A CALCULATION OF INITIAL CABLE FORCE FOR KO-HA BRIDGE

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ABSTRACT : The primary objective of initial shape analysis of a cable stayed bridge is to calculate initial installation cable tension forces and to evaluate fabrication camber of main span and pylon providing the final longitudinal profile of the bridge at the end of construction. In addition, the initial cable forces depending on the alternation of the bridge's shape can be obtained from the analysis, and will be used to provide construction safety during construction.

In this research, we conducted numerical experiments for initial shape of Ko-ha bridge, which will be constructed in the near future, using three different typical methods such as continuous beam method, linear truss method, and IIMF (Introducing Initial Member Force) method [1].

KEYWORDS : cable stayed bridge, cable force, initial shape, initial equilibrium state

1. INTRODUCTION

The structural system of a cable stayed bridge is one of representative systems for long span bridges and, recently, cable stayed bridges, which have very long main spans more than 800m, have been constructed in the world. A cable stayed bridge generally shows high order indeterminate structural behaviors because of its slender shaped stiffening-girders and inclined cables transmitting loads subjected on the girders to pylons. Furthermore, geometrically nonlinear deflection of cables, complex structural behaviors, and persistent cable tension forces and the changes of girders' moment forces during erection cause many difficulties to engineers in designing and construction. Accordingly, accurate estimation of initial shape and fabrication camber of the bridge is indispensable for precise construction works.

The determination of initial shape of a cable stayed bridge is for the sake of finding tension forces of the cables to pursue to accord the bridge's deflected shape at the end of erection to its essential shape for planning.

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2. THE DETERMINATION OF INITIAL SHAPE

2.1 GENERAL

Initial equilibrium state of a cable stayed bridge means that the state ensuring three conditions: 1) to minimize the discrepancy between a shape regarding equilibrium state after construction and a given shape for planning; 2) to distribute approximately equally flexural moments to each stiffening girder after construction; and 3) to minimize the flexural moment of pylons after construction.

The deformed shape at initial equilibrium state denotes initial shape of a cable stayed bridge, and it results from initial equilibrium state analysis or initial shape analysis. From the analysis main design parameters (i.e., the length of each unstrained cable, each final cable tension force, fabrication camber for stiffening girders and pylons, the distribution of flexural moments on the bridge) can be evaluated. It is, therefore, certain that accurate initial equilibrium state analysis is the most important structural analysis for a cable stayed bridge.

2.2 INITIAL SHAPE ANALYSIS

1) Continuous Beam Method

Continuous beam method is a common and convenient method to determinate initial shape of a cable stayed bridge. The method starts from considering that stiffening girders (without cables) behave as a continuous beam, which is supported by rollers at the points of cable attachments and subjected by dead loads. With a classical indeterminate structural analysis for the beam, next, reaction forces at each support are calculated. Then, the reaction forces are transformed into the forces for cables.

While the method is very simple, it yields compressive forces for cables which can not be accepted in practice. Such compressive forces must be corrected by designers' own decision in design stage, that is, additional effort of experienced designers should be cost to satisfy given design requirements.

2) Linear Truss Method

Linear truss method first introduces the concept of a truss element with only axial stiffness substituted for the actual cable member. In addition, the flexural stiffness of a stiffening girder is neglected so that the method allows for alleviation of moment force distributed on a stiffening girder, even it can not control the deflection of a stiffening girder. The method, however, also can results in compressive force on a truss member. Similarly, additional effort is also needed to collect it.

In many modified version of the method, it is commonly used to impose 1/10 of actual flexural stiffness to end girders and center span instead of giving their actual stiffness. Nevertheless, any of methods, either the method or its modified method, can not evaluate perfect initial equilibrium state of a cable stayed bridge.

3) IIMF (Introducing Initial Member Force) Method (see [1])

IIMF method conducts successive iterations of the following four steps until a desired initial shape of a member in figures (1)-(3) is obtained. The steps are:

Step 1. nonlinear analysis for a member subjected only by external loads is carried out to find internal member forces, which satisfy equilibrium state under external loads as shown in Eq. (1) and figure (1);

$$\{P\} = [T'] \{F_L\}, \qquad (1)$$
$$= \{F_G\},$$

where {P} denotes external load vector, [T'] is transformation matrix of the deformed member according to the displacement δ_i and δ_j as shown in figure (1), { F_L } and { F_G } represent internal member force vectors at local coordinate and at global coordinate, respectively.

Step 2. Internal member force vector { F_L } as initial member forces is applied to the initial model (see figure (2)) Then, initial unbalanced load vector { ΔF } results from Eq. (2) and (3).

$$\{F_G'\} = [T]\{F_L\}, \qquad (2)$$
$$\{P\} = \{F_G'\} + \{\Delta F\}, \qquad (3)$$

where [T] denotes transformation matrix of the undeformed member.

