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TECHNICAL MEMORANDUM

Contract No.: **TTI Project 405160-36, Task Order BI**
Project Name: **Transition for Anchored Temporary Concrete Barrier System in Asphalt – Phase I**
Sponsor: **Roadside Safety Pooled Fund**

DATE: **October 31, 2012**

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SUMMARY REPORT:

DISCLAIMER:

INTRODUCTION AND OBJECTIVE

In 2008, TTI developed a pinned-down F-shape temporary concrete barrier system that provides limited deflection and can be used for bridge or roadway applications. This design uses 1.5-inch diameter steel pins that pass through the toe of the concrete barrier and continue a short distance into the underlying concrete pavement or deck. In a subsequent project, TTI extended the use of this pinned-down barrier design to placement on asphalt pavement. In this version of the design, the length and the number of anchoring pins were increased. An on-going TTI project is developing a transition from free-standing to pinned-down anchored barrier, which can be placed on concrete pavement or bridge deck, but not on asphalt.

This project was started as a first phase for developing a transition from free-standing to pinned down barrier for use on asphalt. The objective of this phase was to perform quasi-static and dynamic pull tests to evaluate if equivalency in lateral resistance and deflection can be achieved between an anchoring pin installed in asphalt and concrete. If an equivalency can be achieved, the researchers were to develop details of the transition from free-standing to pinned down barrier for placement on asphalt using the results of the ongoing research to develop the transition for placement on concrete.

TESTING

The researchers performed a series of quasi-static and dynamic pull-tests to determine the response of a single inclined steel pin embedded in concrete and asphalt. The pins used in the pull tests were the 1.5-inch diameter pins used in the existing pinned-down anchored barrier systems for concrete and asphalt (concrete and asphalt system pins are 21-3/8 inches and 48 inches long, respectively). To apply the load at the correct height and orientation of the pins, a steel frame was built to match the toe profile of an F-shape barrier (as shown in figure 1).

