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AGEING MANAGEMENT PLATFORM FOR FINNISH NPP CONCRETE INFRASTRUCTURE

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ABSTRACT

It is possible that many NPPs will be able to operate longer than their operational design lives, provided appropriate and proven ageing management measures are implemented in a timely manner. As a result, attention from the regulators and the utilities has been focused on the ageing of buildings and infrastructures of NPPs. In Europe approximately a third of the operational reactors are within a few years of, or older than, their original design lifetimes. In Finland, the VVER reactors have been granted a licence extension up to 50 years of operation, whereas the BWR reactors operating license has been renewed for a 60 year lifetime. All reactors have to be subject to a safety evaluation every 10 years. Strategies to manage and reduce the consequences of the concrete infrastructure ageing are also currently under development in many fields of civil engineering. Here is presented the MANAGE research project (funded by SAFIR2014). In this project an ageing management platform (AMP) has been developed for Finnish NPPs. The AMP consists of the central database and a group of analysing and planning tools which interact with the database. Both can be used during different phases in the lifetime of a plant: design, operation, inspection, monitoring, maintenance and repair of structures. The AMP consists of the following applications: document archive visualization; condition assessment database (archived reports and documents, inspection reports, etc.); and service-life assessment (ServiceMan).

INTRODUCTION

Ageing management is important part of safety management systems of nuclear power plants (NPP). The main objective of ageing management is to increase knowledge about time-dependent deterioration processes affecting the systems, structures and components (SSC), throughout the NPP's service life. Comprehensive knowledge is a pre-requisite to prevent ageing related failures. Therefore, it is imperative that relevant data is collected, stored and analysed systematically. While a NPP is in service, numerous ageing related events occur which may have an influence on the performance of SSC. Relevant events may be malfunction, maintenance results, operational experience, results of condition assessment, etc. (Schoeckle et al. 2014).

Based on the IAEA Safety Guide NS-G-2.12 (2009) for ageing management systems addresses both physical ageing of structures, systems and components (SSC), and their obsolescence. Effective ageing management is in practice accomplished by coordinating existing programmes, including maintenance, in-service inspection and surveillance, as well as operations, technical support programmes (including analysis of any ageing mechanisms) and external programmes such as research and development. This requires the use of a systematic approach to managing ageing that provides a framework for coordinating all programmes and activities relating to the understanding, control, monitoring and mitigation of ageing effects of the plant component or structure (Vesikari et al. 2011).

According to STUK (Finnish Radiation and Nuclear Safety Authority) guideline YVL 1.0 (1996), in "NPP design, the service life and the effect of their ageing on the safety of all safety significant structures, components and materials shall be assessed using sufficient safety margins. Furthermore, provision shall be made for the surveillance of their ageing and, if necessary, their replacement or repair." Furthermore, guideline YVL 1.4 (2008) states that " a management system shall be planned and implemented to incorporate all the operations of an organisation, and it shall be continuously maintained and improved. The management system shall contain procedures to identify, assess and MANAGE safety risks relating to the operation of the nuclear facility."

It is especially important for the utilities to know the current condition state of their concrete structures. That is only possible by continuous inspection of structures and through an ageing management system which is able to store and treat the inspection reports in a systematic way. It should include predictive methods for evaluating the future performance of structures and to support the definition of a maintenance strategy for the prolonged life time of a plant. The utilities should be able to show the authorities a comprehensive ageing management programme with a description of how the design and qualification of the SSC, their operation and operating experience, in-service inspections and tests, and maintenance are integrated logically and systematically (2006).

Therefore the NPP companies are interested in developing Ageing management systems to avoid premature degradation of NPP facilities and to be able to extend their operating service life. Massive concrete structures (i.e. foundations and containment structures) are not intended to be renewed and cannot be economically renovated. The final service life of NPP may be dependent on the service life of the concrete structures in the facilities.

