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EXTENDED ABSTRACT

Considerations in Design of Joints for Lattice Steel Cooling Towers of Power Plants

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1. Introduction

Understanding the ultimate and the working strength and stiffness of the connections is required for the design of spatial structures. Comparison of numerical modeling with the experimental results is the most useful method to investigate the structural behaviour of the joints. The geometry and proportions of a particular connection depend on various factors such as the magnitude of forces, the size of the structural members, the end-details of the elements, the method of construction and economic factors. This paper studies the structural behaviour of the joints of a steel lattice cooling tower.

A good number research on spatial structures is devoted to obtain the strength and stiffness of the nodes and/or assembly of nodes and structural members. For instance, Maalek (1999) presents the results of experimental and numerical works on Akam socket joints. In this work, Akam spherical socket nodes of diameter 250 mm of ST37 and ST52 are subjected to various biaxial combinations of tensile and compressive forces. Chenaghlou et. al. (2014) study the behaviour of a type of ball joint and propose a model for obtaining its rotational rigidity and strength under various loading conditions. Davoodi et. al. (2012), study the nonlinear behaviour of a ball joint used in spatial structures. Ahmadizadeh and Maalek (2014), investigate the effect of the flexibility of the socket joints in spatial structures.

The size of a 'node', normally, has a reverse relation with its stiffness. For instance, a ball joint has much higher (axial) rigidity than that of the 'equivalent' socket joint. On the other hand, a socket joint is capable of accommodating larger structural elements, and avoiding member and/or bolt clashes at a relatively lower cost than its 'equivalent' ball joint. The interactions of biaxial and/or triaxial forces are more pronounced in socket joints and hence, the redistribution of forces among the structural elements could seriously increase or decrease the axial stresses in the members. A modeling technique should take care of the behaviour of the node with a reasonable level of simplicity for the practicing design engineers.

The design forces and the geometric features of two funnel shape lattice steel cooling towers of heights 123m and 132m are used for the design of the typical joints for these towers. Tower 1, with height 123, has 39m skirt and 84m trunk. The diameter of the trunk of the tower is 62m and the diameter of the base of the tower is 82m. The body of the tower is a 3-way double-layer grid with a thickness of 2m at the base and 4.4m at the trunk of the tower (Heristchian et. al. 2011). The foundation of the tower 1 is a ring with a uniform width of 8m and a uniform depth of 1.2m, but at the supports there is a raised platform. Tower 2, with a height of 132m, has 42m skirt and 90m trunk. The diameter of the trunk of the tower is 72m, and the diameter of the base of the tower 105m. The thickness of the trunk is 4.5m and the depth of the base is 2.5m.

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The cooling towers 1 and 2, were designed against the combined actions of the dead load, wind load, internal suction, thermal loads, earthquake, and uneven settlement, loss of supports, snow and ice. In reinforced concrete cooling towers both wind and earthquakes have detrimental effects, whereas in lattice steel cooling towers, the earthquakes have very minor effects in design of structural elements. This is due to the noticeable lightness of the lattice cooling towers. For instance, for the height under consideration, a lattice steel cooling tower roughly weighs (1/10) of the equivalent reinforced concrete cooling tower. Whereas, the pressure/ suction of the wind depend on the shape and height of the tower that are mainly determined by mechanical requirements, thus it has almost the same value for both concrete and steel cooling towers.

The hexa-node is used as a connector in Towers 1 and 2. Six elements of the tower are connected to this node. Four high-strength bolts of various sizes are used to connect each element.

2. Modeling of the hexa-node

The strength and stiffness of the hexa-node are analysed with Abaqus 6.10-1. The material of the node is S235JR (ST37-2) and the method of analysis is static general as defined in Abaqus.

Considering the different values of multi-directional forces applied to the hexa-node, thirteen load cases are considered in the modeling of the hexa-node. Consequently, the load-displacement diagrams for various cases were obtained. Where, the relative extension/contraction of the points of application of the load was used in diagrams. The initiation of the yielding and failure was specified for every load case

As it is anticipated, the lower stiffness values belong to cases that combine tension with compression. Then, the tensile capacity of the hexa-node will be F=+650kN (for bracing, wall elements) and H=+550kN (for horizontal, ring elements). Under these forces, the deformation of the face of the hexa-node relative to the centre of the node will be 0.4/2=0.2mm.

3. Parametric Studies

In order to select more appropriate design values for the hexa-node, the article carried out a number of parametric studies. The load capacity of the hexa-node is obtained for various flange and stiffener thicknesses. The analyses revealed that the change in the flange thickness has a much stronger effect on the load capacity of the hexa-node. Based on the parametric studies, the thickness of the flange, the web and the stiffeners of the hexa-node for Tower 2, were selected as 30, 15 and 12mm, respectively.

4. Concluding Remarks

This paper, studies the strength and stiffness of the hexa-node used in the construction of double-layer steel cooling towers. The hexa-node is under multi-directional tensile and compressive forces. The paper summarises the extreme forces applied to the hexa-nodes at various levels and under all load combinations of two cooling towers of heights 123m and 132m. Based on the applied load ranges, a hexa-node is modeled for thirteen load cases with Abaqus 6.10-1 and the load-displacement diagrams are produced for each case up to failure. Finally, by comparing the results of all the cases, the lower limit for the capacity of the hexa-node is determined under assumed design criteria. According to the parametric studies, the change in the flange thickness of the hexa-node has a much stronger effect on the load capacity of the hexa-node.

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