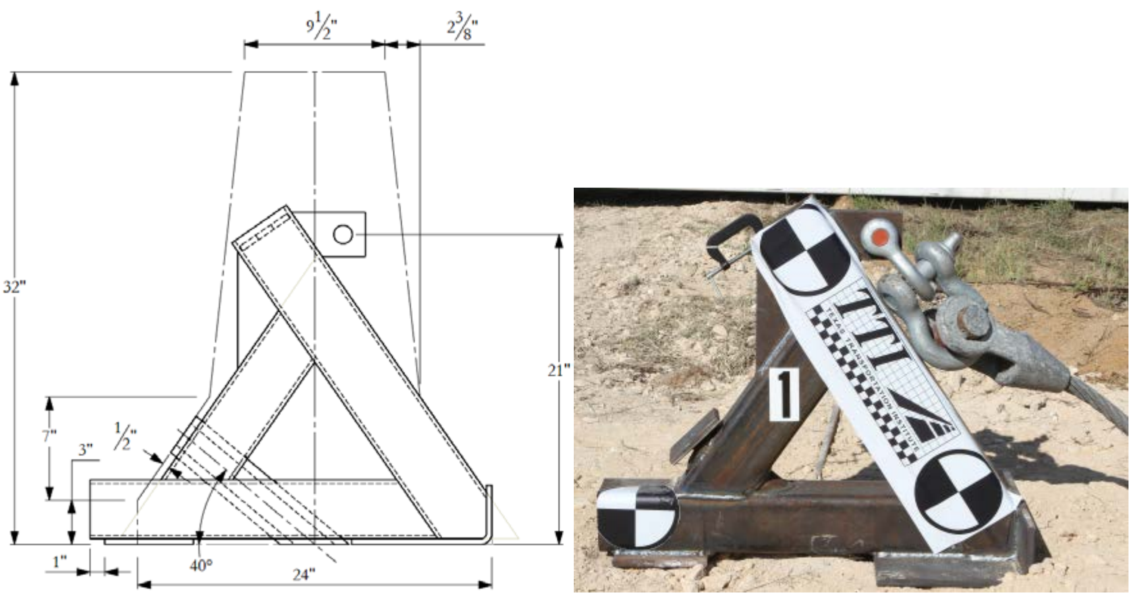

Figure 1. Frame built to hold anchoring pin at correct height and orientation

Installation of the pin for testing in concrete is shown in figure 2. The concrete pavement was 8 inches thick and unreinforced. The installation of the pin for testing in asphalt is shown in figure 3. A 4-inch thick asphalt pad was constructed adjacent and leveled to an existing concrete apron. The pad was constructed on 12-inch thick layer of compacted crushed limestone road base. Additional patches of asphalt were rolled on top of the 4-inch pad in 2-inch increments to achieve total pad thicknesses of 6, 8, and 10 inches. The test installation of the asphalt pad is shown in figure 4. An A4×4×1/4 angle was anchored to the adjacent concrete apron at the edge of the asphalt pad as shown in figures 3 and 4. This angle was installed as a precaution to prevent sliding or delamination of the asphalt above grade.

