Evaluation of the state of the civil engineering structures in the province of Fes-Moulay Yacoub-Morocco

Chaymae NAAZA[1] , *Abdellah* EL BARKANY[1], and *Ikram* ELABASSI[2]

[1]*Mechanical Engineering Laboratory, Faculty of Science and Techniques, Sidi Mohammed Ben Abdellah University, Fez, Morocco*
[2]*ECAM-EPMI, 13 Boulevard de l'Hautil, 95092, Cergy Pontoise Cedex, France*

Abstract. The management of an engineering structures heritage is based on monitoring, maintenance and repair. The detailed inspection of engineering structures is an important element of asset management. Its adaptation to the specificities of the assets play a major role in the effectiveness of the management policies. Indeed, the detailed inspection of a work of art contributes, through the visual assessment of its condition, to defining and planning preventive maintenance operations and, where applicable, specific and special monitoring, complementary investigations or additional repairs. The detailed inspection shall include a review of the literature, visual surveys and measurements. The analysis of all these elements conducts, on one hand, to a logical evaluation of the present situation of the engineering structures and, on the other hand, to proposal for actions to be taken in terms of: user safety, maintenance: routine and specialized maintenance, additional investigations (geometric measurements, static and dynamic instrumentation, material dynamic instrumentation, sampling and analysis of materials, modeling, recalculations...), repairs, specific monitoring actions (reinforced monitoring, high surveillance); At the end of this in-depth inspection, two cases may be presented:

- The causes of the defects and the corrective actions to be undertaken are clearly identified without the need for additional investigations; in this case, the detailed inspection actually constitutes a diagnosis.
- In other cases, the detailed inspection represents a pre-diagnosis. Carrying out additional diagnostics, investigations, implementing specific monitoring actions and developing programs are part of the process.

These studies, which may be suggested after detailed inspections, generally require different skills than those required for detailed inspections.
The objective of this article is to demonstrate the stages of the inspection mission carried out on the heritage of works of art in the wilaya of Moulay Yacoub.

1 Introduction

Morocco, like most developing countries, has a relatively young transportation infrastructure compared to developed countries. The sustained economic development of the country in various fields: agriculture, industry, mining, fishing, tourism, has led over the decades to the construction of a varied transport network of different status.
Thus, the park of engineering structures managed by the Directorate of Roads was constituted and enriched with time to reach today the 6500 road bridges [1]. Today, the awareness is taken, as well by the owners as by the professionals operating in the field, of the interest and the economic and security stakes that constitute the safeguarding and the upgrading of the existing heritage of engineering structures. It is in this perspective that the managers of engineering structures launch inspection missions to detect all the anomalies and degradations that can affect the bridges' heritage.

To conduct an inspection mission, it is essential to follow certain steps [2]:

- The inventory of structures: For the owner, it is essential to know the structures under his jurisdiction. This is why all operations related to the management of the structures must be preceded by a phase of reconnaissance and inventory. The data from the census includes at least the type of structure, its location and its main dimensions. The date or period of construction are also important data because they provide information on the design, dimensioning and execution typologies and therefore on the management characteristics to be considered. All the information collected must be verified in the field to consider possible transformations or information not available in the files
- Preparation of a work file: It is essential to have a file that gathers all the characteristics of the works and the history of all the actions carried out.
- Intervention on site: it is the most important phase of the inspection mission and allows to detect all the anomalies and apparent degradations on the bridges in order to propose technical solutions to ensure their durability.
- Data analysis and writing of the mission report.

The following synoptic represents the essential steps of an inspection mission:

