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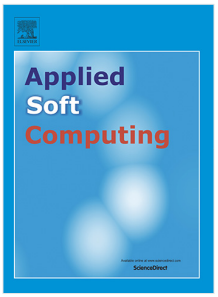


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Vahid Mokarram, Mohammad Reza Banan

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# An improved multi-objective optimization approach for performance-based design of structures using nonlinear time-history analyses

Vahid Mokarram[1], Mohammad Reza Banan[*]

Department of Civil and Environmental Engineering, School of Engineering, Shiraz University, Shiraz, Fars, Iran.

**Abstract** Performance-based design (PBD) of buildings can be properly addressed in a multi-objective optimization framework. However, computational costs of such an approach will be very expensive especially if nonlinear time-history analysis (NTHA) is used as the evaluation tool. In this paper, significant reductions in computational costs of solving structural multi-objective optimization problems is achieved by proposing a new metaheuristic surrogate model called Surrogate FC-MOPSO. In this method, which is an extension of FC-MOPSO algorithm, NTHA and pushover analysis (PA) are simultaneously employed for evaluating system responses. PAs are adopted as an approximation tool in the surrogate model while the responses corresponding to feasible solutions are always evaluated from NTHAs. The final Pareto optimal solutions, which yield tradeoffs between initial and life cycle costs (LCCs), are already evaluated based on NTHAs. It is shown that application of the proposed method results in substantial reductions of runtime of the considered problems. It is also demonstrated that adopting PAs as the only evaluation tool in optimal performance-based design of structures can result in unreliable solutions.

**Keywords** Optimal performance-based design; Expensive multi-objective problems; Surrogate optimization models; Particle swarm optimization; Life cycle cost

## 1. Introduction

The human population living on the earth is growing at a rapid rate. The UN estimates that by 2050 the world population will be about 9.8 billion, which is 30% more than its current number. On the

*Abbreviations:* CSM, Capacity Spectrum Method; CP, Collapse Pretension; DI, Damage Index; DOF, Degree of Freedom; EA, Evolutionary Algorithm; FC-MOPSO, Fast Converging Multi-Objective Particle Swarm Optimization; FEMA, Federal Emergency Management Agency; IDA, Incremental Dynamic Analysis; IO, Immediate Occupancy; LCC, Life Cycle Cost; LS, Life Safety; MDOF, Multi Degree of Freedom; MOEA, Multi-Objective Evolutionary Algorithm; MOP, Multi-Objective Problem; MPA, Modal Pushover Analysis; NDP, Nonlinear Dynamic Procedure; NSP, Nonlinear Static Procedure; NTHA, Nonlinear Time-History Analysis; OP, Operational; PA, Pushover Analysis; PBD, Performance Based Design; PH, Plastic Hinge; PSO, Particle Swarm Optimization; RC, Reinforced Concrete; SDOF, Single Degree of Freedom; SMRF, Steel Moment-Resisting Frame; SOP, Single-Objective Problem; RBF, Radial Basis Function

[1] PhD candidate. E-mail: vahid_mokarram@shirazu.ac.ir

[*] Corresponding author. Professor. Tel.: +98 71 36133105. E-mail: banan@shirazu.ac.ir