Assessment and Optimization of RAMS-performance of Hydraulic Structures

Arno WILLEMS
Head of Risk Analysis Dept.
Iv-Infra bv
Papendrecht, The Netherlands

a.willems@iv-infra.nl

Wouter VAN DER WIEL
Project Manager
Iv-Infra bv
Papendrecht, The Netherlands

w.d.vanderwiel@iv-infra.nl

Summary

Many of the Dutch hydraulic structures were designed and built between 1930 and 1950 with a life expectancy of about 50 to 80 years using the then-current standards and regulations. Signs of ageing are becoming more and more apparent. In this paper we present a sophisticated and practical way of judging and improving the performances of ageing hydraulic structures in terms of reliability, availability, maintainability and safety (RAMS).

Keywords: reliability, availability, maintainability, safety, RAMS, hydraulic structures, inspection, engineering analysis, risk analysis, assessment, performance, optimization, life cycle cost.

1. Introduction

The Dutch Ministry of Infrastructure and the Environment operates and maintains over 500 hydraulic structures (storm surge barriers, locks, weirs, dams, outlet sluices and pumping stations) for maritime navigation, water management and flood protection. Many of these structures were designed and built between 1930 and 1950 with a life expectancy of about 50 to 80 years using the then-current standards and regulations. In general loads on the structures have increased over the decades and signs of ageing are becoming more and more apparent. Some recent (near) accidents with locks and weirs already occurred, not only risking the safety of vessels and crew, but increasing local flood risk and causing significant economic losses due to long-lasting unavailability of the structures.

In order to prevent future incidents and to enable proactive performance-based asset management, comprehensive and integrated reliability, availability, maintainability and safety (RAMS) analyses of the structures were developed and executed. In 2009 the authors developed the Integrated RAMS methodology and up until now applied it to more than 50 hydraulic structures in the Netherlands for the Dutch Ministry of Infrastructure and the Environment. In this paper we present this methodology.

2. Integral RAMS analysis

The Integral RAMS analysis comprises three main parts which are elaborated in full coherence:

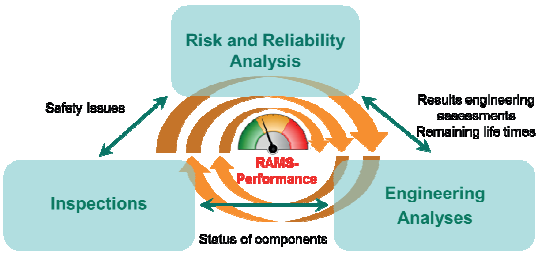

Figure 1 Integral RAMS analysis

1. On-site inspections and measurements (including underwater inspections);

2. Technical engineering analyses of all civil, geo-technical, hydraulic, mechanical and electrical parts of the structure;

3. Risk & Reliability Analysis: Failure Mode & Effect Analysis (FMEA) and quantitative Fault Tree analysis, supplemented with Maintainability analysis and Safety analysis.

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These three main parts are incorporated in the Integral RAMS analysis through an iterative work flow consisting of system analysis, FMEA, on-site inspections, engineering analyses, Weibull Analysis, Fault Tree Analysis, Maintainability analysis, Safety analysis and finally the inventory of RAMS performance-improving measurements. The latter will be described in chapter 3.

3. Improving Reliability and Availability performance

For all functions of the structure those measures are examined which could be taken to improve Reliability & Availability (R&A) performance. For this purpose the highly ranked failure modes in the Fault Tree Analysis are analysed on the possibilities to decrease the probabilities of occurrence or the Mean Times To Repair.

These improvement measures may be different in nature and may lead to different improvements. See Figure 2. The efficiency of each of the measures is calculated by dividing the availability increase by the costs of the measure. The optimal combination of R&A-improving measures can now be determined by taking the most efficient measures within the available budget for improvement or refurbishment.

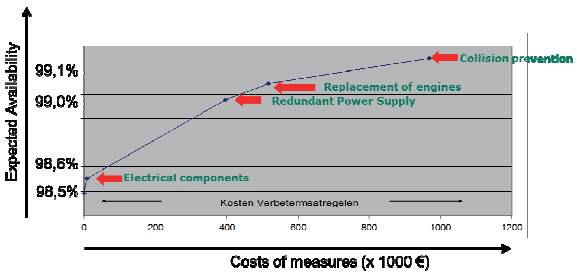

Figure 2 R&A improvement versus costs of measures

4. Discussion and Conclusions

Integral RAMS analysis is a powerful tool to handle the problem of ageing hydraulic structures. In this paper we showed how to combine on-site inspections, engineering analyses and risk & reliability analysis in a sophisticated but still practical way. It was demonstrated that the Integral RAMS analysis not only gives useful information on the actual reliability, availability, maintainability and safety of each of the functions of a hydraulic structure, it also gives valuable insight in the largest contributors (risks) to these aspects. This information yields an important basis for selecting improvement measures and optimizing life cycle costs.

However, it should be noted that the presented Integral RAMS analysis takes significant effort and resources. Being an asset owner or infra provider, one should carefully tune the extent of the analyses to the criticality of the structure.

One way to decrease duration and cost is using extrapolation of data from already executed RAMS analyses of hydraulic structures. Currently the Dutch Ministry of Infrastructure and the Environment is analysing these data, using regression analysis techniques, to be able to assess or even to predict RAMS performances of structures, without analysing them in detail. A reliable regression model could be very valuable for future asset management purposes.