Research on Construction Process of the Cable-net Structure of FAST

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Abstract. With a huge collecting area of more than 30 football fields, Five-hundred-meter Aperture Spherical radio Telescope (FAST) is the largest single dish in the world. There are many construction methods of large span cable-net structures some of what is very complicated, so the distribution of internal force of structures is intricate and alternative. According to a variety of mechanical problems and technical difficulties existing in the construction process determine the general construction scheme of the podium, through simulated the construction process, optimize the construction program. The research showed that it had no effect on the structure to consolidate part of the construction steps of theory construction scheme, the actual construction scheme to be used is safe and feasible, and the important conclusion that cable crane and V-zone system are safe is arrived.

1. Introduction
Five-hundred-meter Aperture Spherical radio Telescope (FAST) is supported by cable-net structure, which enables its surface to form a paraboloid in real time under active control. It belongs to the national “11th Five-Year Plan” projects, the project time is 5.5 years from the commencement of work in March of 2011 to 2016. [1, 2]
The structure of the cable-net of FAST is a spherical dish with a radius of 300m and an opening up to 500m in diameter. It is located at karst geomorphology in China, so the construction area is limited and the large type hoisting machinery is difficulty used. The cable-net of the active reflector of FAST is a complex structure system composed of about 6670 main cables segments, 2225 down-tie cables, 50 latticed pillars and steel ring beam of diameter 500m, as shown in Fig.1. In order to simplify the structure of the main reflector, by reducing the number of movable parts and avoiding heavy civil engineering between actuators and the ground. The effective aperture of 300 m will be illuminated by the feeds in a cabin moving on the focus surface, halfway from the reflector to its spherical center. The telescope is to be pointed by moving the focus cabin and adjusting simultaneously the shape of the illuminated reflector from a sphere to a paraboloid. [3, 4, 5]
There are many construction methods of large span structures some of what is very complicated, so the distribution of internal force of structures is intricate and alternative. We should determine the reasonable order during the process of construction to make sure the cable-net construction go safe and economical. It is necessary to simulate the whole construction process of large span cable structures to make out the mechanics property of structures and study the relevant problems during this process. [6,7]
In this paper, systematically and thoroughly study and evaluations were carried on the construction mechanics of the cable crane, basing on the cable-net structure of FAST. The research methods include numerical simulation, similarity model test and structure analysis based on key area. Based on structure cases, this paper recommends rationally arranging construction procedures and fully utilizing structural characteristics, the analysis shows that if the above mentioned methods are accepted, and the construction is processed according to the optimized process, a shortened construction period, as well as a lowered construction cost, will be obtained. At present, firstly the independent towers were installed in the middle of cable-net in order to assemble of main cable and down-tie cable. Secondly, the installation of cable began form the cable of five-symmetry axis-plan by virtue of catwalks and cable crane. Finally, the height control is the key points to the construction quality and to ensure the success of cable-net closure.

2. The optimization of construction method

FAST project is currently in the construction and implementation stage, the construction method is one of the feasible solutions for cable-net structure, which is an effective supplementary type for the same structure by using cable crane and catwalks, some outstanding problems caused by large span space structures such as complicated topography, large land area, high slope, and so on, can be solved more effectively. However, the application and study of the cable-net are still at a preliminary stage. The systematic study on the mechanical response during construction is fairly few. In structure practice, the guideline for design and construction is insufficient. [8]

The cable-net of the active reflector of FAST is a complex structure system composed of about 6670 main cables segments, 2225 down-tie cables, the main cables are almost 12m long and the driving cables are 3m to 50m long, especially in the middle area the most cable of length are less than 5m. The geodesic meshed cable-net structure has been designed as the supporting structure of FAST, and five-symmetry axis-plan was thus suggested as preferred mesh plan. According to the distribution of the cable-net, main cables and down tied cables are divided into five areas. To diminish the harm caused by the high altitude working platform, consider in the middle area the most cable of length are less than in construction procedure we have made a comparison with standing alone tower directly built on the ground. From this respect, according to the region terrain, the geology and the environment situation of constructs section, the cable-net of FAST can be divided into construction area. in which various support plans such as catwalks, cable crane and hanging basket and so on. The construction sequence of cable-net structure the main reflector of FAST, to be shown up that from left to right panel of Figure 2.
2.1. Simulating analysis on the mechanics theory during the process of construction

