

# Cable Hoisting Technology Development and Application in Bridge Engineering

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**Abstract:** With the progress of material production, machinery manufacturing technology, the cables is developing to the better direction, such as big line across, large hoisting and significantly improve the lifting system etc. ,which widely used in bridge engineering. This paper discusses the basic composition of cable hoisting system and its development present situation, points out the problems of the technology, and introduces the application of the cable hoisting technology in the bridge engineering combined with engineering examples. It is worth reference for the similar projects.

**Keywords:** The cables; Development; Application

## 1. Introduction

Our country is a mountainous country and mountainous area is 69% of total land area, especially in Fujian province, known as "southeast mountainous country". As the in-depth development of cross-strait economic zone construction and the socialist new rural reconstruction, mountain area is proposed to build a large number of transport infrastructure, the first is to build vast bridges. Due to the influence of terrain and bed configuration in the mountains, hoisting technology such as bracket construction, swivel construction and floating crane etc. has been curbed, meanwhile, cantilever construction on the span is limited. Therefore, from the perspective of technology, economy, safety, environmental protection and so on , it has important theoretical and practical value to do further research on the application of cable hoisting technique and technology in mountainous bridge construction.

## 2. An Overview of Cable Hoisting System

### 2.1. Erection with cableway

Erection with cableway refers to the construction methods about cable system, lifting and installation of a bridge. Erection with cableway with great spanning capacity ,applicable to the elevation of vertical lifting and the transportation of longitudinal member and material, it has obvious advantages to use the cable hoisting technology especially in the deep canyons, rapids and restricted navigation on the river and river. At the same time, the cable lifting construction technology is also a kind of new high pier construction technology, used in small span, complex terrain conditions, especially the bridge pier construction in valley area where large-scale construction machinery cannot enter[1], It has important significance for the study of mountain bridge cable hoist-

ing technology due to the advantages of easy to operate, easy to master, simple technology, low cost and high security etc. In recent years, the cable is mainly used for prefabricated reinforced concrete arch bridge, meanwhile, It has been used widely in stiffen framework installation, spandrel structure installation, truss, rigid frame arch bridge construction, and even the general suspension bridge stiffening girder installation. As shown in Figure 1 is the simple signal of cable hoisting construction method.

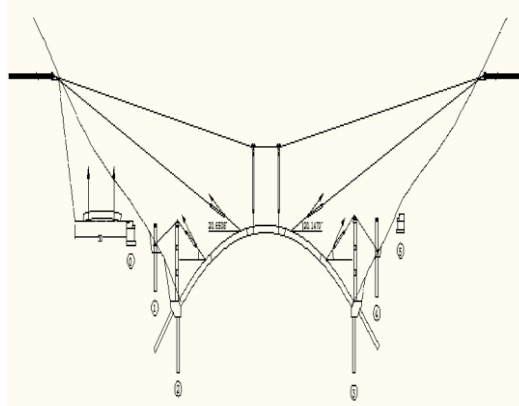


Figure 1. Cable hoisting construction method

### 2.2. System composition

Hoisting arch bridge cable hoisting system is mainly composed of main cable, antenna block, hoisting rope, pulling cable , lifting and towing winch, main cable anchor, tower, wind-cable, cable, cable bent, cable anchor, cable winch etc[2].

#### 1) Main cable

Main cable often using fiber core steel rope. Its diameter, type and root number can be selected in accordance with the cable tower distance (main cable span), hoisting

weight, the calculation of the tension of the main cable by the design of sag.

Main cable in general use mounted action rope in advance to install. The diameter of action rope is smaller, the installation tensile force is not big and it can rely on a finer wire rope or twine to cross the river.

Erection sag of main cable should comply with the design requirements, if it is less than the design value, anchor block, cable tower, and other important components will overload or overload seriously, it is very dangerous. On the contrary, it will affect the progress of the component installation smoothly by oversize work sag and the enhanced slope of components on the lifting downhill.

**2) Hoisting rope**

Hoisting rope set around the antenna tackle to lifting components. Hoisting rope is suitable for choosing steel wire rope due to the hoisting under tension.

**3) Pulling cable**

It is a kind of stepless rope moving along the main cable before and after to drawing antenna block, suitable for use flexible steel wire rope.

**4) Wind-cable**

Wind-cable is also called cable wind-proof wire, sea wind cable and used for stabilizing tower, adjusting and fixing the position of the arch rib.

