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Pathology, Evaluation and Repair of Bridges in Masonry

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Abstract. The field of repair and rehabilitation of civil engineering works is evolving. Indeed, most of these structures, especially masonry structures, are over 50 years old and many of them require maintenance and repair work due to their deteriorated condition. To achieve this objective, a study was carried out concerning the different pathologies affecting the masonry bridges, but also the ways and means necessary for the evaluation and repair of the affected works. The results of this work have not only helped to carry out the diagnosis and verification of the structural state of the bridge over river Kentra Stora Skikda (North-East of Algeria), on the section of the 3AA National Road Skikda, but also for the proposal of repair solutions best adapted to the disorders observed.

Key words: Bridge, Masonry, Diagnosis, Expertise, Repair.

1. Introduction

Masonry is a composite material, a mixture of stones or bricks and mortar joints. The behaviour of masonry structures depends on their physicochemical characteristics (porosity, capillarity, permeability, gelling), thermal and mechanical behaviour. The simple compressive strengths vary greatly depending on the rocks (from 20 to 200 MPa). Bricks are blocks of hardened clay (raw bricks) or artificially (cooked bricks). Whose resistance to simple compression is lower than stone, of the order of 5 to 15 MPa.

The overall mechanical operation of a masonry bridge is related not only to the individual functioning of each part (vault, walls, abutments) but also to the connections and transmissions of forces between the zones. The filling distributes the charges on the vault and pushes on the eardrums. He participates in the lift of the structure by these splitter effects. The vault, the active part of the structure, has for main role to take the efforts due to the loading and to transmit them to the foundations. The ground transmission of the loads is carried out by the stacks, the abutments and the walls in return. The siding is the resistant part of the pile: the loads pass mainly in the facings and leave the filling if it offers less rigidity (Stablon, 2011; Mohammadzadeh et al., 2018; Edwards, 2005; Valluzzi et al., 2005).

Bridges are aging, but given their social importance, they must be given special care so that they can perform their functions for the life they have been assigned (Modena, 2004). They are indeed works, which, even if they do not all have an architectural aspect, constitute economic, transport and security vectors, built with the aim of ensuring a service combining high level of quality, safety and reliability. Bridges are not always in good condition, and it is not easy to diagnose pathology, and then prescribe the right remedy. For several years now, heritage management has suggested that the entire park is regularly monitored, evaluated and evaluated (Hua, 1993). The first goal is to ensure the safety of users. Secondly, asset management must make it possible to respect or even extend the life of works (Tatiana, 2011).

The selection of repair strategies is conditioned by the type of defect, its causes and the features that are intended to be improved (stability, structural and fire safety, thermal and acoustic comfort, energy efficiency, water-tightness, or others) (Sousa, 2014).

In this article we present the various pathologies affecting the masonry bridge on river Kentra Stora Skikda (North-East of Algeria), the ways and means necessary for evaluation and repair and finally the repair solutions best suited to disorders observed.

2. Status of the Algerian bridges

The age of the park is at the same time an essential factor in the assessment of its condition, and is of paramount importance to enable managers to enforce protection measures before deterioration is too advanced.

The part of very old works (built before 1962) is very small but it nevertheless represents 23% of the bridges. These are 920 bridges distributed in Algeria as follows:

- 227 whose age is more than 100 years such as Bridge El-Kantara built in Constantine by Salah Bey in 1792 and the Sidi Rached Bridge built between 1908 and 1912; and these works are of great historical value.

- 693 of them are between 50 and 100 years old; and it can be pointed out that more than 70% of these structures are in masonry or reinforced concrete.

Therefore, in general, aged structures are works that have experienced advanced aging, and must therefore be maintained regularly to avoid reducing their life and worsening their condition, which generates maintenance costs or often significantly increased (Hamlaoui, 2012).

3. The case study: the bridge on river Kentra Stora Skida (North-East of Algeria)

Aged over sixty-five years (65) (Fig. 1), the bridge over river Kentra Stora located on the National road 3AA was built in the 1950, it has the following characteristics (Table 1):

Table 1. Characteristics of the Bridge

Geometric Data	Infrastructure	Superstructure
Trace: Right	Material: Unreinforced concrete	Pile: Masonry
Number of spans: 03	Apron: Low vaul	
Range: 26.40 + 2 x 9.60m	Structure: Hyperstatic	
Opening: (6,00 + 22,80 + 6,00)	Material: Masonry	
Length of the work: 46m	Foundations: Well (probably)	
Width of deck: 9.50m		
[carriageway: 7.00m + 2 sidewalks of 1.25m]		

To ensure their functions, the bridges must be maintained in a permanent acceptable level of service through the various maintenance operations. Because they show signs of fatigue and disorders that amplifies over time.

It is possible to classify two types of pathologies in masonry. These are problems related to materials and structure (Gharib, 2015; O'Neil, 1995; Coignet and Coignet, 2007).

When priority of intervention is given to a certain historical building, a preliminary survey is essential. The main objective of the preliminary survey is to get acquinted with the structure and to see if temporary emergency interventions are needed (Ersoy, 1989).

