Zeitschrift: IABSE reports = Rapports AIPC = IVBH Berichte

Band: 82 (1999)

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DOI: https://doi.org/10.5169/seals-62134

New Developments of Erection Control for Prestressed Concrete Cable-Stayed Bridges

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Abstract

In the last two decades, the technology of design and construction of prestressed concrete cable-stayed bridges has developed rapidly, and over forty of such bridges have been built in China. However these developments were not without problems. There were reports on some bridges in which the geometry and cable forces went out of control during cantilever erection. Therefore the strategies required to ensure the safety of the bridges during erection and the quality of the completed bridges have attracted much attention from bridge engineers in China.

As the method and sequence of cantilever erection of prestressed concrete cable-stayed bridges will affect the resulting geometry and internal forces in the bridge, this problem is recognized as one of the most important issues to address. Very rigorous numerical simulation of the insitu cantilever construction is usually carried out to estimate the amount of preset in the fixing of the mobile carriage. However in spite of such efforts, it is almost impossible to eliminate the discrepancies between the theoretical predictions and the actual structural responses. Should such discrepancies be not corrected in a timely manner and thus be allowed to accumulate, the geometry and internal forces of the bridge may be out of control.

The discrepancies between the theoretical predictions and the actual structural responses can be attributed to the following factors:

1. The assumed structural parameters for the design may be different from the actual values achieved on site. Such parameters include, but are not limited to, moduli of elasticity of concrete, steel reinforcement and prestressing tendons, dead loads, construction live loads, shrinkage and creep of concrete, moments of inertia of the segments as well as the temperature distribution in the bridge deck and tower.
2. The values for the control of geometry and internal forces during cantilever erection are usually given only at certain important milestones such as the beginning of each segment construction cycle. However in reality, the structural responses of the bridge are changing continuously according to the variations of applied loading and environmental conditions.
3. Errors may also be introduced by simplifying assumptions made for the structural model and the method of structural analysis.

It is believed that to achieve the designed geometry and internal forces of a bridge within reasonable tolerance, certain parameters need to be continuously monitored in order to determine the appropriate preset in the fixing of the mobile carriage. All of the above factors should be taken into account.

Three main categories of practical control methods have evolved from the work in the past two decades. They include the Kalman Filter method, relaxation of geometric tolerance and the cybernetics approach. The Kalman Filter method attempts to achieve the intended deck geometry by continuously adjusting the cable tensions. In other words, it tries to achieve the design deck geometry at the expense of the cable tensions. However, apart from significantly increasing the workload on site, this method may also cause adverse distribution of tensions among the cables. The second method involves the relaxation of geometric tolerance. The bridge is so designed that ample tolerance is allowed in the levels of the bridge deck and the cable tensions. The profile of the final running surface is then made good by a certain regulating course. Construction control therefore becomes less onerous. This approach may work well for cable-stayed bridges with steel or composite bridge decks. However it is not suitable for prestressed concrete as the stress limitations impose a lot of restrictions on the allowable tolerance. The third method works on an adaptive control system utilizing modern engineering cybernetics theory. In essence, the profile of the bridge deck and/or the cable tensions are continuously monitored during the construction stage in order to identify the major design parameters and to predict the discrepancies between the design and the completed structure. Corrective actions are then implemented in order to minimize such discrepancies in respect of both the levels of the bridge deck and the cable tensions.

This paper describes an adaptive control system, which utilizes the technique of transfer matrices commonly used in structural analysis. Instead of the entire magnitudes of structural parameters, observed increments in various steps of each construction cycle are used to identify the parameters. The method requires less field measurements and hence it is practical but simpler and effective. A package for the adaptive control system has been developed with Visual C++ for use under Windows 95 or Windows NT. Extensive graphical capabilities have also been built into the package to make it user-friendlier (Figure 1). The package has also been tested and verified in the construction of a few prestressed concrete cable-stayed bridges. Provided that a suitable construction control system is used and that the cantilever erection process is monitored carefully, it is possible to construct prestressed concrete cable-stayed bridges within the permissible tolerances in respect of both the geometry and the internal forces.

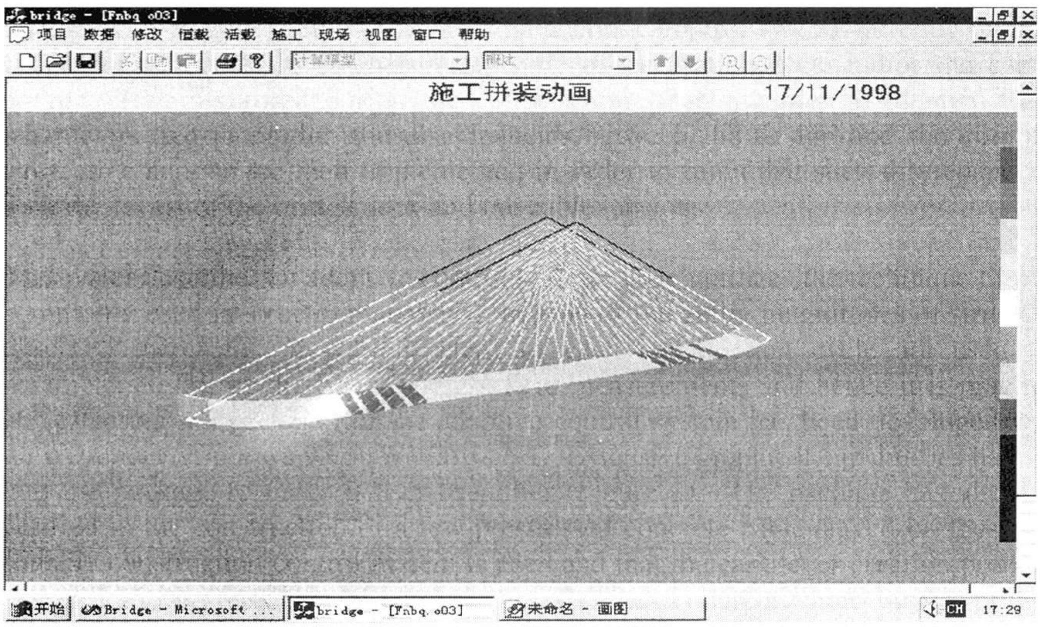

Figure 1. A typical screen of the package for adaptive construction control system.