PERFORMANCE-BASED EARTHQUAKE ENGINEERING DESIGN OPTIMIZATION OF BUILDINGS

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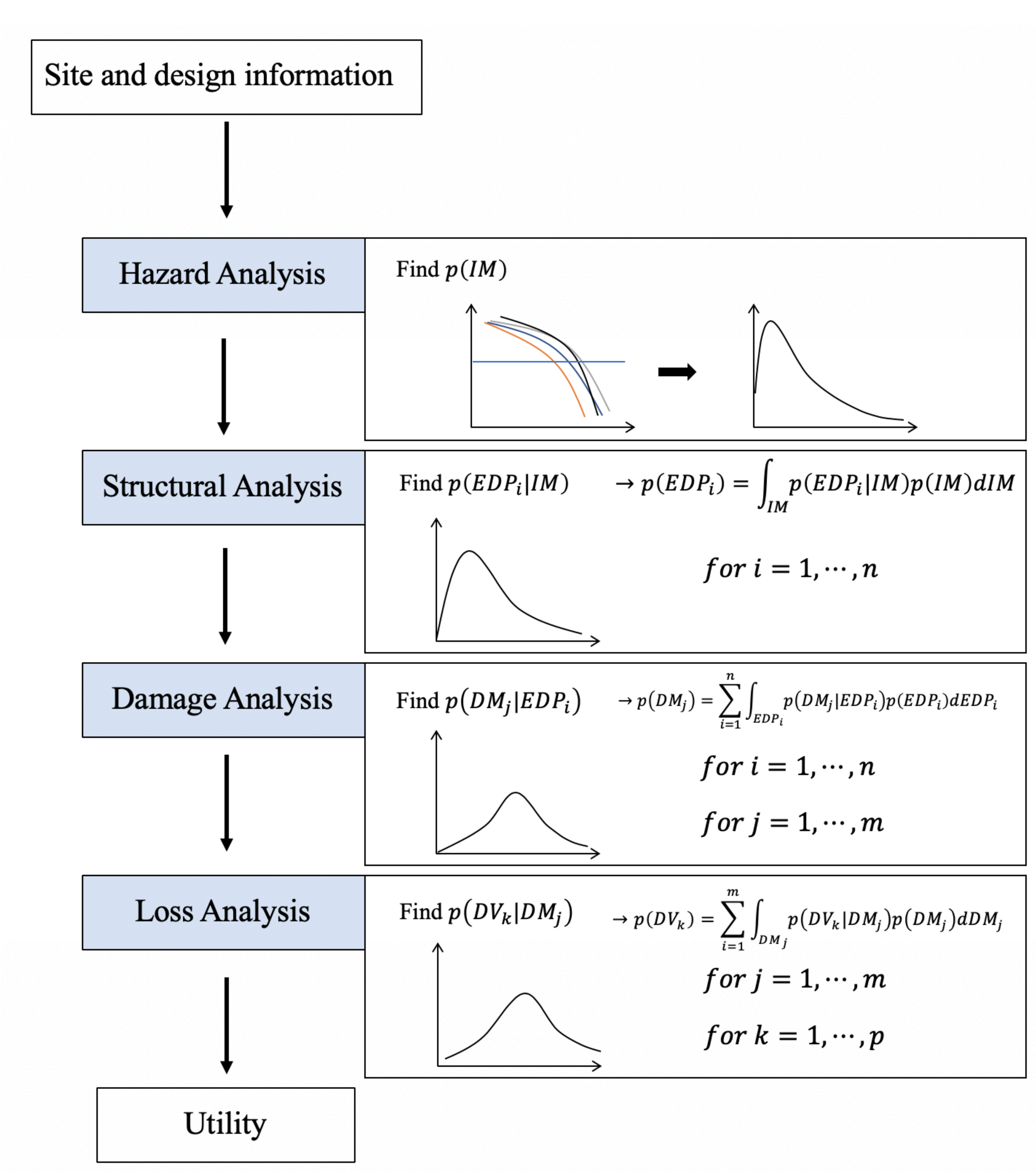
INTRODUCTION

