Louisiana Transportation Research Center

Technical Summary Report 383

March 2004

Continuity Diaphragm for Skewed Continuous Span Precast Prestressed Concrete Girder Bridges

Introduction

Most highway bridges are built as cast-in-place reinforced concrete slabs and prestressed concrete girders. The shear connectors on the top of the girders assure composite action between the slabs and girders. The design guidelines for bridges in AASHTO Section 8.12 indicate that diaphragms should be installed for T-girder spans and may be omitted where structural analysis shows adequate strength. Furthermore, the effects of diaphragms are not accounted for in proportioning the girders. Therefore, the use of diaphragms should be investigated.

Continuity diaphragms used in prestressed girder bridges on skewed bents cause difficulties in detailing and construction. Details for bridges with small skew angles (<30° from perpendicular) have not been a problem for the Louisiana Department of Transportation and Development (LA DOTD). However, as the skew angle increases and the girder spacing decreases, the connection and the construction become more difficult. Even the effectiveness of the diaphragms is questionable at these high skews.

The effects of diaphragm skew angle on the behavior of continuous span precast prestressed concrete girder bridges were investigated using finite element analyses based on information gathered from questionnaires sent to other states' DOTs. Bridges considered in this study were 91.4-meter-wide, three-span, continuous concrete girder bridges. All bridges had a uniform deck thickness of 200 millimeters. In addition to the diaphragm condition (i.e., 30° skew, 65° skew, and no diaphragm), other bridge parameters investigated included: AASHTO Type II and Type IV girders; 10° and 20° bridge skew angles; 1.52-meter girder spacing with 22.8-meter and 34.0-meter span lengths; and 2.75-meter girder spacing with 16.8-meter and 28.0-meter span lengths.

Objectives

The objectives of this research were to (1) determine the need of continuity diaphragms, (2) study the load transfer mechanism through diaphragms, (3) determine when a full depth diaphragm is required, and (4) determine the minimum skew angle at which a diaphragm becomes ineffective.

Scope

The literature search included previous research and on-going studies on continuity diaphragms for precast prestressed bridge girders. The survey questionnaire focused on design procedures, construction practices, maintenance, and limit of practice of other

LTRC Project No. 01-1ST

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states. The analysis concentrated on the effects of the following parameters: girder type, bridge skew angle, girder spacing, span length, and diaphragm condition.

Research Approach

Finite element modeling is among the most popular methods of analysis. Significant advances in computer technology allow complicated models to be constructed and analyzed. The finite element model used in this investigation simulated the behavior of skewed continuous span bridges. The girders were modeled using Tridimensional Elements available in GT STRUDL. Plate Elements were used for the bridge deck. Prismatic members were used to model the continuity diaphragms and the connection between the deck plate elements and the girder elements.

The research encompassed a review of literature and current use of continuity diaphragms. A technology and practice state-of-the-art review was conducted through a literature search and survey of bridge engineers from other states. The literature search was conducted first. Design procedures, construction practices, maintenance, and states' limit of practice were the focus of this review.

A survey was designed and mailed to out-of-state bridge engineers, and the results of the literature search were combined with the following bridge parameters: material properties, relative dimensions of girders and slabs, bridge geometry, skew angle, girder spacing, span length, number of spans, type of loading, location and stiffness of diaphragms, and location of supports. The design of the survey was based on modern methodologies of surveying and sensing.

The bridge parameters considered in the analysis included skew angle, length of the bridge span, beam spacing, the ratio of beam spacing to span (aspect ratio), and the ratio of the girder's stiffness to slab stiffness. The effects of diaphragms on moments from truck and lane loading on continuous slab and girder bridges were studied.

The parameters that may affect the load distribution of a bridge can be divided into five main categories: material properties of the slabs and girders, relative dimensions of the girders and slabs, geometry of the bridge, type of loading on the bridge, location and stiffness of diaphragms, and the location of supports.

A Design of Experiments (DOE) was conducted to identify the factors that contribute the most to the structural performance of continuity diaphragms. The DOE was based on Taguchi and various other techniques. DOE reduced the number of parametric studies (numerical or physical) needed to reach convincing conclusions about a given product's performance. DOE also helped discover an interaction among these factors. Based on the DOE analysis, a deterministic finite element analysis that used elaborate three-dimensional models of skewed bridges including slab, girders, supports and diaphragms, was performed using GT STRUDL. A multi-scale analysis was conducted to allow the use of a refined model of the continuity diaphragm while running cost-effective finite element analyses.

Conclusions

The results of finite element analyses performed in this study indicated that the effects of continuity diaphragms in skewed continuous span precast prestressed concrete girders were minor. However, in order to implement the findings, it is recommended that laboratory tests and field measurements be considered to verify the theoretical results.

Note: This study dealt with the first and second parts of the objective, but the results did not warrant addressing the third and fourth parts. Furthermore, the results may not be conclusive and implementable since the study encompassed only the theoretical aspect. Laboratory tests and field measurements will be initiated in the next fiscal year. If those results do not confirm the findings from this study, the third and fourth parts of the objective will then be addressed.