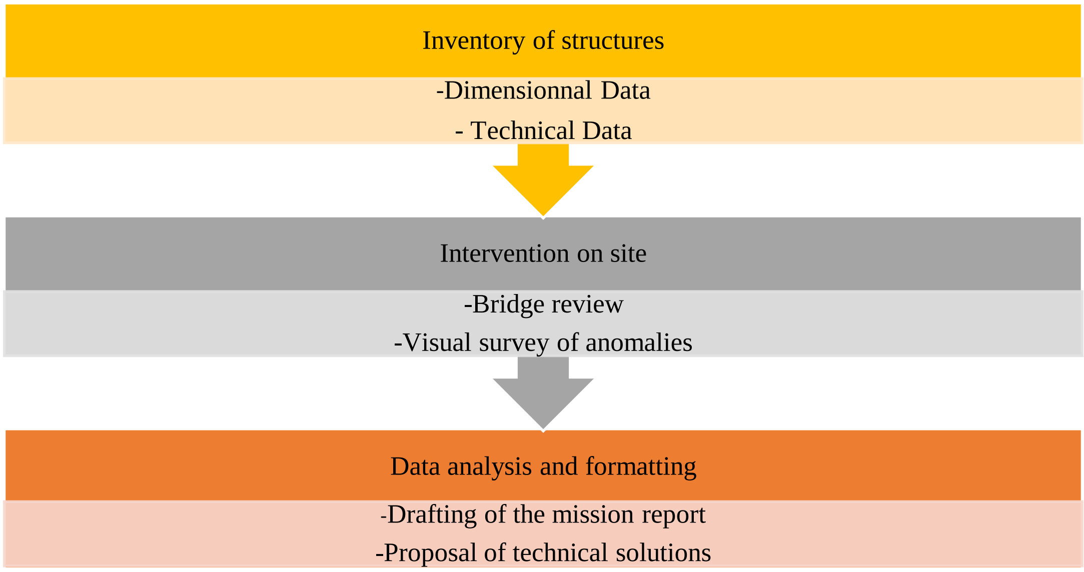

Fig. 1. Steps of an inspection mission

2 Study Case

With the aim of preserving the heritage of the Structures of Art, a mission was carried out in the province of Fez-Moulay Yacoub in order to ensure an inspection of the various existing bridges at the level of the road network. The structures concerned by the inspection are those defined in the "Instruction for the monitoring and maintenance of engineering structures", namely:

- Viaducts and bridges with a length between abutments greater than or equal to 2 m.
- Submersible sills and inverts with a length greater than or equal to 10 m.
- Retaining structures ensuring the safety and protection of a roadway with a height in places greater than or equal to 2 m,
- Other special structures: tunnels and covered trenches.

The objectives of the periodic monitoring of the works are the following:

- Draw up a report on the defects and disorders relating to each structure in order to obtain a reliable picture of the state of the assets;
- Identify the degraded works and the possible risks incurred by the users;
- Prevent any accident resulting from the degradation of the works and to take, if necessary, the necessary measures in time.

During the inspection of the structure, it is necessary to distinguish between two types of deterioration. These are defects and disorders.

- Defects: are often observed on the equipment. They are constructive or evolutionary anomalies that do not, in the long term, affect the mechanical operation of the structure
- Disorders: on the other hand, correspond to constructive or evolutionary anomalies that modify the mechanical functioning of the structure.

2.1. Conduct of the mission

During the mission, 72 structures were inspected including:

- 4 Concrete bridges;
- 64 scuppers;
- 2 masonry vaults;
- 2 sills and submersible structures.

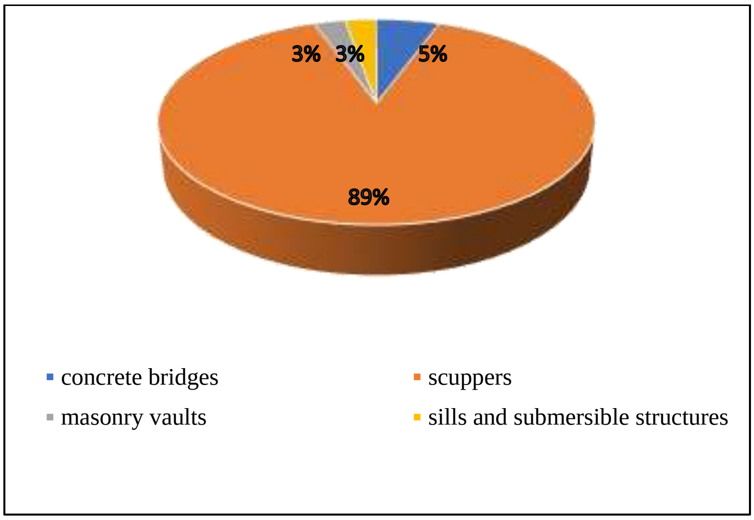

Fig. 2. Distribution of bridges by family

The health status of the structures is as follows:

- 30 structures are in good condition (grade 1 and 2);
- 31 structures are in average condition (grade 3);
- 4 structures are in poor condition (grade 4 and 5);
- 5 structures are not assessed.