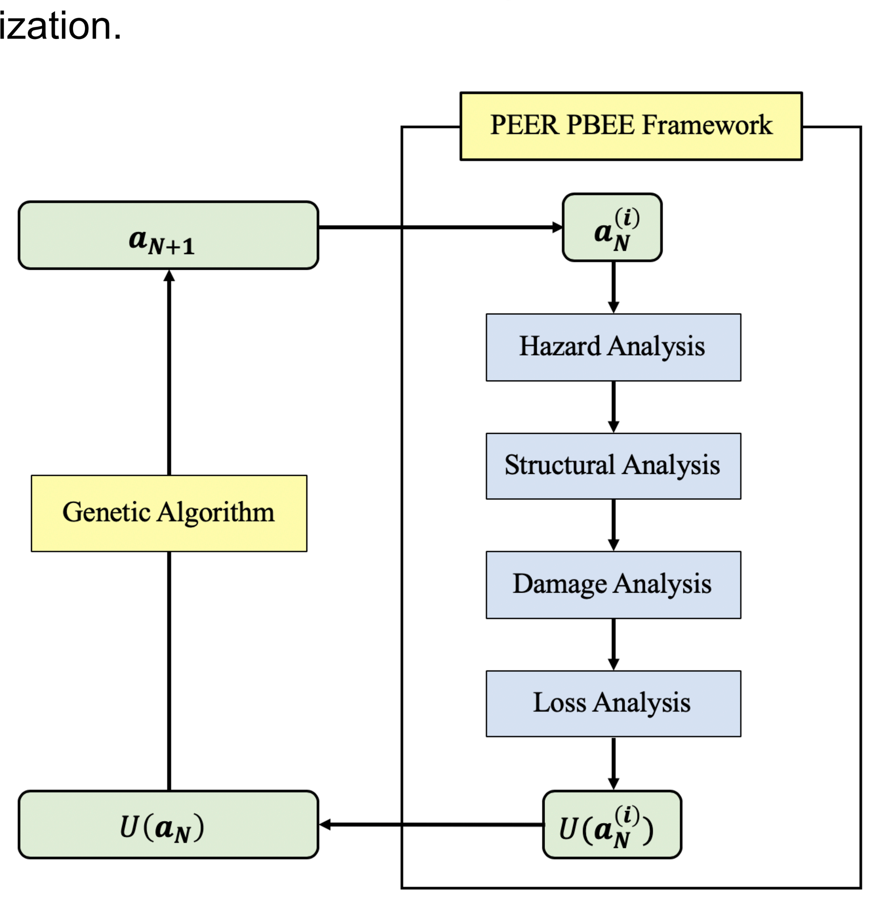
Seismic building design is a complex procedure requiring sophisticated structural analysis (e.g. nonlinear time-history analysis) and has various sources of uncertainties. In addition, engineers should consider not only damages in structural elements of buildings, but also other sources of economic loss (e.g. repair cost and downtime). From the above reason, various design tools and frameworks for supporting engineer's decision making are developed within the earthquake engineering community. The Pacific Earthquake Engineering Research (PEER) Center developed the Performance-Based Earthquake Engineering (PBEE) methodology which is a robust framework for evaluating a system performance measures in the interest of various stakeholders, such as monetary losses, downtime, or casualties.

The engineer's goal in design is to solve optimization problem and find the "best" design. The PEER PBEE methodology is a robust method to determine the model's utility, which is a good metric to decide the best design among the design alternative sets. Proper optimization algorithm needs to be developed for extension of the PEER PBEE methodology into the design space. In this study, Genetic Algorithm (GA) is adopted for design optimization framework.

