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Autor: Chen, Dewei

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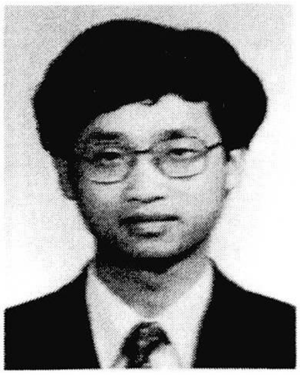
A Method To Assign Initial Cable Forces For Prestressed Concrete Cable-Stayed Bridges

Dewei Chen
Associate Professor
Tongji University
Shanghai, China



Dr. Dewei Chen, born 1956,
received his degrees from Tongji University of Shanghai. He is now an Associate Professor of the department.

Abstract

The cable-stayed bridge is a modern form of bridge which is both economical and aesthetic. It has been extensively employed in the construction of long-span bridges in the past few decades. However this kind of structures are highly statically indeterminate, and therefore many schemes of initial cable forces are possible. In the particular case of prestressed concrete cable-stayed bridges, it is especially important to choose an appropriate scheme of initial cable forces while the bridge is under dead load only. Owing to shrinkage and creep, the deflections will change with the passage of time and the internal forces may also redistribute. Should an inappropriate scheme of initial cable forces be chosen, an unfavorable pattern of internal forces may be locked in subsequently, for which there may be no simple solution.

Theoretically it is possible to search a "stable" scheme of initial cable forces under which there is the minimum redistribution of internal forces and time-dependent displacements. However it is usually very difficult in view of the many factors affecting the subsequent time-dependent deformations. For example, many cable-stayed bridges are constructed using cast insitu segmental cantilever construction, which gives rise to complex effects of shrinkage and creep because of the different ages of concrete. The presence of longitudinal prestressing also complicates the problem further. Inevitably some simplifying assumptions have to be made.

The scheme of initial cable forces giving rise to bending moments in the bridge deck approaching those of an equivalent continuous beam with all the supports from cables and towers considered as rigid simple supports is generally acknowledged to be both rational and practical, as the long term behavior of the bridge is reasonably "stable". The problem hinges upon how to achieve this scheme of initial cable forces. There are two main categories of methods in achieving an appropriate scheme of initial cable forces in prestressed concrete cable-stayed bridges, namely the optimization method and the "zero displacement" method.

In the optimization method, the initial cable forces are chosen based on the optimization of certain objective functions which may either be related to structural efficiency or

economy. In this method, the total strain energy is often the objective function to be minimized. It is necessary to impose the constraints for optimization very carefully, or else the resulting schemes may sometimes become impractical.

On the other hand, the traditional "zero displacement" method is more straightforward in theory, and it enables the designer to fine-tune the initial cable forces as well as the structural configuration. If a straight and horizontal bridge deck is supported on a number of stay cables, the horizontal components of the cable forces have little effect on the bending moments of the deck, and hence the bending moments are primarily governed by the vertical components of the cable forces and the dead load. In the "zero displacement" method, an appropriate scheme of initial cable forces is obtained by making the deflections at the cable anchorages vanish. When the deck gradient is negligible, the resulting bending moments in the deck are essentially those of an equivalent continuous beam with all supports from cables and towers considered as rigid simple supports. However, when the vertical profile of the bridge deck is significant, the basis of this method is itself questionable, as the horizontal components of the cable forces will induce additional bending moments in the deck. In this case, what really matter are the bending moments because they will affect the long-term behavior of the bridge. Whether the corresponding displacements are zero or not is immaterial, as they can be adequately controlled by appropriate pre-camber or preset of the deck during construction.

In this paper, a new method utilizing the idea of force equilibrium is presented for the determination of a "stable" scheme of initial cable forces. The method can easily account for the effect of prestressssing and the vertical profile of the bridge deck, and therefore it is much more rational as well as simpler than the traditional "zero displacement" method. Two numerical examples using real cases of P.C. cable-stayed bridges are presented to demonstrate the versatility of the proposed method.