This paper outlines the control factors and establishes the steps of the mechanics analysis of the cable-net structures during the construction process. The static force analysis during simulating the construction process of the cable-net of FAST, we establish the three dimensions model by means of finite element analysis, simulate the statics property of steel roof during construction process by the effect of dead load, live load and disadvantage accidental action. Then select the reasonable construction scheme and make the relatively economical result and satisfy the structure design scheme at the same time. [9]

The non-linear analysis of space cable structures by the imperfection of construction, the structures will generate geometric or material imperfection in some degree, embody mainly in the variety of distribution of internal force in structural units and the geometric imperfection of key nodes of structures. Compare the result of construction analysis with testing and ideal design model, assess the effect of practical construction process on the formation of cable-net structures, then offer some suggest on the readjust of design and reasonable construction scheme.

2.2. Modelling cables and cable networks

Different numerical approaches have been proposed to model cable structures. In particular, there are various catenary-type finite elements as well as analytical elements available, all stemming from the direct problem-solving of the equilibrium and compatibility equations.

The cable elements adopted are infinitely stiff in the axial direction and cannot experience any increment of length. In fact, the catenary is defined as the curve which an inextensible cable, with negligible resistance to bending, adopts when suspended from its ends and is subject to the effects of gravity. Its mathematical expression has been known for a long time. In 1691, in response to a challenge set forward by Jacob Bernoulli, the scientists Leibnitz, Huygens and Johann Bernoulli found the equilibrium equation for an inextensible catenary. Leibnitz used the theory of infinitesimal calculation to derive the equation of this curve.

In practice, computer applications based on this type of element encounter severe difficulties due to the fact that the curve that relates forces and displacements, in the inextensible catenary, is asymptotic. Solving procedures tend to experience large numerical instability causing, in turn, a very difficult or even impossible convergence.

FAST cable-net is formed using geodesic method, the cable-net is of 1/5 symmetry about the vertical line through the center of the sphere cap. The main cable at symmetrical positions can be classified into a same group of same specifications. Considering the 1/5 symmetry of the cable-net, the calculation load can be effectively reduced. For the cable crane, there will be a calculation case and the cable stresses corresponding to each cable segment are stored, there are 22 working conditions in sum.

Based on statistical data of useful life of tractive-rope and guide-rope gathered from 4 material simulate study as well as practical experiences in the field, problems, such as rope and ropeway profile selection, running conditions and maintenance works, are discussed with recommendations for rational
use of tractive-rope for designer, operators and maintenance workers reference. For the calculation case, the force of the tractive-rope and guide-rope are shown in Fig.4(a) and (b).

![The force of tractive-rope and guide-rope](image)

(a) Tractive-rope (b) Guide-rope

Figure 3. Simulation force results of tractive-rope and guide-rope

2.3. The static and stable analysis of V-zone system

According to the construction control, combining to the catwalk of cable-net, the V-zone was be designed and used to control the anchoring point in complicated system. It is necessary to analysis the statics and stability property of large span cable structures because it’s importance and the complexity of it’s force transmission path system. Ascertain the V-zone system by compare some candidate construction scheme. This paper study on the static and stable property of V-zone system then put forward a kind of assembly all-purpose V-zone systems. The optimize principle of this method is that the internal force in structure and V-zone system is minimal and the process of discharge shortest.

Finite Element Model of V-zone is shown in Figure 4 a (left panel), and stress variation distribution of V-zone structure is shown in Figure 4 b (right panel).

(a) Finite Element Model of V-zone (b) Stress variation distribution of V-zone

Figure 4. V-zone system structure

3. Conclusion

This paper takes the construction mechanical analysis as means, the cable-net structure of FAST as the research object, the key technical problems during the construction process of the large span cable-net structure have been studied, and the following conclusions are obtained:

(1) Construction method of cable-net structure supporting the reflector of FAST is discussed, based on optimization principle of construction methods, and also excavation effects induced by construction sequences and numerical simulation are analyzed by FEM, adopting the typical method of large span
It is indicated that existing construction methods are reasonable during construction, the basis and guidance are supplied for real engineering and some meaningful conclusions are gotten as the reference for similar engineering.

(2). Put forward some key technologies during the installation process of the podium, and make some analysis and studies, the analyzes deformation of the V-zone structure during cable-net installing procedure and study the impact of deformation of precise location when splicing the cable-net at high altitude and determine the construction scheme.

4. References
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