PBEE METHODOLOGY



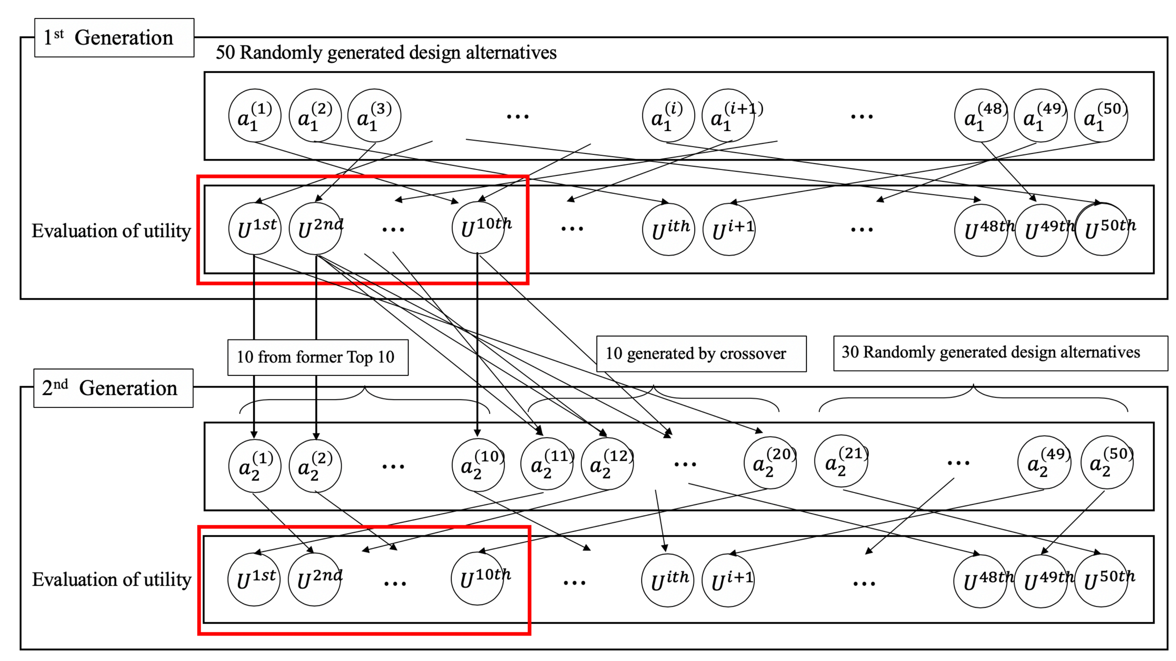
The PEER PBEE methodology is used as the main framework for evaluating the seismic performances of structures or facilities. In the framework of PEER PBEE, there are four consecutive steps: hazard analysis, structural analysis, damage analysis, and loss analysis. The final goal for this process is to obtain the utility of each design alternative which will be the objective function of design optimization.