The type of steel wire rope used by wind-cable is the same as pulling cable, cable and its diameter size is determined by the calculated pulling force.

**5) Cable**

Steel wire rope used in the temporary fixed segmented arch rib is called the cable. The cable use winch or chain block tightening and fine-tuning by tensioner. Cable is divided into the pier buckle (button on the pier), velcro (button fixed on the anchor through the pier on top of the tower), day buckle (Fixed on the antenna), through deduction and so on several forms.

**6) Antenna block**

Antenna block is also called the sports car which running and lifting heavy objects on the main cable, it can use finalized block or own processing according to the actual situation of hoisting. Sports car mostly consists of three parts are running wheels, lifting pulley block and traction system.

**7) Tower**

Tower is grouped into several major parts such as the tower body, tower bottom, cable saddle and so on. The overall arrangement of tower is shown in Figure 2.

The tower body is commonly assembled by profile steel or universal bar and also can be made up of assembled highway bridge steel proglottid and other components.

Top of the tower should set cable saddle. When the main cable through the cable saddle, the diameter of cable saddle must be greater than 12 times diameter of wire rope or 300 times diameter of the steel wire[3].



**Figure 2. The overall arrangement of tower**

**8) Tower foundation**

Tower foundation generally uses mortar rubble or rubble concrete. Tower bottom has hinge joint and solid joint by two forms, the base hinged tower must rely on the wind-cable to maintain stability and some sites set spherical tangent or stow-wood plane tangent free motion joint in the tower bottom. The bottom of the cable bridge equipment set cylinder hinge support under the shared component subuliform column foot section. Some tower foot fixed in the foundation concrete or set insert bolt to fix tower, this form of tower bottom can subject to bending but the stability of the tower still need help from wind-cable.

**9) Anchorage**

Anchorage is an indispensable equipment to fix main cable, the hoisting cable, cable, winch, wind-cable, leading block, various boom and the rope lift etc. Important anchorage should carry on the specialized design and calculation and try to pull before official use.

The types of anchorage can be divided into the alley, steel anchor ring, anchorage in the water and other anchor points according to the structural form.

**10) Electric hoist and hand winch**

Electric hoist and hand winch is a kind of power plant for traction and lifting. The speed of electric hoist is fast but not easy to control, it is more commonly used in hoisting rope and pulling cable. For fine adjustment of wire rope, we mostly adopt the hand winch for manipulating expediently.

**11) Other accessories**

Such as all kinds of chain hoist, Turn buckle, wire clip(wire pierced head) and jack line etc.

There are many forms and specifications of cable hoisting system, all of us must make reasonable choices under the condition of each project according to local conditions to achieve good results.

### 2.3. Hanging method

First of all, according to cable crane's hoisting capacity, arch rib can be divided into different segments along the longitudinal to prefabricate, then transporting precast arch section to installation site through the cable crane, in order to maintain the final closure front arch rib in a certain position unchangeably, we should tie up with the guy temporarily in the upper to maintain balance and then loosen the sling[4]. Arch rib hoisting should start from the ends of the bridge to the center symmetrically to achieve a balance of the force of arch rib, after the arch rib hoisting closure segments in place and adjusting the joint position to the provisions of elevation, we can only loosen the sling and closure each joint, in the end, we can dismantle all of the cable. Schematic diagram of the cables is shown in Figure 3.



Figure 3. Schematic diagram of the cables

## 3. Cable Hoisting Technology Research Status

Cable hoisting technology was developed on the basis of hyperbolic arch bridge construction as one of the arch bridge non- bracket construction methods in the 60's. In the process of a wide range of engineering practice, this method has got great development and accumulated rich experience in construction[5]. According to statistics, since the 1960s, there are almost 60% of the arch bridges construct with cable hoisting construction method in all parts of the country[6]. According to incomplete statistics, in recent years, the number of the installation of large span arch bridge precast arch rib which adopted the cable hoisting technology to construct is more than 70% construction in our country.

### 3.1. Theory technology research

The diversification of the construction plant, augmented bridge span leads to different construction requirements and the increase of construction difficulty, thus the cable hoisting technology should be further studied. At present, our country have carried on considerable research on each component system of cable hoisting equipment to adapt to the development requirements of this construction.