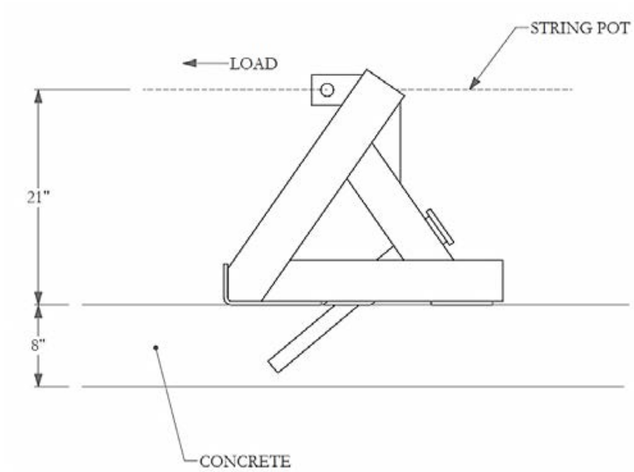

Figure 2: Pin installation in concrete

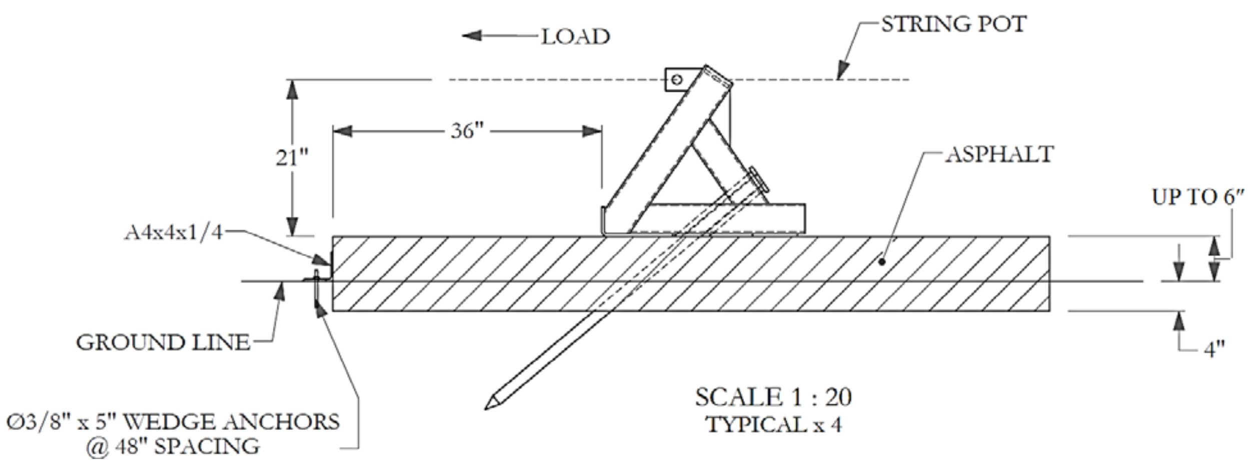

Figure 3: Pin installation in asphalt

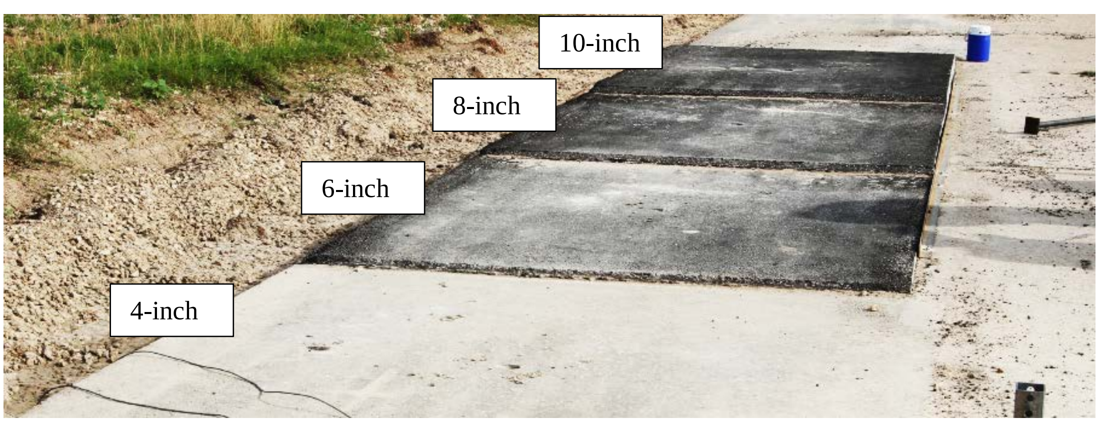

Figure 4: Asphalt pad for pull tests.

QUASI-STATIC TESTING

The researchers performed a total of five quasi-static pull tests. The first test was performed with the anchoring pin installed in concrete. The remaining four tests were performed with the anchoring pin installed in 4, 6, 8, and 10-inch thick regions of the asphalt pad. The load was applied in a quasi-static manner using a hydraulic cylinder that was attached to the frame hosting the anchoring pin, as shown in figure 5. A load cell attached between the hydraulic cylinder and the frame measured the force applied to the frame. A string pot was attached to the rear of the frame to measure the lateral movement. The load was applied until the lateral movement of the frame reached approximately 10 inches, which was more than enough for evaluating the response of the pins installed in a pinned-down concrete barrier installation.

Figure 5: Test setup for quasi-static pull tests (pin installed in concrete is shown).

Results of the pull tests were compared between the pin installed in concrete and in different thicknesses of asphalt. Figure 6 shows the damage to the concrete and asphalt at the end of each test. The force-deflection response from each of the tests is shown in figure 7. A comparison of the force deflection response shows that the pin installed in concrete resulted in a peak force of 4.24 kips, whereas the peak forces from pins installed in the 4-inch, 6-inch, 8-inch, and 10-inch asphalt pads were 2.87 kips, 3.24 kips, 3.09 kips, and 3.28 kips, respectively.

Concrete 4-inch asphalt 6-inch asphalt

Figure 6: Concrete and asphalt damage after pull test

8-inch asphalt

10-inch asphalt

Figure 6: Concrete and asphalt damage after pull test (continued)