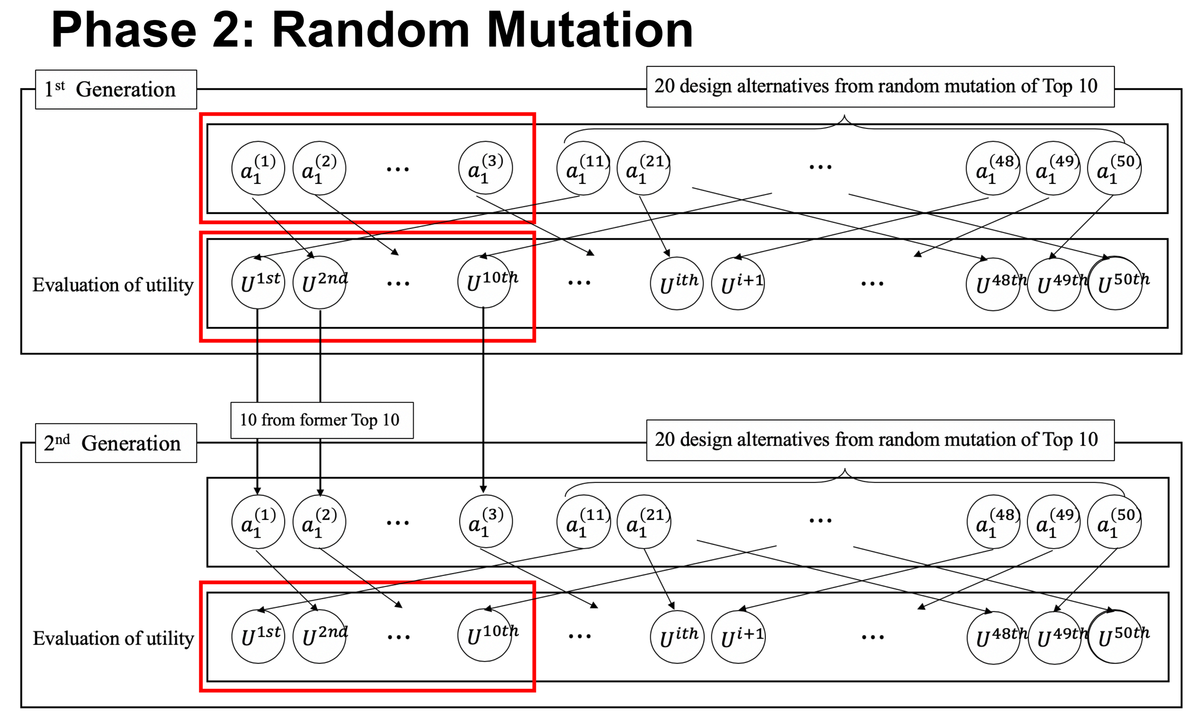
OPTIMIZATION ALGORITHM

In this study, the genetic algorithm is performed with two phases. In this first phase, the algorithm begins with 50 randomly generated design alternatives. For the next generation, 10 design alternatives who have better utility than the others are selected, and 10 offspring are generated from them with crossover. In this second phase, the first generation consists of the top 10 design alternatives from the last generation of phase 1 and 20 randomly generated design alternatives. In this phase, the top 10 design alternatives are also selected for the next generation, but 10 offspring are generated by the random mutation

Phase 1: Crossover



Phase 2: Random Mutation

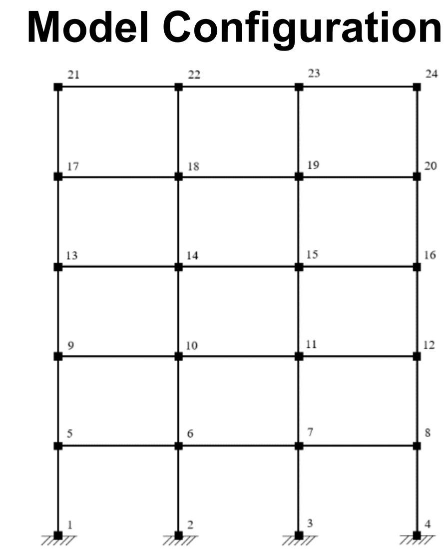


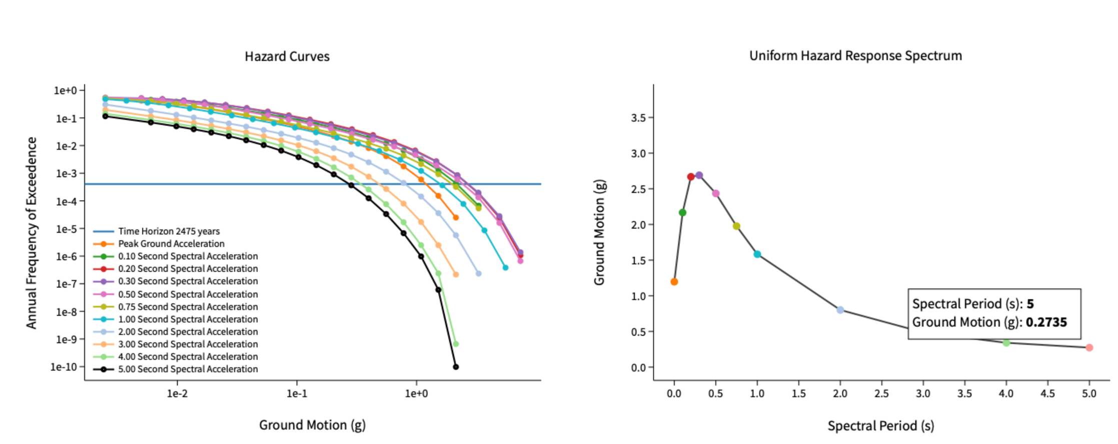
APPLICATION

A hypothetical three-bay, five-story steel-Moment Resisting Frame (MRF) building located in Berkeley, CA (2150 Shattuck Ave. 37.87°, -122.27°) is used as an application example.

All elements of the steel-MRF are wide flange steel beams meeting ASTM standard A36 with a yield stress of 36 ksi. The section properties of the beams and columns for each story are chosen from among 203 wide beam sections.

Model Configuration





The Hayward Fault is located about 3 km east of the site, the San Andreas Fault is located about 30 km west of this site. Soil condition is assumed as stiff soil corresponding to ASCE 7 Site Class D. The above figure is USGS hazard curves and uniform hazard response spectra obtained by USGS Unified Hazard Tool.

