**A****MP322   PRESERVATION OF NON-CONCRETE STRUCTURES DURING DELAYED CONSTRUCTION (VERSION 2021)**

**Programme Description**

This AMP addresses a NPP in a condition of delayed construction whose interruption of works occurred at any stage prior to the beginning of the electromechanical assembly, which means that the civil structures may be at any stage in between. Therefore, this condition monitoring programme aims at guiding NPPs in this condition to manage the ageing of Structures and components (SCs), excepting concrete structures which are covered in AMP 321, in order to maintain the expected condition to allow the resumption of construction work and electromechanical assembly, aiming at obtaining the commissioning and start-up of the plant.

The actions to be taken to manage the ageing are mostly based on the ACI 319.3R [1] and EPRI Report 1015078 [2] that provide the recommendations for the evaluation of existing nuclear safety-related SCs, such as methods of examination including visual inspection, testing techniques and their recommended applications, as well as the acceptance criteria for various types of degradation and methods of repair.

Considering the reactor technology adopted, the programme is suitable for all types of NPPs, but attention must be paid to the particularities of each one.

**Evaluation and Technical Basis**

1. ***Scope of the ageing management programme based on understanding ageing:***

The scope of the programme comprises the SCs of a NPP in a condition of delayed construction including those safety-related and non-safety-related, and all of them relied on safety analyses or plant evaluations to perform a function for fire protection, environmental qualification, pressurized thermal shock, anticipated transients without scram, and station blackout. The scope also comprises periodic visual inspections and, if necessary, the performance of tests on the SCs listed below and covered in AMP 319.

* *Common Components:* various structural steel and support members such as beams, girders, joists, trusses, frames, columns, posts, girts, base plates, bearing plates, bracing, splice assemblies, connections, decking, grating, bolts, washers and nuts, welds, studs, shims, metal partition walls, steel embedments in concrete above the concrete line, pipe whip restraints, jet barriers, missile shields, crane girders and rails, flood curbs, flood and fire doors, stairs, platforms, electrical and instrumentation enclosures, fire hose racks, the exposed surfaces of cast-in-place or grouted steel and all post-installed concrete anchors.
* *Bolting:* threaded fasteners such as joint components such as bolts, studs, nuts, washers, screws, and anchorage to concrete.
* *Elastomers:* vibration isolation, construction and expansion joint sealants, moisture barriers and structural sealants.

The ageing effects and degradation mechanisms for the SCs in this scope are provided in EPRI Report 1015078 [2]. However, there are degradation mechanisms whose occurrence depends on whether the plant is operating. Therefore, since the approach of this AMP is a NPP in a delayed construction condition, it is addressed below only the degradation mechanisms that may occur in this condition:

* *Common Components:*
* loss of material due to general, galvanic, crevice and pitting corrosion, erosion and erosion corrosion, and microorganisms;
* cracking due to stress corrosion (SCC) and/or intergranular corrosion (IGA).
* *Bolting:*
* loss of material due to general corrosion;
* cracking due to stress corrosion (SCC) in those of high strength;
* *Elastomers:*
* change in material properties: decomposition due to exposure to ultraviolet (UV) radiation and ozone, and decrease in tensile strength or ultimate elongation, and cross-linking due to thermal exposure (T > 35°);
* cracking: cracking and checking (splitting) due to ultraviolet (UV) radiation and ozone, and cracking and chain scission due to thermal exposure ( T > 35°).

Aiming at the preservation of these SCs during the delayed construction period, the preventive actions addressed in attribute 2 may be taken.

1. ***Preventive actions to minimize and control ageing degradation:***

The delayed construction programme is a condition monitoring programme that recommends some preventive actions.

Preventive actions are the key point for the preservation of NPPs in a condition of delayed construction. In addition to the protection of the SCs presented in attribute 1, the preventive actions may also comprise temporary constructions and site maintenance as presented below.

