developments of cooling tower design

Structural analysis of large cooling towers is mostly based on the theory of no-moment of rotating shells. This theory ignores the effects of bending moments and transverse shear forces in the shell equilibrium equation, and most of them use hand calculations, and then program on a small machine. After the calculation year, the research group headed by Professor Sun Tianfeng determined the reasonable wind load curves of the cooling tower through wind tunnel test and actual measurement. These curves have been adopted by the domestic cooling tower design specifications in structural analysis. A thin shell-based moment theory based on straight normals can be used, and a high-precision rotating shell element is used in the discretization format, and then the rotating shell and two static dynamic analysis programs are respectively completed. The program has become the main program used by various power design institutes in China to calculate cooling towers.

There are hundreds of large cooling towers analyzed and designed by these two programs, and the two cooling towers have been designed. In the past few years, it has been continuously improved, so that it can solve more problems, such as the stability of the cooling tower. Analysis of the 'cooling tower structure according to the theory of moments in foreign countries, which is also about from the end of the century to the beginning of the year. The theory of finite element method has been developed more thoroughly.

The analysis of various structures by the finite element method has become Mainstream, and other commercial software has become a routine tool in structural analysis.
Although we have been able to analyze the stress of the cooling tower under the action of white heavy, wind load and uneven temperature field in the early years, we have formed a special software system with unique characteristics, but the actual demand of the project is endless. The design unit has successively proposed the rib and reinforcement ring problems of the cooling tower structure, the cooling tower foundation treatment and piling problems, the cooling tower construction defects such as the bulging problem, the tower opening large holes that must be dealt with for the joint design of the cooling tower and the chimney, Peking University, several electric power design institutes, Hebei University of Science and Technology, and Zhejiang University, etc. Developed some special calculation software for cooling towers In recent years, due to the promotion and application of general finite element analysis software, Zhejiang University and other units have developed secondary software based on general finite element software, and compiled software for software analysis of cooling tower structure. For the stress distribution of the cooling tower New practical needs provide analytical tools that greatly advance and improve the design level of cooling towers Peking University, Tongji University, Hunan University
The unit has carried out a large number of experiments on the rigidity and aeroelastic model of the cooling tower.
the study
On the other hand, as the geometry of the cooling tower is getting larger and larger, the area of the shower is correspondingly increased. Some of the problems that the small tower does not need to consider now become important, especially the problem of nonlinearity with the nonlinear problem of the thin shell theory. Proposed and gradually matured, there are more and

more cooling towers analyzed by nonlinear finite element method, and the finite element method is also a more effective method for nonlinear analysis.
The maximum seismic response coefficient and the characteristic period of the horse correspond to different working conditions. There is also a corresponding seismic analysis in the specification. According to the relevant regulations of the industrial circulating water cooling design specification, the load that the natural ventilation cooling tower body should consider includes the wind. Load, self-weight, temperature and seismic action As the height of the cooling tower increases, the stress analysis caused by seismic loads becomes more and more important. Japan’s Omori Fumiji first proposed the theory of seismic analysis using static analysis. Absolute rigid body, the inertial force generated by acceleration is used as the seismic action of the building in the event of an earthquake, and the horizontal seismic action of the structure is simplified to the equivalent horizontal static force acting on the structure, the size is the multiple of the structural gravity load. The method ignores the deformability and dynamic response characteristics of the cooling tower itself, and the calculation results are very different from the actual ones. Therefore, it can only be used in the rough estimation of hydraulic structures such as hydraulic structures with large stiffness or in the preliminary design.

The seismic analysis of the structure is based on the theory of dynamic analysis. There are two methods of “time history analysis” and “seismic response spectrum analysis”. The time history analysis method is to record the actual seismic acceleration time history as dynamic load input. Since the load is real-time seismic data, it can not only fully include the load. The three elements of the earthquake, such as the intensity of the earthquake, the spectral characteristics, and the duration of the earthquake, can also take into account the characteristics of the structure itself that cannot be truly and comprehensively considered in the spectrum analysis.

