The key quality control technology of main cable erection in long-span suspension bridge construction

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Abstract. Main cable is one of the most important structure of suspension Bridges, which bear all the dead and live load from upper structure. Cable erection is one of the most critical process in suspension bridge construction. Key points about strand erection are studied in this paper, including strand traction, lateral movement, section adjustment, placing into saddle , anchoring, line shape adjustment and keeping, and tension control. The technology has helped a long-span suspension bridge in Yunnan Province, China get a ideal finished state.

Main cable is one of the most important structure of suspension Bridges, which bear all the dead load and live load from upper structure. Main cable erection is the key of the suspension bridge construction. Main cables in modern suspension bridges are made from high strength galvanized steel wire. Mature construction technology include prefabricated parallel wire beam method (PPWS method) and air spin method (AS). As advantages such as high erection efficiency, easy control of fabrication in factory and higher precision in site, the PPWS method is deeply adopted in China.

1. The goal of main cable erection

1.1. Precision requirements of main cable erection

Table 1 Precision Requirements of Main Cable Erection

Subject			Allowable deviation
Strand elevation（mm）	Standard strand	Midspan of main span	±L/20000
		Attitude difference between upstream and downstream strand	10
	Normal strand	Interval to normal strand	0，+5
Anchor span force deviation			Comply with design requirements
Main cable void fraction（%）			±2
Out of roundness of main cable diameter（%）			2

1.2. Appearance Requirement

（1）The strand wires are parallel and straight; there is no drum and overlap in strand.
（2）Straight, no cross, no twist
（3）The galvanized layer are protected in good condition; surface of wire is clean.

2. Key control points of main cable erection

2.1. Strand traction

Lift strand by mobile crane and release the strand to necessary length so that anchor head can reach the traction. Lay strand cable on level rollers in front of the cable tray. Adjust the section of strand to standard hexagon starting from the anchor head and fix temporary fixture. Then pull the strand after strand is in position.

Figure 1 Strand Tracking

Strand traction speed should be controlled in 15 ~ 20 m/min. But when anchor head gets through door frame, the speed should be controlled in 5 m/min. The pulling speed should shift smoothly with start, stop, shift.

Monitor strand traction in real-time to prevent twist, wear away, binder fracture, drum in strand.

When the strand tag reach the bulk cable saddle on the other side, stop strand traction. Take the anchor head away from the traction by mobile crane, and temporarily fixed the other anchor head by counter loop wire rope.

2.2. Lateral movement of strand

Install bond tools on positions 20m on both sides of tower tops and cable saddle. Before installation, the section of strand should be adjusted to standard hexagon. Tighten the bolt on bond tools by several times.

Before lateral movement, connect bond tools with hoist on door frames at tower tops and anchorages, then start hoists to raise whole strand from rollers on cat walk in finite lift distance.Use the lateral move devices on the top of the tower and loose saddle to move strand to the given position. After the whole span of strand leaving rollers, strand can be moved on the saddle with suitable tension.