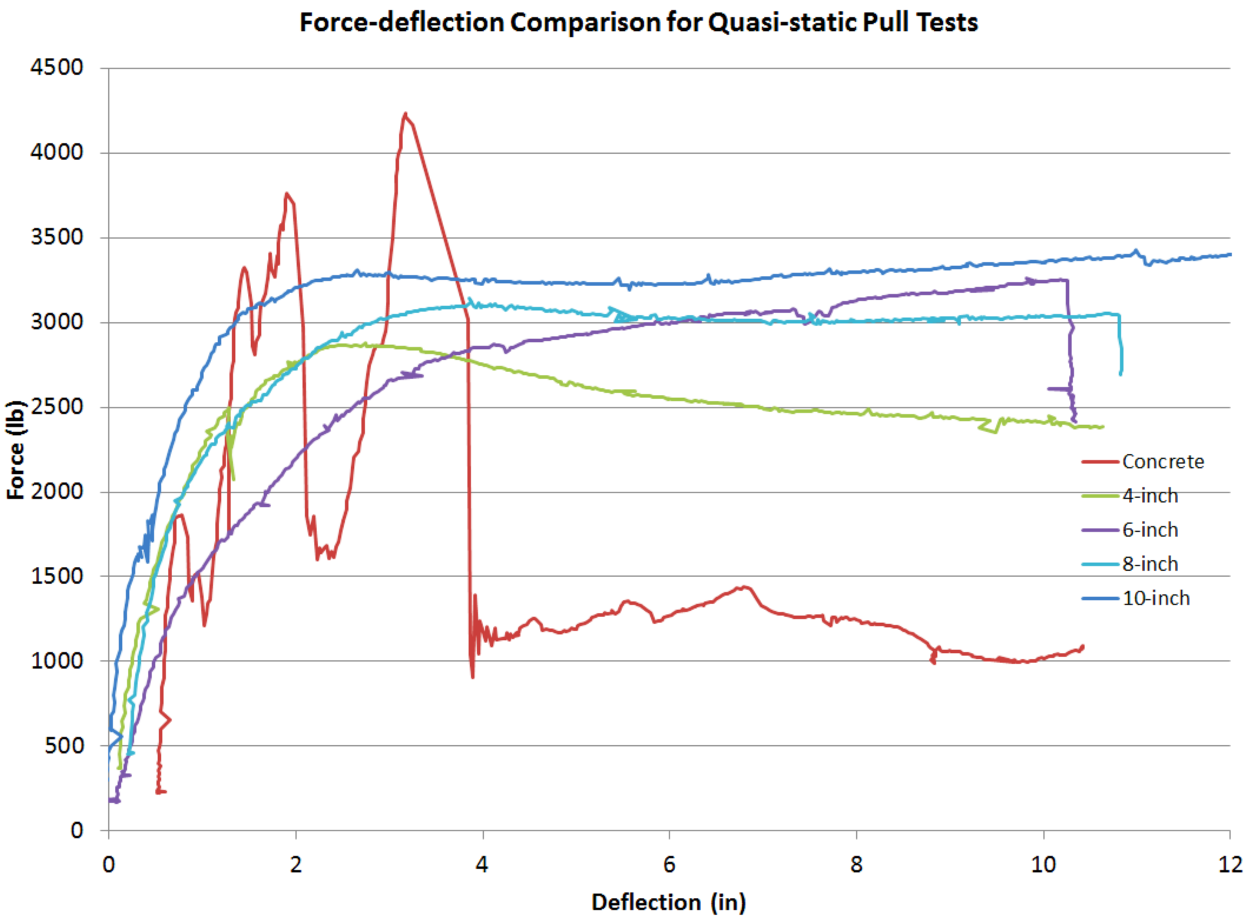

Figure 7: Comparison of force-deflection response for quasi-static pull tests.

DYNAMIC TESTING

The researchers conducted a total of four dynamic pull tests. The first test was conducted with the anchoring pin installed in concrete. The remaining three tests were conducted with the anchoring pin installed in 4-inch, 6-inch, and 8-inch thick asphalt pads. The pins were installed using the metal frame as in previous testing. A tractor was used to apply the load on the pins by pulling on a cable that was attached to the frame (see figure 8). A load cell was used to measure the dynamic tensile force in the cable.