In the seismic analysis, the response spectrum method is usually used first, and then used. Cheng Falai's nuclear time-history analysis method generally has two methods: modal superposition method and direct integration method. The modal superposition time-integration method is suitable for structural linear or weak nonlinear analysis. In the dynamic analysis calculation of the cooling tower, it is generally recommended to consider at least the modal mode and the direct time-integration method, then the nonlinear and non-proportional damping of the structure can be considered, which is a powerful tool for structural nonlinear seismic analysis. The required calculation time when the seismic acceleration time step is large It will become very large and time-consuming and labor-intensive. Compared with many countries, China's seismic design code uses a so-called “reaction spectrum” theory to calculate the seismic action in the “Code for Seismic Design of Structures”. Relationship between seismic response coefficient and period
The height of the cooling tower is small and the thickness of the thin shell is small, which makes the stability problem sharper, especially during the construction period, when the concrete does not reach sufficient rigidity, due to the short construction period in order to complete the construction in one year, It is necessary to remove the template of the first layer as soon as possible to pour the concrete of the previous section. Therefore, the cooling tower accident that collapsed during the construction period occurs when the cooling tower is stable.
At present, the domestic norms generally use static analysis to obtain the maximum stress. According to a certain theory, a so-called wind vibration coefficient is obtained to multiply the maximum stress as the design stress. However, there are different theoretical basis for how to

obtain the wind vibration coefficient. According to the stricter theory. In theory, the stochastic process theory should be used to analyze the response spectrum of the structure according to the mechanical properties of the wind pressure spectrum combined with the structure itself, and calculate the most probable stress according to the response spectrum as the design basis.

However, when this wind vibration coefficient is obtained, it is used today. Most of the schemes use different approximations to calculate the structure as a cantilever beam, and some only calculate the first order of the natural frequency of the structure. These approximations are also reasonable for the special structure of the cooling tower. Further research, in addition, although we have wind pressure on a single tower, but the cooling tower is often not one, sometimes there are hills or high buildings nearby, so cooling towers, other structures and terrain to the cooling tower The influence of water and wind pressure distribution is also the current The structure of the cooling tower of the British Bridge is the same, but the seat downstream of the wind collapses, indicating the interference effect between the towers on the wind pressure. According to the subsequent research by Professor Sun Tianfeng of Peking University, due to the nearby cooling tower or other The influence of the structure, the local wind pressure acting on the cooling tower, can have twice the fluctuation. So some design units have recently required wind tunnel wind pressure test or topographical feature pairs for some special cooling towers. Wind pressure impact test to obtain safe and reasonable design data
2. 1 Wind and water design distribution solutions

2. 1. 1 Optimized layout of tower core material The optimal arrangement of tower core packing is to make the air distribution and water distribution more uniform, and the cooling tower cooling effect is better. In order to make the air distribution more uniform, the packing step arrangement can be adopted, and the effect of increasing the wind resistance can be achieved by increasing the thickness of the packing material in the cooling tower edge area, forcing part of the cold air to move to the tower core region with small resistance; in order to make the water distribution uniform, the cooling tower can be passed The water distribution system is partitioned to make the working heads of the nozzles of the pipeline more uniform. At home and abroad, the water distribution system for large or very large natural ventilation cooling towers generally adopts internal and external divisions, and is also divided into three areas. Taking the inner and outer zones as an example, in order to make the air distribution and water distribution more uniform, the following three arrangements can be adopted:

(1) The single arrangement of the fillers, that is, the thickness of the fillers in the inner and outer zones is uniform, and the large-diameter nozzles in the outer zone are used.

(2) Packing step arrangement, that is, the packing thickness of the outer zone is large, the thickness of the inner zone packing is small, and the inner and outer zones of the nozzle are the same; (3) the step of the packing is arranged, and the large-diameter nozzle of the outer zone is used. Small aperture nozzles in the area. For the actual situation of the project, through the digital and physical model tests on the above several layouts, the most suitable core material placement method is selected to achieve the purpose of optimizing the cooling effect. The 12 000 m 2 cooling tower of the Zouxian Power Plant that has been put into operation adopts the layout method

(3). From the operational situation, the cooling effect is better. The 1 000 m 2 cooling tower of Pengcheng Power Plant under construction and the 13 000 m 2 cooling tower tower core material of Ninghai Power Plant also adopt this arrangement mode.

2. 1. 2 Special measures Some nuclear/thermal power plants have some special measures, such as a large nuclear power plant in France, due to poor meteorological conditions and the cooling effect required by the cooling tower after the method

(1). The plant uses a high water collection arrangement. Although this type of tower does not have the cooling capacity of the rain zone, it solves the problem of uneven distribution of wind due to the rain zone effect of the large and super large cooling towers, and the actual cooling effect is not reduced. The high water collection can also effectively save the head of the circulating water pump (about 6 m), greatly reduce the cycle operation cost, eliminate the wind resistance in the rain zone and reduce the water spray noise. It should be noted that due to the increase in water collection equipment, the one-time investment is relatively large. High-level collection water cooling tower water collecting equipment