Clarifications on Implementing the AASHTO *Manual for Assessing Safety Hardware*, 2016

Updated: March 24, 2020

The following is a compilation of all questions and answers (Q&A) that have been developed since May 2018 for the purpose of clarifying and implementing the 2016 edition of the *Manual for Assessing Safety Hardware* (MASH), which is published by the American Association of State Highway and Transportation Officials (AASHTO). The information in this document, which is updated periodically, has been approved by AASHTO and FHWA for dissemination to the roadside safety hardware community. The answers were developed by a joint technical working group of representatives from state transportation departments, the Federal Highway Administration, and accredited crash testing laboratories.

The numbers associated with each question indicate the date of publication of the Q&A. If a response has been updated since its original publication, the previous answer will be noted as "superseded."

For answers to specific questions about the federal-aid eligibility process, please see FHWA's Roadside Hardware Policy Memoranda and Guidance. The joint implementation agreement may be viewed here.

TEST VEHICLES

Mar 2020 #1. Can a single-unit truck with a flat bed be used for a test instead of a single-unit box truck?

No. Section 4.2.1 of MASH discusses mounting of cargo boxes to single-unit truck frames, and Figure 4-3 shows the cargo box and its dimensions.

TESTING PARAMETERS

Mar 2020 #2. Tests 90 and 91 require that testers choose a critical impact angle (CIA) that maximizes the likelihood of test failure (0-25 deg), but to choose a CIA MASH also encourages testers to examine vehicle behavior during tests of similar channelizers when selecting a CIA for a new design. In our case a CIA to maximize failure is 5 degrees according FEA simulations. But similar industry channelizers have been tested at 25 degrees. The difference between these two angles is large. Which is more important? FEA simulations, or existing tests already performed on similar product? Is rollover or deceleration more critical?

A device may have multiple failure types (such as rollover and excessive deceleration). Each failure type needs to be investigated and a CIA established for each failure type. Designers are encouraged to examine vehicle behavior during tests of similar channelizers when selecting a CIA for a new design. Crash testing each CIA is required. Include the engineering analysis used to determine the CIAs in the crash test report.

Mar 2020 #3. MASH 2016 Section 2.1.2 discusses tolerances on impact conditions and states that the tolerance on desired values for impact speed is ±2.5 mph and for impact angle is ±1.5 degrees. For tests of longitudinal barriers, are speeds or impact angles slightly above the upper tolerances allowable if all of the occupant risk criteria are successfully met during a test – i.e., the test is successful at a greater impact severity?

Impact speeds or angles above the upper tolerance for the desired test value do satisfy the intent of MASH for longitudinal barriers if the occupant risk criteria and all other evaluation criteria are met during the test. The lower limit for the tolerance is the more critical value and is discussed in more detail in Section 2.1.2.

TEST VEHICLES

Nov 2019 #1. Can tests be run with 1100C vehicles from newer model years that do not meet all the properties specified in Table 4-1?

Due to the evolution of the vehicle fleets, it may be difficult to obtain test vehicles as identified in the 2016 edition of MASH. To accommodate this, 1100C small car vehicles with variations to Table 4-1 values in the hood height and track width dimensions can be used as described below.

- Track width: Average of Property M and Property N, as labeled in Figure 4-1, may be 59" +/- 2"
- Hood height: Property O as labeled in Figure 4-1, measured to the top of the radiator mount, may be 28" +/- 4"

Interlaboratory comparisons by seven labs have determined that these variations are appropriate. (*ILC_Report-Followup_Hood_Height_1100C_Vehicle_R0-FINAL.doc*, 2017)

TESTING PARAMETERS

Nov 2019 #2. Can a live driver be used for a temporary work zone device test, without measuring occupant ridedown acceleration or occupant impact velocity?

(UPDATED FROM PREVIOUS Q&A) In general, sensor data is needed to obtain objective measurements during the test. As stated in MASH 2016 (Section 4.2.1.3), the use of live drivers should generally be avoided. However, testing with a live driver may be practical under specific limited low risk conditions of tests of Category 1 devices. The testing facility is responsible for appropriate documentation that supports testing with non-sensor data and shall determine the 'risk' imposed for live driver testing. More substantive devices are to be tested with sensors.

IMPLEMENTATION

Nov 2019 #3. What is included in the December 31, 2019, sunset date in the AASHTO/FHWA Joint Implementation Agreement?

The sunset date specified in the *AASHTO/FHWA Joint Implementation Agreement for MASH* for the use of NCHRP 350-compliant roadside hardware devices for new permanent installations and full replacements on National Highway System (NHS) facilities occurs on December 31, 2019. However, because of the limited number of MASH 2016-compliant devices available in several device categories, existing MASH 2016-compliant devices may not provide the functionality needed by a state transportation agency.