In this section we used the information required to establish a summary of the nature and causes of the most frequent disorders either at the superstructure or accessories after the collection of expert reports of the bridge on river Kentra Stora, the treatment and analysis of the information collected as well as the estimation of the probable causes of these impairments (Hamlaoui, 2012).

Fig 1. Elevation view of the structure

The modern environment conditions can also have considerable effect on buildings and be the cause of damage. It is well known what a dangerous effect pollution of the atmosphere can have on building materials; or the effect of vibration from vehicular traffic on buildings, or even only adjacent construction sites and the thus necessary changes in the groundwater table. Such influences can be the cause of damage; one should therefore investigate and document them (Mann, 1989).

The presence of significant cracks on the entire structure: The slab of the deck also has significant delamination areas in addition to having a thickness insufficient by standards. The vault and the abutment show traces of water infiltration. The bursting of concrete with stripping and corrosion of the reinforcement at the cornices. Cracks are also visible on the masonry in Fig. 2. They usually run along the joints. Locally, splinters between the rubble are also visible.

The cracking developed is due to the presence of microcracking in the mass of the mortar and to the weaknesses of the stone - mortar interface (Stablon, 2011).

Fig 2. Bridge over the River river Kentra Stora, in Skikda.

As the bridge is located in an area close to the sea, special attention has been paid to this factor in order to limit the problems and damages related to this environment (Fig.3 and Fig.4).

Fig 3. Defects affecting the reinforcing concrete.

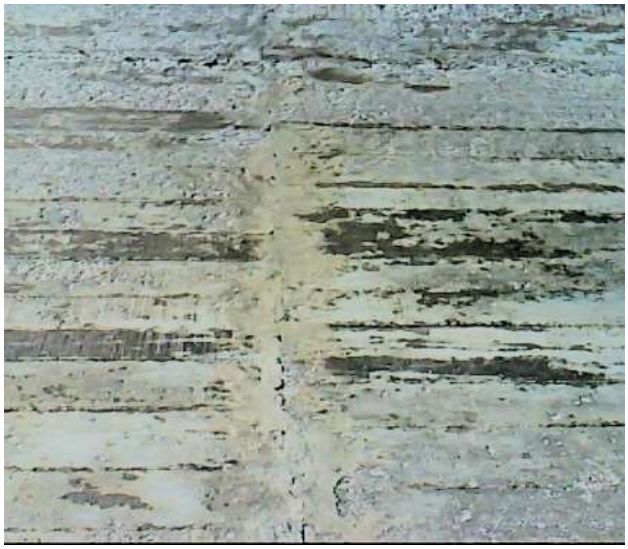

Fig 4. Cracks and stains on the surface.

4. Choice of the repair technique

The term repair means that the damaged structural or non-structural elements achieve a minimum of strength, rigidity and ductility. So the repair is limited only to the damaged elements.

The choice among solutions traditional or innovative is controversial, but if with traditional techniques it is possible to obtain satisfactory solutions of the structural point of view, economic and constructive, its use should be preferred, not only for aesthetic and cultural reasons, but also for compatibility reasons between the new elements and the original ones.

Frequently it is not easy to repair the structural damages with the exclusive resource to a traditional solution, because no longer they are available original materials, as mortars or wood, because qualified labour doesn't exist ("artisans") for this type of constructive techniques, or

still for economical reasons. The most frequent reason to go through modern techniques or innovations is related with the need of significant increases of resistance, that are only gotten with much more efficient materials than the original ones. However, whenever possible the "interventions in masonry should be made with masonry".

Apart from the deteriorations observed, our structure is in an "acceptable" state from the point of view of mechanical functioning. Thus, we offer maintenance and repair of degraded parts of the work (Fig. 5 and Fig. 6), this work which lasts approximately two months and essentially comprises the following stages:

- Paved body debris on a thickness of 30 cm.
- Realization of a screed of 5cm concrete cleanliness.
- Realization of a slab (high seal) to the right of the 15cm structure with reinforced National road 27 concrete mesh welded after cleaning, surface preparation and all subjections of good execution.
- Implementation of a sealing complex.
- Implementation of an asphalt concrete wearing course (8cm thick).
- Washing masonry and reinforced concrete facings with pressurized water (6 bars).
- Stitching and blowing in the compressed area of degraded concrete surface (Corniche + Railing) with energetic brushing of exposed steel.
- Repair of degraded concrete (cornice + guardrail) with hydraulic mortar based on resin emulsion, including primer primer on any thickness <5cm.
- Injection of fissures with the resin (SIKADUR 52 or equivalent).
- Sanding of railings.
- Applying layers of paint on railings

Fig 5. Bridge Repair Works.

Fig 6. Bridge after rehabilitation Works.

5. Conclusion

In order to rehabilitate a masonry structure, it is important to make a diagnosis. This step makes it possible to identify the various pathologies present, their magnitude as well as their cause. Thanks to this, it is possible to propose an adequate method of repair as well as protection against future attacks. A follow-up of the book can be done to determine the evolution of the different pathologies.

The detailed visual inspection carried out on the bridge on river Kentra Stora Skikda, allows us to conclude that this one was not the object of a permanent surveillance, which makes it possible to detect in time the malfunctions and to take corrective measures.

The rehabilitation works of the studied bridge allowed to give a second life to the work and to preserve its architecture.

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