

Suspension Bridge Anchorage by Pre-Stressed Anchor

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ABSTRACT

Anchor technology has been widely extended to many trades after 100 years of its development. This paper discusses the application of pre-stressed anchor reinforcement for anchorage of Xiaoping Island Sheng-island Bridge, carried out safety analysis of reinforced anchorage by software of general finite element analysis, Ansys. The analytical results showed that the use of pre-stressed anchor to reinforce anchorage was feasible and provided effective reference to subsequent actual project.

KEYWORDS: pre-stressed anchor reinforcement; finite element analysis; anchorage

INTRODUCTION

Anchoring technology has a century of development history. Since 1872, North Wales, United Kingdom opened the first page of the application of slope reinforced by bolts; Germany's Devoretz mine used anchoring technology first time in underground roadway in 1912. After the introduction of anchoring technology in China in 1950s, its application has widely been extended to metallurgy, mining, water conservancy, transportation, construction and other industries. In this paper the application of tension bolts in suspension anchorage reinforcement is presented.

ENGINEERING SITUATIONS

Xiaoping Island Sheng-Island Bridge was built in 2003, it was a anchored suspension bridge of reinforced concrete with a four-cable plane, main span of 65m, rise-span ratio 1:6.5, and bridge width 16.5m, as shown in Figure 1. The full bridge was divided into parts of pedestrian and vehicular along the horizontal structure, in which pedestrian bridge width was 7.85m, vehicular bridge width was 8.55m, main beam and anchorage used C50 concrete, main tower was C40 concrete, main cable and back stay used 211 low-relaxation wire $\phi 7$ high-strength galvanized steel wire, hangers used 37 low-relaxation wire $\phi 5$ high-strength galvanized steel wire, foundation of bridges are set on concrete breast wall in which rested on a caisson foundation.



Figure 1: Xiaoping Island Bridge

REINFORCED SUSPENSION BRIDGE ANCHORAGE BY PRE-STRESSED ANCHOR

The principle of structure reinforcement by pre-stressed anchor

The mode of transfer force of tensile type anchor rod is delivered the external force to anchorage outside body through bonding that not only between steel and the cement paste, but also between cement paste and rock and soil mass, the bolt axial force which rely on non-uniform tensile deformation between the start and the end of anchorage segment in order to drive the deformation of anchoring body that combined with bolt is reduced.

The body of traditional tension-type bolt is low-relaxation smooth high-strength strand, the whole body through length was wrapped by paste, free section that filled with paste is not subject to force, a certain tensile load that effect on anchoring paragraph directly is a reinforcement forms of bolt that ensured anchoring paragraph subjected to tension state.

Pre-stressed reinforced concrete structure has been the emergence of a concrete structure known as the technological revolution. It can ensure both concrete and steel work together to improve the flexural capacity, slow development of cracks, reducing the deflection components, in order to reduce cross-section to save the amount of steel, improve durability and reduce costs. Pre-stressed reinforced concrete structure has been widely used in China. Pre-stressed anchor is composed of anchor head, pre-stressed bar, anchorage body, by applying pre-stress to anchor through elastic elongation of pre-stressed tendons free section (tensioned section) for improving necessary active supporting tension.

The superiority of pre-stressed anchor system is: (1) ensure interaction between anchoring body and bolt, enhance the tensile, bending, shear force of reinforced body; (2) prevent cracks and sliding appeared untimely; (3) improve the anchoring strength and stiffness of anchoring body. The above superiority of pre-stressed anchor system, not only ensure the safety of the

anchorage body, but also save construction costs, meanwhile expanded application range of bolt supporting.

Consolidation methods

Retain original anchorage and reinforce it; the reinforcement part concrete and anchorage is connected by inserting reinforcing bar; arrange 16 bundles $6\Phi 15.2$ strand regard as anchor bolt in each anchorage in order to ensure global stability of reinforced anchorage, avoid overturn. One side of strand anchored in breast wall through drilling, the other side in anchorage, meanwhile, set 6 roots $\Phi 32$ precision-rolled reinforced bars to ensure connection firmly between fresh concrete and original anchorage. Special construction shown in Fig. 2, shadow part is original anchorage. Figure 3 shown the layout of pre-stressed anchor and lateral precision-rolled reinforced bars.

