Tie Cable Force Losses on The Mechanical Behavior of the Bridge Impact Analysis

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Abstract: In this paper, the different cable tension losses tied on the complete bridge mechanics, come to this model, when Tied cable force loss of 14% should be considered for cable replacement by finite element analysis.

Keywords: Cable Force; Mechanical behavior; Bridge impact analysis

1. Introduction

Flexible bars usually made of high strength prestressed steel wire or strand, in a post-operation phase, cable tension tie rods loss because of various reasons over time. Tied as an important member of Tied Arch Bridge and offers a tremendous level of force to balance the thrust of the main arch, thus ensuring the safety of the main pier, the loss of its cable force will inevitably result in a significant effect on the mechanical properties of the whole bridge. This article will analyze different Tied cable force loss affect the situation on the mechanics of a full-bridge by finite element model, intended to control the mechanical properties of variation with rope tied force of the full-bridge, in order to identify the extent of cable force losses that the r tie rod should be replaced.

2. Project Background

This paper relies on engineering for a steel concrete Taut Tied Arch Bridge, its cross-arranged to 46m + 202m + 46m. Deck arranged 4 × 3.75m (lane) + 2 × 3.0m , the main bridge width 26.2m, 22.5m wide bridge approach. Design load criteria: steam -20, -100 hanging, the bridge was built in 1998. None thrust arch bridge, horizontal thrust generated by its dead load balancing system mainly depends on the tension rods, horizontal thrust live load is largely dependent on the pier to offset. The span of the bridge is deck, side span is upper deck and the side span use reinforced concrete and a smaller span ratio of thrust to balance the pier.

The bridge main arch rib is 4-Φ750 steel concrete structures, the distance from the main arch ribs is 17.55m, high parabolic arch axis, span ratio of f / L = 1 / 4.5. Rib section above the deck department high 3.5m, width 2.05m, filling 40 # concrete inside , solid section.

Parallel boom of high-strength steel beam, coat PE protective material, the longitudinal spacing of 5.1 m based; each boom wire bundle diameter by the 139 steel wires Φ5. Heading respectively using anchor on the lower edge of the main rib Shangzhui plate and beam, and with the lower end of the beam as the tension side to adjust the deck level.

3. Study Conditions Selected

The internal forces changes of one lever must make the others internal redistribution. Reference analysis shows, For cable-stayed bridge, If a fault in the occurrence of cable, cable force changes in the value of the remaining adjacent to within 15% to 20% range, the magnitude of change is still in its cable tension cable load carrying capacity range.

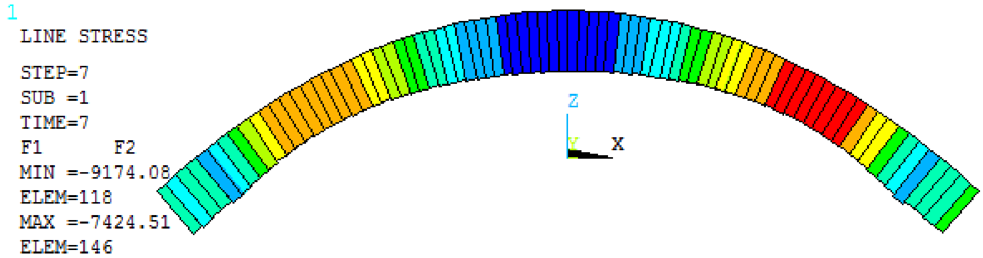
Tied herein cable force loss by applying a force to achieve the anti-rod anchoring roots in each end, the analysis, considering all tied simultaneous cable force loss. Total consideration of nine kinds of working conditions, the size of the reaction force were 5% lower transverse loads Tied internal force mean, 10%, 15%, 20%, 25%, 30%, 35%, 40%, 45%, horizontal Tied load cause internal force between 1630KN ~ 1640KN, mean 1635KN, the case 1 to condition 9 under reaction force size was 81.75KN, 163.50KN, 245.25KN, 327.00KN, 408.75KN, 490.50KN, 572.25 KN, 654.00KN, 735.75KN.

