Influence of the scour phenomenon on the degradation of structures: the case of bridges in Algeria

Influência do fenômeno de erosão na degradação de estruturas: o caso das pontes na Argélia

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ABSTRACT
The scouring of river piles has been the main historical cause of damage and destruction of bridges over the past centuries. Today, the situation is better throughout the world due to modern techniques for carrying out work in the river (foundation work) and the ability to carry out long-distance work, reducing the number of piers in the river. But the scouring of bridge piers remains one of the most frequently recorded degradations in our country. Scouring of bridge piers is a serious issue that can threaten the stability of a bridge. It refers to the erosion of sediment...
Scour of bridge piers one of the most frequently recorded cases of work subject to scouring. Scour holes can undermine the foundation of the pier and expose the foundation of the pier, reducing its ability to support the weight of the bridge. This can lead to cracks in the pier itself, or even complete collapse in severe cases. On the other hand, scour is the erosion of soil around a bridge pier by flowing water. It’s a major concern for bridge safety in Algeria, especially as many bridges were built before stricter seismic codes were introduced in 2010. Scour can weaken the foundation of a bridge pier, making it more susceptible to collapse during earthquakes or floods. The aim of this work is to try to study the phenomenon from different angles in order to clearly define the problem in the Algerian context, based on the analysis of several cases of work subject to scouring.

Keywords: scouring, river piles, damage, bridge, erosion, Algeria.

1 INTRODUCTION

The geographical location of Algeria and its vast territory mean that the hydrologic network is characterized by great variation and rich relief. This diversity has given rise to a rich road network with very heterogeneous structures in terms of technology and materials used.

Several structures in the National Park are located on watercourses, making scour of bridge piers one of the most frequently recorded degradations in our...
country. Each bridge located on a watercourse needs to be assessed for its vulnerability to scour in order to determine the safety measures to be taken for that bridge or the whole park during its lifetime (Richardson et al., 1995; Briaud, et al., 2007; Zurich Insurance Group, 2015). This vulnerability is defined as: "The degree to which a bridge is susceptible to damage under the conditions that cause scour" (Wang et al., 2014). On the other hand, foundation scour is the leading cause of bridge collapse, causing hundreds of millions of dollars in annual repair costs (Melville et al., 2000; Briaud et al., 2005).

This work is based on expertise carried out on carefully selected samples, namely 50 works in the coastal region "Tizi-Ouzou", one work in the highland region "Setif" and 5 works in the region of Oum El Bouaghi.

This paper aims to analyse several cases of structures subject to scouring. In each case an attempt will be made to study the phenomenon from several angles, namely: the types of damage, the ruin caused by the phenomenon and the most appropriate solution for repairing the damage caused by the phenomenon. The results of this study will help better understand the problem of scouring and will serve as a guide for future research.

2 DEFINITION

Scouring can be defined when material is excavated and removed from riverbeds and banks by erosion (Khosronejad et al., 2012). This hydrogeological mechanism of soil degradation is more evident around the supports of bridges built in a watercourse. In fact, by concentrating the flow between the abutments and reducing the width between the supports, there is a lowering of the undisturbed water (Calgaro, et al 1997; Ballio et al., 2009; Hong-Wu et al., 2009). Water is so powerful that it can strip away a foundation block and make a structure unstable. Every year, entire structures are washed away or damaged due to access embankments are generally left unprotected, creating cut-off points on sensitive axes and reducing the stiffness of foundation systems and causing bridge piers to fail without warning (Pizarro et al., 2020; Ciancimino et al., 2022).

On the other hand, there are three main types of scour: general scour, contraction scour and local scour. General scour, which is related to the evolution of the channel and is associated with the progression of scour and filling in the
absence of obstructions. This scour occurs naturally in the river and oued beds due to changes in flow rate or changes in the amount of sediment in the channel (Federico et al., 2003; Kirby et al., 2015). Contraction scour occurs as a result of the reduction in the cross-sectional area of the channel caused by the construction of structures such as bridge piers and abutments that increase flow velocity and resultant bed shear stresses (Briaud et al., 2005). Local scour occurs due to the downward flow that is induced around the individual piers and abutments of the bridge (Khosronejad et al., 2012). Figure 1 shows the scour process.