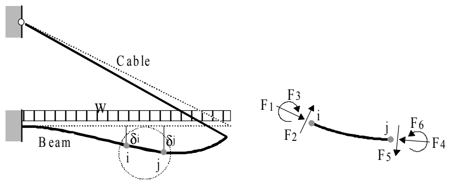


Figure 1. Deflection of Nonlinear Analysis (Step 1)

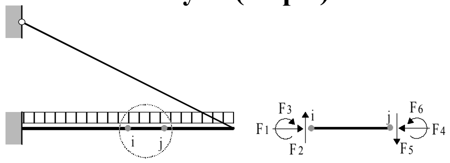


Figure 2. Introducing Initial Member Forces (Step 2)

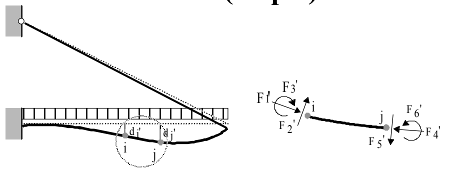


Figure 3. Deflection of Nonlinear Analysis Introducing Initial Member Forces(Step 3)

Step 3. To eliminate initial unbalance load vector $\{ \Delta F \}$ resulted from the previous step nonlinear analysis is conducted again. Note that new internal member force vector $\{F_G'\}$ and transformation matrix $[T'']$ according to the displacement δ_i' and δ_j' as shown in figure (3) and Eq. (1) is changed as follow;

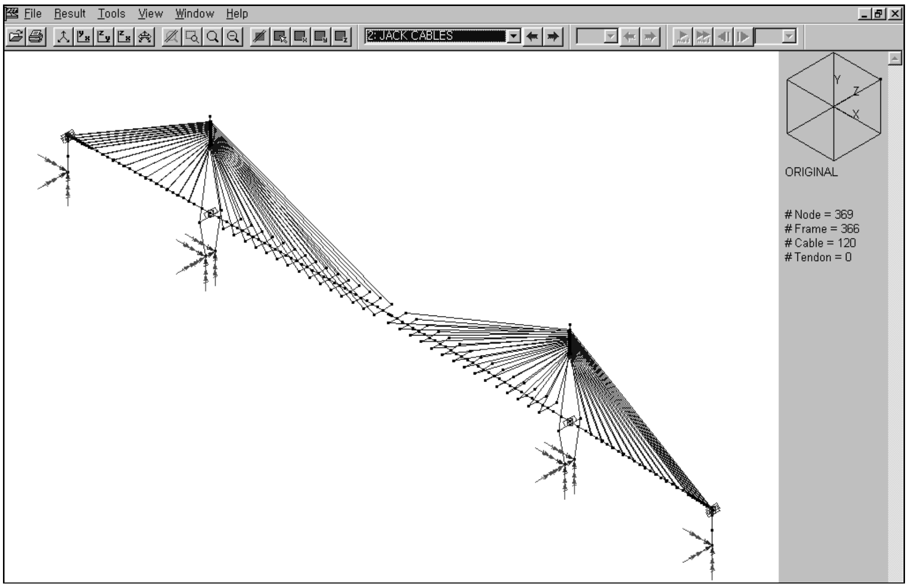
$$\{P\} = [T''] \{F_L'\}, \qquad (4)$$
$$= \{F_G'\},$$

Step 4. After substituting $\{F_L'\}$ instead of $\{F_L\}$ into Eq. (2) in step 2, successive iterative works are performed from step 2 until initial unbalanced loads satisfy convergence criteria which is given at the beginning.

3. NUMERICAL EXAMPLES

3.1 KO-HA BRIDGE

Ko-Ha bridge will be constructed in the coast of Mok-Po city, Korea by 2010. The bridge, as a road bypassing the city, consists of a cable stayed bridge with steel stiffening girders and P.S.C. box bridges as connection bridges, and its total length of the bridge is 3.06 km. The cable stayed bridge is a three-span continuous bridge with total span length, main span length, and side span length are 900.0m, 500.0m, and 200.0m, respectively. It has steel stiffening girders, total 120 cables, and two inverse Y type pylons. Interestingly, it is the first 3-way cable system using one-way cable system for the two side spans and two-way cable system for the main center span as can be seen in figure (5).



Node = 369
Frame = 366
Cable = 120
Tendon = 0

Figure 4. Three-dimensional model for Ko-Ha bridge

Figure. 5 Ko-Ha bridge

Figure 6. initial cable tension forces

Initial shape analysis of Ko-Ha cable stayed bridge is conducted using three methods mentioned in section 2 and resulting initial cable force is showed in figure 6. In the figure, the first method (Continuous beam method) yields compressive force in both main and side spans, and the second method (Linear truss method) represents somewhat big cable tension force and its irregular variation at pylons. As a result, it is difficult that either of the previous two methods can be considered as a reliable initial shape analysis. On the other hand, the last method (IIMF method) shows moderate variation of cable tension force along the bridge.

4. CONCLUSION

We presented numerical results using three different methods such as Continuous beam method, Linear truss method, and IIMF method. From the results we found that initial cable forces resulting from both Continuous beam method and Linear truss method can not be acceptable for a cable stayed bridge, even the methods have been generally used and are simpler methods. The results also showed that IIMF method is the most appropriate method for calculating initial cable force for a cable stayed bridge.

5. REFERENCE

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