Optimum Design of Steel Ribbed Domes Using Genetic Algorithms

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Abstract

This study deals with the problem of optimum design of steel domes as a type of steel space frames. The optimization problem is formulated to take the weight of the dome as the objective function. The actual design variables are the joint coordinates and members size. Dealing with joint coordinates as a design variable make hundreds of design variables in the problem and dealing with such number of variables is extremely tedious. An automated procedure to generate the joint coordinates is followed in this study to overcome this problem. This procedure reduces the number of variables to five only which are the number of meridians in the dome, the total number of rings in the dome, the factor (B) that controls the distance between successive rings, the vertical spacing between the first and second ring and member sizes. The first four variables are treated as continuous design variables, but for member sizes this is followed by the selection of nearest available discrete values which provided from standard lists of AISC section tables. The side constraints for this problem were considered as the lower and upper bounds of number of meridians, number of rings, the factor B and the vertical spacing between the first and second rings. The behavior constraints are the restrictions on the maximum stress, displacements and buckling. The classical matrix stiffness method is used for the analysis of the dome. The design of steel dome members is done according to LRFD-AISC provisions. A program was coded in MATLAB programing language for generating the geometry of dome,

calculation of external loads (dead, wind and earthquake loads) and analysis and design of the dome members. The procedure for solving this problem consists of two main levels; level 1 investigating the optimum dome geometry using genetic algorithm, while level 2 generating the geometry of dome, calculation of external loads (dead, wind and earthquake loads) analysis and fully stressed design of the dome members and calculating the weight of the dome using the developed program.

The results showed that the optimum sections were not fully stressed and the displacement constraint controlled the problem. It is also concluded that the height of the domes increased with the increasing in dome diameter in an approximate linear manner with an optimum height to span ratio ranging from 0.48 to 0.49. The results also showed that the number of meridians and rings were increased with the increasing in dome diameter.

The results also revealed that with the increasing in dome diameter (from 10 m to 20 m) the factor B increased and the vertical spacing between the first and second ring is decreased.

It was found out that the case of domes subjected to combined dead and wind loads with fix support and varied spacing between rings gave lighter domes with a maximum reduction percentage of 11.89% in compared with the case of domes with hinge supports and a maximum reduction percentage of 23.46% in compared with the case of domes with fix supports and constant spacing between rings.

It was also found that the case of domes subjected to combined dead and earthquake loads with fix support and varied spacing between ring gave lighter domes with a maximum reduction percentage of 18.26% in compared with the case of domes subjected to combined dead and earthquake loads with hinge support and varied spacing between rings and a maximum reduction percentage of 29.36% in compared with the case of domes subjected to combined dead and earthquake loads with fix support and constant spacing between rings.