Dagang Wang etc. designed a new type of micro wire rope fatigue test device based on the mining area aerial ropeway; Miguel etc. put forward a new way to solve the 3d cable structures based on the catenary theory; Carlo etc. analyzed the failure of wire rope; Wojciech studied the safety of hoisting rope under the large lifting force and uneven role; Zhao Yueyu etc. researched the buckle cable force and carrying amount in advance of cable hoisting construction method by using finite element software, and pointed out that the finite element method has higher simplicity and accuracy in the calculation of it[7]; Chao-yang zhao etc. carried out the mechanical analysis on the main cable system of long-span cable hoisting equipment and has obtained a kind of more accurate finite element algorithm; Deng Xuetao etc. studied the influence of wind load on the cable hoisting system based on the finite element theory and it is concluded that wind load has large effect on the stability of the tower; Luo Caiying etc. studied the flexible suspension bridge cable lifting construction technology based on the bridge construction specifications and cable hoisting construction experience, he put forward the key technique in the construction process systematically and it provided the scientific basis for the flexible suspension bridge construction in the mountains which are under complex conditions; Yuejing Luo etc. researched the stability and security in the process of arch rib hoisting by using finite element software ANSYS for and it is concluded that the stability coefficient and safety factor of each arch rib segmental hoisting stages; Kaixin Li etc. combined unstressed state control method with the calculation of suspension cable, meanwhile, they derived the calculation of unstressed suspension cable length considering the temperature influence to counterpose the shortage which existed in the traditional method of suspension cable in the current cable hoisting construction.

### 3.2. Development status

Traditional erection with cableway using hoist wire rope system to finish the segmented cantilever erection of the main arch, but when the bridge span is larger, main arch rib segments are more or the weight is very heavy, it is hard to avoid unreasonable conditions such as control error, inaccurate arch rib elevation, so that, the construction difficulties appeared. At present, when designing the cable-hoisting system without-supporting frame in our country, we often do some simplified and mainly by

hand such as taking no account of the influence of tower deviation, assuming that the main cable gravity distributed along the chord length direction Uniformly, regardless of the change of the point of tangency which belongs to cable saddle etc. At the same time, we also did not do in-depth research on main cable sliding along the cable saddles in the process of hoisting. Only by finite element analysis technology can we conduct a comprehensive and accurate analysis on the non-bracket cable-hoisting system[8].

So it is an urgent need to adopt new technology, new process to remould and innovate the original system. Jielian Zheng, an academician, put forward jack strand slanting pull and buckle cantilevered assembly technology in the construction of Guangxi towns NingYi river bridge in 1992. The prestress wire with high strength, low relaxation and accurate tension control is used in this technology as the cable of arch rib cantilever construction, so that the linear control of the main arch rib become easier[9].

Today, the single span limit value of the cables has been more than 500m, from the single span cable evolved into double span continuous cable, its single span limit for has been more than 400m, lifting quality has also achieved 75t, we can lift segmented precast box arch bridge which span achieves about 160m. Meanwhile, the cable bridge equipments continue to improve and our country have begun to gang production at present.

**4. The Application of Engineering Practice**

Many project examples show that the arch bridge which constructed with cable hoisting technology have higher economical efficiency and higher adaptability of topography and geological conditions. The mike. Mr Callaghan - pat tillman memorial bridge in America's Hoover dam downstream 500 m adopted cable hoisting construction method and the safety of the construction on steep cliff has been implemented[10]; Yonghe bridge which built in Guangxi Nanning in 2004 used the cable hoisting system method for lifting work and when it was completed, it is the largest span concrete-filled steel tubus arch bridge in the world .Xiangjiang bridge built in 2007 in Hunan province is a composite structure arch bridge which main span is birds suspension type of concrete-filled steel tie bar and auxiliary for cables, this bridge used cable hoisting system method when constructing the concrete-filled steel tubular rib and fully adjust measures to local conditions by using the completed both sides of the bridge tower as hoisting tower, while the stay cable as the fastening stay, it has reduced the project cost and ensured the economical efficiency of the construction; Aizhai bridge in Hunan province opened to traffic on March 31, 2012 has set up four world first by adopting cable hoisting system method with construction; Mountain Yangtze river bridge in Sichuan province which

mainspan is 500m built in 2012 have achieved the final closure by using cable hoisting technique , when it was completed, it is the biggest span concrete filled steel tube arch bridge in the world; Zhijinghe River Bridge on the shanghai-chengdu Expressway is a deck type of concrete-filled steel tube arch bridge whose main span is 430m,both sides of the bridge need to connect the tunnel and both of them are high cliffs, adopting the cable hoisting technology can realize the lifting safely when the construction site is limited and transportation conditions are wicked.

