Full Paper Transactions, SMiRT 28
Toronto, Canada, August 10-15, 2025

MODIFICATION OF ISI AND AGEING MANAGEMENT FOR LTO OF CIVIL STRUCTURES

Jan Stepan [1]

[1] Designer, UJV Rez div. Energoprojekt Praha, Prague, Czech Republic (jan.stepan1@ujv.cz)

ABSTRACT

The paper discusses important areas of necessary modifications of building ageing management as part of extending the service life. The issues are illustrated by practice and experience with the modification of ageing management in the Czech Republic. The given examples cover the area of material degradation, the need to expand in-service inspections to include the new degradation mechanism, and the rearrangement of the inspection schedule to maintain knowledge and skills.

INTRODUCTION

Long-term operation (LTO) of existing NPPs raises the need to extend the service lifetime of individual SSCs beyond their original design lifetime. The original design required and specified in-service inspections (ISI) of building structures mainly for selected, safety important structures. Following ageing management review covered all structures of safety important buildings but the review still considered the service lifetime of the structures according to their design specifications.

In the case of the ageing management review for long-term operation, it is necessary also consider the degradation mechanisms previously excluded from ISI and ageing management due to their unexpected occurrence in the original design lifetime of structures. This paper summarizes findings from an ageing management review of civil structures for long-term operation carried out for NPPs in the Czech Republic and discusses the newly added ISI to ageing management to cover long-term operation.

ORIGINAL SETTING OF ISI AND AGEING MANAGEMENT PROGRAM

Original design required and specified in-service inspections (ISI) of building structures just for selected, safety important structures. Typical examples are containment or liner in some rooms, where collecting of leakage from equipment is required. For these structures, the method and criteria of inspections were determined in individual programs of quality assurance. These programs cover entire lifetime of safety important structures or equipment, starting with manufacturing and ending with decommissioning. During the operation period, the execution of periodical inspections is monitored by ISI program under supervision of the regulator. Each inspection is documented in the form of an inspection protocol, containing the type and location of the inspection, results of the inspection and their evaluation according to the criteria. In the case of building structures, the location of inspection is mainly represented by means of control points corresponding to the most representative parts of the structure. If there is a part of the structure requiring more interest or causing failures, the regulator usually requires to include this structure into ISI program even though there is no requirement for the inspection in the design.

Independently on the ISI program of safety important structures, standard periodical checks of buildings are taken. These mainly visual inspections are focused on the overall condition of the building and are the basis for a maintenance schedule or a more detail inspection. The results of these inspections are projected into the maintenance schedule and the corresponding financial plan. There is no detail technical documentation of inspections allowing future systematic processing of the inspection results.

Along with the introduction of an ageing management, the unification of inspection programs was initiated. The methodology of inspections under the ageing management program is able to replace regular

global checks of building and offers a uniform and more sophisticated form of documentation of inspections results. During the inspection, all deviations from the usual state are documented as a finding. If the criteria are exceeded, the status of the finding is changed to a fault and a repair is scheduled with the priority according to the importance of the fault. The inspections carried out within the ISI program are usually performed and evaluated separately in a manner approved by the regulator. However, the results of these inspections are transferred into the ageing management program either at the same level of detail or generalised to a larger view.

TRANSITION TO LONG-TERM OPERATION

The review of the ISI program and ageing management, carried out in preparation for long-term operation, have focused mainly on two areas – the exposure of structures to already expected degradation mechanisms for a longer period than expected in the original design and the importance of previously excluded degradation mechanisms.

The first step of the assessment was to summarize the already known degradations causing faults of structures. Following steps focused on the long-term exposure of the structures leading to a higher significance of currently neglected degradations and on the ISI and maintenance schedule for an extended NPP lifetime.

Material degradation

In the case of safety important structures, most failures correspond to conventional structural degradations:

- mechanical damage or degradation of coatings or roof waterproofing
- mechanical damage of the concrete surface or steel liner (wear and tear)
- corrosion of steel structures and anchor plates on the surface of concrete in outdoor environment

Thanks to the massive dimensions of the structures, there is no problem with the depth of carbonation of the concrete and the resulting reinforcement corrosion. The effect of carbonation or corrosion can also be easily eliminated by regularly renewing coatings on concrete or steel surfaces.

Corrosion of the reinforcement due to carbonatation has already occurred in other, non-safety important, buildings, where the dimensions of the structures correspond to the requirements of the standards valid at the time of design and the required cover of reinforcement was too small compared to the requirements of current standards. This degradation is typical for prefabricated roof panels designed for minimal loads with reinforcement coverage at the limits of old standards. The combination of insufficient coverage of the reinforcement with aggressive environmental conditions caused corrosion of the reinforcement. The solution is to replace the panels as part of a complete roof renovation.

