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Stay Adjustment: From Design Perspective to On Site Practice

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Abstract

Stay adjustment is a major topic in cable stayed bridge construction. As a matter of fact, this issue, which directly controls the stress distribution in the structure as well as the final geometry, concerns both analyses during detailed design and tensioning procedures during erection on site.

Experience shows that there exist a great variety of approaches for characterizing stay adjustment at design level and for performing the related adjustment operations on site.

The purpose of this paper is to re-visit the subject of stay adjustment, from both a theoretical and a practical perspective. Some concepts are presented, which enable one to tackle this problem efficiently, while taking into account technological constrains.

1. Review of Current Practice

From the designer's perspective, stay adjustment traditionally consists in specifying:
- either, the value of the stressing force applied to each stay at given phases of the construction,
- or, more recently, the unstressed cable length l_0.

Using software programs, which allow simulating stage by stage construction, the designer seeks stay adjustment specifications such that stresses in the structure remain allowable, both during erection and service stages, and such that pylon and deck positions at bridge completion are satisfactory.

Very often, the values of the tensioning force or the unstressed cable length l_0 taken as input of the computational model are then directly used as the adjustment instructions for on site operations. In case of very flexible structures, the tensioning force is replaced by the geometric deflection it produces.

The apparent advantage of this approach is that operations follow very precisely the erection stages planed by the designer, with as consequence an actual state of the structure being very closed to the model prediction.

However, the following issues must be raised:

- the tension applied to a stay when installing it does not characterize intrinsically its adjustment; as a matter of fact, the action of the stay on the structure depends on the temporary erection loads, such as the actual weight of the formwork, the presence of a crane or heavy coils on the deck, etc. some of which are hardly possible to predict.

- the set of tension values at a given state is not an accurate description of the stay adjustment. Practical examples have shown that re-tensioning the stay system to compensate for creep effects can produce a vertical displacement of the midspan section of 0.60m whereas the increase of tension values is only 3%, i.e. hardly more than the measuring precision.

- the actual loading conditions may differ from their theoretical counterparts (stay and structure temperatures). These discrepancies must be taken into account in the adjustment procedure on site.

Using the unstressed cable length l_0 to describe stay adjustment represents a significant improvement from the theoretical standpoint, as it makes it possible to determine the structural state at a given stage, without having to consider the cumulative effects of all elementary actions during erection history. Indeed, the unstressed cable length constitutes an intrinsic description of the adjustment of the stay.

However, l_0 is a parameter that can be successfully used on site to adjust stays, only if cable marking and anchorage positioning can be achieved very accurately. In a workshop, prefabricated stays can be cut at length with a tolerance of about 0.01m per 100m of cable length, but the tolerances are far higher when placing anchorages in a formwork.

2. The Reference Tension Concept

The reference tension notion was introduced as a parameter representing intrinsically stay preloading and aimed both at designers and site engineers responsible with stay adjustment operations.

The reference tension of a stay is defined as the force at tensioning anchorage which would exist, if the structure deformations were frozen, i.e. if the structure was forced to coincide with its theoretical geometry, called the reference geometry (generally the one defined by the drawings). The value of the reference tension does not depend either on the anchorage location tolerance or the temporary loads on the bridge; therefore, it represents the appropriate parameter to describe numerically stay adjustment.

The principle of stay adjustment procedure using the reference tension consists of the following steps:

1. Determine the target value of the reference tension to be reached at the end of tensioning operation, using the relevant data extracted from the design model,
2. Evaluate by survey the anchorage displacements and deduce the tension to apply to the strands in order to impose to the stay a given fraction of the target reference tension,
3. Measure the actual stay tension and the related values of the anchorage displacements; then deduce the elongation to apply to the stay to reach the target value of the reference tension,
4. Perform a check by evaluating the actual value of the reference tension through simultaneous measurements of stay tension and anchorage displacements.