PREFACE

The objective of this monograph is to summarise the scientific research in the structural integrity analysis field as applied to Nuclear Power Plant reinforced concrete structures. The described research areas were performed by the authors of this monograph during the years 1995-2006. The research presented in this monograph applies to structural integrity investigations of Ignalina NPP buildings due to static and dynamics loads.

The nuclear reactors of the Ignalina nuclear power plant (NPP) belong to the RBMK class of reactors, designed and constructed by the Ministry of Nuclear Power Construction of the former Soviet Union. These reactors do not possess the conventional Western containment structure that could confine the radioactive products of a severe nuclear accident. Instead, the Ignalina NPP has a suppression type containment, which for Soviet-built reactors is referred to as the accident localisation system (ALS). The ALS encloses about 65% of the entire cooling circuit and this includes the most dangerous sections of piping to rupture in case of the loss-of-coolant accident (LOCA).

The ALS reinforced concrete building for the RBMK-1500 reactors is comprised of two similar towers adjacent to the reactor unit. The ALS towers are interconnected through a system of the leak-tight compartments designed for steam discharge in case of rupture in the primary coolant circuit. The ALS is required to prevent the release of radioactive materials from reaching the atmosphere in case of the coolant piping rupture, including the Design Base Accident (DBA). The importance of the ALS analysis is the demonstration of the structural integrity of ALS in case of maximum design basis accident (MDBA) which refers to a guillotine rupture of the pressure header of the main circulation pumps.

Both deterministic and probabilistic methodologies were used for structural analysis of reinforced concrete structures. These structures are made from materials with very different material properties, i.e. concrete and steel. Therefore, for strength analysis, sophisticated methods that account for these differences must be used. The finite element method was applied for structural analysis of reinforced concrete structures. The deterministic structural integrity analysis considered loadings due to operation and accident conditions and was based on the accepted geometrical data and material properties of constructions. However, the loadings, geometrical data and material properties are uncertain. The estimation of the uncertainties of initial data to strength of structures is very important. Thus, probabilistic analysis methods are used for the evaluation of uncertainties. A probability-based structural integrity analysis was performed as the integration of deterministic and probabilistic methods using existing state-of-the-art software for Ignalina NPP buildings. The NEPTUNE and ProFES software were coupled for these analyses. Using the coupled software, the analysis of the dependence between loading, geometrical data, material properties parameters on the failure probability of reinforced concrete structures was obtained.

Many individual and several cooperative projects designed for structural integrity analysis of Ignalina NPP buildings, mainly ALS, were performed in the years 1995 - 2006. In this respect the following projects should be mentioned:

- Ignalina ALS Safety Case, Probabilistic Safety Analysis of Level 2;
- Simulation of Ignalina RBMK-1500 ALS Containment Capacity Using NEPTUNE;
- Evaluation of Pipe Whip Impacts on Neighbouring Piping and Walls of the Ignalina RBMK-1500 NPP;
- Strength Evaluation of Steam Distribution Header and their Connections to the Vertical Steam Corridors of the Ignalina NPP;
- Analyses of Ignalina RBMK Nuclear Power Plant Buildings and Structures for External Loading Conditions.

Some of these projects were carried out in cooperation with specialists from Argonne National Laboratory. The material presented in this monograph describes the main results of the mentioned projects.

The methodologies and results of linear and non-linear analysis of the reinforced concrete structures subjected to static and dynamic loads are presented in this monograph. Normal mechanical properties of concrete and reinforcement bars were used in the linear analysis. The concrete strength in compression was also considered and assumed to be equal to zero in tension. The results of the linear analysis are conservative. The experimental mechanical properties of the concrete and reinforcement bars were used for the non-linear analysis which also evaluated the concrete strength for tension and compression. The failures of concrete and reinforcement bars as well as the thickness of destroyed concrete were determined in the non-linear analysis.

The static structural integrity analysis of buildings was performed using internal pressure, concentrated and temperature loadings. The dynamic structural integrity analysis of buildings was performed using the loads from internal impact events onto the internal surface of walls and transient loads onto the external surface of walls from an aircraft crash. The non linear analyses under dynamic loads were performed using both deterministic and probabilistic structural integrity analyses. The following methods were used for numerical probabilistic analysis of reinforced concrete structures: Monte Carlo simulation, the First-Order-Reliability- method and Response Surface / Monte Carlo Simulation.

The deterministic and probabilistic methodologies for structural analysis of reinforced concrete structures are presented in this monograph. The applications of these methodologies were applied to Ignalina NPP buildings, as examples. However, these methodologies can be used not only for NPP buildings, but also for other reinforced concrete structures that have strict requirements for safety: for example, bridges, dams, chemical plants energy facilities, and pylons for electricity lines. In addition to reinforced concrete structures, these methodologies can be used for steel constructions where failure would create dangerous environment conditions: for example, heat, gas and oil pipeline systems, steel devices within chemical plants and energy industry.

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