ISSN Online: https://doi.org/10.35534/asrj.
Advanced Scientific Research Journal – 2025, 1(1): 14–18

Brief Analysis on the Application of Prestressed Construction Technology in Highway and Bridge Engineering

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Abstract: Modern prestressed technology has promoted the rapid development of civil engineering and is also the most widely used construction technology in the construction of large structures, especially bridges, nowadays. With the continuous development of prestressed construction technology, especially the emergence of technologies such as prestressed materials and anchorage systems, the application scope and application effect of prestressed construction technology have been enriched. This article analyzes the development history of prestressed technology and discusses the prestressed materials currently developed in China and the application of prestressed technology.

Keywords: Highway and Bridge Construction; Prestressed Construction Technology; Civil Engineering; Prestressed Materials; Anchorage System

1. Overview

The prestressed technology in China began to be applied in the 1960s and has been in use for nearly half a century, achieving remarkable achievements in the construction of roads and bridges. Although the application of prestressed technology in China started later than that in other countries, its development speed has been astonishing. Now, a complete application system covering theoretical calculation, construction technology, materials and equipment, inspection, design, and construction has been formed, and it has played a crucial role in the construction of highway bridges. Besides being used in the construction of highway bridges, it has also been of great help in the maintenance, reinforcement, upgrading, and anchoring of existing bridges. Moreover, with the continuous progress of prestressed technology in China, its application scope will also expand.

The core of prestressing lies in applying stress to the components and structures of highway bridges in advance so that the stress can tension and reinforce the components. Therefore, prestressed technology has also become an anchoring and tensioning system. This technology was first invented by the French engineer Eugène Freyssinet and applied in the construction of concrete projects, from which prestressed materials, prestressed equipment, and key technologies were derived, bringing new development ideas and directions to modern construction.

With the continuous development and research of prestressed technology, the performance of prestressed tendons and prestressed tensioning and anchoring systems has been greatly improved. The technical level and scientific nature of prestressing have been significantly enhanced and perfected through practical applications. It can be seen that prestressed technology has become a construction technology with the highest technical level, the widest application range, and the greatest application value and prospects in the world.

Citation: Xie Feijun. Brief Analysis on the Application of Prestressed Construction Technology in Highway and Bridge Engineering [J]. Advanced Scientific Research Journal, 2025, 1(1): 14-18.

2. Analysis of Prestressed Materials in China

In the nearly half-century development of prestressed technology in China, the development of prestressed materials cannot be ignored. Currently, prestressed materials in China include steel wires, steel strands, steel bars, and non-metallic prestressed tendons. These materials are selected and applied according to different construction requirements and construction technologies. Due to the significant differences in production processes and construction methods of these materials, they can also be classified into bonded, slow-bonded, unbonded, and external prestressed tendons according to whether they are bonded or not.

Analyzing from the perspective of development time, China began to apply prestressed materials in the 1960s. At that time, prestressed materials were mainly used in the tensioning and anchoring technologies of medium and low-strength prestressed concrete tendons, including screw end rod anchoring technology, high-strength steel wire buttoned-head anchor system, JM anchor system, and Freyssinet anchor system. These systems have all brought great help to the construction of highway bridges in China, and relevant prestressed concrete anchor fixture standard drawing albums have been published. As time goes by, China's prestressed technology has been continuously innovated, and the technical system has become more abundant. The prestressed concrete steel strand group anchor tensioning and anchoring system emerged and entered its golden period starting from the 1980s. At this time, China's prestressed technology was able to provide equipment support for large-tonnage concrete anchors and supporting tensioning technologies and received wide attention from society as a major scientific and technological achievement in China. In order to improve the application effect of prestressed technology in China, China has gradually studied and applied supporting technologies such as unbonded prestressed concrete tendon coating and wrapping equipment, single steel strand tensioning and anchoring equipment, and technical regulations for the design of unbonded prestressed concrete structures. By using the unbonded method to organically combine prestressed technology and materials, this technology has had a huge impact on the current cast-in-place prestressed concrete structures in China. To date, China's unbonded prestressed technology and its related supporting equipment have been widely used in the construction of highway bridges in China. In the current use process of highway bridges, the application traces of this technology can still be seen, bringing huge technological innovations to the construction of highway bridges in China.

Currently, prestressed materials in China have been transformed into high-strength and highly corrosion-resistant materials, which can effectively extend the service life of highway bridges in China. A systematic technological system has been formed, and through a variety of processes and construction technologies, remarkable achievements have been made. Prestressed technology has become a very mature construction technology in China and is of great help to the construction of highway bridges of different types and scopes.

3. Analysis of the Current Application of Prestressing in China

China has achieved the localization of prestressed technology and its supporting equipment. It can carry out localized production of concrete with different properties, steel wires and steel strands of different specifications and degrees, and put them into practical applications. In particular, significant technological progress has also been made in the improvement and perfection of anchors and tensioning equipment. Among tensioning equipment, jacks, oil pumps, pressure gauges, and wire-passing machines can all be effectively produced and put into use. With the continuous progress of the above technologies, the construction of highway bridges in China has been fully utilized and applied and has occupied an important position in the construction of highway bridges.

3.1. Application of Prestressed Technology in Concrete Hollow Slabs

In the construction of conventional highway bridges in China, with a basic span diameter mainly ranging from 16 to 25 cm, concrete hollow slabs are usually used as the main materials. Prestressed technology is applied, and hollow slabs, prestressed steel bars, and low-relaxation steel strands are used in bridge construction. The main prestressed technologies applied include pretensioning method, post-tensioning method, and medium-tensioning method. The pretensioning method is mainly used for the construction of single steel strands, while the post-tensioning method uses flat anchors or group anchors. The medium-tensioning method requires a fixed tonnage, and different prestressed

technologies are adopted under different tonnages. Prefabricated installation and cast-in-place on supports will not be used in concrete hollow slabs. Currently, there are also concrete hollow slabs with a span diameter ranging from 30 to 35 cm in China, but this span requires higher material usage costs and has lower stiffness.

