Executive Summary Report

Uncontrolled Concrete Bridge Parapet Cracking

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Project Background

The Ohio Department of Transportation identified the problem of wide-spread premature cracking of concrete bridge parapets throughout its District 12 region (Northeast Ohio). Many of the bridge decks that contain these prematurely cracked parapets are of relatively recent construction. In severe cases, replacement of the parapet may be required before replacement of the bridge deck itself. This cost is ultimately wasted, since the parapets will again be replaced during the regularly scheduled replacement of the bridge deck. In a recent instance, the replacement of a cracked parapet (without replacing the deck) cost District 12 approximately $140,000. Cracked parapets are a safety concern, and the potential cost to the Department to remove and replace prematurely deteriorated parapets could be significant.

Study Objectives

The overall objective of this study was to determine the reasons for the widespread premature cracking of concrete bridge parapets, and to provide recommendations to ODOT to prevent such cracking in the future. These objectives were completed by identifying all relevant factors potentially contributing to concrete parapet cracking, and determining those factors which are the most likely causes of this problem on District 12 bridges. Four specific District 12 bridges were identified to be studied in detail for the determination of the most likely causes. Based on the results of this research, recommendations can be made to account for the identified causes, with the hopes of preventing this problem from occurring on new bridges.

Description of Work

A forensic engineering approach was taken to achieve the objectives of this study. The major aspects of this research included the following: literature review, development of case studies, development of a list of hypotheses, desk study of available construction records, field site visits, and analysis.

A literature review was performed to obtain background information regarding the history of this problem.
and the factors involved. Some information was found indicating that other DOTs have had similar problems with cracked parapets in recent years. Their observations were reviewed and compared to the bridges in this study. Causes of cracking in concrete were reviewed from various technical references. In addition, several other recent academic studies that are relevant to the objectives of this study were also consulted.

Detailed case studies were developed for the four District 12 bridges identified. The bridges are: Canterbury Road over Interstate-90 (Westlake, OH), Sheldon Road over Interstate-71 (Middleburg Heights/Brook Park, OH), Spring Road over State Route 176 (Cleveland, OH), and Wagar Road over Interstate-90 (Rocky River, OH). The case studies include general structural information, design and construction history, bridge dimensions, analysis of inspection and maintenance records, and field observations.

A list of all possible hypotheses for the causes of cracked parapets was developed. Available construction records were reviewed to help narrow the focus of these hypotheses with respect to the bridges in this study. Additional details for the case studies were also obtained from the construction records. Site visits included the following work: detailed field observations, comparison of as-built to planned conditions, measurement and mapping of parapet cracks, and various non-destructive tests. This information obtained from these site visits was used to confirm or refute certain hypotheses.

Using the information obtained from the activities described above, the list of hypotheses was narrowed down. The factors determined to be the most likely causes of parapet cracking on the bridges under investigation were identified. Applicable conclusions and recommendations were made for the identified causes.

**Research Findings & Conclusions**

The problem of prematurely cracked concrete bridge parapets can be seen on bridges throughout District 12 and other districts throughout the state of Ohio. The literature review showed that this problem has been recognized by several other agencies throughout North America. However, the type of deterioration reported in other instances appears to be slightly different than the cracks seen on District 12 parapets. While other agencies identified problems such as issues with slipform construction and joint sealant materials, the cracks seen on ODOT District 12 bridges show a high frequency of cracking between control joints and near the vandal protection fence posts. The four case study bridges all displayed nearly identical patterns of parapet cracks and were all constructed within about a six year time frame. Similar types of parapet deterioration can commonly be seen on many other District 12 bridges that were built during the same time period and are of similar structural design. Therefore, the factors which have been identified as the probable causes of cracking for the case study bridges are most likely applicable to many other bridges throughout District 12 as well as the state of Ohio.

The factors identified as the most likely causes of parapet cracking are as follows. The parapet control joints are often ineffective at controlling cracking. This is likely due to both improper construction techniques and an insufficient joint design. In many cases, the sawcuts in the parapets at the joints are too shallow to initiate cracking. As a result, the joints do not function properly and cracks form between the joints. Cracking also occurs more frequently at vandal protection fence post base plates. This can be caused by a variety of factors, and redesign of the fence and fence post anchorage details may be necessary. Parapets may also be prone to cracks caused by excessive shrinkage from improper curing techniques, as well as composite action with the bridge deck. Horizontal parapet cracks and spalling of the top concrete are usually the result of poorly consolidated concrete at the top layer of horizontal reinforcing bars. The horizontal cracking problem appears to be solved by a recent change in the reinforcement detail.
Implementation Recommendations

For effective implementation of the results of this research, several actions are recommended. The results and conclusions of this study should be disseminated among relevant industry professionals in order to increase their awareness of this problem. It is also suggested that a more detailed procedure for evaluating the structural and aesthetic condition of the parapets should be developed. Finally, the most effective way of preventing premature cracking of bridge parapets in the future would be to adopt new design or construction specifications for any of the factors suspected of causing these cracks. The following changes are suggested for consideration:

1. Use a smaller spacing between parapet control joints
2. Use a smaller spacing between vandal protection fence posts
3. Form control joints by placing inserts within the formwork
4. Use discontinuous lengths of reinforcement, with gaps at the control joints
5. Redesign the vandal protection fence post base plate detail to reduce restraint to the concrete parapets

The expected benefits of implementation are that the frequency and severity of uncontrolled parapet cracking could be significantly reduced in future construction, and hopefully eliminated altogether. The only conceivable obstacles to implementation are the receptiveness to this information of the involved parties and their willingness to adopt the necessary changes. The estimated costs of implementation are not expected to be significant. Potential costs include those needed to make the appropriate changes to design or construction specifications and the costs of disseminating information to the appropriate personnel. It can be expected that construction costs would increase slightly if a more labor-intensive specification or design detail is adopted.

After this study was substantially complete, the research team was informed that ODOT District 12 was considering field tests of improved bridge parapet designs for the 2013 and 2014 construction seasons. Thus, this project was extended until June 30, 2013. The scope of the project extension was:

1. Review other transportation agency (e.g., state DOT) details and specifications for parapet construction, and summarize.
2. Meet with District 12 personnel to refine the experimental plan and design for the implementation.
3. Develop a field monitoring plan.
4. Observe construction of test site parapets and gather data (for projects prior to June 30 2013).
5. Revise the final report — revise conclusions and add appendices to document 1 through 3 above, as well as any work done on item 4 by April 30 2013.

ODOT D12 had already developed the experimental matrix for the test sites, and had begun developing change orders. The bridge parapet test sites and the field test variables are shown in Appendix E. There will be a total of 11 bridge projects as part of the program, each with two sides, for a total of 22 test sites. Eleven will have experimental treatments, and eleven will be controls.

Subsequently, the CSU research team developed the field testing plan discussed in Appendix F. Also, preliminary work on the review of other transportation agency (e.g., state DOT) details and specifications for parapet construction is provided in Appendix G. So far, details from ten different transportation agencies have been reviewed.

At the time of drafting of this revised final report, none of the test parapets have been constructed. Some are scheduled for June 2013, which is before the start of the follow on project “Development, Field Testing, and Implementation of Improved Bridge Parapet Designs.” In addition, three of the control bridges were built during the 2012 construction season.