

Structural and Physical Aspects of Construction Engineering

Experimental and Numerical Analysis of the Hermetic Tightness of NPP Bubble Tower Structure

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Abstract

This paper describes the experience from the experimental testing of the hermetic tightness of bubble tower (BT) of the nuclear power plant (NPP) type VVER 440 under the high internal overpressure after 30 years of the performance. The results from the experimental tests were used for the checking of the numerical model of the reinforced concrete structures. There is showed summary of calculation models and calculation methods for the reliability analysis of the structural integrity due to extreme overpressure. The tightness testing of the steel internal liner during the NPP performance was realized in accordance of the international standards. The methodology and results of the optical and mechanical measure are presented. On base of the nonlinear analysis the safety and reliability of the concrete structure were considered.

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Peer-review under responsibility of the organizing committee of SPACE 2016

Keywords: Nuclear Power Plant; Safety; Reliability; Concrete; Experimental test; Nonlinearity; CRACK; ANSYS

1. Introduction

The International Atomic Energy Agency set up a program [8, 9] to give guidance to its member states on the many aspects of the safety of nuclear power reactors. The resistance of the building structure must be checked for extreme steam pressure in the case of small or a medium-sized accidents, such as a Loss of Coolant Accident (LOCA) or a High Energy Line Break (HELB) or a Steam Line Break Accident (SBLA) on the other primary loop piping system. Compliance with the IAEA [8, 9], NUREG [23, 24] and Eurocode [11] will be considered in three load combinations: Normal Conditions (NOC), Design Basic Accident (DBA) and Beyond Design Basic Accident (BDBA) [17]. The

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safety and reliability of the NPP concrete structure of hermetic zone was considered for various scenarios of the accidents in previous works [15, 16, 17, 18 and 19].

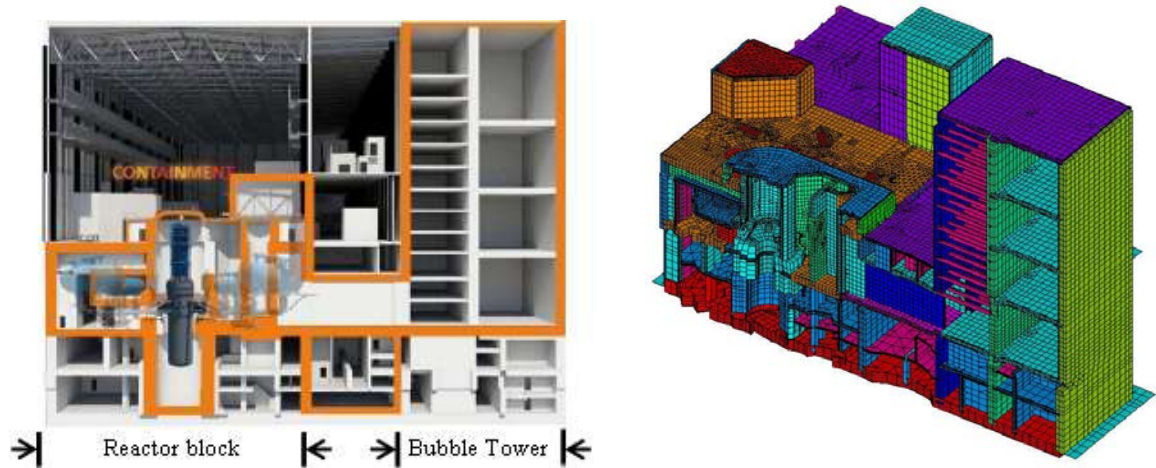


Fig.1 Solid and finite element model of NPP reactor building and the bubble tower.

On the base of the IAEA requirements the experimental test of the airtightness of hermetic zone must be realized each 10 years of NPP performance [8]. The stiffness of the structure can be tested during this experiment too [18]. The experimental results were compared with the results of numerical analysis of the structures on the FEM calculation model. For a complex analysis of the concrete structure for different kind of loads, ANSYS software and the program CRACK (created by Králik) [16] were provided to solve this task. The building of the power block was idealized with a discrete model consisting of 28 068 elements with 104 287 DOF (see Fig. 1) [18].

2. Experimental test of the airtightness

The airtightness of the hermetic zone and stiffness resistance of the structures was tested by compression of the interior space of NPP [12, 17]. The overpressure increase with the speed of 25 kPa by 2 hours and each compression step (a' 25 kPa) were stabilized during 2 hour. The overpressure increase from the 0 kPa to 100 kPa and since it decrease to 0 kPa with the same tempo. The results of the measurements were recorded at overpressure 0, 25, 50, 75 and 100 kPa. The inspection of the critical places were realized by the experts (STU Bratislava, VUEZ Levice, VUJE Trnava, SE Bratislava) after each changing step. The optical and mechanical methods were used to check the deformation of structures in the critical places during the overpressure change in interior of the hermetic zone. The critical places of the structures were determined by the numerical analysis. The mechanical indicators were installed in the wall centrum of the gas-tank and the roof-plate of the bubbler tower (see Fig.1). The mechanical indicators were fixed with cable system in interior of BT. The optical measurements were realized from the exterior by LIPG Bratislava [12].

The results from the optical measurements are presented in the Fig.3a for the overpressure interval from 0 to 100 kPa. The behavior of the deflection above 100 kPa are calculated using the extrapolation methods using the spline functions and results from the nonlinear numerical analysis of the reinforced concrete walls of the BT structures (Fig.3b).

The results of the measurements are determined by the influences of the four factors - errors due to the climatic factors (temperature, heat emission,...), errors due to inaccuracy of the measure instruments, errors due to anchorage, errors due to uncertainties of model.

The climatic factors (temperature changing during the experiment) were indicated as the dominant influence to the global movements of the BT structure. The deformations from the temperature changes during the experiment were eliminated from the absolute results. The global movement of the BT structure during the experiment is significant if

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