Investigating the Potential Applications of Elastomeric Polymers (Such As Polyuria And Polyurethane) For Accelerated Bridge Construction And Retrofit

Quarterly Progress Report
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1. PROJECT ABSTRACT

Elastomeric polymers such as polyurea and polyurethane are nonlinear elastic materials with high tensile strength and strain capacity, adhesiveness, and resistance to permeability and environmental conditions. They have been used commercially as waterproofing and anti-blast coating for reinforced concrete components. While the elastomeric polymer is an interesting material with unique characteristics, there has been limited research on its potential structural applications. A number of research studies have shown the remarkable increase in flexural and shear strength of polyurea coated reinforced concrete beams. Further research is needed to explore the application of polyurea coating system as a new structural material in the bridge industry.

This proposal takes the first step of a long-term research vision to examine and investigate the innovative applications of elastomeric polymers and specifically polyurea coating in accelerated bridge construction. Our focus is on the application of elastomeric polymer coatings for design and retrofit of bridge girders. There are three aspects that can be considered for this application: *(i)* enhancing the flexural and shear strength of the beam through the application of a spray coating, *(ii)* enhancing the weather resistivity, which is especially important for side beams, and most importantly, *(iii)* overheight vehicle collision impact resistance. This proposal only focuses on the flexural and shear strength of polyurea coated RC beams. This simple step is taken to start gaining experience and knowledge on this relatively new material, and incrementally examine other aspects of the applications and other potential applications through future proposals and other funding opportunities. We plan for an experimental-analytical research effort, to develop simple phenomenological material models for the polyurea coating system and to investigate the potential cost vs. benefit of the coating in design and retrofit of side girders.

2. RESEARCH PLAN

2.1. STATEMENT OF PROBLEM

Based on the collective studies in the literature, it can be concluded that polyurea coating system (Figure 1):

- Increases the flexural and shear strength of RC beams and slabs. It also increases the ductility and failure deformation of RC beams and slabs (which adds to the structural safety by providing alarming deformations before failure) (e.g., [5], [7], [12]),
- Provides waterproofing and environmental resistance to RC surfaces, and has a good resistance to deteriorating environmental conditions (e.g., freeze-thaw and deicing agents),
- Provides a remarkable local energy dissipation capacity, due to the deformation-induced glass transition of material, which can enhance the impact resistance of members,
- Is easy to apply (spray coating), dries fast, and has a good bond with concrete surface, which makes it a solution for on-the-ground as well as in-situ construction and retrofit applications.

Based on the outlined conclusions from the literature, the polyurea coating system is an interesting material with remarkable characteristics that can help improving the multi-hazard design, construction, and retrofit of accelerated bridge components, with minimum impact on the construction time and site. Figure 2 summarizes the potential applications of the polyurea system in accelerated bridge construction. Despite the significant body of related literature, the practical development of design and construction guidelines requires further experimental and analytical research. This is considering the relatively new introduction of polyurea system in the structural application and especially bridge industry.

(a) (b) (c)

Figure 1: Application of polyurea coating (a) masonary slab (photo is taken from [6]), (b) RC beam specimens (photo is taken from [12]), and (c) concrete pipe (photo is taken from [2]).

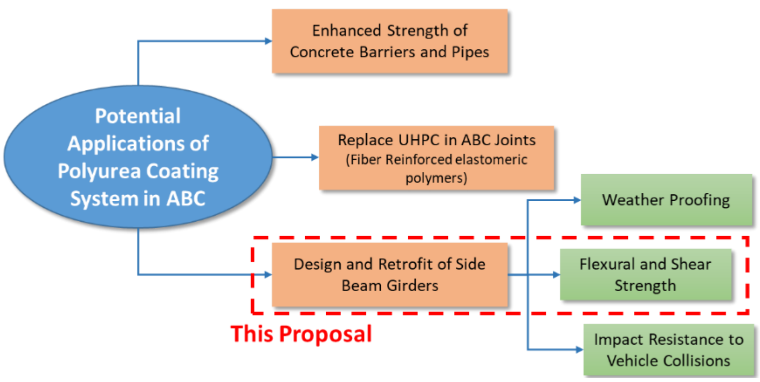

Figure 2: Potential applications of the polyurea system in accelerated bridge construction. This proposal takes the first step of a long-term research vision to examine and investigate the innovative application of polyurea coating system.

2.2. RESEARCH APPROACH AND PLAN

This proposal takes the first step of a long-term research vision to examine and investigate the innovative applications of elastomeric polymers and specifically polyurea coating in accelerated bridge construction. The focus of this proposal is on the application of elastomeric polymer coatings for design and retrofit of side beams in RC girder bridges. There are three aspects that can be considered for this application: enhancing the flexural and shear strength of the beam through the application of a spray coating, enhancing the weather resistivity – which is especially important for side beams – and, most importantly, overheight vehicle collision impact resistance. This proposal only focuses on the flexural and shear strength of polyurea coated RC beams. This simple step is taken to start gaining experience and knowledge on this relatively new material, and incrementally examine other aspects of the applications and other potential applications through future proposal and other funding opportunities (see Figure 2).

The research proposal included 4 tasks as summarized below.

Task 1 – Literature Review

A Comprehensive literature review will be performed on the polyurea material and coating system for structural application, including the experimental results, numerical modeling, material models, etc.

Task 2 – Coupon Sample Tests

A series of polyurea coupon samples will be tested under uniaxial cyclic loading scenarios to develop a phenomenological stress-strain and viscosity material model.

Task 3 – Material Model Implementation and FE Numerical Studies

The phenomenological material model will be implemented in a FE simulation platform (e.g., LS DYNA) and will be used to model the response behavior of coated RC beam specimens tested in the literature. The analysis results will be compared with the experimental counterparts provided in the literature to validate the modeling techniques. A model calibration method based on Bayesian inference will be utilized for model calibration and reducing the discrepancies between simulation and experimental results.

Task 4 – Parametric Studies & Economic Analysis

With the calibrated FE model and modeling techniques developed in Task 3, a parametric study will be performed to examine the increase in flexural and shear strength capacity of bridge girder beams due to the polyurea coating. The cost of polyurea system vs. the increase in strength will be compared with similar solutions (e.g., FRP) to provide an estimate of the economic feasibility of the new material. This step will pave the way to investigate the other potential benefits of polyurea system for side girder design and retrofit.

The project was planned to be completed in 12 months starting from August 2020 (Table 1).

Table 1: Proposed project timeline.

Month	1	2	3	4	5	6	7	8	9	10	11	12
Task												
Task 1: Literature Review												
Task 2: Coupon Sample Tests												
Task 3: FE Studies												
Task 4: Parametric Studies												

3. PROGRESS REPORT

<u>**COVID19-related delays:**</u> Due to Covid-19 pandemic and the closure of U.S. embassies, we could not admit the targeted student researcher that was supposed to join us from fall semester of 2020 and work on the project. Therefore, the project progress has been delayed for about 5 months (August-December).

We were able to identify and hire another master's student that has joined our program from January 2021. Although our progress will technically start from January 2021, the Co-PIs had limited progress with Task 1: Literature Review.

The updated project timeline would be as follows.

Task 1: January 2021 – March 2021 (in progress – 10% completed)

Task 2: March 2021 – April 2021

Task 3: May 2021 – August 2021

Task 4: September 2021 – December 2021