In response to this need the "MANAGE project – Ageing Management of Concrete Structures in Nuclear Power Plants", funded by SAFIR 2014 (The Finnish Research Programme on Nuclear. Power Plant Safety 2011 – 2014) (SAFIR 2010), was initiated in 2011. MANAGE is a joint project with VTT Technical Research Centre of Finland and Aalto University.

THE MANAGE AGEING MANAGEMENT PLATFORM

The premises of the MANAGE ageing management platform are based on those presented in the YVL Guides and in the IAEA Safety Guide NS-G-2.12. The main objective of the MANAGE project was to develop a platform for the ageing management of concrete infrastructure of existing Finnish NPP.

The platform provides access to the structural, material and environmental information and through the acquisition of essential, up-to-date and proactive data on the condition and performance of concrete structures, it assists the designers and engineers of a NPP in the planning, inspection, monitoring, condition assessment, maintenance and repair of structures. The implementation of an ageing management platform in practice helps guarantees a safe and uninterrupted use of the NPP for the whole intended lifetime. The ageing management platform helps provide useful information for the utilities and the authorities regarding the concrete structures ability to fulfil the serviceability and safety requirements during the whole licensed operating life.

Structure. The development of the ageing management platform took into account the recommendation of the Finnish Regulatory guide YVL 1.1 (2006) by providing in a systematic way the following information:

- new monitoring data on structures based on sensors and samples taken from structures;
- condition assessment and identification of potential risks related to degradation and performance of concrete structures over a long design period;
- improved timing of inspections and future repairs;

- structural safety and performance analyses with improved models;
- improved availability of data and visualisation, and
- electronic storage and treatment of inspection data.

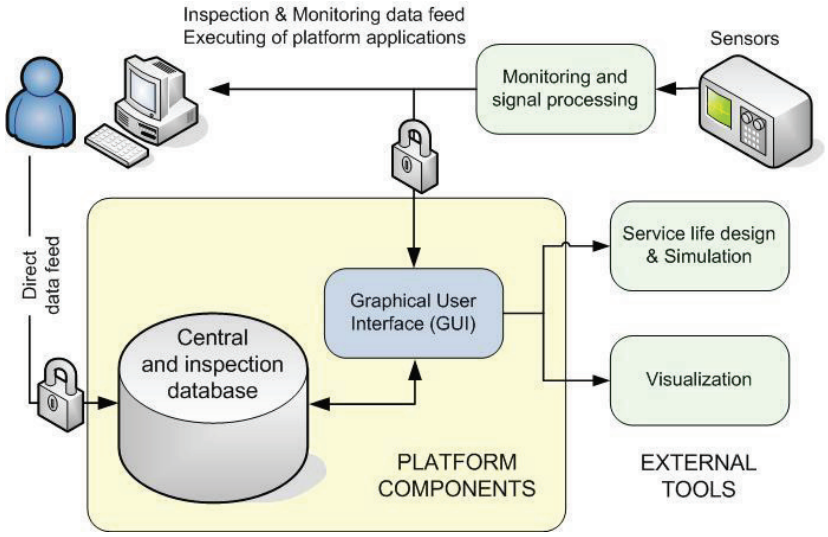

Figure 1. Schematic representation of the structure of the MANAGE platform and the user applications.

Based on these recommendations the conceptual structure of the ageing Management platform was defined (Figure 1). Access to the platform is through the Graphic User Interface (GUI) which connects the user to the various applications and the central database. The platform consists of a harmonised central database and a group of analysing and planning tools which access the data from the data-base. The applications currently available are: i) ServiceMan – an independent service life management system (Vesikari 2011), a visualization tool, and an inspection database. Direct access to monitoring data was not implemented at this stage.

THE GUI & THE CENTRAL DATABASE

The GUI provides the user with access to the central database and the applications. The GUI features are organized by four access levels. Each access level has different screen pages providing various functionalities. The diagram in Figure 2 shows the layout of the platform screen pages. The application screens pages are accessed using navigation menu.