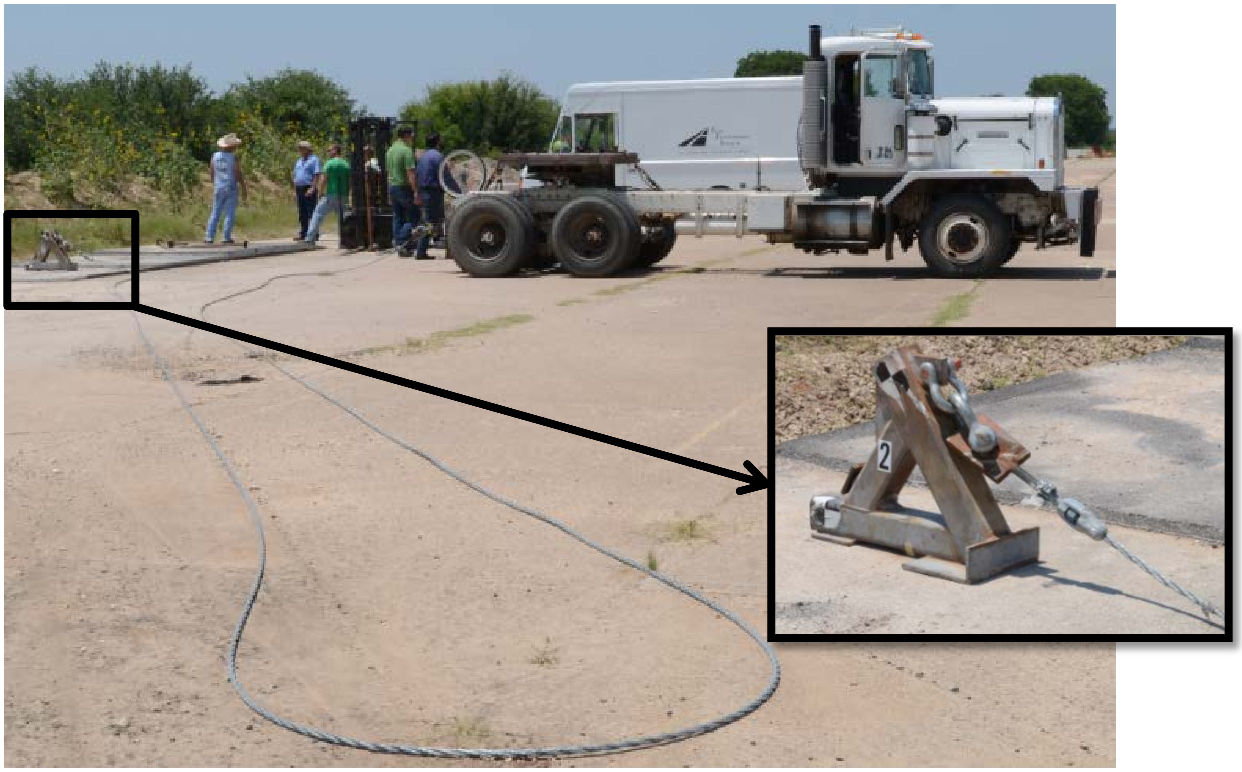

Figure 8: Test setup for dynamic pull tests.