After December 31, 2019, states will use MASH 2016-compliant devices on NHS projects for new permanent installations and full replacements. However, states may specify MASH 2009-compliant or NCHRP 350-compliant devices when:

a) a MASH 2016-compliant device does not exist to address the situation; or
b) a MASH 2016-compliant device exists but does not meet the state's needs given project or regional conditions; or
c) the state is awaiting completion of MASH-2016 testing for a specific device, in which case the State must document the plan for testing the device that will be used on future projects in lieu of the specified NCHRP 350 device; or
d) the device is a temporary work zone device that has been in use prior to December 31, 2019, and is still within its normal service life.

States must maintain documentation of non-MASH-2016-compliant devices used and the basis for use. When sole-sourcing MASH-compliant devices, States must comply with Federal and State procurement requirements.

TESTING PARAMETERS

May 2019 #1. Is it acceptable to use metric components (such as bolts) in lieu of imperial components?
Use of any alternate component must demonstrate equivalent capacity, physical properties, and mechanical properties.

May 2019 #2. Can surrogate testing be used for low-speed performance evaluation for small sign supports in lieu of full-scale testing under MASH?
As outlined in MASH Section 4.2.2, surrogate bogie testing vehicles are not allowed for these devices.

May 2019 #3. Tests 3-40, -41, -42, -43, and -44 are run on a non-redirective crash cushion sand barrel array, and the back row of barrels was not engaged in tests 40 through 43. The array failed test 3-44 however. If the back row is modified, do tests 40 through 43 need to be run again?
If the rear barrels were not engaged during tests 40 through 43, those tests do not need to be performed again. A basic inertial analysis on the modified array should be documented to show that the performance of the array in those tests would not change.

May 2019 #4. If a MASH test resulted in a failure, and the same exact test was re-conducted and it passed, how would this be viewed? Would the failed test need to become part of the submission for eligibility?
A failing test is not acceptable. If a test fails, the issue should be identified and the device should be redesigned and retested.

May 2019 #5. If a MASH test conducted using an 1100C vehicle was a failure, can another 1100C test vehicle make/model be used to conduct the same test?
No. Since the cause of all failures should be fully analyzed by the laboratory, barring any testing procedure violations, the device should be fully reviewed for modifications before any ensuing testing is conducted**.**

May 2019 #6. Where should splices and tensioners be located during testing?

For a given crash test, cable splices and tensioners should be positioned within each cable element downstream from the critical impact point of the test article but upstream from the location of the expected maximum dynamic barrier deflection.

May 2019 #7. If w-beam ruptures during a test and the vehicle is redirected, does the test fail?
Yes, w-beam rail rupture on length-of-need testing would be a failed test regardless of test results.

May 2019 #8. Can a live driver be used for a temporary work zone device test, without measuring occupant ridedown acceleration or occupant impact velocity?
No. Sensor data is needed to obtain objective measurements during the test.

SUPERSEDED. See Nov 2019 #2.

IMPLEMENTATION

Aug 2018 #1. What is included in the December 31, 2018, sunset date in the AASHTO/FHWA Joint Implementation Agreement?
The AASHTO/FHWA Joint Implementation Agreement is amended for contracts on the National Highway System such that new permanent installations and full replacements of cable barriers and cable barrier terminals must be MASH 2016-compliant by the December 31, 2019, sunset date for "all other longitudinal barriers" and "all other terminals." New permanent installations and full replacements of crash cushions will still require compliance with MASH 2016 by December 31, 2018.

IMPLEMENTATION

Jun 2018 #1. What is included in the June 30, 2018, sunset date in the AASHTO/FHWA Joint Implementation Agreement?
The AASHTO/FHWA Joint Implementation Agreement states that for contracts on the National Highway System with a letting date after June 30, 2018, new permanent installations and full replacements of w beam terminals must be MASH 2016-compliant. This sunset date covers tangent terminals. Other applications, such as double-sided or median terminals, flared terminals, and terminals installed on a flare, are included in the December 31, 2019, sunset date for "all other terminals."

IMPLEMENTATION

May 2018 #1. What is included in the December 31, 2017, sunset date in the AASHTO/FHWA Joint Implementation Agreement?
The AASHTO/FHWA Joint Implementation Agreement states that for contracts on the National Highway System with a letting date after December 31, 2017, new permanent installations and full replacements of w-beam barrier and cast-in-place concrete barrier must be MASH 2016-compliant. This sunset date is intended to cover standard installations. Special applications of these devices, such as barriers utilizing reduced post spacing, barriers installed on a flare, barriers mounted behind curbs, and barriers located at bridge ends in restricted areas, are

included in the December 31, 2019, sunset date for “transitions" and "all other longitudinal barriers."

