WYOMING DEPARTMENT OF TRANSPORTATION

PROGRESS REPORT

Project title: Pooled Fund for the Development of Approach Guardrail Transitions for Box Beam and MGS

Project Number: TPF-5(393)

Progress period: 2/14/2019 – 3/31/2020

Principal Investigator and all others who have worked on the project (provide name and ORCID number): Roger Bligh (#0000-0001-5699-070X), Nauman Sheikh (#0000-0003-1718-4881), Nathan Schulz , James Kovar (#0000-0002-1542-7010)

1. Please state whether the project is ahead of schedule, on time, or behind schedule:

   The project is currently behind schedule. Task 1 *Engineering Design and Concept Development* took much longer to complete than initially scheduled. However, this was a critical task in the project because it defined the design options that will be simulated and tested in subsequent tasks and ultimately adopted into Wyoming and Montana DOT standards. Therefore, it was important that the process and WYDOT review was thorough, deliberate, and considered as many factors as possible.

   The circumstances surrounding the pandemic may possibly slow progress on Task 2 *Finite Element Modeling & Simulation.* Researchers are currently adapting to a remote work environment. While most work can be successfully performed remotely, access to computer resources required for evaluating simulation runs is more limited. The task is currently on schedule and will be monitored moving forward.

2. Percentage of overall work completed.

   20%

3. Activities and Accomplishments: The information provided in this section allows WYDOT to assess whether satisfactory progress has been made during the reporting period. Please be as detailed as possible, but try to keep your report to three to four pages in length, if possible.

   a. What are the major goals and objectives of the project?

   The research objective is to develop two non-proprietary approach guardrail transition systems from box beam and MGS guardrail that are MASH Test Level 3 (TL-3)

compliant. The transitions are being designed to connect the guardrail systems to the Texas Department of Transportation (TxDOT) Type C2P TL-4 bridge rail system. Direct connection between the transition section and bridge rail is desired to avoid use of a solid concrete parapet end that could hinder snow clearing operations. The work plan for the project is divided into seven tasks. These include:

Task 1: Engineering Design and Drawing Development
Task 2: Finite Element Modeling & Simulation
Task 3: Test Installation Construction
Task 4: Crash Testing of the Box Beam Transition
Task 5: Crash Testing of the MGS Transition
Task 6: Final Report
Task 7: FHWA Eligibility Letter

b. Describe what was accomplished under these goals.

1. Major activities.
2. Specific objectives.
3. Significant results (both positive and negative).
4. Key outcomes and other achievements.
5. Goals not met.

Task 1 has been completed. Researchers received input from WYDOT regarding design goals, constraints, and preliminary ideas. This information was used to develop multiple design concepts for both the box beam and MGS guardrail transitions to the C2P bridge rail. Previous research and MASH testing were reviewed and promising features were identified and considered in the design process. Attention was given to the strength required to resist impact loads, connections to provide continuity of strength and stiffness, and geometry to reduce vehicle snagging potential from both directions of travel (i.e., onto and off of the bridge structure).

Designs developed for the box beam transition included three options: direct rail element connection (without a connection plate), a connection plate with bolted connections on the field side of the plate, and a connection plate with bolted connections on the traffic side of the plate. Each of these design options had multiple variations that were presented for consideration. Four design options were developed for the MGS transition. These included: a tapered connection plate, a “hidden” connection plate with the top bridge rail flared down, a hidden connection plate with the bridge rail post exposed, and direct connection using tubular spacers (no connection plate). Three dimensional models were developed for each design option using SolidWorks to aid in the visualization of the designs from different viewing perspectives. Additionally, key attributes of each design option were described, and their perceived advantages and disadvantages were developed and summarized. These included considerations such as weight, fabrication complexity, and ease of installation.

The information was transmitted to WYDOT for review, comment, and selection.