* Use of Coatings: Among all preventive actions, the use of coatings stands out to protect the external surfaces of the SCs in their respective service environments. Those generally used consist of paint and cement paste. Paint is applied to structural steel and steel components, exposed steel embedments in concrete, threaded fasteners, and any other metallic surfaces to be protected from corrosion. Anticorrosive paint offers protection through its inhibiting pigments that react with the steel in the presence of moisture forming a passive layer on the steel that retards the corrosion process. Cement paste is applied to elastomers exposed to weather aiming at preventing water from entering the structures which may result in their degradation. Every surface must be cleaned before the coating application and if there is rust it must be removed beforehand. EPRI Field Guide 1025323 [3] is a helpful tool concerning coatings.
* Use of Wax and Grease: Wax and grease are used to protect metallic surfaces from corrosion. As well as coatings, the surfaces must be cleaned before the application and if there is rust it must be removed beforehand. They are generally used on machined surface of mechanical components.
* Use of Caps: Caps are used to provide physical protection, for example, for nozzles and threaded holes.
* Periodic Cleaning – Housekeeping: In a NPP in a condition of delayed construction, it is mandatory to keep all areas within the structures built clean, including roofs, gutters and existing drains, as well as the entire construction site. Concerning the roofs, special attention should be paid to nests and bird droppings. The latter may attack carbon steel surfaces owing to uretic acid, which is highly corrosive in the presence of moisture. In addition, bird droppings are an environment conducive to the growth of fungi and bacteria that generate the necessary conditions for the development of anaerobic microorganisms that may deteriorate coatings and steel SCs. Places with a high concentration of birds must have effective and, above all, ecological means to scare them, such as, for example, the installation of bird control spikes and the use of ultrasound technique.
* Installation of Drainage Systems: Water is usually the main cause that leads to the degradation of SCs. Therefore, both entry and accumulation of it must be avoided. To achieve this condition, it is necessary to install an efficient drainage system inside and outside the structures. The periodic clearance of the drainage systems during the delayed construction period is essential for their effectiveness.
* Sealing of Penetrations, Seals, Edges of Waterproofing Membranes and Joints: Regarding the entry of water, penetrations, seals, edges of waterproofing membranes and joints, including expansion joints, exposed to weather are critical zones. They must be carefully and very well sealed, and their functionality must be observed over rainy periods. When they are located on horizontal or slightly inclined surfaces, a system to collect the water and lead it to drains is necessary. Typically, elastomers are used in NPPs as vibration isolators, construction and expansion joint sealants, moisture barriers and structural sealants. In a NPP in a delayed construction condition, cement paste coating shall be applied to elastomers exposed to weather in order to prevent water from entering the structures which may result in degradation.
* Assembly of Temporary Roof: Temporary roofs, such as tents, may be assembled over roofless buildings to avoid entry of water that may damage the SCs.
* Use of Dehumidifiers: Dehumidifiers can be used to control moisture in specific locations.
* Use of Sacrificial Anode: Sacrificial anode may be used to provide chemical protection for SCs in a marine environment.

1. ***Detection of ageing effects:***

This AMP applies the periodic evaluation method that can be used to demonstrate satisfactory performance of the SCs of a NPP in a condition of delayed construction to identify the presence and activity of age-related degradation [1]. This method does not intend to address a specific issue, but rather is employed to determine physical condition and functionality of the SCs with respect to the design basis. Periodic evaluations shall be repeated at a certain frequency using a standardized procedure and should be established by considering factors such as accessibility, physical condition, environmental exposure, and tolerance to anticipated degradation. This form of evaluation shall provide an effective method for technical justification in a license application for the NPP as a whole.

1. ***Monitoring and trending of ageing effects:***

As several degradation mechanisms often produce visible indications, patterns, or features on exposed surfaces during initial manifestation and propagation, the monitoring and trending activities of this programme consist of performing a visual inspection on the SCs in this scope, in order to identify any degradation. The basic criteria for prioritizing and selecting structures for periodic evaluation must be adopted before the visual inspection whose results may indicate a behavioural trend and/or the necessity of tests to be carried out. The intent of the prioritization process is to inspect a representative sample of the areas that are most likely to experience some form of degradation, as well as those areas where degradation can be critical to the structural integrity of the SCs. The three primary factors pertinent to each SC that are common to the prioritization are safety significance, accessibility, and environmental exposure conditions.

Visual inspections can provide quantitative and qualitative data regarding the structural performance and the extent of any degradation. They can be used to define the current condition of an accessible SC in terms of the extent and cause of degradation, material deficiencies, performance of coatings, and current response to applied loads. Visual inspections should be carried out periodically and should be repeated at a certain frequency that depends on accessibility, physical condition, environmental exposure, and tolerance to anticipated degradation. Typically, visual inspection is both the initial and primary technique used for any evaluation, supplemented as needed by non-destructive tests and other methods. Evaluation for inaccessible areas, including below grade structures, can be broadly divided into SCs with nonaggressive exposures and SCs exposed to aggressive environments. Concerning the condition of delayed construction, it is not expected SCs exposed to aggressive environments. In the case of nonaggressive environment, the evaluation for acceptability of inaccessible areas can be performed when conditions exist in accessible areas that could indicate the presence of, or result in, degradation to such inaccessible areas. However, examination of representative samples must be carried out when, for any reason, portions of the structure are exposed. There must be an evaluation procedure document comprising detailed information and recommendations for addressing subjects, such as scope and applicability, description of applicable degradation mechanisms at the plant for periodic evaluations, evaluation-team qualifications and responsibilities, SCs selected for periodic evaluation and reasons for selection, documentation and archival requirements, approved evaluation methods that will be used, including uses and limitations for selective and periodic evaluations, acceptance criteria, evaluation equipment use and calibration, and frequency of periodic evaluation.

