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Assessing the Need for Intermediate Diaphragms in Prestressed Concrete Bridges

Introduction

Reinforced concrete intermediate diaphragms (IDs) are currently being used in prestressed concrete (PC) girder bridges in Louisiana. Some of the advantages of providing IDs are disputed in the bridge community; the use of IDs increases the cost and time of construction. There is no consistency in the practice of providing IDs among various states and codes of practice, and the overall effectiveness of IDs in prestressed concrete bridges is unclear. There are many arguments in favor of using IDs because they can:

- Transfer lateral loads to and from the deck;
- Distribute vertical live loads between girders, thus reducing maximum deflection and moment for each individual girder;
- Provide lateral supports to girders during construction; and
- Distribute lateral impact loads from overheight trucks to all girders, thus reducing the total damage.

However, there are also many arguments in favor of eliminating the IDs because:

- Using IDs increases the cost and time of construction;
- Instead of limiting damage from overheight truck, IDs may actually spread the damage, according to some studies; and
- Some analytical results show that IDs do not necessarily reduce the controlling moment in girder design.

Objective

The objectives of this research were: (1) to assess the need for IDs in concrete highway bridges and (2) to investigate if the use of steel diaphragms is justified.

Scope

This study focused on Louisiana practices, synthesizing previous nationwide research results, and developing a comprehensive plan to provide supplemental information to reach conclusions and recommendations. Both finite element analysis and experimental research were conducted.

One of the important components of the current study was to determine the effect of diaphragms on the vertical live load distribution of the bridges. For this reason, a parametric study was conducted. Bridges of various configurations were analyzed, and the

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results of these analyses have been used to deduce formulas for the influence of IDs on load distribution. A relation between the effective stiffness of diaphragms influencing the load distribution and the load distribution factor (LDF) was developed. An alternative configuration of steel diaphragms that could potentially replace the reinforced concrete (RC) IDs was determined.

Research Approach

In this work, two finite element models were used. A simplified 3-D model developed in GT-STRUDL was used to perform the parametric study in determining the effectiveness of IDs in load distributions for various bridge configurations. The use of this model was limited to cases where the loading is vertical. In cases that needed a more refined analysis or required analysis for lateral loading, a 3-D solid model built in ANSYS was used.

Through analysis of the identified parameters, the effect of IDs on load distribution was quantified. The current AASHTO design codes do not include information about quantifying the ID performance in load distribution. A systematic parametric study was carried out using a wide range of values for possible parameters that were representative of the current prestressed concrete girder bridges existing in Louisiana. From the results obtained through this parametric study, formulas were developed to determine the diaphragm effect on load distribution for both interior and exterior girders.

Current Louisiana practice was investigated through a survey sent to all nine LADOTD districts, a review of the Louisiana Bridge Design manual and other technical literature, and direct interaction with experienced bridge engineers. Bridges that were of interest for this study were selected for visiting and field inspection.

Conclusions and Recommendations

IDs decrease the load distribution factor for interior girders and increase the load distribution factor for exterior girders. RC IDs provided the greatest protection to exterior girders undergoing impact when the impact occurred at the ID location. When the impact took place at a location away from the ID, the ID configuration did not significantly influence the bridge performance. If the reinforced concrete diaphragms were provided only for the purpose of providing girder stability during construction, then this could be served by providing steel diaphragms.

If sufficient supports, either temporary or permanent, are provided during construction and overheight truck lateral hitting is not the concern (as in the cases where there is no traffic underneath the bridge), IDs can be eliminated. If IDs are to be provided to protect against lateral impact, they should be placed as close as possible to the locations of possible impact. Concrete IDs are recommended for this purpose since they provide better impact protection than steel IDs.

If IDs are completely eliminated, there will be an increase of strain action for the interior girders. The developed formulas can be used to estimate the ID effects, i.e., the change of load distribution factor. However, for simplicity, the live load design moment of interior girders can simply be increased by five percent to maintain the same safety level as that of bridges with IDs, which will result (in most cases) in one or two extra strands per girder. When the LADOTD becomes more confident in completely eliminating the IDs, then the increase of live load will not be necessary.

If IDs are provided, four continual rebars (instead of one rod) are recommended across the web of the interior girders. A stronger connection between the IDs and girders will reduce the strain in the interior girders. Regarding the exterior girder, we may keep the details the same as the current practice for two reasons. First, anchoring rebars to the web of exterior precast girders will increase cost (maintenance and construction). Second, a stronger connection will put more loads on exterior girders. Using a weak connection is beneficial to exterior girders.

In rating existing prestressed concrete bridges with IDs, if the interior girders are five to 10 percent underrated, the developed formulas can be used to account for the beneficial effects from IDs, which will result in some unnecessary load posting or strengthening of bridges.