4. Model and Analysis

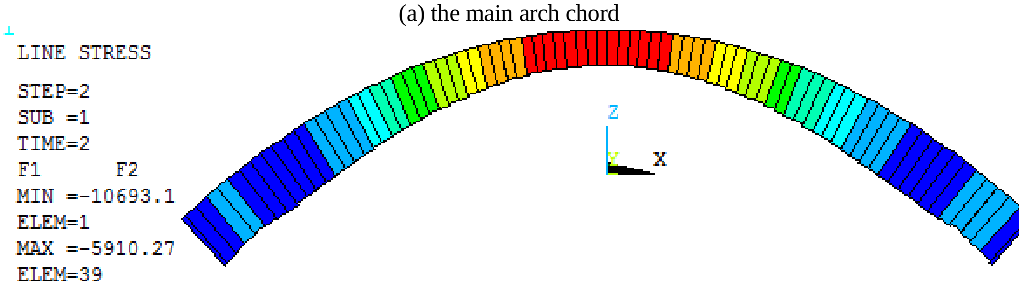
4.1. Main arch and side arch internal force

(1) The main arch internal force

Since the main arch is rib truss form, it is divided into upper and lower chords, moment-section of the winding change into chord axial force. Therefore, the single main Rib chord moment is small, the axial force is larger and as the control of internal forces; The side span reinforced concrete arch, moment and axial force are larger, Therefore, the following shows only the axial force main arch rib chords, while across the axial forces and bending moments with cable tension loss Tied changes.



(a) the main arch chord



(b) the main arch bottom chord

Figure 1. Condition 0:00 Main Arch axial force (unit: KN)

Figure 1 based on conditions Rib chords zero axial force, the minimum axial force chord of -9174.1KN, occurred in the mid-span span, the maximum axial force is -7424.5KN, occurred in the junction of the bridge deck and the main arch; The minimum bottom chord axial force is -10693.1KN, occurred in the junction of the bridge deck and the main arch, the maximum axial force is -5910.3KN, the occurrence of cross-span. During Tied cable force loss, the most value chord axial force values occur only change position does not change, it does not list the shaft trying here.

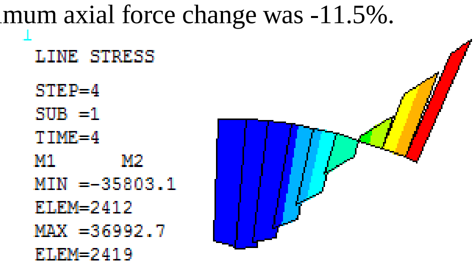
According to the calculation results, the axial force chord of the best value for small change, one of the smallest axial force change was 1.0%, the maximum axial force 0.9%;Bottom chord axial force most value compared with chord changes significantly, the smallest axial force increases, the change was 3.2%, the maximum axial force is gradually reduced, the change was -3.7%.

(2) Side arch internal force

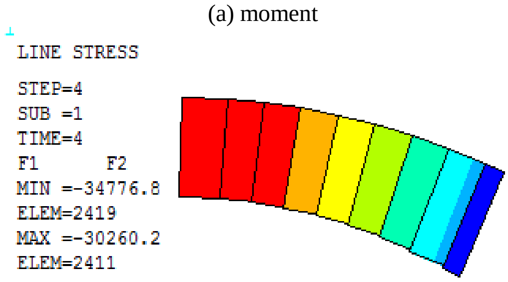
Figure 2 is a side arch in conditions of axial force and bending moment is 0, the smallest moment side arches of -35803.1KN • m, occurred in the side ends of the arch, the maximum bending moment of 36992.7 KN • m, occurred in the side arch roots; The minimum axial force side arches of -34776.8KN, occur in the side arches roots maximum axial force -30260.2KN, occur side arch ends.

During Tied cable force loss, the side arches best value for the internal forces occur only on a value change, does not change the value of the position, bending moment diagram with the shaft in a bid not to list here.