Researchers responded to various questions posed by WYDOT during the review process. After a very deliberate and thorough review, WYDOT provided their selection of preferred design options for both the box beam and MGS transitions. These were the connection plate with bolted connections on the traffic side of the plate for the box beam transition and the tapered connection plate for the MGS guardrail transition. Researchers modified the preferred design options to address the review comments received. The revised designs were presented to WYDOT during a meeting on February 20, 2020, and approval to proceed with Task 2 was authorized.

Work was initiated on Task 2. Under this task, finite element models of the selected transition designs for both the box beam and MGS guardrail systems are being developed for use in simulations to help assess impact performance and ability to meet MASH criteria. The model development is progressing in parallel with each other. The finite element models include detailed representation of the Type C2P bridge rail, the approach guardrail, the transition rails and posts, and the various connections between them. The soil in which the transition and approach guardrail posts are embedded has been explicitly modeled to capture post-soil interaction. A concrete failure model has been incorporated at the end of the bridge rail to capture possible damage at the bridge rail post location from the impact loads. This includes modeling of the reinforcing steel in the curb as well as anchor bolts from the bridge rail post into the concrete curb. Damage to the bridge rail end post is likely and any concrete failure may influence the impact performance of the transition.

Modeling of the C2P bridge rail, box beam shoulder rail, box beam transition, and connection plate has been completed. Various parts of the model are being loaded to failure to evaluate their behavior and determine if enhanced material models or connection details are required to capture the range of damage and deformation that is anticipated in the vehicle impact. A rendered image of the box beam is shown in Figure 1. This figure shows the box beam transition, which includes the upper tubular box beam rail, a lower tubular rub rail, several support posts, and the soil buckets into which the support posts are embedded. The transition rails are attached to the front of a connection plate that is tapered on the top leading edge and flares back behind the transition rails. The C2P bridge rail is also shown, which is comprised of two fabricated steel support posts mounted on a concrete curb and deck, an upper pipe rail at the top of the posts and two tubular rails attached to the front of the posts between the curb and upper rail.

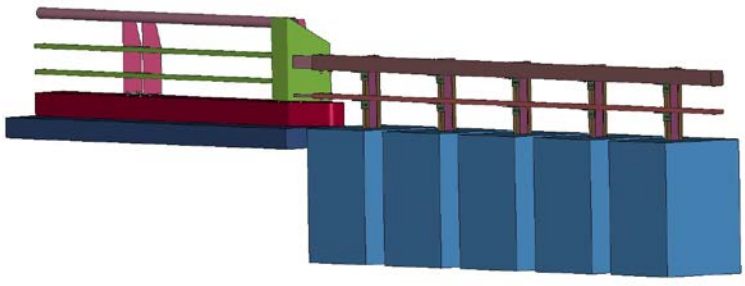

Figure 1. Model of Box Beam Transition to C2P Bridge Rail

Progress has also been made on the MGS transition system. The MGS approach

guardrail has been modeled and transition details are currently being developed as shown in Figure 2. This figure shows the approach W-beam rail and its steel support posts, the non-symmetric W-beam-to-thrie beam transition section, the nested thrie beam transition rail, and the thrie beam end connector. The MGS transition will connect to the same C2P bridge rail model using a different connection plate that is adapted for attachment of the thrie beam end connector as designed in Task 1.

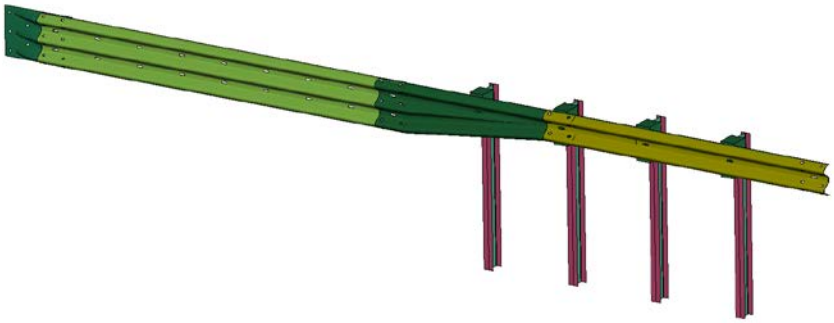

Figure 2. Model of MGS Transition

c. What opportunities for training and professional development has the project provided? If the research is not intended to provide training and professional development, state "Nothing to Report". Otherwise, describe opportunities for training and professional development, training activities, and professional development.