Long-term maintenance feasibility

The need to rearrange the ISI and maintenance schedule arose in the case of the containment prestressing system. The prestressing system is designed as unbonded and allows the replacement of the tendons during the life of the containment. There is a workshop on-site for the manufacturing of new tendons, including a storage of the material for tendon manufacturing and the operator owns all the equipment need for the tendon replacement.

The critical point is the amount of stored material. The capacity has been designed for the expected design life of the NPP. Long-term operation leads to the need for future restocking of wire and grease. Due to the long period of restocking, it is difficult to obtain a product of the same specification on the market. Therefore, it is necessary to plan each restocking in advance and complete the qualification of newly supplied materials before the final renewal process.

It is also necessary to ensure the transfer of knowledge for both, the manufacturing of tendons as well as their replacement in the containment. On each unit, the design expected the period 12 years for the replacement of 3 tendons, selected for detail inspection. Considering two units on site, this means a period of 6 years for the tendon manufacturing and replacement. Accumulation of all activities within one year reduces the total cost of the inspection. However, this period proved to be too long to maintain the contractor's knowledge and capabilities in this area of activity. As a result, the schedule of tendon inspections was revised in order to ensure continuous activities related to the prestressing system inspections. The current schedule includes at least one activity each year, so the knowledge transfer and the maintenance of prestressing system is ensured.

Implementation of new tests and inspections

The need to introduce new tests and inspections arises when existing inspections do not sufficiently cover knowledge about long-term degradation or when new types of degradation appear. In the case of the discussed NPP, this occurred for the case of spent fuel pools.

The original design assumed full tightness of the spent fuel pools, and this requirement was proven by tests during construction (local tests during construction and global test at the end of construction). A double liner with a gap between the liner layers is used to detect leaks. The gap is drained by a system of pipes to collection sumps where the inflow of leaks is measured. In the event of inflows, the original design expected repairs of leak points in the primary liner.

In the first years of operation, the repairs of newly occurred local leak points were possible due to sufficient space for the rearrangement of spent fuel. Later, however, as the spent fuel pools reached full capacity, the repairability of some local leak points locations became very difficult due to limited accessibility of these locations. Therefore, the question of the admissibility of long-term leakage arose.

Permanent leaks up to the capacity of the drainage system are not a problem with regard to the water supply of pools. The research therefore focused on the effect of permanent leaks of boric acid solution into the gap between the liner layers and into the concrete (a possible leak of the secondary liner is assumed).

To supplement the knowledge on the effects of boric acid solution on structures, new long-term laboratory tests have been conducted. These tests are based on samples immersed in a boric acid solution and two boundary conditions of the boric acid action are expected – limited flow through the structure and continues flow simulating an open crack allowing free penetration through the structure. As a result, for each type of sample, the influence of three different type of conditions is tested – pure water, solution of boric acid without exchange and solution of boric acid with continuous exchange (renewal of acidity). The following types of samples are tested:

- concrete of various types found in structures around pools (degradation of concrete is tested)
- concrete with reinforcement or steel anchor (degradation of steel elements inside the concrete is tested)
- samples of liner, with and without coating (degradation of secondary liner is tested)

Independently of the laboratory tests, the chemistry of existing concrete was checked to see if there is a potential risk of degradation due to the permanent presence of water inside the concrete.

The functionality of the drainage system is ensured by periodic cleaning of the system and checks of pipe patency.

In order to detect the presence of leaks in the concrete, moisture monitoring of concrete structures around the pools has been newly initiated. The main purpose of this measurement is to detect a permanent increase of moisture in the concrete at an early stage. If this occurs, more detailed inspections of the hermetic liner and penetrations will be implemented into the ISI program to cover increased risk of corrosion of the hermetic liner.

CONCLUSION

The results of the ageing management review for long-term operation showed that in the case of degradations expected in the design along with the absence of weak points in the design, the extension of the NPP lifetime does not create any extensive increase in inspections, testing or structure modifications. Timely and regular renewal of coatings is important to reduce the progression of degradation.

Degradations neglected in the design require more effort. Samples of the original material of the structures are usually missing and the manufacturing of new samples is limited by the availability of raw material from the same source. Another problem is the time required to perform laboratory tests. Degradation processes often cannot be accelerated and must occur in real time. Obtaining results requires testing over a period of several years, and early initiation of testing is therefore also very important.