جـــامعة الفـــيوم
Fayoum University

Name of Candidate: Eng. Khaled Ibrahim Mohamed Ismail **Degree: M.Sc.**
Title of Thesis: Seismic Behavior of Onshore Wind Turbine Towers Foundations

Supervisors: 1- Prof. Dr. Gihan Elsayed Abdelrahman
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ABSTRACT

Wind turbine towers are a non-conventional structural and there is not a separate code for them in Egypt. Also, most of international wind turbine towers codes and standards deal with the wind turbine tower as a single degree of freedom system not including the effect of soil structure interaction into the design consideration. This assumption may result in under or over estimation due to earthquake excitation.

Recently, there are many researches use substructure approach by dividing the problem into two parts soil and super structure and every part has been studied individually. The substructure method may be suitable in static calculations, however, in dynamic analysis that is needed to get the response of the earthquake loads, the direct method in which soil and structure are modeled together is required to assess the effect of change in soil, earthquakes and structural frequencies on the response of tower and its foundations.

This study focused on the onshore wind turbines tower foundation which are designed as a large rigid reinforced concrete type and will be constructed in an active seismic region. There are two objectives of this study, the first one is estimation the site response analysis at Zafarana Wind Turbine Towers Farm in Egypt using equivalent linear and nonlinear approaches by Shake, 2000 and DEEPSOIL v.7. For this scope, the effect of soil dynamic properties of eight Zafarana farms on the acceleration time history, peak ground acceleration with depth and spectral acceleration at ground surfaces were analyzed.

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According to International Building Code that classifies the soil depending on its shear wave velocity, the classification of soil at Zafarana farms is wadi deposit and silty sand (very dense soil and soft rock) that classified as Soil Class C. The other type of soil is Clay Stone (Rock) that classified as Soil Class B. The results of these analyses stated that as the soil is softer, the nonlinear method shows higher amplification compare to the equivalent linear analysis. Also, as the soil is stiffer, the nonlinear and equivalent linear approaches have the same results and the amplification factors approximately equal. So it is recommended to use real nonlinear analysis in critical projects such as wind turbine towers that are very sensitive structures to low frequencies.

The second main scope of this research is assessment the seismic behavior of onshore Vestas V47/660 wind turbine tower including dynamic soil structure interaction. This scope has been performed by finite element method using licensed Plaxis 3D, 2017. The aerodynamic effect induced due to the turbines has been excluded, while the static dead loads of the turbines as well as the seismic loads have been considered. The dynamic response deformations at footing and top of wind tower have been determined for three soil types, two of them are Rock (Soil Class B) and very dense silty Sand (Soil Class C) at Zafarana 3 and Zafarana 5 respectively. Also, the third one is Sand with fine Gravel (Soil Class D) at Gabel El-Ziet zone. These three different soil models have been exposed to three different earthquakes records (Alaqaba, 1995, Kocaeli, 1999 and Loma Prieta, 1989) that have different frequencies.

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It has been concluded that the change in earthquake frequency does not have a significant effect on the response acceleration of footing for Soil Class B and C, however, an effect appeared in Soil Class D. On the other hand, this change in earthquake frequency has a significant effect on the acceleration and translation deformations of top point of tower as fundamental frequency of earthquake is closer to natural frequency of tower and its foundation, the response acceleration and deformation of tower increase. Also, as the soil is softer, it has an effect on the dynamic response of footing and top of the tower.