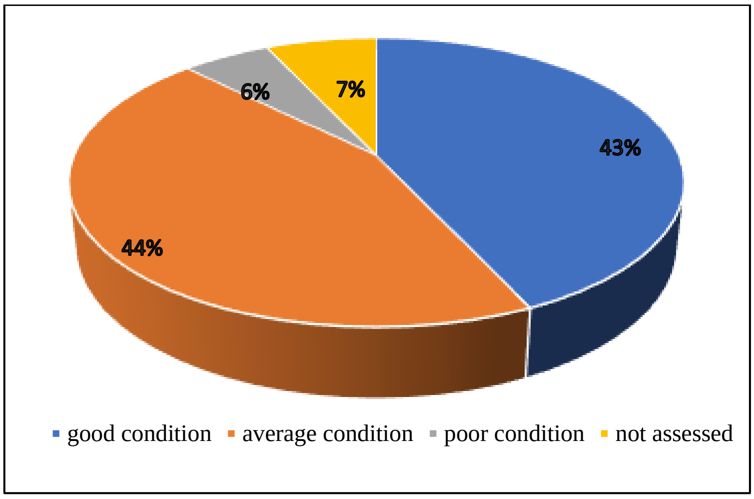

Fig. 3. Distribution of bridges by health status

2.2. Concrete bridges

The number of bridges that were the subject of this mission is therefore 4. 3 are in average condition and the last one is in good condition. The distribution by condition class is as follows:

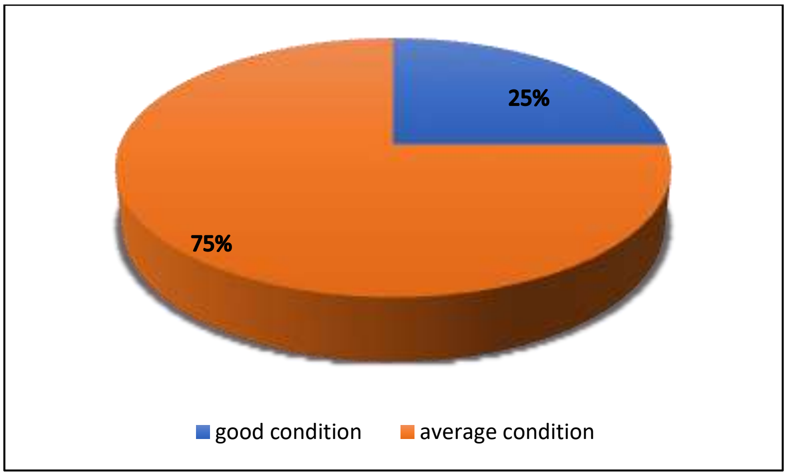

Fig. 4. State of health of concrete bridges

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25% of the inspected structures (1 structure) are in good condition. These structures show defects or degradations that are localized and superficial. However, the defective equipment and protections must be replaced to ensure the durability of the structures. 75% are in an average condition. These bridges show minor defects that require surface treatment and protection against the risk of short-term evolution of the structure to bad classes (grade 4 and 5).

2.3. Scuppers

There are 64 scuppers distributed as follows:

- 24 single scuppers,
- 15 double scuppers;
- 17 triple scuppers;
- 8 batteries of scuppers.

