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Structural integrity assessment of the welded joints of the constitution of 1812 bridge (Cádiz, Spain)

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ABSTRACT

As required by the current Spanish regulations, an inspection and maintenance plan has been completed for the Constitution of 1812 Bridge over the Bay of Cádiz (Spain), which defines the work to be performed on the different elements of the bridge during its service life. The part of the plan related to the inspection of the steel structure has a section dedicated to the inspection of the defects that may be present in the welded joints of the steel deck, providing critical defect sizes above which the safety of the structure would be compromised. With this purpose, in the most stressed points of the deck, the structural details that are most susceptible to fatigue and fracture phenomena have been identified. Moreover, fatigue tests of these details have been performed to complete a structural integrity assessment that also comprises the determination of the material fracture toughness and the definition of the corresponding critical crack sizes. The tests were carried out on specimens obtained with the same steel grades as those used in the bridge and with the same welding procedures as those practiced in the structure. The results show that the fatigue test results are above the S—N curves provided by the Eurocode 3, and also that numerous critical crack sizes would not be detected by the usual inspection techniques used in bridges (visual inspection), so that further research into how to manage this issue is recommended.

1. Introduction

Following the latest revisions of Spanish standards such as EHE-08 [1], EAE [2] or IAP11 [3], more and more resources are being allocated during design and construction phases to the preparation of inspection and maintenance manuals that cover the complete life cycle of civil structures. These manuals define the tasks to be performed in the different elements of the structure being analysed, and the periodicity of these tasks until the end of the corresponding service life.

Requested by the “Ministry of Public Works and Transport” of Spain, these documents have been prepared for the Constitution of 1812 Bridge, located on the Bay of Cádiz (Cádiz, Spain) [4]. In this case, as part of the inspection of the metallic structure, a structural integrity analysis has been completed on the welded joints of the bridge deck, covering both fatigue and fracture assessments. The analysis determines, among others, the experimental S—N curves of the main structural details, as well as their corresponding critical crack size, something that, in principle, would allow the following points to be addressed:

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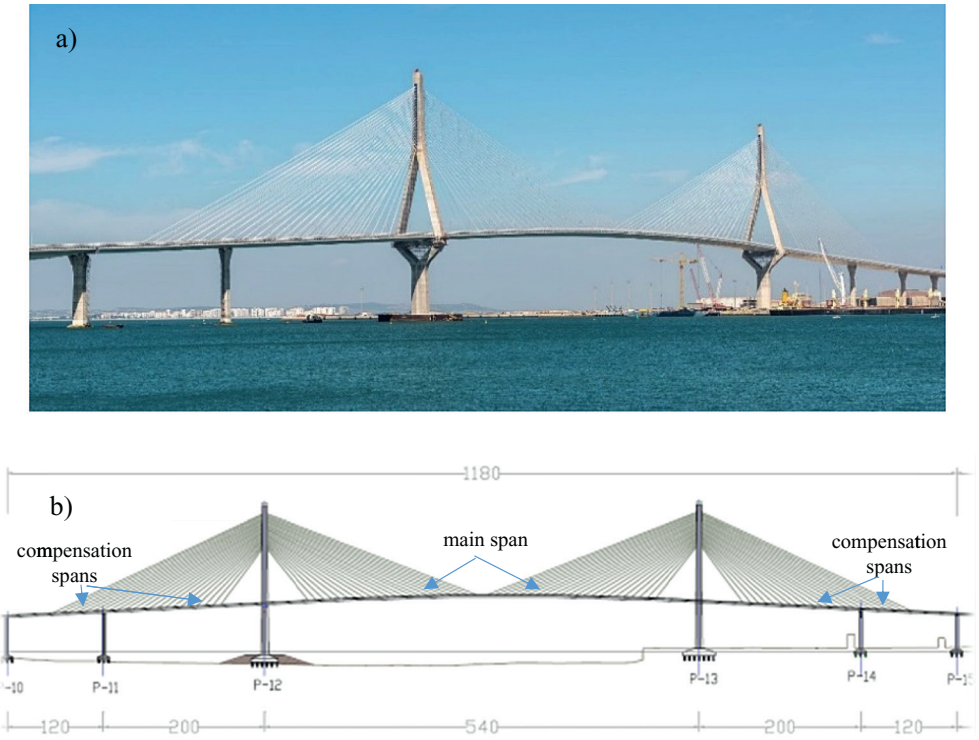

Fig. 1. Bridge of the Constitution of 1812: a) photography taken from Cádiz Bay; b) schematic (dimensions in m). Main span, main towers and compensation spans of the cable-stayed bridge.

- To analyse whether the fitness-for-service of the bridge is guaranteed
- To establish the corresponding safety margin against failure
- To establish inspection periods and strategies when no cracks are detected, and to modify such periods and strategies when cracks are found
- To establish the limits on the use of the bridge according to the defects found

Fracture assessments have been carried out following the BS7910 [5]. This standard (and others such as FITNET FFS [6] or API RP 579-1/ASME FFS-1 [7]) is widely applied in different industrial sectors, such as oil and gas (pipelines, tanks, …) and in the nuclear sector (pipes, vessels, …), but its application to civil structures such as bridges is scarce (e.g., [8,9]). Moreover, as shown below, the critical crack sizes obtained through its application come into conflict with the fact that the inspection of bridges and their structural components is generally performed by means of visual inspection, whereas more sophisticated techniques (e.g., ultrasonic testing) are not applicable due to their high costs.

With all this, Section 2 gathers a description of the bridge, Section 3 identifies the most stressed parts of the bridge deck, Section 4 describes the experimental programme and the results obtained, Section 5 gathers the structural integrity assessments and, finally, Section 6 summarises the main conclusions.

2. Basic description of the bridge

The Constitution of 1812 Bridge on the Bay of Cádiz [4], see Fig. 1, gives access to the city of Cádiz from the end of Puerto Real, giving rise to the third access to the city along with the isthmus to San Fernando and the Carranza Bridge.

It has a total length of 3157 m with a 32.5 m width crosssection formed by three roadways separated by medians. Two of the roadways, with two lanes each, are intended for light and heavy traffic and the other roadway now serves as a bus lane, but in the future will host the tram that will link Cádiz with Puerto Real, see Fig. 2.

The bridge can be divided into four stretches (starting from the Cádiz bank):

- Stretch 1: completing a length of 580 m, is composed of an initial span of 55 m and seven consecutive spans of 75 m. The section of the deck is trapezoidal, with a height of 3 m (including a 0.3 m thick concrete slab) and maximum width of 33.2 m. The height of the piers sustaining the bridge deck varies from 7.8 m up to 32.0 m.
- Stretch 2: 150 m long, and known as the detachable bridge, it is composed of one span with a similar crosssection to that presented in the previous stretch.