



Fatigue of Hydraulic Steel Structures

Design, Analysis, Assessment and Maintenance

Terms of Reference

Background

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, the designers must take account of an additional failure mode of these structures – the failure by fatigue.

Until about 1970's, fatigue was of minor or no concern for hydraulic engineers and the managers of hydraulic structures. This changed, however, with the following developments:

- Increase of navigation, and higher gate opening and closing frequency;
- Advance of welding and disappearance of riveted steel structures; welded joints are more vulnerable to fatigue;
- Higher demand for infallibility, low maintenance and repair of hydraulic structures.

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

Therefore, it is recommended to set up a PIANC InCom Working Group that would collect and assess the international expertise on the fatigue of hydraulic structures. The report of that Working Group should offer comprehensive guidelines to the professionals in this field.

Objectives of the Working Group

Establish an international Working Group of structural and mechanical professionals, specialized in hydraulic structures such as lock gates, movable weirs, gates of harbor and shipyard docks. Let the group collect and assess the existing know-how on the fatigue of such structures. That know-how should cover all relevant aspects, like the design, analysis methods, structural detailing, monitoring, fatigue damage assessment, maintenance and repair techniques.

Earlier reports to be reviewed

The fatigue issue of hydraulic steel structures has not been handled in a PIANC report yet. There is also little, if any, literature in this field published outside PIANC. This issue has, however, been handled in relation to other structures, which fatigue behavior resembles that of, e.g., lock gates. Cranes, ships, pressure vessels and to less extend steel bridges are particularly interesting in this view. The Working Group should collect and study such reports and publications, evaluate their relevance for hydraulic engineers – and consider applying the selected expertise to the design and other practice for hydraulic steel structures.

Final product

The final product of the Working Group should be a comprehensive report that offers guidelines for an optimal approach to fatigue-related issues in the design and management of hydraulic structures. The report should provide a summary of the appropriate design tools, like technical codes and analysis methods. It should also give examples of both correct and incorrect solutions, discuss the crucial issues and details of correct solutions and present the lessons learned from incorrect ones. Apart from the design, the report should provide proper recommendations and best practices for the repair of different fatigue damages and the management (particularly monitoring and assessment) of structures exposed to fatigue.

Matters to be investigated

The Working Group shall collect case studies from different countries to compile lessons learned on the fatigue of hydraulic structures. The existing norms and guidelines that handle fatigue of structures in other fields shall critically be reviewed and recommended if and where appropriate. The matters that shall be investigated include:

- Nature of fatigue in hydraulic structures, source and character of fatigue loads.
- Requirements and boundary conditions of fatigue management, e.g. permissible damage, accessibility for repair, conditions imposed by maintenance program.
- Fatigue analysis methods and their assessment in view of hydraulic structures. This shall include a study of literature and a critical discussion of the existing design codes.
- Material aspects, detailing and execution issues in view of fatigue prevention.
- Monitoring, assessment, maintenance and repair of fatigue damage.
- General conclusions and recommendations.

The Working Group shall keep in mind that the report should answer the practical needs of the PIANC community concerning the management of fatigue, rather than deliver an exhaustive scientific discussion on this issue.

Working Group membership

The desirable expertise of the Working Group members includes the following profiles:

- Structural and/or mechanical design engineers, specialized in hydraulic structures
- Field managers and/or operators experienced in handling fatigue problems
- Fatigue experts in other similar fields, e.g. shipbuilding, cranes, pressure vessels, steel bridges, industrial structures and devices
- Scientists and technological university employees with relevant expertise

- Young professionals willing to specialize in the field of the Working Group.

Relevance for Countries in Transition

The investigation field of the Working Group – Fatigue of Hydraulic Steel Structures – is relevant for any country that maintains waterborne infrastructure. This includes Countries in Transition.

Climate Change

There is no direct link between the fatigue of hydraulic structures and the issues brought upon by the climate change. Indirectly, one can talk of a link because climate change has impact on the design loads of hydraulic structures, including fatigue loads. For fatigue, however, the most critical parameters of these loads are their variation frequency and amplitude. The correlation of these parameters with climate change is not strong, according to the current views. The Working Group should verify this point and present a proper discussion if required.