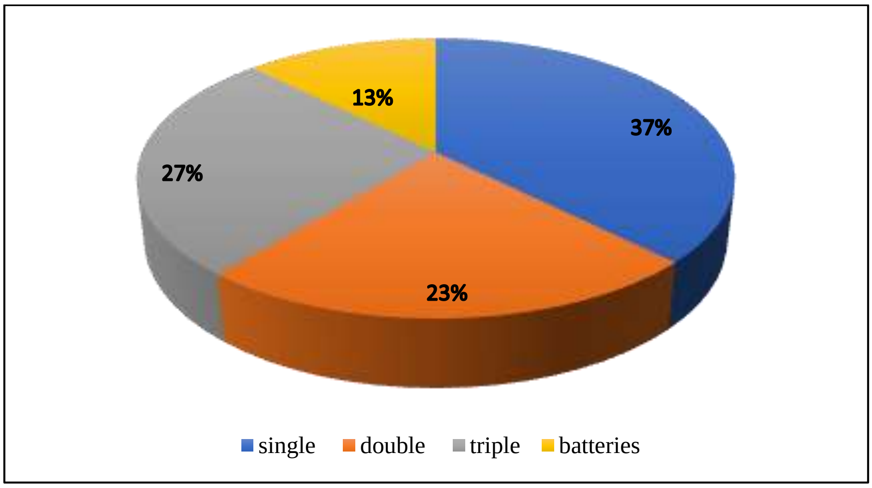

Fig. 5.Distribution of scuppers by sub-family

The breakdown by state class gives the following results:

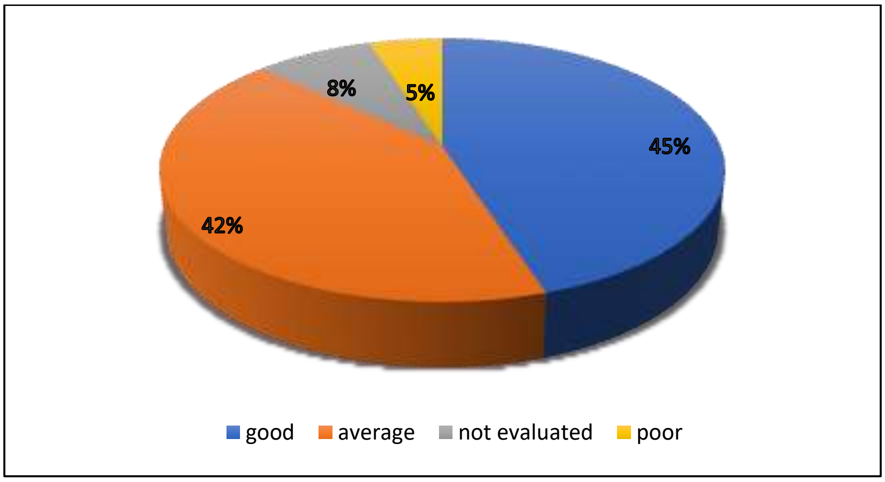

Fig. 6. State of health of scuppers

- 45% of the scuppers have a score of 2 or less, which means that these structures have localized and superficial defects or deterioration;
- 42% of the scuppers have a score of 3. These structures must be repaired to ensure the durability of the structure;
- 5% of the scuppers are in poor condition and require urgent intervention to avoid compromising the stability of the structures;
- 8% of the scuppers have not been evaluated because of their blockage and / or difficulty of access to the slab and pedestals.

3 Summary of the mission

3.1. Scour phenomenon

During this mission, it was noticed that most of the degradations suffered by all the inspected structures are due to the water flow and to the scouring phenomenon which can sometimes lead to the collapse of the structures. Scouring is a phenomenon caused by the flow of water in rivers, and is translated by the displacement of sediments as a result of the erosive action of water [3]. The instability of the structures caused the lowering of the level of a river bed especially when the flood is very severe and the scouring pit is very pronounced [4].
The shock between the water and the pier leads the flow towards the bed ('down flow') and causes local erosion around the hurdle, which gives rise to horseshoe vortices ('horse shoe vortex'). On the sides of the pier, the tearing off of the materials creates wake vortices [5]. These two vortices tear off the materials surrounding the side surface of the pier as demonstrated in the figure 7.