Users access to the GUI from server is by using a web browser. Web browser facilitates user access because there is no need to install additional applications to a user's computer. The GUI has been programmed by using Active Server Page (ASP.NET) and Visual Basic (VB.NET). Both ASP.NET and VB.NET are widely known technologies.

The central database is the core of the platform. It assembles and systematically organizes the information gathered from all applications (Al Neshawy et al. 2007, Al Neshawy et al. 2013). The goals and objectives of the central database are to (1) collect the essential and up-to-date data of the condition and the performance of the NPP concrete structures, (2) store and update these data effectively, (3) allow sophisticated search strategies, (4) produce detailed reports automatically for the condition and the performance of the NPP concrete structures and (5) enable data transfer to other software for further analysis: for example act as a data source for ServcieMan for the estimation of the service life of the NPP concrete structures.

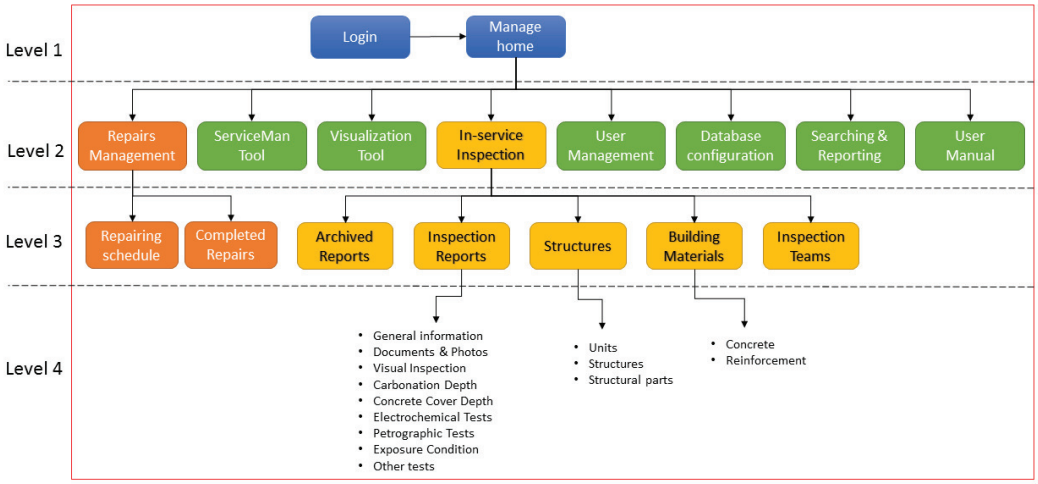

Figure 2. The access levels of the platform and their screen pages.

The components of the platform's central database are organized into a series of sub databases relating to the ageing management system of the NPP concrete structures. These sub-databases are:

- User's management database for user's data and their authorized limits.
- Visualisation database for dealing with the geometrical input and out for the visualisation tool.
- Service life management database for the input and output data for the service life calculation application (ServiceMan).
- Structural database for storing information about the structural types and components of the NPPs concrete structures.
- Inspection database for the data gathered from the investigation and the diagnosis of the NPPs concrete structures.
- Monitoring database for monitoring and simulating the performance of the NPPs concrete structures

The authorized users of MANAGE platform come in two levels: the administrators, and end users. Administrators are responsible for managing the database system and have full access to modify the platform code and design. The end users are the persons that use the platform for querying, updating, generating reports, etc.

THE SERVICEMAN APPLICATION

ServiceMan is a service life management tool for life cycle planning of concrete structures in nuclear power plants. It is able to predict the degradation of concrete structures and to evaluate the timing of necessary maintenance and repair actions over the remaining licensed life time of the plant or longer (extended life time). The tool can also be used for planning, organizing and optimizing the maintenance strategy of concrete structures in NPPs. A detailed description of the ServiceMan tool is presented in (Vesikari 2007).

The system was programmed based on Microsoft Excel. Macros, such as the user interface, were coded using Visual Basic for Applications. The actual service life management system includes the database and tool for service life management. The service life management tool includes prediction of degradation in structures, guarding of safety limits, timing of condition assessments, timing and specification of MR&R actions, and evaluation of life cycle costs and environmental impacts. In-service operations of the service life management system are condition assessment for structures, maintenance, repair and rehabilitation (MR&R) actions, and, updating the degradation models.

