Big Bang-Big Crunch algorithm based optimum design of steel frames

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Abstract

In this paper, the Big Bang-Big Crunch algorithm is utilized for the optimum design of steel frames following the AISC-LRFD specification. The BB-BC optimization is a population-based meta-heuristic search procedure that relies on one of the theories of the evolution of the universe namely the Big Bang and Big Crunch theory. The objective of the optimization is to minimize the total weight of the structure subjected to serviceability and strength constraints following the AISC-LRFD. Design examples considered in this paper consist of a rigid steel frame and a braced steel frame. The braced steel frame is optimized using two systems, Building Frame System (BFS) and Dual Frame System (DFS). Finally it is shown that the frame designed as the DFS is lighter than that designed as the BFS. Also the results obtained by the BB-BC algorithm for the rigid steel frame demonstrate the efficiency of the algorithm.

Keywords: Optimum structural design, Big Bang-Big Crunch algorithm, Rigid steel frames, Braced steel frames, AISC-LRFD.

1. INTRODUCTION

In the last decades, different natural evolutionary algorithms have been employed for structural optimization including Genetic algorithms [1-5], Ant Colony Optimization [6-11], and Harmony Search [12-14]. These are heuristic procedures that incorporate random variation and selection.

Recently a new optimization method relying on one of the theories of the evolution of the universe, namely the Big Bang and Big Crunch theory, has been introduced by Erol and Eksin [15]. This method has a low computational time and high convergence speed. According to this theory, in the Big Bang phase energy dissipation produces disorder and randomness is the main feature of this phase, whereas, in the Big Crunch phase, randomly distributed particles are drawn into an order. The Big Bang–Big Crunch (BB–BC) optimization method similarly generates random points in the Big Bang phase and shrinks these points to a single representative point via a center of mass in the Big Crunch phase. After a number of sequential Big Bangs and Big Crunches where the distribution of randomness within the search space during the Big Bang phase becomes smaller and smaller about the average point computed during the Big Crunch phase, the algorithm converges to a solution.

The BB-BC algorithm has been used to optimize some kinds of trusses, frames and domes [15-19]. In this paper it is used for optimal design of rigid steel frames and braced steel frames. These steel frames are designed according to the AISC-LRFD specification and the optimal designs obtained for the rigid steel frames are compared to the previous studies. Also the braced steel frames are designed using two systems, Building Frame System (BFS) and Dual Frame System (DFS) and the optimal solutions for these two systems are compared to each other.

2. Optimum design of steel frames following the AISC-LRFD specification

The optimum design of steel frames requires the selection of steel sections for its members so that the frame satisfies the serviceability and strength requirements specified by the code of practice while the weight of the frame is minimum. If the design constraints are implemented from the AISC-LRFD[21], the following programming problem is introduced.

$$Minimize\,W = \sum_{r=1}^{ng} m_r \sum_{s=1}^{t_r} l_s \qquad (1)$$

Subject to: