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Investigating The Effect of Thermal Loading on Cooling Tower Shells

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ABSTRACT: Thermal load is one of important loads on the cooling towers, which reduce the final resistance of the cooling towers by creating micro Cracks at the end of the wind load. In the past, the impact of these loads has been less considered. Due to the progress of the finite element methods, nowadays it is possible to model cooling towers under thermal loads. In this research, the cooling tower of Shahid Rajaee power plant was modeled using ABAQUS finite element software. Damage plasticity model was used to model the crust of this tower. Behavior of cooling tower shell under two loading was compared. In the first loading, gravity, wind and heat, and in the second loading, the gravity and wind load were applied. The difference in shell displacement, tensile and compression cracking and ultimate strength in the shell was compared in both loading. Based on this study, the difference in the displacement of the shell in two loading was 6.4%. The difference in compression damage was about 3%, and the difference in tensile damage was about 10%. The pressure damage and tensile damage was developed in the presence of thermal loading. The difference in the bending moments in two loading was about 40% at the back side of the wind. Finally, the tower shell was reached to its ultimate strength in the presence of thermal load at a lower wind pressure.

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1- Introduction

Cooling towers are one of the most important components of nuclear and thermal power plants and have always been of interest to researchers due to high altitude, hydrologic geometry, thin shell thickness and special issues of analysis and design. In areas where seismic activity is not high, the weight of the tower itself and the load of the wind are important loads in the design of the cooling tower [1]. The shell behavior of the tower under weight load is symmetrical and close to the membrane. The crust behavior in all parts of the crust except the upper edge of the crust is compression and is tensile at the upper edge of the crust. Bending may occur in the vicinity of the abutments [2-3].

Under the wind load, the behavior of the concrete shell is completely different. In 1961, Martin et al. [4] developed a precise computational method for membrane fouling for weight and wind loads, which their focus was on wind load. Eight years later, Gardner [5] used a computational method Based on the finite difference method and calculated the natural period of the cooling tower. In 1974, Hashish and Abu-Sitta provided a method that was supported by a laboratory model and examined static-tension and exacerbated stresses. In 1980, Sollenberger et al. [7] conducted experiments to wind pressure in the cooling tower, and concluded that the typical amount used in the design was much higher than the actual pressure of the wind. At the same time, Neimann [8] assessed the static pseudo-static pressure of the wind in the cooling tower using a wind tunnel. More experimental studies [9] showed that the dynamic stresses of cooling towers with static methods are not always properly evaluated.

In 1977, a precise measure of the shell deformation of the cooling tower under sun load was performed on one side of the crust, and the result exhibited that the crust section was oval and the shape changes were small and within a centimeter [10]. With the development of finite element methods, the thermal analysis of cooling towers was provided. In 1988, Blocki [11] analyzed the values of thermal stresses of a concrete cooling tower based on experimental measurements of the temperature field. In the recent years, the crack phenomenon has been considered in the concrete shell of coolant towers. Due to the nature of the concrete's brittleness, the crack propagation in the tensile region is fast and, as a result, most of the forces are supported by the reinforcement. With the yielding of the reinforcement in the cracked region, the crack expansion continues, which it results in a general failure of the structure [12]. Gupta and Maestrini [13] showed that after the yielding of the reinforcements, a significant stress distribution was created that affected the ultimate shell capacity. In 1991, Meschke and colleagues [14] conducted tests of the residual resistance of a cooling tower in Greece using finite element method. In addition to cracking, this model was able to consider the corrosion of the reinforcement and also was able to consider the thermal load history and estimate the contribution of the

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heat effect to the total failure of the structure. In 2006, Noh [15] carried out comprehensive studies on a cooling tower, and used the non-linear behavior of the tower for a smeared model, loading the tower, weight and wind, and not using the heat load. In 2017, Zhang et al. [16] studied the dynamic load response and static equilibrium load response in a cooling tower using a wind tunnel.

In this research, Damage plasticity model was utilized to model cracks in concrete, which was able to express all damage states by a scalar variable called Damage for the first time.

2- Methodology

In this study, in order to assess the real samples, Shahid Rajaee cooling tower at Qazvin was studied and modeled by ABAQUS software. Figure 1 shows the geometric characteristics of Shahid Rajaee cooling tower.

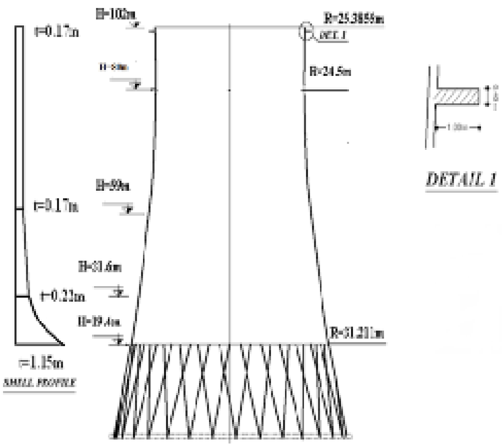

Figure 1. A view of geometric characteristics of Shahid Rajaee cooling tower

To analyze the tower, the damage plasticity model has been used. This model is capable of demonstrating the behavior of concrete in alternating loading with the help of two parameters of compressive and tensile damage. In this model, two rupture mechanisms for concrete are assumed to be tensile cracking and compression crushing. The variation of the yield surface was controlled by two pressure and tensile hardening parameters. Noh and colleagues researches [17] were employed to determine the compressive and tensile parameters, and the stress-strain curve of Saenz [18] has been used. The shell and foundation of the cooling tower were modeled by 4-node S4 elements and the shell pillars were provided in form of the B-31 Timoshenko beam elements. Wind loading and thermal loading were based on the VGB German Regulation [19]. After finite element analyzing of the cooling tower, the obtained results were included the displacement of the shell in the direction of wind load, compressive damage and tensile damage in both loading, i.e., cooling tower under load weight + Heat + wind, and cooling tower that is only under weight and wind were compared and concluding remarks were obtained.

3- Conclusions

In this research, the cooling tower of Shahid Rajaee Qazvin Power Plant was numerically analyzed under the influence of wind load and heat waves, and the following results were obtained.

1. With the addition of thermal load to wind load, the maximum displacement of the crust was about 11% and at a height of 70 m at the wind load side of the shell.
2. The thermal load increased the compressive damage by a maximum of about 3% and at a height of 63 meters at the wind side. Meanwhile, shell damage was spread to more areas of the shell.
3. Shell tensile damage was increased by applying thermal load up to 10 percent and at a height of 63 meters at the wind side. In addition, shell tensile damage was spread to more areas of the shell.
4. The greatest effect of thermal loading on the bending moment was in the back side to the wind. In this area the bending moment under thermal loading was increased more than 40%. Even for the bending moment in the backward direction, the positive bending moment was changed to the negative bending moment.
5. With thermal load, the crust of the tower was reached to its final resistance at a lower wind load (about 2.5%). In general, it was necessary to consider the effect of thermal load on the design of cooling towers, although its effect was not significant compared to the wind load.

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