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Evaluation of Continuity Detail for Precast Prestressed Girders

INTRODUCTION

Building multi-simple span bridges using precast prestressed concrete girders is an easy construction. However, the existence of expansion joints often leads to a host of problems in their vicinity due to drainage leaks. Furthermore, debris accumulation affects the performance of expansion joints. Building continuous bridges reduces maintenance costs and adds redundancy to the structural system. Therefore, the development of connection details between precast elements has been the subject of research for an extended period of time. A new continuity detail is adopted in the John James Audubon Bridge that differs from the current standard detail in Louisiana. The detail is based on the recommendation of the National Cooperative Highway Research Program (NCHRP) Project 12-53 (Report 519). The performance of the new detail was monitored using a 96-channel monitoring system that has embedded and surface-mounted sensors to measure strains, temperatures, rotations, and gap openings in critical locations in the monitored segment. Data from about 24 months of monitoring were collected, processed, and analyzed. Analyses based on Project 12-53 (NCHRP Report 519) models and finite element models were also conducted to further understand the behavior of the new detail. Finally, static and dynamic load tests were carried out on the monitored segment.

OBJECTIVE

The main objective of this project was to install a monitoring system for the purpose of investigating the performance of a continuity diaphragm detail that is newly introduced in Louisiana. The investigation of the detail's performance under long-term (creep, shrinkage, and thermal) and live load effects was conducted to study the applicability of Project 12-53 (NCHRP Report 519) continuity detail in skewed spans with Bulb-T girders.

SCOPE

This study focused on the performance of Project 12-53 (NCHRP Report 519) positive moment continuity detail in a skewed bridge segment that exists in one of the eight bridges that are part of the John James Audubon Project. Because of the nature of the adopted methodology [i.e., structural health monitoring (SHM)], the project activities and findings are limited to the specifics of the monitored bridge (skewed segment with Bulb-T girders). The main focus of the project activities was to monitor long-term (creep, shrinkage, and thermal) effects on the continuity detail. The effects of live loads on the detail were also investigated. However, due to the lack of monitoring data from similar bridges with different continuity details, comparison between the performance of the monitored bridge segment and bridges with different continuity details was not possible.

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METHODOLOGY

A field monitoring approach of a newly constructed bridge was adopted to investigate the performance of the new continuity detail. Data from a 24-month monitoring period were collected from embedded and surface mounted sensors that measured strains, temperatures, rotations, and gap widths. The long-term effects on the continuity detail were captured by the 66 active sensors in the monitoring system. Analyses based on the finite element method and the NCHRP 519 analysis tool were conducted to extend the information about the this detail beyond the monitored segment to other bridge configurations.

CONCLUSIONS

The conclusions from this study can be summarized in the following:

1. Positive moments develop in bridges employing the new continuity detail. They are caused by long-term effects such as girder creep and thermal variations.
2. The continuity detail has the ability to transfer forces from one girder end to the adjacent girder end across the continuity diaphragm.
3. Positive restraint moment can cause cracking in the diaphragm and/or girder ends. Both types of cracking affect the performance of the diaphragm and hence the bridge. More importantly, girder cracking may have adverse effects on the durability and on the shear capacity of the girders. Therefore, special care should be given to the level of positive restraint moment during design.
4. Seasonal and daily temperature variations can cause large restraint moments in the bridge, especially temperature gradients. The level of restraint moment due to the combined seasonal and daily temperature is probably the most important factor in the design of this detail since the designer has little influence on the temperatures at the bridge site. The other positive-moment causing factor (i.e., girder creep caused by prestressing forces) can be greatly reduced by not introducing continuity until a large portion of the creep takes place prior to pouring the diaphragm.
5. It appears, based on the parametric study, that the girder age at which continuity can be introduced to achieve acceptable positive moment levels varies based on bridge configuration. Therefore, the recommended 90-day age from NCHRP 519 will need to be evaluated for each design project.
6. The live load test revealed that the continuity detail transferred negative and positive moments across the diaphragm. The strains from the live load test were much lower compared to other long-term effects. Even if the actual design load were to be applied (approximately twice the live load test), the strains would still be small. Therefore, the live load case should be considered in the design; however, it is not the most demanding action on the detail.
7. The construction cost of the detail is not substantial for the precaster although they would rather build girders without the detail. The contractor's critique of the new detail was stronger than the precaster's. The contractor is of the opinion that the continuity diaphragm, especially for skewed bridge configurations, is cumbersome and adds to the construction time. Simpler details would expedite the construction of slab-on-girder bridges.

RECOMMENDATIONS

The research team recommends that the employment of this new detail be allowed only after thorough investigation of its benefits (both structurally and economically) on a per project basis. When employed, the design should account for factors affecting the development of the positive moment acting on the continuity detail including creep due to prestressing forces, differential shrinkage, and seasonal as well as daily thermal variations. Special consideration shall be given to the effects of temperature gradient in the design of this detail. Simpler details expedite the construction of this type of bridge and need to be one of the studied alternatives for new projects. Partial Integration is one such detail that eliminates the expansion joint without developing large continuity moment over the supports. This can be achieved by pouring continuous decks over simply supported girders.

The modified `RESTRAINT` program (`mRESTRAINT`) does not consider temperature gradient effects, which is one of the most important causes of positive restraint moment. It is therefore recommended that thermal effects be studied using other structural analysis tools. Future modifications of `mRESTRAINT` to include the effect of thermal gradients are possible and recommended to keep the design of the new detail in one tool.

The John James Audubon Project involves many bridges that employ the new detail. This is an excellent long-term testbed for the performance of the new detail. It is recommended that visual inspections of the hundreds of employed joints, similar to the one investigated in this report, be conducted. This opportunity can provide invaluable long-term performance information.