RELIABILITY ASSESSMENT OF INDIAN NUCLEAR POWER PLANT INNER CONTAINMENT STRUCTURES

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ABSTRACT

This project concerns the reliability based design of the inner containment (IC) structure of Indian nuclear power plants (NPPs). The driver for this work is the new draft design standard issued by AERB in 2007 intended to replace the French RCC-G used until now, but whose provisions have been vehemently opposed by other stakeholders in the design and construction process. The objective of this work is three-fold: Determine the reliability of existing Indian NPP IC structures under accidental pressurization; decide on acceptable target reliability level for new power plants; derive design equations for new NPPs.

This work starts with a comprehensive literature survey to ascertain the state-of-the-art in the mechanics and modes of failure of prestressed shells, target reliabilities and calibration of partial safety factors, NPP containment load combinations and performance-based design of structures. A comprehensive algorithm to achieve the project objectives has been developed and tested from first principles comprising of first order reliability (FORM) analyses of normalized limit states (incorporating the gradient projection algorithm, Nataf and Rackwitz-Fiessler transformations) for determining optimal partial safety factors for design of rectangular partially prestressed concrete sections at two different performance levels - ultimate (collapse) and serviceability (cracking) limit states over the feasible range of design parameters. Detailed numerical examples have been provided. This algorithm was later extended to bidirectional flexure of partially prestressed shells with voids designed according to Wood's criteria. Data made available by NPCIL and BARC from finite element modeling of Rajasthan Atomic Power Plant IC was used to determine the statistics of the basic variables and the implied reliability in the design of existing Indian NPP ICs.

Keywords: Reliability, partial safety factors, nuclear power plant, inner containment, prestressed concrete shell, optimization, FORM, gradient projection