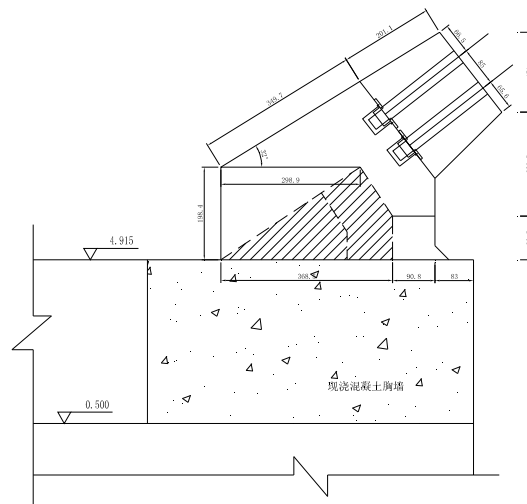


Figure 2: Vertical layout drawing of anchorage

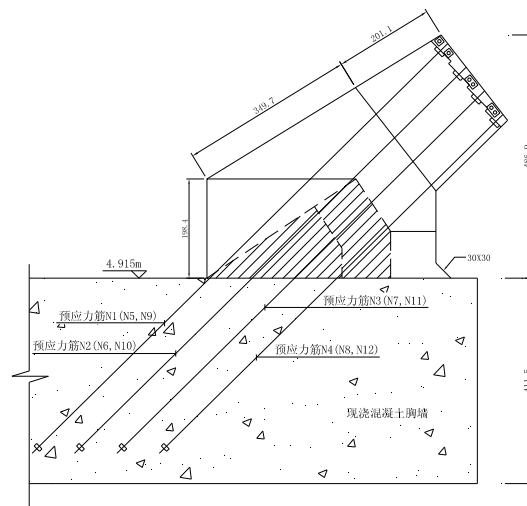


Figure 3: Layout drawing of pre-stressed and lateral precision-rolled reinforced bars anchor

Design and Analysis of Reinforcement

Use element solid85 to proceed entity analysis for anchorage by common software-Ansys, analyze stress of anchorage both in construction stage and service stage, Fig. 4 - Fig. 11 show the special analysis results. The results show that structure is in elastic stage both in construction and service stage, principal compressive and tensile stress of concrete all less than permissible value except local stress of anchored point.

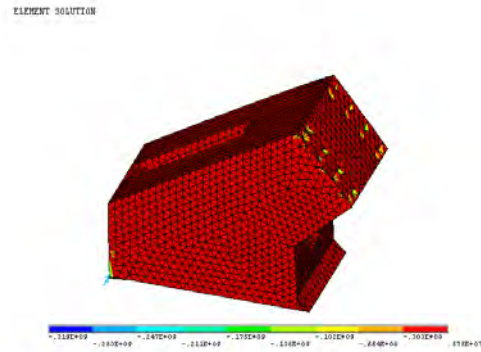
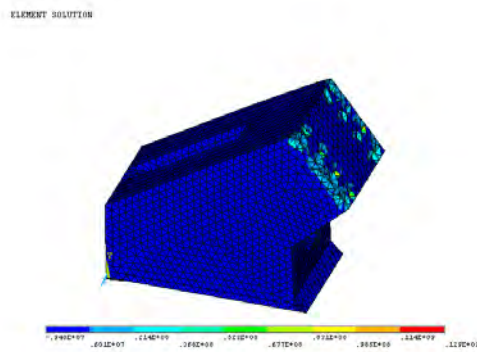


Figure 4: First main stress of construction stage **Figure 5:** Third main stress of construction stage

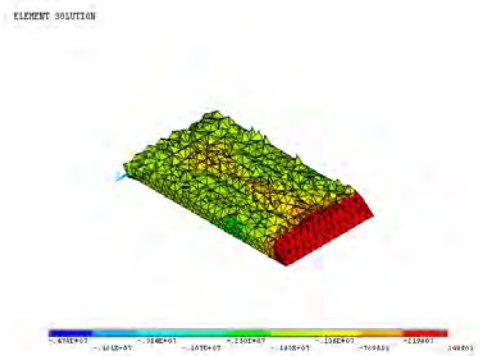
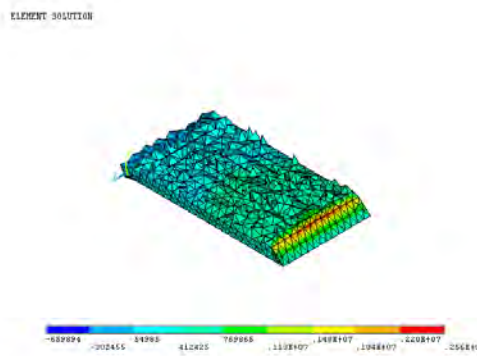


Figure 6: First main stress of construction stage **Figure 7:** Third main stress of construction stage on the bottom of anchorage