The licensee engineering defines the frequency of inspections according to the licensing requirements and design basis of the plant that may change depending on the environment to which the SC is exposed and its observed condition. If degradation is observed in excess of the second-tier acceptance criteria, increased visual inspection frequencies or enhanced testing could be required [1]. Periodic inspections carried out in SCs of a NPP in a condition of delayed construction shall not exceed six months.

1. ***Mitigating ageing effects:***

This AMP is a condition monitoring programme and no recommendations are provided to mitigate ageing effects. However, whether degradation occurs exceeding the acceptance criteria, plant specific actions should be taken based on the monitoring carried out and the trending observed, leading to an evaluation to mitigate the root cause or source of degradation and analyse the impact on the performance of the SC.

In the case of delayed construction, coatings must be replaced immediately if any sign of degradation is detected, as well as elastomers protected from weather that are not covered with cement paste. Elastomers exposed to weather, which are covered with a cement paste, must be replaced until the completion of the construction work.

1. ***Acceptance criteria:***

The acceptance criteria adopted in this AMP for the SCs in the scope are basically the same as those regarding the 40 years of lifespan of a NPP, but counterbalanced by the adoption of a much shorter time interval between periodic inspections.

The acceptance criteria for structural steel and steel components, threaded fasteners and elastomers can be found in EPRI Report 1015078 [2].

This AMP addresses the references from which the acceptance criteria can be obtained but does not present them since they may change over time. Therefore, it is essential to use the latest version of the documents.

1. ***Corrective actions:***

Corrective actions are recommended for the cases in which the acceptance criteria are not met. The corrective actions recommended in this AMP are those adopted for safety-related SCs because they must follow the design basis and, therefore, are more rigorous in terms of loading conditions and demands, plant hazards, elastic behaviour/response and overall regulatory requirements, are also adopted for non-safety related structures. The repaired SC will meet the original design basis unless a license change is otherwise approved by the regulatory agency to revise the basis. However, the approval must be obtained in advance of actual repair selection and implementation. In addition, the means, methods, and materials used for repair must conform to the nuclear quality assurance (QA) programme, as stated in the plant licensing basis. These limitations individually or collectively influence options that can be considered or used in the repair.

1. ***Operating experience feedback and feedback of research and development results:***

This AMP considers the operating experience cases of the six IAEA Member States in NPPs in a condition of delayed construction reported in IAEA TECDOC 1957 [4], as well as the case of Argentina. All experience related to the ageing of the NPP during the delayed construction phase, including issues detected, and corrective actions carried out and their effectiveness are analysed, documented and recorded by each Member State, allowing the plant to implement a feedback process which is taken into account in its periodical evaluation, as well as the industry-wide experience and the results of research and development (R&D) programme. If necessary, the AMP of the plant may be modified to include additional actions or a new AMP is developed, ensuring the effectiveness of continuous ageing management.

1. ***Quality management:***

A management programme must be implemented to ensure the quality of administrative controls, data collection and record, quality of materials, procedures and reports, review and approval of processes, and personnel qualification that must be in accordance with the local regulations [5].

**References**

[1]  AMERICAN CONCRETE INSTITUTE – ACI 349.3R-18, Report on evaluation and repair of existing nuclear safety-related concrete structures, January 2018.

[2]  ELETRIC POWER RESEARCH INSTITUTE – EPRI Report 1015078, Plant Support Engineering: Aging Effects for Structures and Structural Components (Structural Tools), December 2007.

[3]  ELECTRIC POWER RESEARCH INSTITUTE - EPRI 1025323, Field guide: coatings assessment, May 2012.

[4]  IAEA-TECDOC-1957, Ageing Management of Nuclear Power Plants during Delayed Construction Periods, Extended Shutdown and Permanent Shutdown Prior to Decommissioning.

[5]  UNITED STATES NUCLEAR REGULATORY COMMISSION, 10 CFR Part 50, Appendix B, Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants, National Archives and Records Administration, USNRC, latest edition.