According to the calculation results, the moment the minimum variation smaller side arches, a trend of decrease, change of -4.9%, the maximum bending moment tended to increase, change of 12.8%; Side arch axial force most value variations are more significant significant, showed a decreasing trend, the minimum axial force is 10.0%, the maximum axial force change was -11.5%.



(a) moment



(b) axial force

Figure 2. Condition 0:00 Side Arch Internal Force (unit: KN • m / KN)

4.2. Main pier foundation reaction force change

(1) Pile bottom axial force - bending moment

Relying on engineering Taut Tied Arch Bridge without thrust, after losses tied cable tension, excess levels of the main thrust will be the main pier arch balance, it will cause huge levels of shear on the main pier pile, the pile

Shear spread top to bottom, it will cause a huge moment in the pile bottom, two situations are likely to cause pile damage.

Due to the symmetry of the structure, we choose two pile study, which ranked # 1 in the pile to pile on the left, two on the left efflux # piles pile. Taking into account the two cases is not considered the most unfavorable vehicle and consider the most unfavorable Car.

Table 1 shows the changes of the pile at the end of internal forces in each condition, the minimum moment 1 # pile of 366.42KN • m, the maximum bending moment of 12006KN • m; Minimum moment 2 # pile of 365.85KN • m, the maximum bending moment of 11772KN • m.

Table 1. Pile bottom conditions of internal forces (unit: KN • m / KN)

Project Working conditions	Irrespective of vehicle				Consider Car			
	1 # pile Momnt	1#pile Axial force	2# pile Momet	2#pile Axial force	1# pile Momnt	1#pile Axial force	2# pile Momnt	2# pile Axial force
Working Conditions 0	366.4	18859.0	365.9	13393.0	2259.6	17905.0	2034.6	15189.0
Working conditions 1	1417.8	18598.0	1464.6	13611.0	3261.2	17655.0	3035.4	15393.0
Working conditions 2	2503.1	18247.0	2924.3	13919.0	2009.5	18422.0	2228.4	14372.0
Working conditions 3	3701.2	17830.0	4399.5	14323.0	3251.4	17983.0	3802.9	14803.0
Working conditions 4	4967.4	17444.0	5639.6	14708.0	4506.9	17581.0	5070.5	15208.0
Working conditions 5	6265.4	17080.0	6804.9	15072.0	5797.7	17214.0	6239.0	15581.0
Working conditions 6	7623.5	16711.0	7965.6	15436.0	7141.9	16846.0	7388.3	15949.0
Working conditions 7	9052.8	16310.0	9172.0	15825.0	8569.8	16450.0	8596.7	16334.0
Working conditions 8	10517.0	15879.0	10439.0	16227.0	10031.0	16022.0	9861.5	16741.0
Working conditions 9	12006.0	15438.0	11772.0	16643.0	11539.0	15574.0	11210.0	17160.0

Table 2. Pile bottom shear conditions (unit: KN)

Project Working conditions	Irrespective of vehicle		Consider Car	
	1# Pile	2# Pile	1# Pile	2# Pile
Working conditions 0	85.1	85.0	330.2	297.3
Working conditions 1	253.8	259.8	492.0	458.8
Working conditions 2	431.8	483.2	363.0	387.5
Working conditions 3	623.5	715.2	562.6	631.5
Working conditions 4	820.6	913.8	759.8	836.5
Working conditions 5	1018.8	1095.1	957.9	1019.4
Working conditions 6	1223.4	1272.5	1160.1	1195.2
Working conditions 7	1437.4	1455.1	1372.8	1376.6
Working conditions 8	1658.7	1646.4	1592.9	1566.1
Working conditions 9	1885.8	1846.7	1821.2	1766.8

The mechanics of materials formula:

$$s = -\frac{P}{A} + \frac{M}{W} \quad (1)$$

Where is the pile axial force, assuming that compression is positive.

If you ignore the tensile strength of concrete, and assuming pile in elastic stage, it can make under load, and stress is 0:00 assumed that the pile can be cleaved to obtain the pile in a particular bend axis force cracking moment. Pile seen from the table in various conditions of maximum axial force 18859.0KN, take the maximum axial force is 2400KN, cracking moment corresponding to 6000 KN • m, this time corresponds to the maximum compressive stress of 12.1MPa, C40 is much smaller than the design value of compressive strength, it is assumed that the basic right of pile in elastic stage.

