TECHSUMMARY January 2015

State Project No. 30000660 / LTRC Project No. 12-3C

Investigation of Best Practices for Maintenance of Concrete Bridge Railings

INTRODUCTION

The development of biofilms on concrete structures has a negative impact on aesthetics as well as on the performance and integrity of concrete structures. Biofilms develop and grow easily when the right conditions are present, such as high relative humidity (60 to 100%) and temperature (70 to 95°F). These conditions are encountered in the hot-humid climatic region, which includes the state of Louisiana. As a consequence, visible stains and a relatively fast deterioration of bridges, roads, highways, and other structures are encountered in the state of Louisiana. This issue has triggered public complaints which, as a result, have raised the need to find a practical and economic solution to be used by the Department.

To address this problem, this study conducted a comprehensive literature review to identify the causes and types of biofilm deterioration and surveyed state agencies on currently used methods to prevent and eliminate biofilm development on concrete surfaces. It also identified other DOTs facing similar problems and the methods they use to prevent biofilm growth. In addition, the report also surveyed private companies that clean biofilm growth on concrete surfaces across the US to identify innovative solutions to this issue. A comparative analysis between the widely used cleaning methods was conducted and presented in order to determine which method(s) should be evaluated for possible implementation in Louisiana.

OBJECTIVE

The primary objective of this study was to conduct a comprehensive literature review to determine causes of concrete biodeterioration and to present current practices employed or evaluated for cleaning and maintaining vertical concrete elements on bridges. The goal of this review was to identify possible preventive maintenance alternatives or construction materials that will enhance the resistance of these structures to biofilm growth and in turn reduce labor, costs, and traveling time delays.

SCOPE

To achieve the aforementioned objectives, a comprehensive review of previous research studies was conducted to investigate the main types of microorganisms involved in the development of biofilms on concrete surfaces and the following deterioration. A questionnaire survey was conducted in order to identify current practices used by different states DOTs. Collected information was used to conduct a comparative analysis that summarizes and compares each maintenance and preventive technique in terms of cost, effectiveness, schedule, and environmental impact. Based on the results of this synthesis, the research team developed the details for a follow-up study in order to identify biofilm mechanisms in Louisiana and to conduct an experimental program to test a number of cleaning and preventive methods in the laboratory.

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CONCLUSIONS

The primary objective of this study was to conduct a comprehensive synthesis to determine causes of concrete biodeterioration and to present current practices employed or evaluated for cleaning and maintaining vertical concrete elements on bridges. The goal of this synthesis was to identify possible preventive maintenance or construction materials that will enhance the resistance of these structures to biofilm growth and in turn reduce labor, costs, and traveling time delays. Emphasis was given to the methods used in states with climatic conditions similar to the ones encountered in Louisiana (i.e., hot-humid climatic conditions). Survey results showed that that none of the states that participated are currently employing any treatment method to address biofilm issues. Literature review showed that the following methods are currently being used to fight biofilm growth on concrete surfaces:

- Pressure washing
- Sandblasting
- CO_2 blasting
- Soda blasting
- Application of biocides
- Temperature, pressure, and humidity control
- UV rays, gamma rays, and microwaves
- Use of titanium dioxide in the concrete mixture and application of TiO_2 coating
- Zeolite coating

Based on the results of the survey and literature review, it appears that pressure washing and TiO_2 coatings are the only methods applicable to the transportation industry. Given its long lasting effect, TiO_2 coatings seem to have an advantage over pressure washing, since TiO_2 coatings are expected to last up to 10 years of service based on manufacturer's warranty, while pressure washing must be performed on a periodical basis (approximately once a year). Furthermore, water usage and disposal over water streams is a difficult task as stricter environmental regulations are emerging.

Results of the synthesis also showed that concrete mix design parameters, especially porosity and water/cement ratio, play an important role in controlling biofilms. As surface roughness of concrete increases, void ratio also increases, creating more space for water retention, which can support microorganism growth. In addition, water/cement ratio has been proved to influence the bioreceptivity of concrete to certain deteriorating species of microorganisms. As the water proportion in a concrete mix increases, the permeability of concrete also increases, thus resulting in larger areas for moisture and nutrient retention.

Based on the results of this synthesis, a comparative analysis was conducted to identify strengths and weaknesses of each treatment method. Based on this analysis, the research team recommends that a follow-up study be conducted in order to identify biofilm mechanisms in Louisiana and to conduct an experimental program to test a number of cleaning and preventive methods in the laboratory. Four research tasks were developed for the follow-up study. Based on the results of the follow-up study, a recommended state of practice should be developed to address biofilm growth in Louisiana. The developed practice should present recommended application of preventive methods as well as modifications to current concrete design and production practices in order to minimize or delay biofilm growth.

RECOMMENDATIONS

Based on the results of this study, the research team recommends that a follow-up study be conducted in order to identify biofilm mechanisms in Louisiana and to conduct an experimental program to test a number of cleaning and preventive methods in the laboratory. Based on the results of the follow-up study, a recommended state of practice should be developed to address biofilm growth in Louisiana. The developed practice should present recommended application of preventive methods as well as modifications to current concrete design and production practices in order to minimize or delay biofilm growth. To this end, the following four research tasks are recommended for the follow-up study:

Task 1: *Sample and test biofilm and stained areas of concrete highway infrastructure to determine the type and amounts of fungi and bacteria that attack concrete bridges in Louisiana to develop potential treatment methods.*
Task 2: *Prepare laboratory concrete samples to evaluate different treatment methods against biofilm growth.*
Task 3: *Evaluate laboratory performance of preventive methods such as TiO_2 and zeolite compounds for extended periods up to several years.*
Task 4: *Assess cost-effectiveness of preventive methods and development of treatment guidelines for combating biofilm growth.*