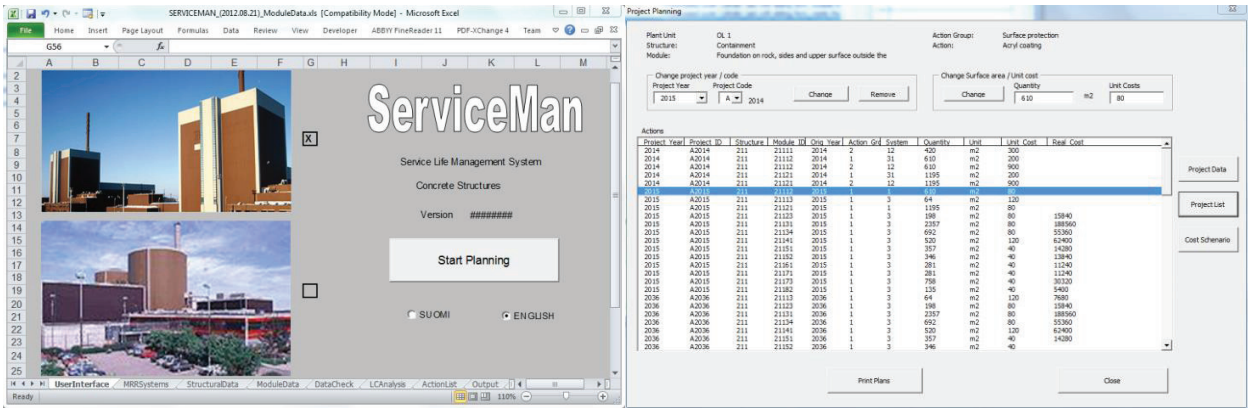

Figure 3. Screen shots of the ServiceMan tool.

An interface between ServiceMan's Excel sheet and the ageing management system's central database is done through the GUI. The application can read from and write to the database and make calculations using ServiceMan tool. Calculation results can also be stored back in the central database.

THE INSPECTION DATABASE

The ageing management system's inspection database is part of the central database which includes all the NPP condition survey data. New inspection data is transferred to an electronic form then stored in the inspection database. The data consists of observations during both periodical inspections and special inspections. The design process of the inspection database is similar to the design of the central database. The structure of inspection database includes four main tables:

- Electronic documents and digital photos
- Visual investigation and diagnosis
- Non-destructive tests
- Destructive and laboratory tests

The components of the inspection database are organized into a series of data-base tables related to the ageing management of the nuclear power plants concrete structures as shown in Figure 4.