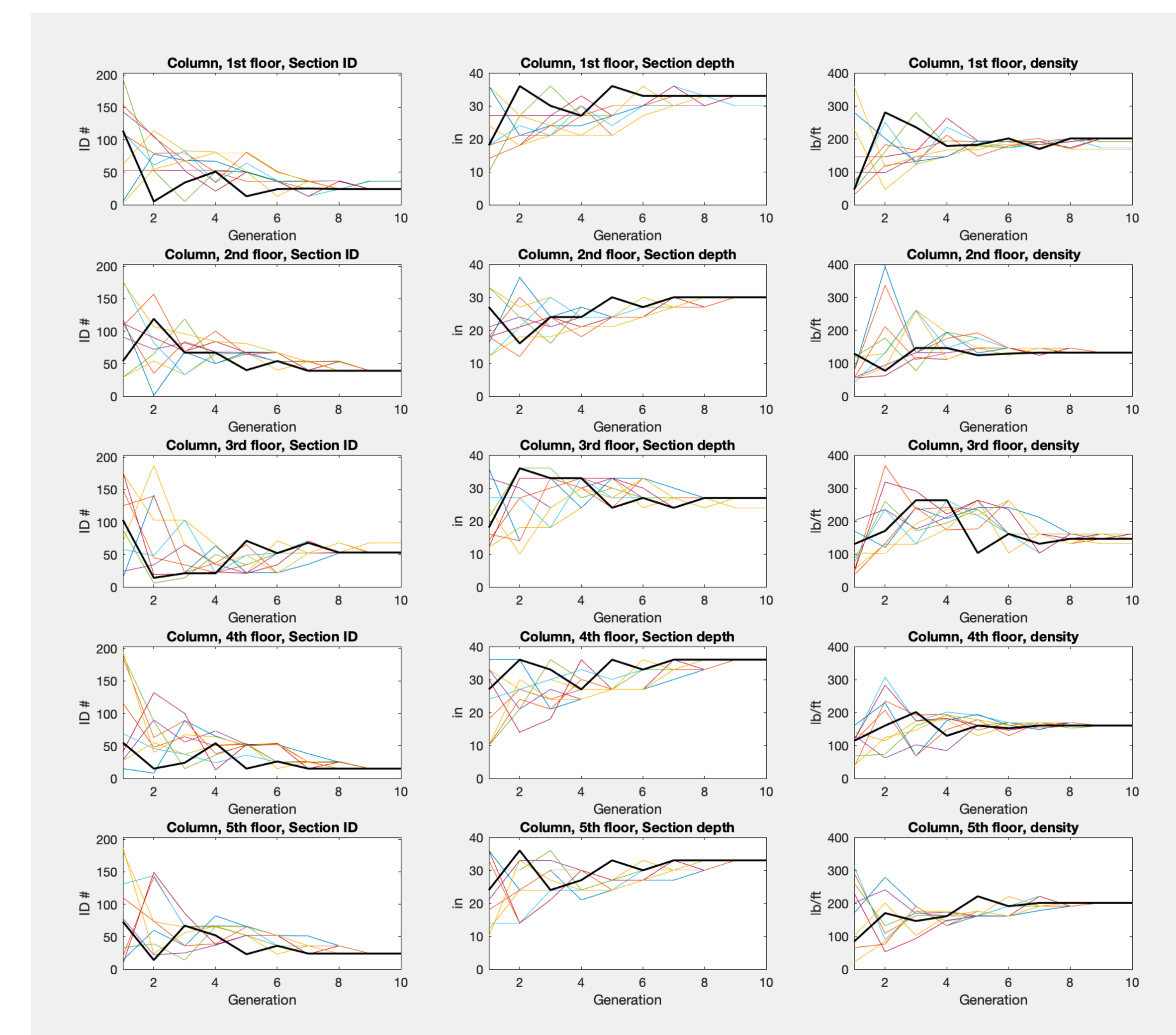
Artificial ground motions conforming the response spectra are generated for structural analysis.