In addition, Chongqing Wanxian Changjiang river highway bridge municipality built in 1997 (the arch bridge reinforced with concrete-filled steel tube whose mainspan is 420m) is shown in figure 4, Shanghai Lu Puqiao built in 2003 (all steel structure half through bridge arc bridge whose mainspan is 550m), Hunan changsha blackstone Xiangjiang river bridge is shown in figure 5, Chongqing Wushan Wu gorge Yangtze river bridge built in 2004[11] (the half-through concrete filled steel tubular arch bridge whose mainspan is 460m), Hunan Nanxian thatched street bridge (the half-through concrete filled steel tubular arch bridge whose mainspan is 368m), Zhejiang Hangzhou Qianjiang four bridge (the Renaissance bridge) and so on are all using non-bracket cable hoisting construction.



**Figure 4. Chongqing wanxian changjiang river highway bridge municipality**



**Figure 5. Hunan changsha blackstone xiangjiang river bridge**



## 5. The Advantages and Disadvantages of Cable Hoisting Technology

Cable hoisting technology is widely used in bridge construction, It shows that this technology has merit. But the application of hoisting technology is becoming more and more and the resulting problems are also more up.

### 5.1. The advantages of cable hoisting technology

Using the cable hoisting system method to set up arch bridge has the following advantages:

- 1) Great spanning capacity, high bearing capacity, the steel strand used as the stay cable has high strength, large bearing capacity, small elongation and stable deformation, it can reduce the non-elastic deformation of the instability line during the construction;
- 2) Linear and stress distribution of arch rib is easy to control;
- 3) It can accurately calculate the cable force, elongation of each stage during the process of the erection and the resulting higher values in advance of a large section of the joint as the basis of construction control[12].

### 5.2. Open question

At present, the cable hoisting arch bridge construction technology still exist the following problems:

- 1) Based on the principle is economic and applicable, the main, buckle tower system integration is often used in current cable hoisting. For modern Bridges, large-span bridge is the trend of future development. With the rapid development of highway construction in our country, high rise-span, lifting section, large hoisting hoisting cable hoisting system has been appeared to meet the requirements. It put forward higher requirements for the tower system which belongs to the big tall structures, how to determine the strength, stiffness and stability requirements of tower system in the process of construction is the key.
- 2) Large hoisting is the developing trend of cable hoisting technology in the future, it put forward higher requirements for the stability of the main cable system of the cable hoisting technology in the construction process. It is lacking of the research on drawing speed in the process of cable hoisting construction because we just at a constant speed slow, general requirements without giving more precise value.
- 3) Cable hoisting technology is widely used in railway, highway and bridge construction, its characteristic is strong spanning capacity, big lifting height and convenient dismantling. But the anchor and cable wind rope etc. has the need of stress, the distance is far from the fulcrum, so it leads to the difficulties in setting up surrounding buildings because of the terrain conditions. Therefore, the cable hoisting technology is used more in the

open field without buildings near the bridge in bridge construction, however, it is limited in the city.

4) In the process of construction, arch rib docking precision is difficult to control, arch rib axis linear control also have difficulty, the arch rib section is more, the construction period is longer, the construction quality will be hard to ensure and the construction cost will be also increased. Moreover, reasonable measures should be taken to ensure lateral stability in the process of hoisting construction.

5) For cable hoisting technology has yet to have relevant country industry construction acceptance specifications now and the values of safety coefficient is generally larger in the design process, finally, the economy remains to be improved.

## 6. Conclusion

Although cable hoisting equipment is a temporary construction equipment in the erection of permanent bridge structure, it accounted for a higher proportion in the bridge construction cost. Therefore, It has great significance for shortening the construction period of the bridge and reducing the cost to make sure that the cable hoisting system can be safe operation. Cable hoisting system is in order to realize the safe hoisting of the arch rib segmental, but the hoisting of arch rib section is the core content of main arch embowing and the bridge forming, so all of us must carefully design cable hoisting system and the construction scheme, at the same time, the scheme should be calculated systematically to ensure foolproof. In addition, we need to cooperate well in the clarification of technology, safety, quality and require participants to specific construction method, process and operation requirements.

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