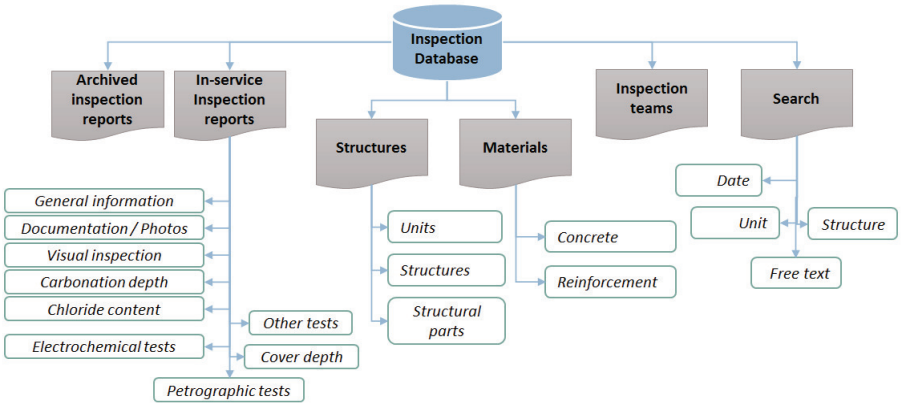

Figure 4. Conceptual design of the inspection database tables

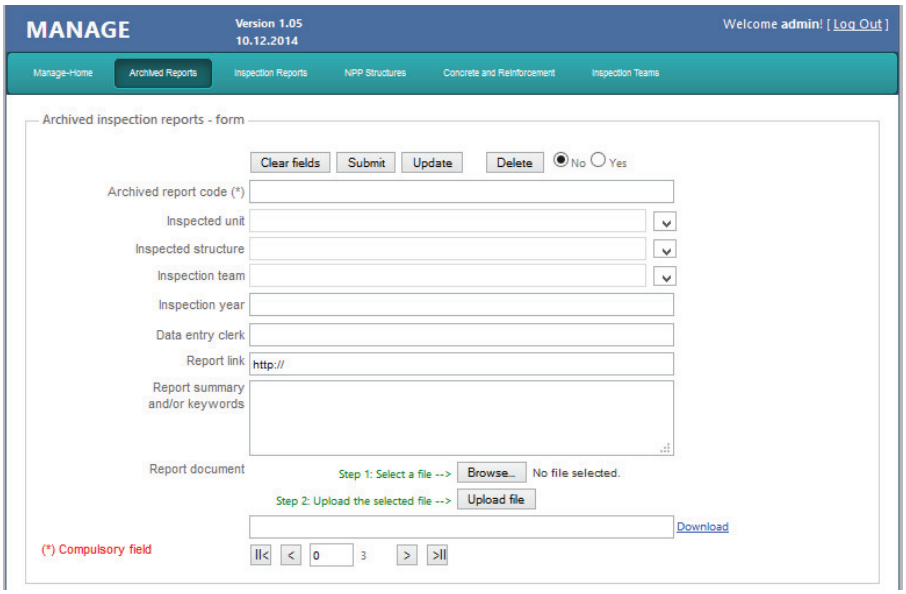

Figure 5. The archived inspection reports home page.

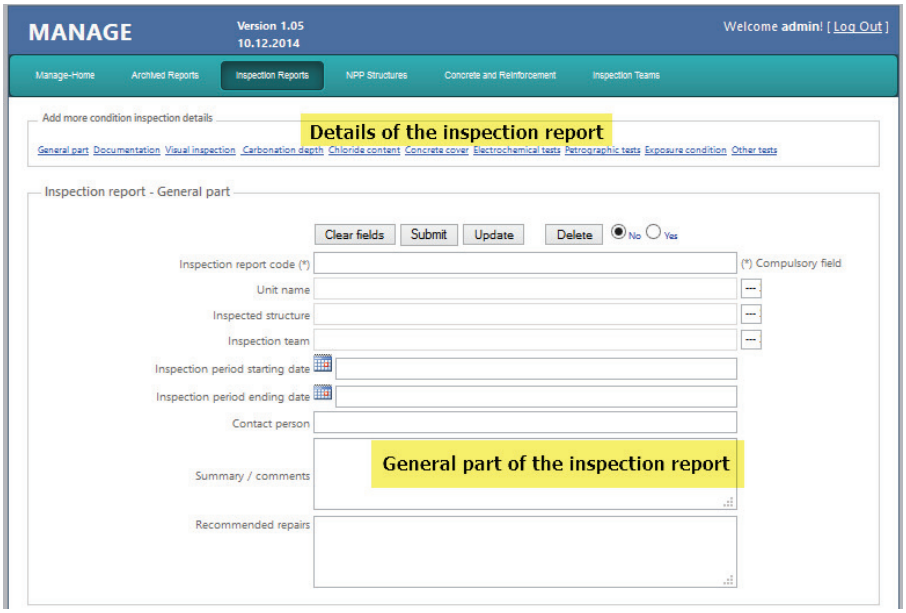

Figure 6. Print screen of the inspection report's general part.

