Undergraduate Research Program

Department of Civil Engineering and Construction Management

Research Duration: Summer 2024 (June – August 2024)

Faculty: C. Shawn Sun, Assistant Professor

Email address: shawn.sun@csun.edu

Contact No: Office: JD3315; Tel: 818-677-6276; Office Hours: 11:15-12:15 (Tuesday and Thursday)

Title of Project: Time-dependent Working Stress Analysis of Precast Prestressed Ultra-high Performance Concrete Bridge Girders

Background

The deterioration of U.S. infrastructure due to concrete degradation and steel reinforcement corrosion incurs billions in annual costs. Ultra-high performance concrete (UHPC) emerges as a revolutionary material with triple the strength of regular concrete and superior resistance to deterioration, promising more sustainable infrastructure. Yet, the absence of design specifications for UHPC bridge girders hinders its application in bridge engineering. This project aims to bridge this gap by conducting numerical analysis of precast prestressed UHPC bridge I-girders, focusing on time-dependent working stress analysis under various loads, including dead and live loads.

Goals

This research aims to: 1) investigate the numerical analysis of UHPC bridge girders, emphasizing working stress analysis under various loads; 2) educate undergraduate students in advanced bridge analysis techniques and expose them to cutting-edge bridge engineering practices.

Approach

The research team will undertake an in-depth finite element analysis of a multi-span bridge structure. This analysis will account for the nonlinear material properties of the UHPC and high-strength steel. A detailed case study is presented in Fig. 1, showcasing a three-span bridge that serves as a representative model for this analysis. To facilitate this comprehensive study, the team will employ MIDAS CIVIL, a cutting-edge software package suitable for time-dependent analyses. This software will enable the team to meticulously simulate the unique stress-strain relationships inherent to UHPC, as depicted in Fig. 2. This is crucial for understanding how UHPC behaves under various load conditions and over time, considering its significant differences from traditional concrete materials.

The analysis will not only take into account the static loads that the bridge will bear in its lifetime, such as the weight of the bridge itself (permanent loads) and the vehicles it will support (vehicle loads), but also the time-dependent effects that can impact the bridge's integrity and longevity. These include factors such as creep and shrinkage in UHPC, which can affect the bridge's structural performance over time. Moreover, the study will incorporate a sensitivity analysis to determine the optimal mesh size for the finite element model, ensuring that the simulation results are both accurate and computationally efficient. By fine-tuning the mesh size, the research team can achieve a balance between detailed simulation results and manageable computation times.

The team aims to identify the most efficient I-girder geometry that meets the allowable stress limits and minimizes live-load deflections, ensuring that the bridge design is both safe and cost-effective. For illustrative purposes, Fig. 3 showcases a model of a concrete girder bridge, providing a visual reference for the kind of finite element model that will be developed for the UHPC bridge project.

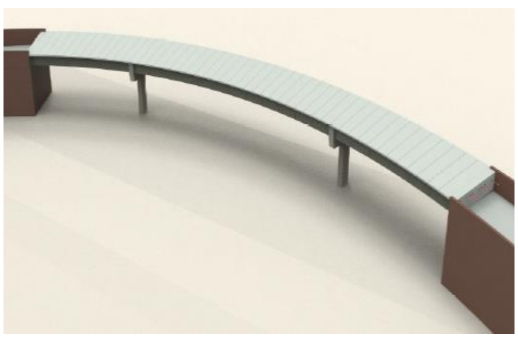

Fig. 1. 3D model of a three-span bridge

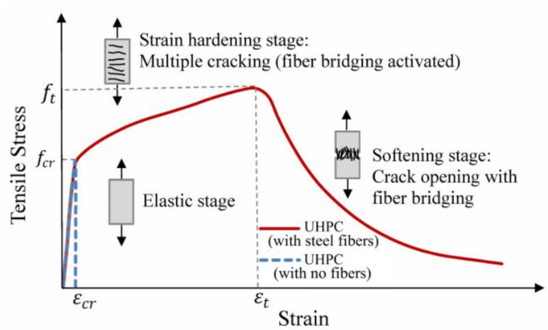

Fig. 2. UHPC stress-strain diagram (Kaka et al., 2016)

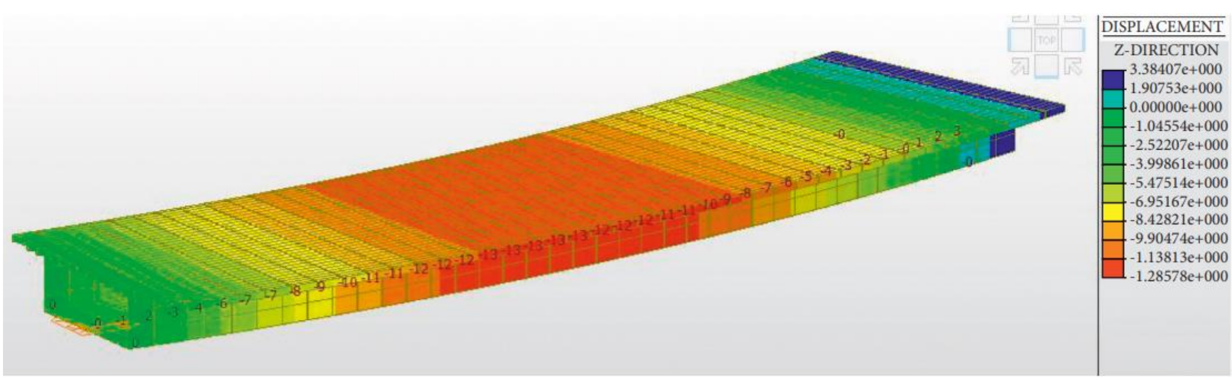

Fig. 3. Example finite element model of concrete bridge girders (Wang et al., 2022)

Expectations and Outcomes

Completing this project will yield finite element models that effectively incorporate the time-dependent properties of UHPC, such as shrinkage and creep, offering bridge engineers valuable guidelines for modeling precast prestressed UHPC girders and promoting UHPC's use in highway bridges. By leveraging advanced simulation tools and a rigorous engineering approach, the research team aims to contribute to the development of more durable, sustainable, and economically viable bridge structures for the future.

More importantly, the project will engage undergraduate students in finite element analysis, introduce them to advanced concrete materials, and teach fundamental bridge analysis and design concepts. These hands-on experiences will enhance their problem-solving abilities and readiness for future careers. The PI will specifically encourage transfer students to participate, offering customized support and transfer-specific advising to smooth their transition into the academic community and aid their successful adaptation.