

On green management of existing civil infrastructure

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Abstract. The paper deals with maintenance and service life extension of existing civil infrastructure in Norway; concrete bridges, concrete dams and concrete offshore structures, and based on the Norwegian joint R&D project Excon - green management of existing civil engineering infrastructure. The overall objective of the project is to develop a generic decision-making and interaction model for choosing a management strategy for existing concrete structures, and which also includes environmental performance in the same way as cost.

1. Introduction

An effective management strategy for the built environment is an important instrument to meet the requirements from society on shortage of resources, carbon footprint, investments, and safety. This has triggered many initiatives on the subject worldwide and is the background for the Norwegian joint research project “Excon” (2023-2025) presented in the following. The overall goal is to develop a generic decision-making and interaction model for choosing a management strategy for existing concrete structures, and which also includes environmental performance on an equal footing with cost. It involves a change of focus from demolishing and building new to rather increasing the service life of existing structures. It is expected to contribute to Norwegian industry and society savings in the order of EUR 10 billion and to reduce national greenhouse gas emissions by in the order of 10 million tonnes (CO₂-eq) in the decade following the project period. The vision is that the structures will have their digital twin, as a tool for efficient management, operation, and maintenance. Sub-goals: - Digital platform for handling and storing of data. - Automated and digitized solutions for condition analysis. - Model for determining the environmental performance of different solutions and strategies. - Model for lifetime assessment of damaged and rehabilitated structures.

Civil infrastructure constitutes the backbone of modern civilization, but also huge challenges in that they are often exposed in aggressive environments, difficult accessible to maintenance, and not least represent huge costs and greenhouse gas emissions/resource use by building new, since they are typically large. More than 70% of such structures can be defined as concrete structures. Note however that concrete is used to in steel and wooden constructions as well. Therefore, the project concentrates on concrete civil infrastructure, but it is expected that the results can adapted to buildings and other applications.

2. Motivation

2.1 Circular economy - extension of service life

EU has initiated what they call a new "renovation wave" both in its European Green Deal and in the circular economy action plan. The most effective single strategic way to reduce greenhouse gas emissions, and thus an important contribution to green conversion in the building and construction industry, is probably to extend the service life of the existing building mass instead of demolishing and building new. Based on the current situation concerning bridges, it can be assumed that both greenhouse gas emissions and costs for rehabilitation to increase the service life by 30 years are less than 10 % compared to the construction of new crossings.

2.2 Maintenance backlog

As in many countries the maintenance backlog in Norway is enormous. In addition to the economic consequences, i.e. huge investments in maintenance and repairs, it also questions safety of the structures. The projected lifespan of the concrete structures in question varies between 30 and 100 years, depending on the area of use, and requires a minimum of maintenance. However, it turns out that maintenance often starts too late and/or is insufficient and that the need for maintenance is significantly greater than expected. The result of the project is

expected to contribute to reduce the backlog by making maintenance more efficient and targeted. Also, reduced construction needs to which this project contributes, potentially frees up funds for increased efforts to reduce the maintenance backlog.

2.3 Environmental performance

Cost-benefit is usually the most important driver for choosing a management strategy to maintain the performance the structure is designed for. Now the environmental performance, and especially the greenhouse gas footprint, is perhaps at least as important a driver. This significantly complicates the choice of management strategy, whether it is a question of extended service life or not. How the environmental performance will be handled in the management strategy is currently unclear.

2.4 Interplay

Interaction in the value chain: There are many links in the value chain for the problem in question. A lack of interaction and a common data base and verification system is a significant obstacle to effective management. The project comprises therefore the whole business chain including owners of the three structure types in question, consultants, intervention contractors, repair system suppliers as well as research organisations and specialists in digitalisation and data management (a total of 21 partners).

3. Overall methodology – work content

A number of case bridges, dams and offshore structures have been identified and made available for the project by the owner partners. This includes also historical data from initial design, construction, interventions, and repair (if any). It allows testing of “Excon” solutions on real structures and verification of lab. testing and test methods. The project is organised in five work packages:

1. Decision-making model (DMM): Advanced models for decision support have been developed to a much greater extent for industries other than the construction industry, but these models have not yet included environmental performance (EP) as a criterion either. The research need lies in developing a total TEA (Techno-Economical-Assessment) model for the structures in question that includes also EP. It involves an overall interaction sustainability model where LCA/LCC, emissions basis, business and interaction models, lead up to a TEA as a joint decision-making basis for the management strategy.

2. Data management: The present situation is that data is scattered among actors in the chain, poorly systematized and stored in such a way that it is difficult to access, and various data storage platforms are used. A digital data platform is being developed where old data can communicate with new data and organised for use in DMM as well as in a digital twin concept.

3. Condition analysis: The ambition is that condition analysis can be carried out automatically, i.e. based on non-destructive test methods (NDT) assisted by drone/robot technology and artificial intelligence (IA). A comprehensive STOA on NDT for the purpose has been made and prioritized by maturity, i.e. a) whether they are ready for use on the present case structures or subjected to b) further development within or c) beyond the project period. A lab. based mock-up system with built in damages has been established to verify (and later certify) the methods. The possibility of combining data from various NDT measurements as a proxy for other parameters that are difficult to measure by NDT is being investigated. Combined with advanced structural analysis to derive reliability-based acceptance criteria for robustness, durability and functionality, it will also form the basis for modelling existing structures with damage and repairs. A comprehensive STOA has been prepared to decide on the best suited framework for advanced structural analysis. Sound detection methods for condition assessment of prestressed reinforcement are lacking and is therefore given special attention.

4. Environmental performance: Climate budget and accounts have already become a weighting criterion in calls for tender. A weakness of the current emission accounts, and which is the R&D challenge, is that they rarely include maintenance activities or that they are treated in a very simplified and limited manner. Model for assessment of environmental performance is being built up for implementation in accordance with the international standards ISO 14040 and 14044 for LCA assessments. Life cycle costs assessment is included and made in accordance with current Norwegian Standards with a view to making visible the economic benefit of reduced maintenance and possibly extended service life. It includes Identification of critical parameters and a holistic approach to environmental performance assessment to avoid problem displacement; between life cycle phases such as construction, operation and maintenance frequency, and between different types of environmental impact.

5. Intervention and service life assessment: The work comprises rehabilitation methods and methods for service life assessment, also for rehabilitated structures. Structural health monitoring systems is an important

part. Reinforcement corrosion is the main reason for rehabilitation and cathodic protection is the main method considered in the project. The service life of rehabilitation methods is questioned and therefore in focus. This is strengthened by the fact that it is uncertain whether the test methods specified for verification are sufficient, and that more knowledge about the correlation between such tests and performance in situ is needed. Repair of pre-stressed reinforcement system damages is presently not reliable and is therefore given special attention. Also, silica-aggregate-reaction (ASR) is an important damage mechanism (in dams mainly). Since mechanism-based models for service lifetime assessment of structure with ASR are lacking and there are no practical/economical methods to stop ASR or repair ASR damaged structures, the main strategy is to follow the development and its consequences. Structural health monitoring is therefore important. Fibreoptics applied on the structure has proven to be a very promising approach to follow deformations and is being further developed and verified in the project. A belonging advanced structural design tool (non-linear FEM) is being developed for the purpose, also to form the basis for development of digital twin.