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Research Article

Optimal design of circular concrete water tanks by MCMC subset simulation method

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Extended Abstract

Introduction

In recent years, Reliability-Based Design Optimization (RBDO) has emerged as a critical area of interest for researchers in structural engineering. RBDO focuses on optimizing structural designs by incorporating probabilistic constraints, ensuring that structures meet safety and serviceability requirements under uncertain conditions. This study addresses the optimization of a circular water storage tank, a vital infrastructure component, using RBDO principles. The objective is to minimize the construction cost of a reinforced concrete tank while adhering to probabilistic constraints related to strength and serviceability, such as demand-to-capacity ratios, crack widths, and structural deformations. The design is based on the Iranian Code of Practice No. 123, which provides guidelines for loading, strength, and serviceability criteria. The study employs the Markov Chain Monte Carlo (MCMC) simulation method to solve the optimization problem, demonstrating its efficiency in handling probabilistic constraints.

Materials and Method

The optimization process begins with the modeling of the circular water tank in SAP2000, a structural analysis software. The tank is subjected to combined loads, including dead, live, seismic, and hydrostatic pressures, as per Code No. 123. The MCMC method, implemented in MATLAB, is used to generate random samples of design variables, such as wall thickness, slab thickness, and reinforcement ratios. The MCMC algorithm, combined with the Metropolis-Hastings (MH) acceptance-rejection criterion, ensures efficient sampling and convergence to the optimal solution. The optimization problem is formulated to minimize the construction cost, which includes the cost of concrete and steel reinforcement, while satisfying probabilistic constraints related to structural performance. The interaction between SAP2000 and MATLAB is facilitated through a C# interface, enabling the exchange of design parameters and optimization results.

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Results and Discussion

The optimization results indicate that the MCMC method effectively identifies the optimal design parameters for the circular water tank. The optimal wall thickness is approximately 310 mm, while the slab thickness is around 393 mm. The reinforcement ratios for different sections of the tank are also optimized, resulting in a total construction cost of approximately 25.77 million Iranian Tomans. The MCMC method demonstrates superior computational efficiency compared to traditional Monte Carlo simulations, requiring fewer samples to achieve convergence. The study also explores the impact of varying the number of samples per simulation level, showing that increasing the sample size improves the convergence and accuracy of the optimization results. The final optimized design meets all probabilistic constraints, ensuring the structural reliability and serviceability of the tank.

Conclusion

This study highlights the importance of incorporating probabilistic constraints in the design optimization of reinforced concrete structures, particularly circular water tanks. The MCMC method proves to be a powerful tool for handling uncertainties in design variables, offering a computationally efficient alternative to traditional optimization techniques. By integrating MCMC with structural analysis software like SAP2000, the study achieves an optimal design that minimizes construction costs while ensuring compliance with safety and serviceability standards. The results demonstrate the potential of RBDO and MCMC in advancing the field of structural engineering, particularly in the design of critical infrastructure components. Future research could explore the application of these methods to other types of structures and loading conditions, further validating their effectiveness and versatility.

Keywords: Reliability, Optimization, Probabilistic constraints, RBDO, MCMC