA method which returned us an exhaustive list of failure modes of the tank components, their causes, effects and associated symptoms. These results allowed us to model scenarios of aging using a causal graphs representation.

2. Description of the dependability method

2.1. External functional analysis

According to external functional analysis, we will translate the needs that are satisfied by the tank (the system) towards functions: the main functions and constraint functions. The system of civil engineering that we study is composed of the tank itself (structure out of the ground), its foundation, hydraulic equipment, drainage system and the soil around the foundation as shown in Fig. 1.

By examining the environment of the tank, we establish an inventory of hardware components that can act on the tank and examine their interactions. We obtain Table 1.

Using an external functional analysis, we obtain the main and constraint functions accomplished by the global system. We materialize the interactions between the system and its environment using a functional diagram. We differentiate between contact relations (represented by straight lines) and flow relations (represented by arcs) (see Fig. 2). The main function reflects the action object of a system. Consequently, the analysis is reduced to a single main function which is "The tank is used to contain water".

About the constraint functions, they are obtained by examining the external environments interacting with the tank. All these constraint functions that provide the stability of the tank (see Table 2), can be summarized into one that is: "**The tank resists to sollicitations**."

2.2. Internal functional analysis

After analyzing the global system, we are now looking the role and participation of its components. Each of them, providing functions, contributes to the global functioning of the tank. Structural analysis is used to list the whole components