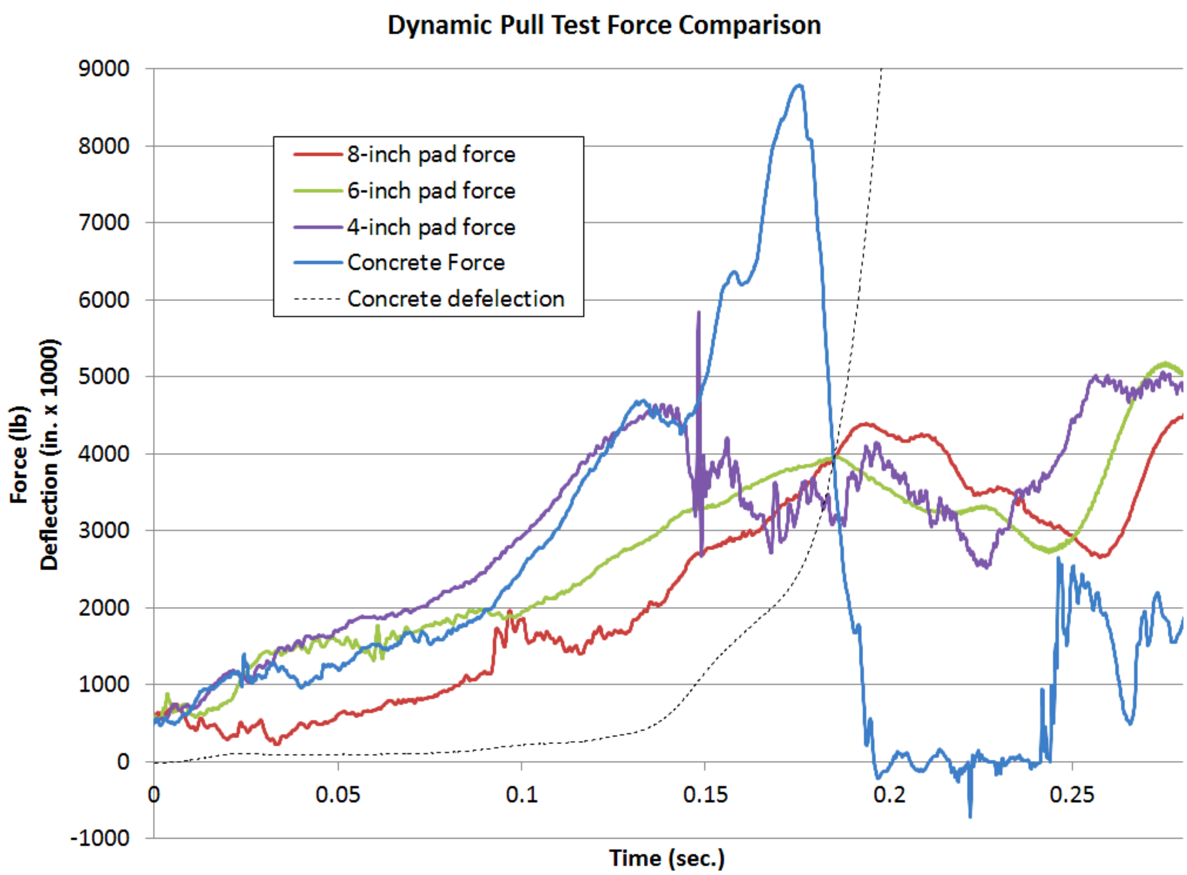

Figure 9: Comparison for peak forces for dynamic pull tests.

A string pot was attached to the frame hosting the anchoring pin to measure the deflection. After the first test (with pin in concrete), the recoil of the string pot spring damaged the string pot and it could not be used in subsequent testing. The researchers therefore used the force versus time data to compare the response of the anchoring pins. The nominal speed of the tractor in all of the tests was maintained at 12 mi/h at the time the cable started pulling on the frame hosting the anchoring pin. The corresponding force-time responses from the dynamic pull tests are compared in figure 9.

A comparison of the force deflection response shows that the pin installed in concrete resulted in a peak force of 8.73 kips, whereas the peak force from pins installed in the 4-inch, 6-inch, and 8-inch asphalt pads were 4.94 kips, 5.12 kips, and 4.41 kips, respectively.

CONCLUSIONS

The primary motivation behind this project was to design a transition from a free-standing F-shape temporary concrete barrier to the pinned-down temporary concrete barrier developed by TTI. This first phase had the objective of determining if there is an equivalency between an anchoring pin installed in concrete pavement and a pin installed in some thickness of asphalt pavement. If such an equivalency could be established, the results of an ongoing project developing a transition design for placement on concrete can be used for placement on asphalt, without having to carry out additional analysis and testing on asphalt.

This project was started as a first phase with the objective to perform quasi-static and dynamic pull tests to evaluate if such an equivalency in lateral resistance and deflection can be achieved between an anchoring pin installed in asphalt and concrete.

The result of the quasi-static testing showed that the peak lateral restraint for the pin installed in concrete is 4.24 kips. While there was some increase in lateral restraint as the thickness of asphalt was increased, the peak load was not significantly dependent on the thickness of the asphalt. The peak lateral loads for pins installed in asphalt were very closely banded, as can be seen in figure 7. The average peak restraint load for all thicknesses was 3.12 kips, with lowest being 2.87 kips and highest being 3.28 kips. This average peak load associated with asphalt was 26% less than the peak quasi-static load obtained in concrete.

It is known that asphalt behaves as a viscoelastic-viscoplastic material, which can have dependency on the strain rate, i.e. the speed at which the load is applied. Furthermore, dynamic loads are generally greater than static loads due to inertial effects of masses being accelerated suddenly. For these reasons, the researchers performed the dynamic pull tests in addition to the quasi-static tests.

The dynamic pull test with the pin installed in concrete resulted in a peak load of 8.73 kips. The results of dynamic tests performed in asphalt showed once again that the peak forces for different thicknesses of asphalt were closely banded. A significant difference in lateral restraint between different thicknesses of asphalt was not observed. The average peak load for all thickness of asphalt was 4.82 kips, with lowest being 4.41 kips and highest being 5.12 kips. This average load in asphalt is 44.8% less than the peak load obtained in concrete.

Results of the testing performed in this project enhanced understanding of the behavior of pins installed in asphalt. Useful insight was gained into the force-deflection response of the anchoring pins installed in both asphalt and concrete. The results of the testing however did not indicate an equivalency between the response of the pins installed in concrete and asphalt. Pins installed in asphalt had significantly reduced lateral restraint loads compared to concrete. While the lateral restraint of the pin was somewhat sensitive to the thickness of the asphalt, the effect of the thickness was not significant enough to achieve the restraint level needed to match the performance of the pin in concrete. Consequently, a transition design for use on asphalt needs to be developed independently by performing more comprehensive analyses and full-scale crash testing.