3.2. Application of Prestressing in Concrete Simply Supported Beams

Simply supported beams are relatively common construction parts in highway bridges, with a span ranging from 20 to 50 cm. Prestressed technologies mainly include high-strength steel strands, low-relaxation steel strands, post-tensioning method, and group anchors. The tonnage is fixed by medium-tensioning. Simply supported beams need to be fabricated by prefabricated assembly technology and installed by using supporting bridge erection equipment. Especially under the current condition of high driving requirements, the cast-in-place beam technology is used for the construction of joints, which can form a "quasi-continuous" structure for the bridge deck and make the bridge deck smoother.

3.3. Application of Prestressing in Concrete Box Girders

Concrete box girders are relatively important parts in bridges, with a main span ranging from 40 to 60 cm. Prestressed technologies mainly include high-strength steel strands and low-relaxation steel strands, and the tensioning tonnage is fixed by longitudinal prestressing. The tonnage is mainly medium. According to the different construction technology requirements of bridges, the anchorage of longitudinal prestressed steel strands is continuously configured. According to the configuration of box girders and steel strands, the longer the overhanging length of the cantilever plate of highway bridge box girders in China is, the more steel strands are used. When the length of the cantilever plate is more than 1 m, 3 to 5 steel strands are required for construction. The main construction technologies include cast-in-place construction on supports and slip form main hole pouring construction. During the construction process, the cantilever pouring construction method is widely used. In addition, prefabricated assembly also has a certain application. However, with the continuous changes of highway bridges in China, the "two-way" prestressed structure with a span of 40 to 60 m has gradually become the main structure of highway bridges. At this time, large-tonnage bearings are used for construction, and prestressed concrete continuous rigid frame bridges are taken as the main construction technology.

3.4. Prestressed Reinforcement Technology

Prestressed reinforcement technology is currently the most common prestressed technology. In the process of highway bridge construction, it mainly applies external prestressing to the structure of the bridge to offset the internal forces generated by the bridge. Specifically, prestressed reinforcement technology can be regarded as a phased post-tensioned prestressed technology. This technology can avoid applying prestressing to parts that do not require external forces on the basis of the original structure and effectively improve the application level of prestressing according to different loads. Elastic supports are used to offset the internal forces of the bridge's own structure.

It can be seen that prestressed reinforcement technology is an active reinforcement technology that can change the shape of the structure of highway bridges through different prestress values to improve the bearing capacity of components. Due to the flexibility of prestressed reinforcement technology, it has been widely applied in the construction of highway bridges in China in recent years, achieving high application effects. For example, when constructing beams, the prestressed application of shotcrete on the beams can make the steel strands and the beam body effectively bonded, playing a reinforcing role. This method is more effective for functions such as the stiffness and shear strength of the beam and effectively improves the bending resistance of the beam. It also effectively prevents steel strands from rusting due to exposure to the air, simplifies the future application, maintenance, and inspection of highway bridges, and has higher economic and safety values.

4. Prestressed Construction Process

First, the construction of the anchoring end, the cross ribs for the mid-span turning of the cross beam, and the guide grooves on the top of the pier should be carried out. The above construction processes can help steel strands confirm their spatial positions, and the construction of cable-shaped tensioning can be carried out on steel strands to help them determine the equivalent load amount so that the prestressed technology can confirm the extrusion pressure. To ensure

the construction effect, the position of the anchor plate has high requirements during the construction of the anchoring end. During the construction of the turning cross ribs and the guide grooves on the top of the pier, it is necessary to strictly follow the design requirements and actual application needs for construction, and strictly control and observe the bending degree of steel strands and the smoothness of the top to ensure construction quality and safety.

Second, after confirming the bending degree and position of steel strands, the cutting and threading of steel strands can be carried out. Before construction, grouting operations should be carried out on the anchor plate and steel pipes to make the two materials effectively bonded together, and the position of the PE layer needs to be ensured. At this time, grease should be cleaned first, and the length and position should be tightly controlled to ensure that the PE layer can enter the sealing cover and fully understand the impact of tension elongation on the position of the PE layer so that it can be in an appropriate position. During the threading construction operation, the length of the steel strands for construction is all greater than 150 m, which makes the threading work rather difficult. Therefore, the installation of guide grooves or mid-turning devices can be carried out. If multi-strand threading cannot be carried out, single-strand threading can be used for construction. During the construction process, it should be ensured that steel strands will not be wound, and the steel strands, anchor plate holes, and small holes in the sealing cover should be numbered. Use the numbers to avoid the winding of steel strands and straighten the wound steel strands.

Third, the tensioning of steel strands is a way to help steel strands meet the specified construction requirements. Tensioning is carried out on both sides of a single steel strand. Tensioning mainly includes pre-tightening construction and high-stress tensioning. Both construction processes should meet the construction design and actual requirements. During the tensioning process, since tensioning will cause prestress loss of prestressed tendons, it is often 5% higher than the design requirements. The tensioning effect is verified by elongation value calibration. If the difference between the tensioning result and the requirement is within 6%, the tensioning can be stopped.

5. Conclusion

The application of prestressed construction technology is very extensive, which can make the construction of highway bridges more convenient and safer. Especially in today's era of rapid development of science and technology, the application prospects of prestressed construction technology are even broader and can make greater contributions to the construction of highway bridges in China.

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