According to the calculation results can be seen, after considering the car, the moment the first three conditions than the vehicle is not considered a significant increase, consistent with trends in other conditions in both cases; In addition, # 1 cable tension pile with tie rod axial force in reduced losses, at the moment is increasing, while No.2 pile on the contrary, its axial force is increasing, decreasing at the moment.

1 # pile without considering the vehicle, in the case 3 into the cracking zone, consider car after 4 into the cracking zone conditions; The # 1 car pile does not consider the case 2 after entering the cracking zone, considering the car, in case 3 when entering the cracking zone. Therefore, when tied in the loss of cable tension condition 3:00 cable replacement should be considered.

(2) Pile bottom shear change

Table 2 shows the changes in the pile at the end of each shear conditions, the minimum shear 1 # pile of 85.1KN, maximum shear is 1885.8KN, occurs when the vehicle is not considered; The minimum shear 2 # pile of 85.05KN, maximum shear is 1846.7KN, occurs when the vehicle is not considered.

Reinforced concrete and prestressed concrete highway bridges and culverts (JTG D62-2004) provides a shear capacity of rectangular, T-type and I sectional flexural members formulas, Relying on engineering pile of circular cross-section diameter of 2m, specification does not provide a circular cross section shear capacity formula, Therefore, as shown in Figure 7, according to the area moment of inertia equal to equal in terms of the Pier Section rectangular section rectangular section you want to convert to engage were 1.813m wide and 1.732m, then rectangular section shear capacity according to the specifications provided by calculated.

Specification rectangle, flexural member T and I of section when configuring stirrups and bent steel, which Shear Carrying capacity is calculated as follows:

$$g_0 V_d \le V_{cs} + V_{sb} + V_{pb} \tag{2}$$

$$V_{cs} = a_1 a_2 a_3 0.45\times10^{-3} bh_0 \sqrt{(2+0.6P)\sqrt{f_{cu,k}}\, r_{sv} f_{sv}} \tag{3}$$

$$V_{sb} = 0.75\times10^{-3} f_{sd} \sum A_{sb} \sin q_s \tag{4}$$

$$V_{pb} = 0.75\times10^{-3} f_{pd} \sum A_{pb} \sin q_p \tag{5}$$

Where: - Compression end oblique section shear combination maximum design value (KN) by the action (or load) effect arising;

- Internal oblique section of concrete and stirrups joint shear capacity design value (KN);
- Shear Capacity design values and common intersecting oblique section bent steel (KN);
- With oblique section intersecting shear bearing capacity of prestressed bent steel design value (KN).

Meanwhile, rectangular, T-type and I sectional flexural members, the shear cross section shall comply with the following requirements:

$$g_0 V_d \le 0.51\times10^{-3} \sqrt{f_{cu,k}}\, bh_0 \tag{6}$$

Where: - shear composite design value (KN) Checking section was by the action (or load) generated;

According pile bottom Shear Strength above formula is 2412.6KN.

In a variety of conditions, most shear value 1885.8KN, less than pile bottom Shear Strength of 2412.6KN, shear failure does not occur in the existing conditions pile.

5. Conclusion

Relying on finite element analysis of the mechanical properties of these bridges vary in different Tied cable force loss condition and find the extent of the loss of cable force need to be tied replaced. The obtained results are as follows:

(1) With the loss Tied cable force, the main arch of the upper and lower chords internal forces smaller side arches and internal forces are more significant, in which the side arches maximum bending moment is 12.8%,while the minimum change arch axial force change -10.0%, the maximum axial force change -11.5%.

(2) In a variety of conditions, which are less than the Shear Strength Shear, shear failure does not occur in the existing conditions pile. But pile bottom-section will be in working condition before entering the cracking zone 4, and # 1 car pile without considering the conditions in post 2 will enter the crack area. Therefore, when the cable tension Tied loss of 14% should be considered for cable replacement.

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