The inspection home page, is working as a dashboard for the inspection database. It offers access to the sub-level inspection webpages which are: the archived in-service inspection reports; detailed inspection reports; NPP structures; building materials used in the NPP structures; and information about the inspection teams involved in the condition assessment of the NPP structures. The sub-level in-service inspection home pages are shown through Figure 5 to Figure 8. Condition inspection report search allows the platform user to enter one search criteria and view or print the matching report if there are any that match the searching criteria. The report searching criteria are (i) date of the condition inspection report, (ii) free text search, (iii) inspection report code name and (iv) research for units or structures of the nuclear power plants.

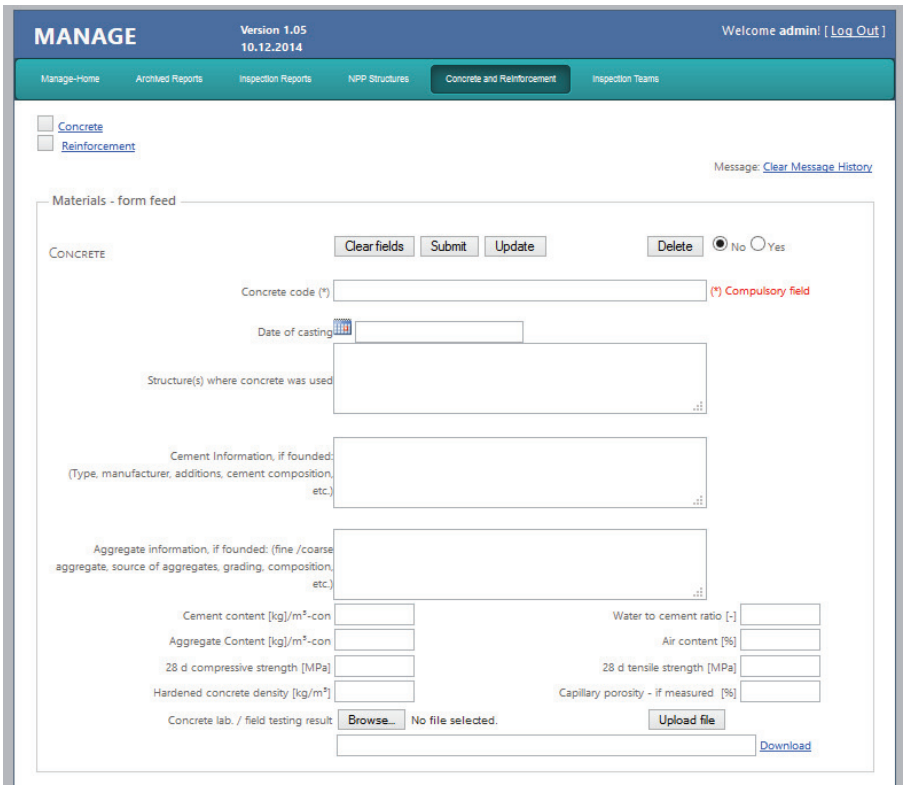

Figure 7. Concrete and reinforcement information webpage.