Nothing to report.

d. How have the results been disseminated to communities of interest? Describe what results have been disseminated and in what manner, including publications, conference papers, and presentation. Please list ALL derivative reports/publications which were generated from this project, and provide an electronic copy of the report/publication.

Nothing to report.

e. What do you plan to do during the next reporting period to accomplish the goals and objectives? Describe briefly what you plan to do during the next reporting period to accomplish the goals and objectives.

During the next reporting period, researchers will complete the development, debugging, and refinement of the finite element models for both the box beam and MGS transition systems (including C2P bridge rail and approach guardrails). The modeling efforts will continue in parallel. Impact simulations will be performed using LS-DYNA, an explicit finite element code. The simulated impacts will follow the impact conditions of MASH for Test Level 3 (TL-3) transition systems. The MASH test matrix for transitions includes two tests. Test 3-21 involves a 5,000-lb pickup impacting the transition at a speed of 62 mph and an angle of 25 degrees. Test 3-20 involves a 2,420-lb passenger car impacting the transition at a speed of 62 mph and an angle of 25 degrees.

The simulation results will be used to evaluate impact performance and the ability of the systems to meet MASH criteria. Various design parameters will be investigated for each system to achieve the desired level of impact performance. For example, design parameters for the box beam transition include post size and spacing, rubrail size and height, and rubrail termination. The impact performance of the box beam transition system will be evaluated at both the downstream and upstream ends. The MGS transition will be evaluated only at the downstream end where it connects to the C2P bridge rail system. The upstream end of the MGS transition has been evaluated under previous research and will not require further investigation under this project. The results of the simulations will be transmitted to WYDOT for review as meaningful results are obtained.

f. List any products resulting from the project during the reporting period. Include in this list:

1. Publications, conference papers, and presentations.
2. Website(s) or other internet sites (List the URL).
3. Technologies or techniques.
4. Inventions, patent applications, and/or licenses.
5. Other products, such as data or databases, physical collections, audio or video products, software or NetWare, models, educational aids or curricula, instruments or equipment.

Nothing to report.

g. Impact:

1. How will this project impact WYDOT?
2. How will this project impact other agencies?

WYDOT's Mission Statement is to "provide a safe, high quality and efficient transportation system." One of the goals within the mission statement is to "improve safety on the state transportation system." Successful implementation of the transitions developed under this project into WYDOT's standard plans will provide an improved level of safety. The transitions will provide continuity of motorist safety from MASH guardrail systems to MASH bridge rail systems. Full implementation of MASH compliant roadside safety devices, including transition systems, will provide an enhanced level of safety that will help reduce the severity of lane departure crashes that represent over 75% of highway fatalities in Wyoming. Additionally, the AASHTO/FHWA MASH Implementation Agreement requires state DOTs to provide MASH compliant roadside safety features to obtain federal funding reimbursement on projects. The results of this research will be useful to other agencies. This project is being funded as a pooled fund effort between WYDOT and Montana DOT. It will provide transition details that will be immediately implementable by both of these agencies as well as other agencies that use similar guardrail and bridge rail systems.

h. Changes to Scope of Work. Provide the following changes, if applicable:

1. Scope of work or objectives of the project.
2. Changes in key persons.
3. Disengagement from the project for more than three (3) months, or a twenty five (25) percent reduction in time devoted to the project.
4. The inclusion of costs that require prior approval.
5. The transfer of funds between line items in the budget.
6. The subawarding, transferring or contracting of work.
7. Changes in the approved cost-sharing or match.

Nothing to report.