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Deflection of in-span hinges in prestressed concrete box girder bridges during construction

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ABSTRACT

Multi-span cast-in-place (CIP) post-tensioned concrete (PS) box girder bridges undergo upward deflection (curl) at hinges due to post-tensioning forces. Adjustments in falsework height are often necessary in the field to address the curl and avoid bumps, which cause traffic safety concerns and present a road hazard. A current method to estimate hinge curl has often led to results that are significantly different than those measured in the field thus causing construction delays and costly change orders. The main purpose of the study presented in this article was to measure bridge deflections at and near in-span hinges in ten hinges within five bridges during construction over a period of several months and compare the results with the current theory. Based on the analysis of data, the correlation between the measured and calculated data was studied. Both short-term and time-dependent hinge curls were evaluated. Substantial differences between the field and theoretical data were observed and quantified. The data was used to identify the causes for the differences and directions for development of a new method to more accurately estimate hinge curl. A new method was developed as part of this study to address the sources of differences. Description of the new method, however, is beyond the scope and page limits of the current article.

1. Introduction

Cast-in-place (CIP) post-tensioned concrete (PS) box girder bridges are widely used in highway bridges in western United States. In-span hinges (Fig. 1a) are used in the superstructure of long bridges to divide the structure into shorter frames to accommodate horizontal movements due to prestressing, temperature, creep and shrinkage within the superstructure and reduce the resulting stresses in columns. The span in which the hinge is located is called hinge span and comprises short and long cantilevers where the long cantilever is supported on the short cantilever and connected at the hinge (Fig. 1b). The in-span hinge is a relatively complicated part of the bridge that requires special consideration with respect to design, detailing, and construction sequence (Fig. 2).

Deflection of in-span hinges is referred to as "hinge curl" is an initially upward deflection of the short cantilever caused by prestressing forces. Upon loading by the long cantilever, the curl is reduced and may even become a downward deflection. Hinge curl is also affected by time-dependent material properties of concrete and prestressing steel.

Hinge curl must be accommodated during construction by adjusting the superstructure falsework to properly match the elevation on the two sides of the hinge and avoid a bump in the road, which presents a road hazard. An existing method presented in the California Department of Transportation (Caltrans) memo to designers (MTD) 11-34 [1] provides an estimate of hinge curl. The estimate is shown on bridge plans to guide the contractor in adjusting the height of the falsework. Significant discrepancies between the estimated and the actual hinge curl have been reported by field engineers. Fig. 3 shows an example of observed hinge curls in a bridge during construction.

CIP/PS bridges are supported on falsework (Fig. 4) during construction until the superstructure attains the specified concrete strength and the bridge becomes self-supporting. The superstructure is normally cambered to account for long term deflections. In-span hinges need to be cambered properly to ensure a smooth road surface between bridge frames for safe and comfortable ride. The final location of the hinge is influenced by the time from stressing the short cantilever until the transfer of reaction

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Fig. 1. (a) In-span hinge of CIP/PS box girder bridges (N170-N5 Connector, Los Angeles); (b) hinge span (Del Paso Park Overhead, Sacramento).

Fig. 2. Construction of in-span hinges in CIP/PS box girder bridge.

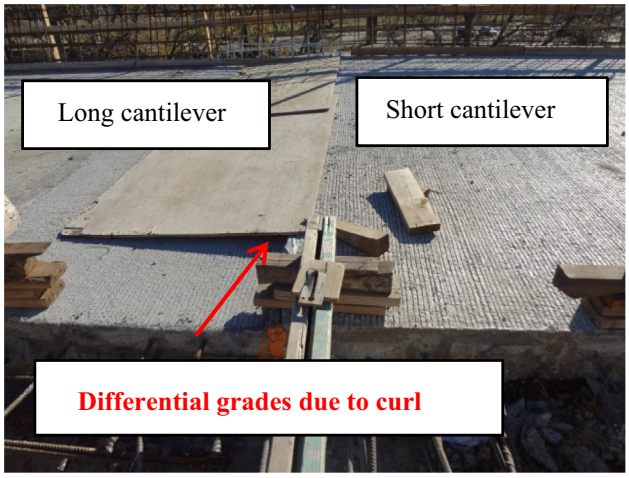

Fig. 3. Hinge curl during construction.

Fig. 4. Bridge falsework (Del Paso Park Overhead, Sacramento).

from the long cantilever. This time period is usually between 30 and 180 days, but is unknown at time of bridge design as it depends on the actual construction schedule. Therefore, a table of time-dependent cambers (upward deflection) that takes into account hinge curl is typically provided as part of the contract plans.

The short cantilever of in-span hinges tends to deflect upward after post-tensioning until the load is transferred from the long cantilever. It is important that the position of the short cantilever matches that of the long cantilever at the hinge at the time of load transfer. Otherwise, remedial measures are necessary during construction (Fig. 5) to correct the grade differences. These measures are considered "change orders" and result in extra cost and delays.

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