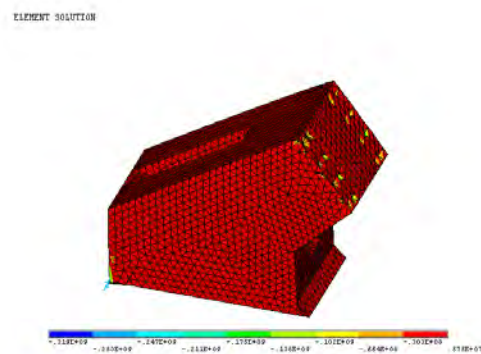
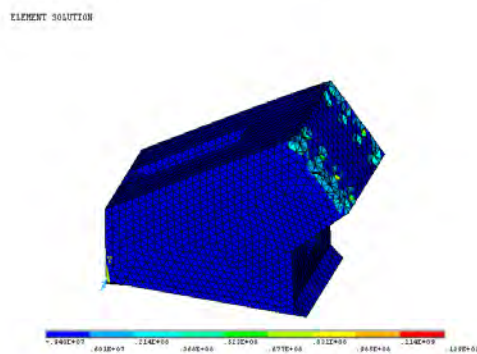


Figure 8: First main stress of service stage **Figure 9:** Third main stress of service stage

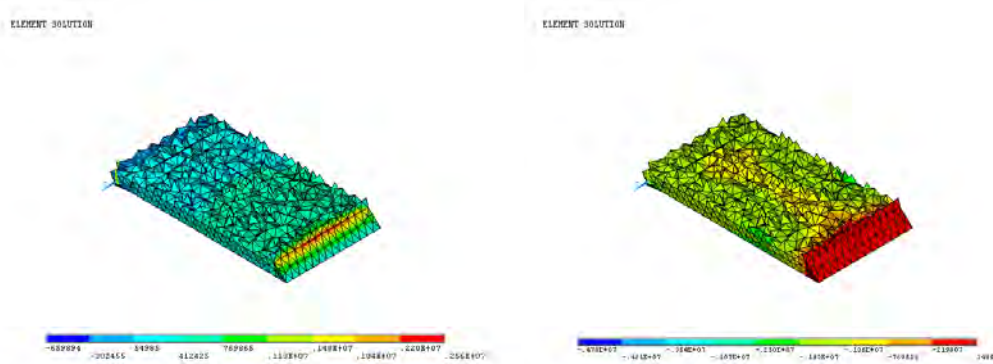


Figure 10: First main stress of service stage on the bottom of anchorage **Figure 11:** Third main stress of service stage on the bottom of anchorage

We should check the stability coefficient of resisting capsizing and sliding of structure that regard as community of anchorage and breast wall, because of the role of anchor that made the anchorage and concrete breast wall became one fresh, the detailed result show in Tab.1.

Table 1: Checking of resisting capsizing and sliding

	Stability coefficient of resisting capsizing	Stability coefficient of resisting sliding
Construction stage	1.3	1.7
Service stage	1.4	1.4

CONSTRUCTION OF PRE-STRESSED ANCHOR

(1) Drill after clean the surface of concrete breast wall, meanwhile implanted common steel. Clean the drilling, install pre-stress bolt, grouting, meanwhile ensure bolt and breast wall became one fresh, after drilling reach design depth in the design of drilling depth. Use effective method to make each strand of $\Phi 15.2$ separated from each other in order to increase power of gripping between strand and cement paste.

(2) Construction method of anchor bolt is grouting twice. First, press grouting under the top of breast wall, so that strands and original structure can joint one body. Pre-stressed strands which above the top of breast wall need bury bellows. After steel lashing, and fresh concrete strength reached 80% designing strength, tensioned pre-stressed strands under guiding of construction controlling department. Then press grouting second time, close anchor. The monitoring of pre-stress bar stretching program is the most important in whole construction process, in tension process mainly of stress controlling and subsidiary role of elongation indicator proofread, meanwhile, tensioning process completed by batching and graded method, in order to ensure structure force slowly and uniformly, lest the anchorage appeared large displacement.

(3) Depending on the special conditions, be cautious of the drilling whether or not infiltrate sea water appropriately adjusted depth of drilling based on actual situation, meanwhile ensure anchor device of pre-stress fixed end buried in concrete breast wall, in order to avoid corrosion by infiltrating sea water.

CONCLUSIONS

According to the analysis above, some results are concluded as follows:

(1) Careful attention has to be paid to the joint surface between the old and the new concrete, because of entire analysis is based on safety bonding and no relative sliding of concrete between post-pouring and anchorage. The surface of old concrete must roughened, cleaned, void oil pollution, and take effective measures(for example ,set tooth type shear slot) in order to guarantee new-to-old concrete combined well, meanwhile, embed common steel under guidance of professional engineer by chemical glue.

(2) The results of the analysis by finite element method show that in both the construction phase and service phase, principal compressive and tensile stresses in concrete remain below the permissible values except local stress of anchored point and local region under cable anchor plate. So we believe that the use of pre-stressed anchor to reinforce anchorage satisfies design requirements.

(3) When safety factors against capsizing and sliding for anchorage reinforced by pre-stressed anchor are less than permissible values, we may improve safety factors by adjusting anchoring force of pre-stressed anchor.

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