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Comparison of comprehensive stress performances of super-large cooling tower in different four-tower arrangements under 3D asymmetric wind loads

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ABSTRACT

Different four-tower arrangements have a great impact on wind-induced response and stability performance of super-large cooling tower. However, a single indicator (eg., interference factor of overall wind load) cannot provide a comprehensive and objective evaluation of wind-resistance safety of cooling tower. Here five typical four-tower arrangements in engineering practice were experimented, namely, row, rectangular, rhombic, L-shape, and oblique L-shape arrangement. Wind tunnel tests for rigid body were performed to determine the wind loads distribution pattern on the surface of group tower under different four-tower arrangements. Finite element method was employed to analyze the internal force and deformation distributions under the design wind load of return period. The influence of different four-tower arrangements on wind load-induced response was discussed under different incoming wind angles. Then the local stability and overall buckling stability of the cooling tower were estimated, and the ultimate bearing capacities under different four-tower arrangements were compared considering geometric nonlinearity. Instead of using a uniform structural design standard for cooling towers group, the influence rule of different arrangements on wind-induced response and safety performance of the cooling tower group was summarized.

1. Introduction

Group tower-induced interference is one of the major factors influencing wind resistance of cooling tower. More and more complex arrangements of cooling towers are emerging recently, and four-tower combination are the most common arrangement. The wind-induced collapse of cooling tower group at the Ferrybridge power station in England in 1965 attracted unprecedented attention to the issue of wind resistance for cooling tower. Many surveys (Bearman, 1967; Swartz et al., 1985; Pope, 1994; Bamu and Zingoni, 2005) were then conducted into the reasons of this wind-induced damage, and the following reasons were proposed: (1) The design wind speed of the cooling tower was lower than the basic wind speed of return period specified in the design code of England; (2) The effect of group tower-induced interference on the wind load of cooling tower has not been considered; (3) Only one reinforcing mesh was designed for the tower shell, and it could not withstand the moment of the tower shell. These reasons for wind-induced damage, include stress and stability performance of cooling towers under interference, are still the priority concerns of wind-resistance design of large cooling tower. However, the existing cooling tower design codes (DL/T 5339-2006 2006, GB/T 50102-2014, 2014, VGB-Guideline, 2005) rarely provide recommendations in this field.

Many of the studies (Niemann and Kopper. 1998; Orlando, 2001; Ke et al., 2012; Cheng et al., 2013; Rajan et al., 2013; Zhao et al., 2016) concerning wind resistance of cooling tower group focus on interference factor. For large cooling tower built as a symmetric towering concrete shell structure with large span, assessment methods and indicators for wind resistance have not yet established. The inference effect estimated from different structural response indicators varies from one study to another, and some are even in conflict with each other (Niemann and Kopper. 1998, Orlando, 2001, Cheng et al., 2013). Other researches (Zhou et al., 2014; Zhang et al., 2017) presented a few response indicators to estimate interference effect based on wind-induced response. However, it remains uncertain whether a specific response indicator can