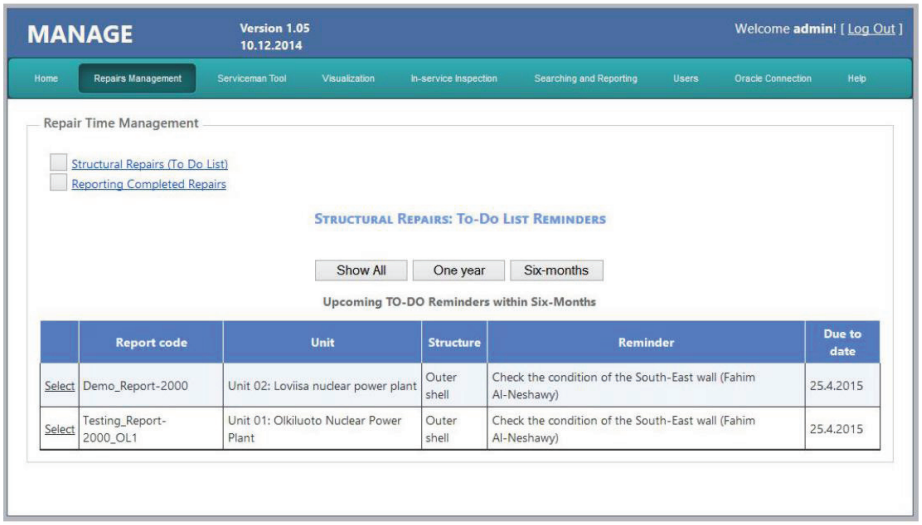

Figure 8. View of the upcoming to-do list.

THE VISUALIZATION APPLICATION

The objective of the visualization application module is to propose an interactive system for visualization of data and documents related to the concrete structures of NPP. The proposed visualization environment is able to provide visual representations of the database content. It is also able to provide direct access to all the digital content, both in terms of physical access to the structural data files as well as in terms of searching and retrieving information.

The visualization interface can be used to import the geometrical data of the structures and report the in-service condition of these parts as attached notes to the geometry drawings. The application is currently using a simple procedure of visualization of all document types in their native format by external visualization software (e.g. AutoVue) that is able to interpret the data. Any kind of original (DWG, DXF, PDF, JPG, TIFF, etc.) can be stored in the central database and linked to the structure it represents. The platform interface will enable users to download process the drawing in an external application and then save the processing results and the original file in the MANAGE central database.

Visualization data is stored in a local Oracle database that consists of 4 tables. Visualization document data is stored in the first table and there are tables for possible unit, structure and module numbers also. Visualization document files are not stored in the database, just the path of the files. Each document is linked to only one unit, structure and module number. These numbers are stored in the Visualizations table example of search screen for specific document is given in Figure 9.

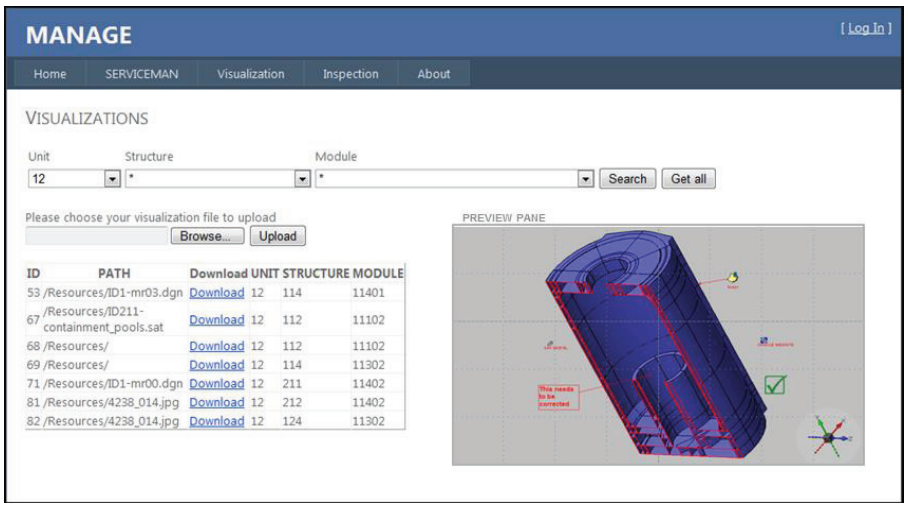

Figure 9.Screenshot of the GUI showing the Visualization interface

COMPLEMENTARY ANALYSES & INTERNATIONAL COOPERATION

Throughout the MANAGE project several complementary studies/analyses have been performed to provide additional support into the ageing management of NPP:

- Condition assessment of cooling water channels in Finnish Nuclear Power Plants (VTT-R-00342-11) – The objective was to evaluate the condition of cooling water channels in Olkiluoto 1 and Loviisa 1 NPP. The research was based on testing of concrete samples taken from the structures (Vesikari 2011b).
- Condition assessment of cooling water channels in Finnish Nuclear Power Plants – Based on sample tests in 2011 (VTT-R-08960-11) – Similar to [12] but with different locations for specimen extraction in the cooling water channels of Olkiluoto 2 and Loviisa 1 (Vesikari & Ferreira 2012)..
- Half-cell potential measurements in Loviisa 1 cooling water chambers (AALTO-R-001-12 2012) – The goal was to measure half-cell potential values of the reinforced concrete structures of the cooling water chambers in Loviisa 1 NPP to verify the state of corrosion of the reinforcement. The half-cell measurements were performed at the same positions in the cooling water chambers as with the condition assessment carried out in 2010 (Piironen et al. 2012).
- Structural failure analysis of post-tensioned containment building of Olkiluoto 2 NPP (VTT-R-00327-11) – The main goal of this report is to conduct structural failure analyses which help to evaluate the above mentioned probability. The intent is to calculate how possible tendon breaks affect the structural integrity of the whole containment building, and to be more precise, how the stress state of the containment wall changes and whether there is an underlying mechanism by which the degradation

propagates further in the structure to concrete, adjacent tendons and liner. To evaluate damage in the concrete induced by tendon breaks and/or pressure tests, supplementary cracking analyses are also conducted (Calonius et al. 2011).

- Condition assessment of pre-stressing tendons by NDT inspection techniques (Ramboll Report) – The aim is to verify the suitability of non-destructive test methods (NDT), for example by Ultrasound MIRA 3D Tomographer system, for detection of voids in grouted pre-stressed structures tendon ducts. In addition, other NDT techniques were used for general evaluation of concrete structures: the Impact – Echo DOCter system, the Surfer System, and the Impulse – Response s'MASH system. The structure chosen for the investigation task was the protective concrete structure of the containment structure of Olkiluoto 2 NPP (Rapaport 2012).
- Condition assessment of the seawater system – Ancillary cooling water outlet tunnel at Olkiluoto 2. (VTT-R-07703-13) – The objective was to evaluate the condition of outlet tunnels of Olkiluoto 2 NPP. The research was based on in situ testing, and from of concrete samples taken from the structures (Ferreira 2013).

During the course of the MANAGE project, VTT was involved in the NUGENIA project ACCEPPT assessing the behaviour and ageing of pre-stressed concrete containment of NPP including steel liner and tendons, which focuses its research to the environmental and mechanical loads and their effects on the structural security of NPP concrete structures. VTT is also involved in the OECD/NEA/CSNI ASCET project on the assessment of structures subject to concrete degradation with focus on alkali-aggregate reaction (AAR). This is also done in cooperation the RILEM TC-ISR on the prognosis of deterioration and loss of serviceability in structures affected by AAR.

CONCLUSIONS

This paper presents a brief overview of the MANAGE ageing management platform developed and the complementary activities that took place within the project. The focus is on the inspection database and the application for durability service life and life cycle assessment. The platform provides access to structural, material and environmental information regarding NPP concrete infrastructure.

The ageing management system consists of the central database and a group of analysing and planning tools which access data from the database. The database together with the analysing and planning tools can be used during different phases in the lifetime of a NPP: design, operation, inspection, monitoring, maintenance and repair of structures.

The implementation of an ageing management system in practice assists in guaranteeing a safe and uninterrupted use of the NPP for the whole intended lifetime.

The purpose of the inspection database is to transfer the condition assessment data of NPP concrete infrastructure to an electronic form. The data consists of observations during both periodical inspections and special inspections. The inspection database allows for sophisticated data search strategies, produces detailed reports automatically for the condition and the performance of the NPP concrete structures and enables data transfer to other software for further analysis.

The ServiceMan tool for durability service life and life cycle assessment can be used for systematic and proactive maintenance of concrete structures in nuclear power plants. The core process of the system is the combined condition, cost and environmental impact analysis. The application estimates the degradation of concrete structures with respect to different degradation types and also the timing of special inspections and MR&R actions for the remaining operating life of the plant.

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