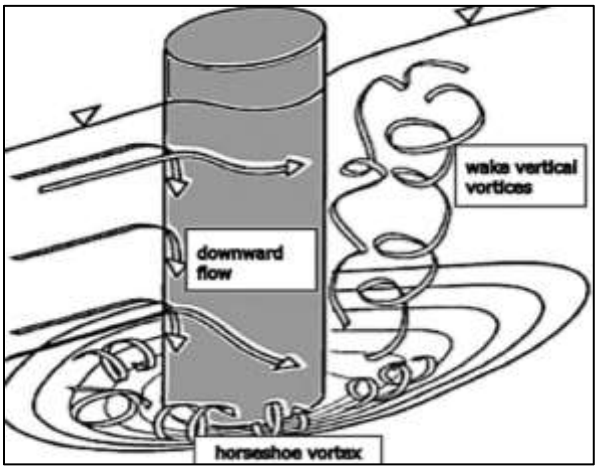

Fig. 7. Apparition of scour phenomenon

The depth of scour depends on many factors such as geotechnical, structural and hydraulic parameters [6]. It is very important to take into consideration all these factors in order to ensure regular monitoring of the scour phenomenon [7]. In the literature, many equations were developed in order to calculate the depth of the scour ([5-10]) but since they are based on simplified models in laboratories they don't give accurate results. Thus, it was necessary to develop numerical models based on Computational Fluid Dynamics (CFD) in order to calculate the depth of the scour hole and ensure regular monitoring of this phenomenon. ([11-15]).
In the United States of America, Wardhana and Hadipriono made a research on 503 bridges and found out that the most frequent reasons of the apparition of degradations are scour and floods (almost 53%) [16].
The two figures below present the apparition of scour phenomenon near the foundations of two bridges situated in national roads and that needs protections.


(a)


(b)

Fig.8. Manifestation of scour phenomenon in inspected bridges (a)piers (b)abutments

3.2. General recommendations

To ensure the preservation of the heritage of the existing works at the level of the road network of the province of Moulay Yacoub, it is recommended to:

- Carry out regular routine maintenance;
- Proceed regularly to the cleaning of the clogged works;
- Put in place adequate protection against scouring;
- Proceed to the repair of the noticed cracks;
- Proceed to the treatment of the disjunctions of the masonry works;
- Proceed to the protection of the exposed steels;
- Proceed to the regular maintenance of the guardrails and the equipment of the works of art.

3.3. Scour protection techniques

3.3.1. Riprap

This technique involves placing boulders in scour holes. Indeed, this technique is the most widely used in Morocco, given its effectiveness in protecting against this phenomenon if the technique is very well executed. However, it is very important to include a filtering layer between the riprap and the bed to reduce the risk of sinking, since the bed materials are fine and mobile. The filter layer is traditionally composed of gravel with a grain size of 1-200mm (minor riprap) followed by a layer of major riprap. When flooding occurs, the riprap may be displaced downstream, requiring regular recharging during low-water periods, hence the need for periodic inspections to determine the need for riprap [17].

3.3.2. Geotextile filters

Geotextile filters are used to replace the granular filters already discussed. They provide permanent stability against erosion. For many years, geotextiles have been used as separation layers to prevent mixing and contamination of different layers of materials. They have also been used as filter layers to retain fine particles and ensure water flow [18]. These filter layers have been extraordinarily successful in Germany, and have never failed or caused any serious problems (damage to geotextiles during rockfill).

3.3.3. Geotextile containers:

For effective scour protection, you need to look for elements that resist hydraulic force and hold back the soil. Geo-synthetic containers are sand-filled bags that act as a protective layer against scouring. Their main advantage is that they adapt perfectly to the geometry of the soil. They are manufactured taking into account the nature of the starting material, site conditions... The bed materials are, in the majority of cases, fine and therefore can be easily removed with the effect of water, so it is very important to provide a filtering layer made up of geo composites consisting of two layers of geotextiles and a layer of sand enclosed between the two [19].

4 Conclusion

Monitoring the condition of structures is a key factor in the maintenance of assets and the safety of users. This monitoring is essential because, like most constructions, engineering structures are designed to be maintained and repaired. The maintenance of bridges makes it possible to spread out their lifespan. During this inspection, it was noticed that 50% of the bridges in poor condition have not undergone periodic maintenance operations, which further degrades their structure and makes the repair cost enormous. It was also noticed that scouring affects most hydraulic structures, hence the interest in regularly monitoring the depth of the scouring pit and proposing precise techniques to protect bridge piers and abutments to avoid their collapse and thus human and material damages.

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