2.3. Section adjustment, placing in saddle and anchoring

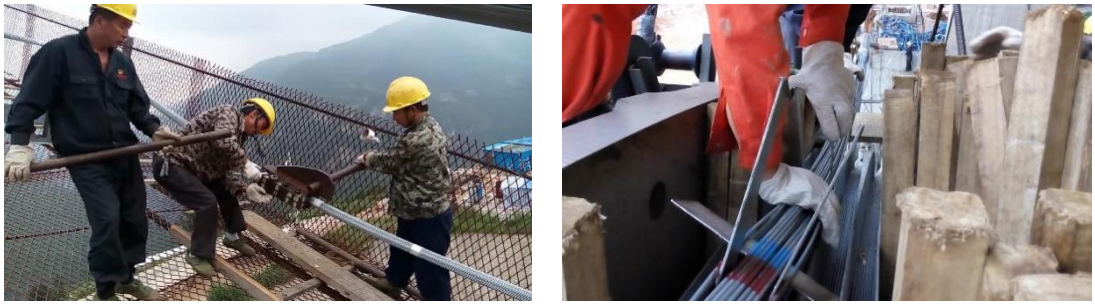

Figure 2 Section Adjustment of Strand

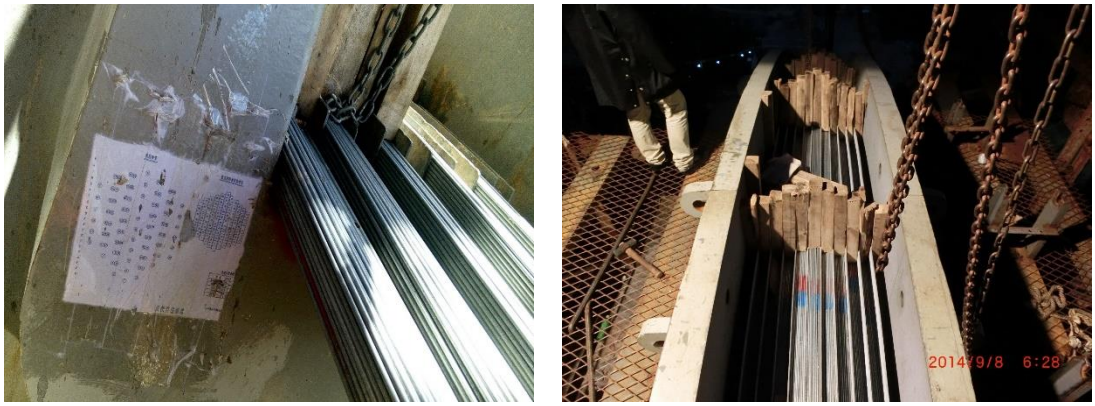

Figure 3 Strands in saddle

Set hexagonal fixtures between the two torpedo clip at tag position in order to clamp strand, then remove fiber bundle bands between fixtures and torpedo clips. Adjust strand to quadrilateral section 1m next to hexagonal fixtures and fix quadrilateral fixtures. Starting from quadrilateral fixture, using stalloy comb steel wire while tap strand with rubber hammer, and insert lateral and vertical stalloy in adjusted strand (when necessary, fix the strand temporarily with galvanized sheet fasten or adhensive bonding belt). Strand adjustment should start from mid-span direction to saddle direction.

After strand adjustment complete both at main cable saddle and bulk cable saddle, remove galvanized sheet fasten and adhensive bonding belt. Then place strand into saddle according to direction , order and goove number from design, and remove strand clamp. At the tower top, strand should be placed into saddle from side-span direction to main-span direction, otherwise, at bulk saddle strand should be placed into saddle from anchorage direction to side-span direction. Strand should be placed in main-cable-saddle before bulk-cable-saddle. After strand is placed into saddle, it need to be clamped by chock temporarily to prevent slide. At last, the right steel seperators are installed in saddle according to blue print.

2.4. Line shape adjustment

2.4.1. Line shape repetition survey before erection

After main tower, abutment pier and anchorage are completed, all related geometric parameters need to be remeasured precisely under stable air temperature before cable erection, including the coordinate of reference points on towers and piers, the perpendicularity of towers, the posture of main saddles and bulk saddles, center line error of saddles. After the erection of catwalks, these parameters should be remeasured again.

2.4.2. Sag adjustment of standard strand

For strand, the critical process of line shape adjustment is to adjust the sag about the point at mid-span. Standart strand adjustment base on absolute height, besides on relative sag to standard strand. Strand in mid-span is prior to side-span. The adjustment starts late in night with stable air temperature and weak wind.

Elevation is measured through trigonometric leveling by total station. The theoretical sag and internal force of strand in anchorage span is computed based on dead load, air temperature, real span between saddles, and other parameters measured in-site. If sag of mid-span is match with theoretical requirement, adjust sag in side-span, and temperarily fix strand in bulk saddles. When sag adjustment in all spans is finished, the internal force of strand in anchorage span should be adjusted to theoretical value through jack pushing and screwing the nuts on rod at the end of strand.

After the first round of adjustment, the strand should be surveyed at least 3 days and nights. Everynight, make sure that there are at least 3 valid survey times, and the results of each time is in the range of allowable error. In the end, take the average level at mid-sapn as the control level of standard strand.

2.4.3. Sag adjustment of normal strand

Sag adjustment of normal strands takes standard strand as the reference, using relative sag adjustment method. That follow the same order with the standard strand. Mark method is used during the day, night by sag adjustment method.

Specifically speaking, in night with stable temperature, measure the sag difference to standard strand at control points in every span. The tension or loosen value is computed according to sag difference, span and temperature correction. The sag is adjusted till the relative sag difference is in the range of allowable error according to disign.