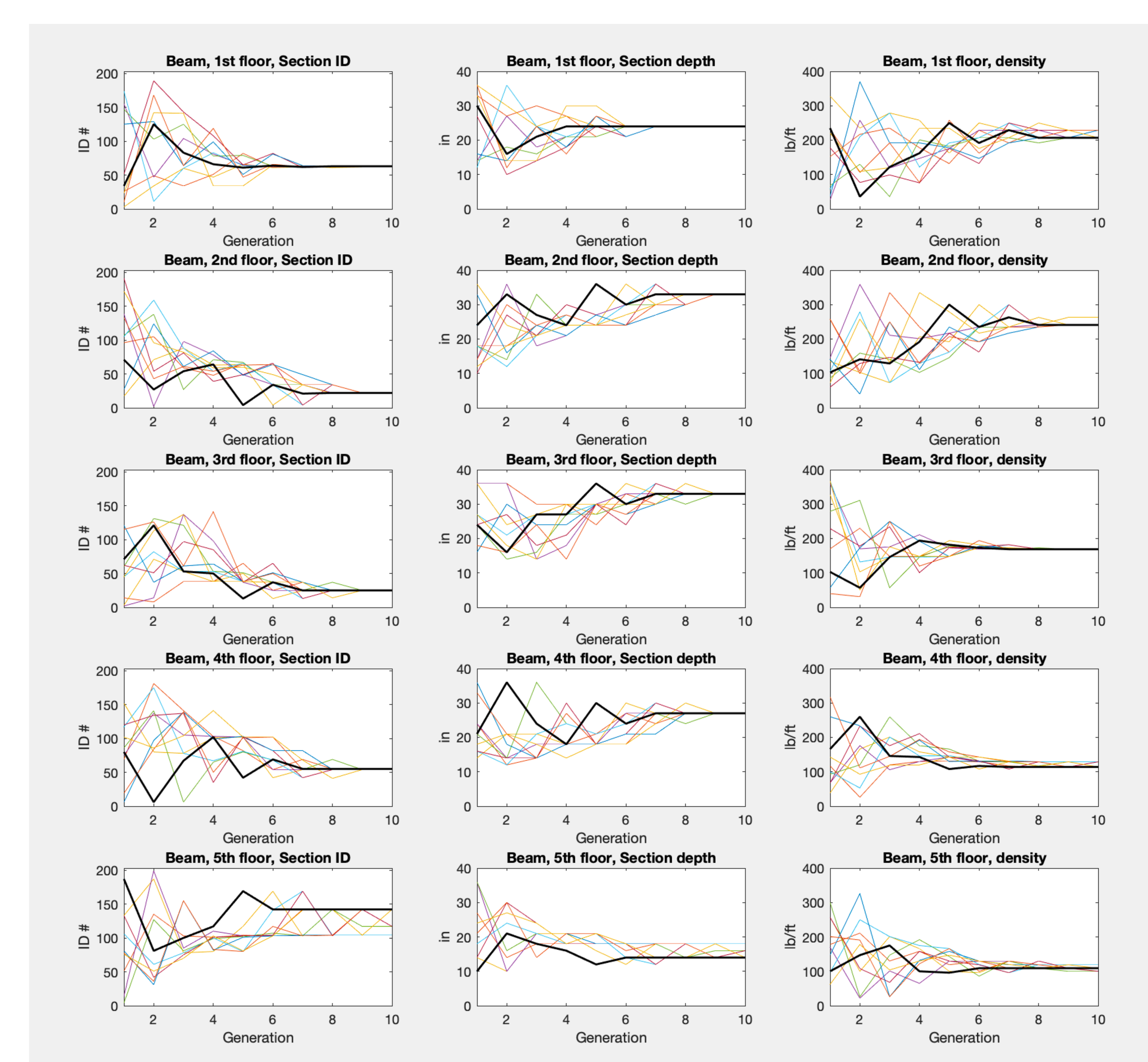
We obtain repair and construction cost as utility of design alternative

RESULTS

Phase 1: Crossover

[Optimization results for columns and beams, black line indicates the design of the best alternatives in each generation]





Phase 2: Random Mutation

[Best design from phase 2: Random Mutation]

Floor	Column	Beam
1	W30×261	W27×94
2	W30×90	W33×201
3	W27×161	W33×130
4	W36×135	W27×129
5	W33×130	W18×55

CONCLUSION

In this study, an optimization framework for the PBEE methodology using a genetic algorithm is developed and performed with the steel-MRF. Two common methods in the genetic algorithm, crossover and random mutations, are used in difference phases of the optimization process in the application. Design alternatives converges well with the crossover operator. In the application, the solution converges with a few generations (10 generations).

The PBE approaches are powerful tools for multi-objective designing and also hugely effective for multi-hazard design. In this application, only repair and construction cost are used as utility, and only single hazard (earthquake) is considered. However, in further study of PBE approaches, the optimal design frameworks for various performances (not just cost, e.g. CO2 emission, energy efficiency) considering multi-hazard (e.g. fire, tsunami) are expected to be developed.

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