FATIGUE OF HYDRAULIC STEEL STRUCTURES – PIANC WG 189

by

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1. INTRODUCTION

Hydraulic Structures are subject to varying loads of more or less cyclic character. These loads are primarily generated by differential water heads on, e.g. navigation lock gates, but also by waves, drive system forces and other actions. As a result, designers must consider an additional failure mode of these structures – fatigue.

Prior to the 1970's, fatigue was of minor to no concern for designers, constructors and managers of hydraulic structures. This changed, however, with the following developments:

- The increase of navigation resulting in a greater gate opening and closing frequency;
- The advance of welding and disappearance of riveted steel structures for production (welded joints are more vulnerable to fatigue);
- Higher demand for infallible, low maintenance hydraulic steel structures.

A number of serious fatigue damages, particularly to lock gates, emphasized the need for guidelines in this field. Such guidelines exist for other steel structures, such as bridges, cranes or pressure vessels. They do not, however, cover all specific operation conditions and demands that apply to hydraulic steel structures.

2. INVESTIGATION PROCEDURE

To fill this gap, the PIANC Inland Navigation Commission (INCOM) set up a Working Group that compiled, investigated and assessed the international expertise of fatigue on hydraulic structures. This report is a result of the Working Group activities. It aims to offer comprehensive guidelines in the field of fatigue to all professionals involved in design, construction and management of hydraulic steel structures.

Working Group 189 consists of 13 primary members and several alternate members from six PIANC member countries. Team members include designers from various agencies including engineering design firms as well as government agencies responsible for the design, fabrication, and maintenance of hydraulic steel structures. The Working Group began work in February 2015 with a meeting at PIANC headquarters in Brussels, Belgium. Subsequent meetings have been held in Rotterdam, The Netherlands; Utrecht, The Netherlands; Oostende, Belgium; London, England; Berlin, Germany and Portland, Oregon, United States.

To meet objectives, the Working Group comprised a number of international experts in both structural and mechanical aspects of hydraulic steel structures such as lock gates, movable weirs, gates of harbor and shipyard docks. The represented expertise of the Working Group included – among other – the following profiles:

- Structural and mechanical design engineers with extensive experience in hydraulic structures.
- Field managers, project and program leaders experienced in handling fatigue related problems.
- Fatigue experts in similar fields, like cranes, pressure vessels, steel bridges, industrial structures and ships.
- Young professionals willing to specialize in the field of the Working Group.

In the first phase, the group collected and assessed the existing know-how on the fatigue of such structures. This covered all relevant aspects, such as the design, analysis methods, structural detailing, monitoring, material aspects, fatigue damage assessment, maintenance and repair techniques.

Fatigue of hydraulic steel structures has not yet been addressed in a PIANC report. There is also little literature in this field published outside PIANC. The issue has, however, been extensively handled in relation to other structures. A review of the design guidance for similar structures like cranes, ships, and

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to some extent, steel bridges, was necessary to summarize existing fatigue principles. The Working Group collected and studied the reports, standards and other publications on the fatigue behavior of such structures. The approaches have been reviewed for their relevancy and accuracy for hydraulic steel structures.

The Working Group favored a practical approach to fatigue issues, determining the report should first address and answer the field-borne needs of the PIANC community concerning practical design work to avoid fatigue damage and the management of occurred fatigue damage, as opposed to a scientific discussion of the issue.

3. WG 189 FINAL PRODUCT

The final report will be a summary of the Working Group activities; it contains a detailed analysis of the current engineering practice and offers guidelines for a more uniform, systematic approach to fatigue related issues. The report provides a summary of the appropriate design tools, such as analysis methods, technical codes, other guidelines and best practices. It gives examples of both correct and incorrect solutions, provides the discussion of crucial issues and presents the lessons learned from fatigue failures of hydraulic structures. Apart from the design, the report also provides proper recommendations and best practices for the repair of different fatigue damages and for the management (particularly monitoring and assessment) of structures exposed to fatigue.

The Working Group collected a number of case studies from different countries in order to compile the lessons learned. The existing guidelines and norms that handle fatigue of structures in other fields have been thoroughly reviewed and recommended if, and where, appropriate. The matters that have been investigated include:

- Nature of fatigue in hydraulic structures, significance and specific character of fatigue damage.
- Identification of fatigue loads, their sources, characters and correlations and modeling these loads for analytical purposes;
- Requirements and boundary conditions of fatigue management, e.g. gate service life, permissible damage, accessibility for repair, and conditions imposed by maintenance;
- Fatigue analysis methods and their assessment in view of hydraulic structures. This includes a study of literature and a critical discussion of the existing design codes;
- Relevant material aspects of fatigue, like fatigue behavior of various steel alloys, connectors, welding details, etc.;
- Detailing and construction of hydraulic gate components that are crucial in view of fatigue prevention;
- Evaluation of existing cracked and un-cracked structures;
- Monitoring, field inspections, assessment and maintenance of fatigue sensitive details;
- Available repair techniques of fatigue damage and other methods of service life extension, like better control of fatigue loads;
- General conclusions and recommendations.

The Working Group final report is being compiled at the time of the 2018 PIANC World Congress. The final report will include summary recommendations regarding successful design, fabrication, and repair procedures to address fatigue in hydraulic steel structures. The Working Group intends to hold its final meeting in June 2018. Final publication of the Working Group findings is anticipated in the final quarter of 2018.