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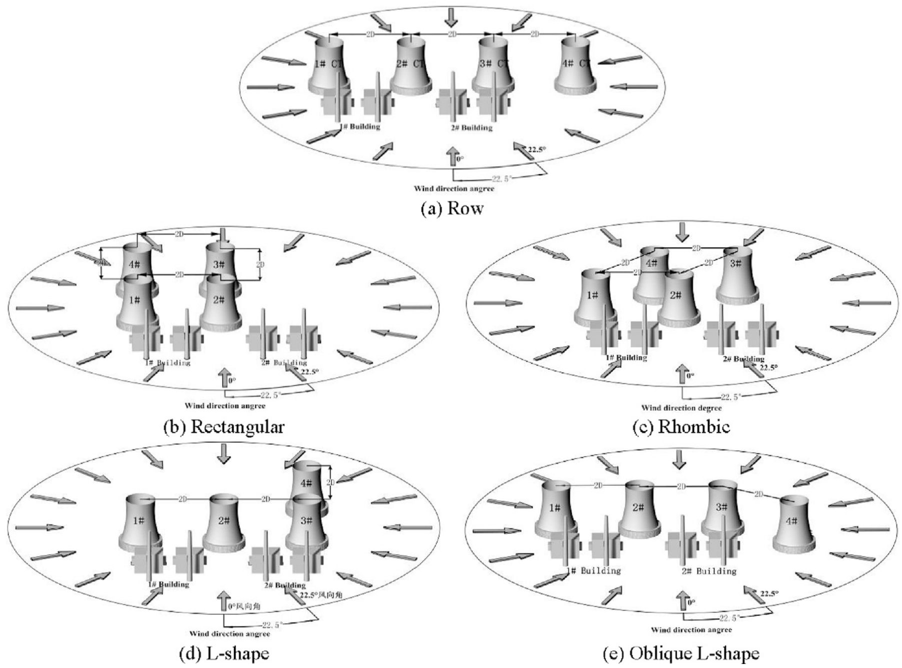
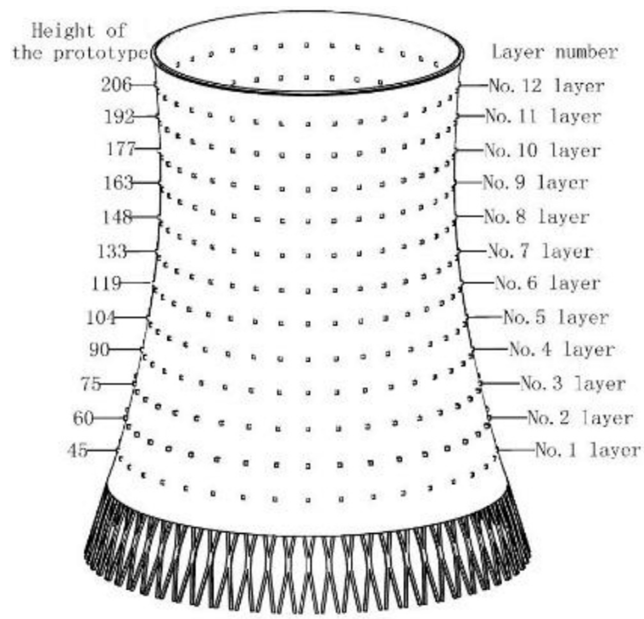


Fig. 1. Diagram of different layouts of grouped towers.

Table 1
Geometrical dimension of the cooling tower and layout of the measuring points.

Part	Size(unit: m)	Schematic of the measuring points (unit: m)
Tower height	220	
Throat altitude	165	
Inlet altitude	31	
Top diameter	128	
Bottom diameter	185	
Throat diameter	123	
Thickness	0.39–1.85	
Rect. cross sections of columns	1.7×1.0	



take the place of interference effect of tower group.

There are three other documented cooling tower collapse accidents (power plant in Ardeer, England in 1973, power plant in Bouchain, France in 1979, and Fiddler's Ferry Power Station in England in 1984). The major cause of wind-induced damage of cooling tower at these power plants is all attributed to impairment of stability under group tower-induced interference (Bamu and Zigoni, 2005). Some systemic researches have been conducted in local and overall buckling stability of cooling towers under the group tower interference and interference imposed by surrounding structures (Noh. 2006, Viladkar et al., 2006, Xu and Bai, 2013). Other scholars are concerned with the ultimate bearing capacity of large cooling towers considering nonlinear effect (Noorzaei et al., 2006; Li et al., 2014; Ke et al., 2015). However, these studies only included one specific group tower arrangement and did not provide a general principle for guiding the choice and engineering design of four-tower combinations.

To this end, we compared the wind-induced response and stability performance of five typical four-tower arrangements (Fig. 1) in a