Static and dynamic soil–structure interaction response of Kazeroon cooling towers

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Abstract

To get a better insight about the soil properties and their effects on the structural behavior of Kazeroon cooling towers, a finite element model has been prepared by considering the structure and a huge amount of its underneath soil. Nonlinear static analysis for the dead load and nonlinear dynamic analysis for the earthquake load are done because of the importance of these loads in the design of cooling towers. Analysis results of this model are compared with the results obtained from the model used for the design of the cooling tower. Comparison showed that the effects of soil-structure interaction should be noticed carefully for cooling towers.

Keywords: Cooling tower, Finite element method, Soil-structure interaction, nonlinear dynamic analysis.

1. INTORDUCTION

Natural draft cooling towers are reinforced concrete shell structures used in thermal and nuclear power plants as cooling devices. These structures are one of the largest shell structures being constructed nowadays. These are the hyperbolic shells of revolution in form. The largeness and slenderness of these shells makes them vulnerable to earthquake and wind disturbances [1-6]. This was evident in the spectacular failure of the cooling towers at Ferrybridge, England in 1965 during a gust storm, the collapse of another cooling tower at Ardeer, Scotland in 1973 and a cooling tower at Fiddlers Ferry in 1984 and failure of a cooling tower at Bouchain in Northern France in 1979. These failures have attracted the attention of many investigators for an improved and robust analysis of cooling towers [2].

Soil–structure interaction states the mechanics of interaction between soil, foundation, and the superstructure. In most of the Civil Engineering analyses, structure is assumed to be fixed at the base. Thus, the flexibility of foundation and the compressibility of the supporting soil medium are neglected. Consequently, the effect of uneven foundation settlements on redistribution of forces and moments in the superstructure is neglected too [2]. Lots of work is available in the literature on analysis of fixed base hyperbolic cooling towers [3-6]. However, a more realistic analysis would be the one in which the influence of the soil–structure interaction is also included. Lu et al. studied the effect of unequal settlement of foundation on stress resultants in the tower shell using finite element representation of column supported cooling towers [7]. Tilak et al. considered a soil–structure interaction effect in which the supporting compressible soil was treated as a Winkler medium [8]. However, due to limitations of the Winkler model, this analysis does not reflect the true interactive response of cooling towers. Kato et al. introduced a modified thin-layered far field soil element for considering soil–structure interaction analysis of axisymmetric structure [9]. Kato et al. presented an analysis of cooling towers on a soft soil layer subjected to the horizontal incident earthquake motions from the base rock [10]. In addition, based on the complex spectral element method and the theory of fractional calculus, a hybrid complex decoupled spectral method has been developed by Horr and Safi for studying the dynamic soil–structure interaction of cooling towers [11].

Kazeroon Combined cycle power plant is located near city of Kazeroon in Fars province with capital Shiraz. The nearest city to the plant is Kazeroon with 14km distance. The three cooling towers are located in the east part of the plant in a triangular arrangement with approximately 150m distance to each other. The cooling towers are natural draft heller type with indirect dry cooling system and forgo T60 heat exchanger. To get a better insight about the soil properties and their effects on the structural behavior of Kazeroon cooling towers, a model has been prepared by considering the structure and a huge amount of its underneath soil. In this analysis the real behavior of structure, soil and interaction of them can be evaluated. The finite element program Ansys 8 is used to prepare the three dimensional model of the cooling tower, its foundation