![Figure 1. Schematic of the scour process](source: Kothyari, U. C. 2007)

2.1 CAUSES OF SCOURING

2.1.1 The original defects

Some foundations may have original defects because of incorrect installation of structures during construction or because of the following:

- insufficient depth of the supports: insufficient residual embedment with regard to the development of the bed;
- excessive reduction of the wetted section (very large masses, small spans between supports, implantation in an elbow, etc.), which increases the speed and amplifies the aggressive action of the water;
- highly eccentric or irregularly shaped massifs;
- insufficiently cemented or thick masonry (massifs), in the abutments of rafts or the upper parts (paving, framing);
- poorly calibrated riprap, lack of embedding under the roof of the bed, arranged in configurations that are too small or too large;
- inadequate constructive precautions due to cost-cutting or ignorance.
2.1.2 Natural Causes

The natural evolution of some watercourses which have not reached their equilibrium profiles already causes a lowering of the bed, either by general scour (movement of the alluvial layer above a certain flow threshold), or by local scour (center on the right of the most upstream part of the supports), or by some disturbances of unfixed minor beds or the formation of landings, which modify the orientation of the currents. These can aggravate the action of the water (Link et al. 2013).

2.1.3 Human interventions

The modification of the flow can in the long term disturb the balance of the bed or to accelerate the development of scouring even on areas distant from those of realization. Among the operations that can cause this disturbance (Bolduc et al. 2008):

- material sampling, rebalancing;
- construction of dams, new roads, car parks, etc.;
- partial closure of the flow section of the structure by the waste jet;
- incomplete cleaning of the material deposited by the floods. It is imperative to remove debris and objects that can obstructing the flow.

2.1.4 Repair defects

- pile driving by vibrating structures and soils causes settlement;
- poor re-balancing of river or oued beds.

2.2 REAL STUDY OF THE PHENOMENON OF SCOURING

2.2.1 Case of scouring in Tizi-Ouzou

The photos of structures that have been studied are located on the National Road (NR) and State Road (SR) of Tizi Ouzou- Algeria are summarized in Figure 2. Table 1 summarizes the characteristics of these structures.
In this part, after collecting, processing and analyzing the information gathered from the cases of structures, we make a synthesis on the nature and causes of scourings at the infrastructure level, noting that scouring occurs in more than 50% of the structures. Analysis of the structures in Figure 2 shows that:

- the scouring phenomenon is present in all structures at different stages;
- there will be evidence of scour or subsidence around and under foundations;
- it can be seen that there is scour around and under one of the abutments;
- it can be seen that the scouring around one of the abutments is a result of the curvature of the river bed;

### Table 1. Distribution of structures according to their characteristics

<table>
<thead>
<tr>
<th>Distribution by type of foundation</th>
<th>Shallow foundation</th>
<th>Deep foundation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>National Road (NR)</td>
<td>State Road (SR)</td>
</tr>
<tr>
<td>Distribution by age-group</td>
<td>0-25</td>
<td>25-50</td>
</tr>
<tr>
<td></td>
<td>10%</td>
<td>46%</td>
</tr>
<tr>
<td>Distribution by type of structures</td>
<td>Concrete</td>
<td>Masonry</td>
</tr>
<tr>
<td></td>
<td>50%</td>
<td>10%</td>
</tr>
</tbody>
</table>

Source: Authors
• a scour phenomenon can be seen under one of the abutments resting on a fractured rock mass;
• it can be seen that the bed of the river is scouring towards one of the openings;
• it can be seen that the bed of the river has been severely scoured, stripping away the soles and threatening the stability of the structure during the next flood;
• it is possible to see the removal of the ground in foundations and of the retaining wall;
• risk of scour under abutments causing loss of lift;
• the beginning of settlement at the abutments can be seen;
• destabilization of the system of protection for banks.

On the other hand, some signs are more visible at the level of the supporting structure. They reflect certain defects at the level of the foundations, for example:

• crack at abutment wing wall joint;
• cracking and bursting of concrete slabs.

2.2.2 Case of scouring in Setif

In this part we will study scouring, but in a different way. It is an expertise for a bridge located on the national road 77 at Kilometer point 101+350 at Setif (Algeria) that is degraded by scouring. The structure studied is in ruins after an exceptional flood. The damage caused by the flood led to the total collapse of the structure (Figure 3). This bridge which is composed of two independent spans with characteristics summarized in Table 2.

Figure 3. Photo of the damage bridge

Source: Authors
Table 2. Characteristics of the damage bridge

<table>
<thead>
<tr>
<th>Length</th>
<th>Width</th>
<th>The pier</th>
<th>Road width</th>
<th>Number of spans</th>
<th>Height of bridge</th>
</tr>
</thead>
<tbody>
<tr>
<td>18 x 2</td>
<td>10</td>
<td>3x1.1</td>
<td>7.60</td>
<td>9x2</td>
<td>2.60</td>
</tr>
</tbody>
</table>

Source: Authors

The Analysis of the bridge and the CTC (Technical Construction Control) report shows that there were no reservations about the dimensions, which were considered satisfactory, or about the size, which was considered inadequate. Regarding the apparent condition of the abutments and structural issues, we note that they are satisfactory and no settlement has been recorded at their level. The type of collapse that was recorded in our case is not related to the condition of the abutments that were left intact.

In addition, a hydrological study of the Oued in which the structure is located should have been carried out and its catchment area determined.

On the other hand, the scouring caused a total deterioration of the central support (the pile) and of the whole of the apron. At the level of the central support, scouring has produced a differential settlement.

However, there are other anomalies that can be mentioned such as:

- the design error represented by the implantation of the central support on the axis of the OUED was a fatal one. The proof is in the old work (from the colonial period), which was constructed in a single span without any intermediate support, and which has remained intact and has survived all the trials of the years, even those to which our work, although more recent, has succumbed;
- the structure was built with a template height lower than that of the old structure, which causes the overflow of water in our structure, while the old one does not have this problem;
- the central pile rests on superficial foundations. These are not recommended in similar cases (support implanted in the bed of the oued) because of their susceptibility to scour;
- examination of the ground and the cofferdams shows that the calculated scour depth is 6m and the cofferdams should be designed accordingly.

There are other hypotheses that can be put forward as to the probable causes of the collapse of the bridge such as:

- either the calculated scour depth was incorrect;
• the cofferdams were poorly constructed;
• there was a lack of maintenance;
• the dimensions, and in particular the radius of the foundations, meant that we had to build cofferdams that were too large, which disrupted the flow of water around the structure.

At the end of this evaluation, we can say that the bridge was considered irrecoverable, with towards the solution of the production of a new bridge with taking into account mentioning recommendations for the elimination of the errors contained in the first bridge.

2.2.3 Case of scouring in Oum El Bouaghi

In this section we will analyze the scouring of hydraulic structures (scuppers) located in Oum El Bouaghi-Algeria. This type of structure is one of the most suitable solutions or used in Algeria, which has a lot of a mountainous region, which makes the water attacks more aggressive. This aggressiveness results in a very anarchic development of the oued beds. Photos of degraded structures are shown in Figure 4.

![Figure 4. Photos of degraded structures (scuppers)](image)

Source: Authors

The gabion system is the best solution to this problem (Figure 5). The gabion protections are system designed to work by creating a hard layer of stones of carefully selected sizes, surrounded by grids. This layer is so hard and resistant to wear that it prevents any contact between the intruding water and the weak foundation layers. As the basic principle of scour protection is the reinforcement of weak foundation layers.
3 CONCLUSION

This paper presents an expertise of the influence of the scour phenomenon on the degradation of structures in the case of Algeria. The different data showed the problem of scouring is very common in Algeria. It occurs in different forms and different types of structures. The problem was solved at several levels: study, expertise, maintenance, repair or demolition. Time will be the judge of whether these solutions are effective or ineffective.

This study can be seen as an appeal to bridge park managers in Algeria and around the world to prevent the phenomenon of scouring and to maintain the durability of bridges in the future. Scouring is a phenomenon that has caused, is causing, and will continue to cause damage to bridges if it is not taken seriously.

On the other hand, based on the results obtained, it can be concluded that's why it's important to consider the problem of scouring since the realization study takes into account sizing of the structure, materials of realization, taking into account the flow of water in the oued and river and, above all, the monitoring of the structure during its life cycle.

Further research could recommend several points, such as the identification of patterns of occurrence in each region and for each type of bridge to build a database that will help us to capitalize on feedback, whether in terms of maintenance, repair or correction of design and construction errors. The development of micro-zone maps of vulnerability for existing bridges based on regional climatic data and finally, to draw up an inspection for all bridges similar to those seriously affected by this phenomenon.
REFERENCES