For convenient, the normal strand should be pre-evevated about 200mm～300mm higher than design in main span, and 100mm～200mm in side span. Let the strand suspen in the air, then loose strand according to computed value till the normal strand get close to standard strand.

2.5. Line shape keeping

After every 10 strands are erectied, vertical steel shim line shape keeper should be insert into main cable with interval of 160m in order to keep the relative position of strands.

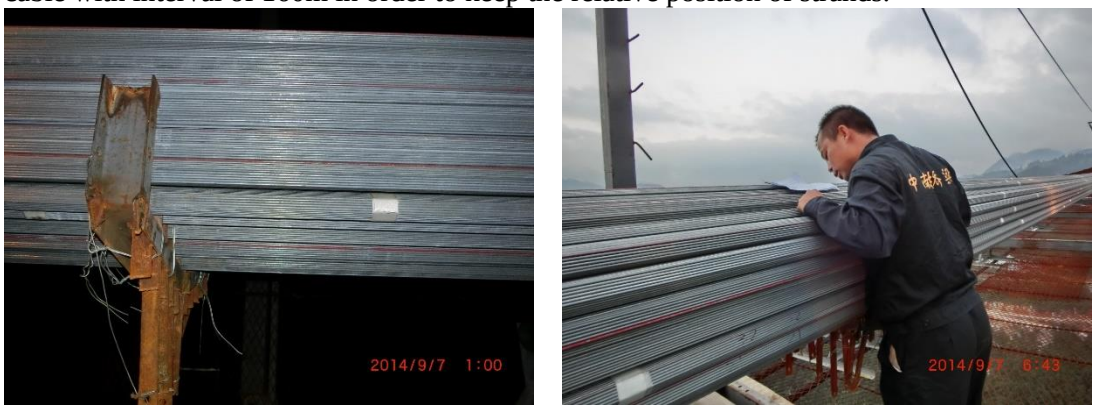

Figure 4 Steel Shim Insert between Strands

Adjusted strand between line shape keepers should be bind with φ2cm manila rope till subsequent strand is ready for adjustment.

2.6. Tension control in anchorage span

After the strand in side span has been adjusted and fix in bulk saddle, start tension jack to adjust strand tension. Considering the effection of temperature, tension of each strand is compared with design till its difference is in the range of allowable error. The tension is evaluated by jacking force and displacement of anchor slab which is measured by micrometer gauge.

in the process of tensioning, jacks should be feed oil slowly and evently. Make sure oil guage is stable after every level of load, then start the next level. Meanwhile, check whether strand anchor head is tilted or the strand anchor plate is perpendicular with the pull rod. Otherwise, unload the jack and adjust the anchor, then tense the strand again until the tension is in the allowable range.

When jack is working and achor moves to anchor surface, the hexagonal nut should be screw up and locked in time in personnel. The torque value of two nut on rod fixed the same strand should be consistent.

Figure 5 Tension Adjustment of Starnd

3. Conclusion

By tracking survey the construction of a long-span steel box-girder suspension bridge in Yunnan province, China, perfect line shape and ideal inter force are achieved with adoption of the key points to control the erection of main cable in this paper.

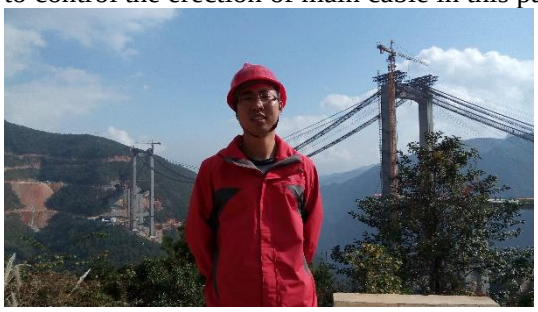

Figure 6 Research in Construction of Suspension bridge

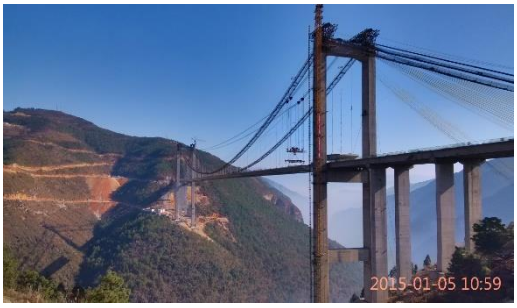

Figure 7 The Overall View of the Bridge

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