Research Summary

GFRP Reinforced Bridge Barriers: Numerical Modeling


GFRP Reinforced Bridge Barriers: Numerical Modeling

August 2022
Final Report

Project number TR202112
MoDOT Research Report number cmr 22-009

PREPARED BY:

Congjie Wei, M.S., Graduate Research Assistant

John Myers, Ph.D., Professor

Chenglin Wu, Ph.D., Assistant Professor

Missouri University of Science and Technology

PREPARED FOR:

Missouri Department of Transportation

Construction and Materials Division, Research Section

Concrete road barriers play an important role in protecting lives from injury or fatal damage and preventing vehicles from entering the opposite lane or other dangerous areas by dividing opposing lanes of many types of roads. Being the last protection after a vehicle loses control, the concrete barriers should be able to prevent the vehicle entering the opposite lane or steering into a field that would introduce more severe accidents than hitting the barrier. It is essential to understand the behavior and possible failure of the concrete barriers under different impact scenarios that comes with different types of vehicle and impact angles, among many factors that would influence the impact results.

The main objective of this research is to design a concrete barrier that is reinforced with glass fiber reinforced polymer (GFRP) materials. The design is based on the MoDOT Type D concrete barriers with steel bar reinforcements. The constructability of the GFRP reinforcement was also considered during the design process. This design adjusts the sizes and dimensions to match the properties of GFRP reinforcements. This exchange of the reinforcement materials is meant to take advantage of the preservative properties of GFRP materials to enhance the resistance to corrosion introduced degradation and damage.

To verify the safety and feasibility of this design, as well as understanding the performance of this GFRP reinforced concrete barrier under impact of different types of vehicles, static and dynamic finite element modeling cases are conducted with different commercial software.

Behavior of GFRP reinforced concrete barrier under static loading conditions is conducted to provide quantitatively analysis and comparison between concrete bridge barriers reinforced with different types of materials (GFRP & steel bar) and different casting procedures (as a whole & separated). Parameter study is also conducted on the interspace (Δl=6, 9, 10, 12 $in.$) for all setups to explore the optimized reinforcement setup. All the cases studied in this part are carried out in commercial finite element software, ABAQUS. Results show that the strength of the GFRP reinforced concrete barriers have similar strengths as those reinforced with steel. The effects of stirrups space were found to be alike for both GFRP and steel reinforced concrete barriers. All barriers showed failure strength above 150 kips in terms of reaction forces, which are much higher than the design strength of 54 kips.

Behavior of GFRP reinforced concrete barrier under dynamic loading conditions is then studied for different impact angles. Car and truck shell modeling results with ABAQUS showed that the vehicle after impact has a large deformation on the front and lower parts, which are also the locations of stress concentrations. Meanwhile, the barrier has shown limited deformations. The maximum stress is located at the contact point with the car, as expected. The influence of this impact on the deformation and damage of the nearby area is very limited. The reaction force from this impact has a maximum much lower than the strength of the concrete barrier calculated in the static loading scenarios.

> *"For all cases, the maximum reaction force in the barrier is lower than the design strength…. This verifies that the GFRP reinforced concrete barrier design meets the requirement specified by the MASH standards."*

For the truck impact case modeled using LS-Dyna where different truck parts are assigned with corresponding material properties and meshed with mass, beam, shell, or solid element types, 4 different crash cases with different impact angles are modeled to simulate different impact scenarios. Results show that with the impact angle increasing, the maximum reaction force along x-direction is increasing and reaches the peak value at 90-degree impact angle. Meanwhile, the y-direction reaction force decreases. For all cases, the maximum reaction forces are much lower than the barrier strength obtained in static loading cases.

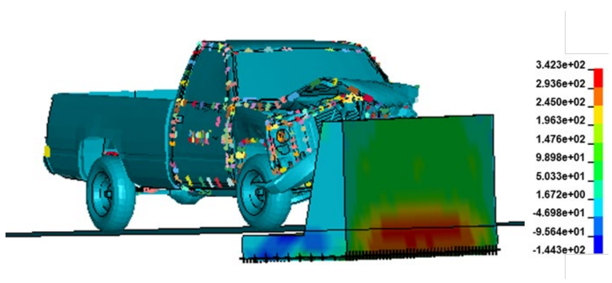

Figure 1: First principal stress distribution

Project Information

Project Name: TR202112—GFRP Reinforced Bridge Barriers: Numerical Modeling

Project Start/End Date: February 2021-August 2022

Project Cost: $75,000

Lead Contractor: Missouri University of Science & Technology

Principal Investigator: Chenglin Wu

Report Name: GFRP Reinforced Bridge Barriers: Numerical Modeling

Report Number: cmr 22-009

Report Date: August 2022

Project Manager

Contact Information:

Brent Schulte
Intermediate Research Analyst
Missouri Dept. of Transportation
1617 Missouri Blvd.
Jefferson City, MO 65109
(573) 526-4328
Brent.Schulte@modot.mo.gov