For additional information on system configurations that are planned for crash testing, see *A Synthesis of MASH Tested 31-in. Tall, Non-Proprietary, W-Beam Guardrail Systems*, dated February 27, 2017.

May 2018 #2. What is the definition of “letting date”?

The letting date is equivalent to the owner-agency’s definition of “bid opening date” for traditional design-bid-build projects. For design-build projects, the date on which the funding is obligated may be used.

May 2018 #3. How is it determined whether a modification to a device is significant or non-significant?

A significant modification to a device is a modification that adversely affects the crashworthy performance of the device based on the crash testing criteria in MASH. Owner-agencies may make determinations as to whether a modification is significant and what additional testing and/or engineering analysis is required for them to approve a modified device.

TEST VEHICLES

May 2018 #4. What is an acceptable model year for a test vehicle?

MASH 2016, Section 4.2.1, p 147, is clarified as follows: Passenger vehicles used for crash testing should be 6 years old (or less) when the test occurs. Regardless of age, test vehicles should adhere to the properties specified in MASH. For situations where the vehicle is more than six years old, the test facility must document and certify that all other stipulations regarding the condition and configuration of the vehicle provided in MASH 4.2.1 and MASH A4.2.1 are met and address all properties that are outside of tolerances set in MASH Table 4-1.

Note that the 6-year limit is not a requirement for heavy trucks. MASH 2016, Section 4.2.1, states, "Although it is cost-prohibitive to apply the 6-year limit to heavy truck test vehicles, it is desirable to utilize vehicles of recent vintage. Heavy truck test vehicles should be representative of widely used designs." In addition, MASH 2016, Section A4.2.1, states that, "Whenever possible, it is recommended that heavy trucks not be more than 12 model years old." Thus, for heavy truck test vehicles that are older than 12 years, the test facility must document and certify that all other stipulations regarding the condition and configuration of the vehicle provided in MASH 4.2.1 and MASH A4.2.1 are met and address all properties that are outside of tolerances set in MASH Table 4-2.

May 2018 #5. May NCHRP Report 350 small car tests be used to determine MASH crashworthiness for breakaway devices (e.g., small sign supports)?

The crashworthiness of breakaway devices under MASH cannot be determined using NCHRP Report 350 small car tests (820C), as the small car properties in MASH, including mass and dimensions, are different from NCHRP 350. In addition, the use of a MASH-compliant test vehicle enables test results to be used as a baseline on which to justify the crashworthiness of any future modifications to a device.

May 2018 #6. Are cab-over-engine trucks acceptable for use in crash testing?

Cab-behind-engine models are encouraged, but not required, for testing at TL-4, TL-5, and TL-6, as stated in MASH 2016, Section 4.2, p 82: "All heavy truck test vehicles should incorporate a cab-behind-engine configuration, not a cab-over-engine design."

May 2018 #7. Can surrogate testing be used for low-speed performance evaluation of small sign supports in lieu of full-scale testing under MASH?

All sign supports should be evaluated to MASH criteria. MASH 2016, Section 4.2.2, p 96, states that "Surrogate test vehicles, including pendulums and bogie vehicles, may be used to evaluate the impact performance of breakaway systems and work-zone traffic control devices." However, no MASH-compliant bogie vehicle currently exists for testing.

TEMPORARY TRAFFIC CONTROL DEVICES

May 2018 #8. Must all variations of a given device (such as a work zone device) be crash tested?

Owner-agencies may accept modifications made to or variations of a tested device based on engineering analysis and/or additional crash testing in accordance with MASH.

May 2018 #9. May "Category 1" devices (i.e., drums, cones, road tubes) be self-certified by the manufacturer as crashworthy?

Low-mass, single-piece traffic cones, tubular markers, single-piece drums, and delineators (known as Category 1 devices under NCHRP 350) may be manufacturer-certified as MASH-compliant as long as there are no attachments to the device. If there are attachments, crash testing and/or evaluation to MASH criteria is required.

May 2018 #10. If an attachment to a "Category 1" device, e.g., a warning light attached to a cone, is tested on Manufacturer A's cone, must it be tested on Manufacturer B's equivalent cone as well?

Owner-agencies may accept modifications made to a tested device based on engineering analysis and/or additional crash testing in accordance with MASH.

May 2018 #11. May two temporary work zone signs be tested in one test run?

Two free-standing work-zone traffic control devices of light mass (< 100 kg) may be tested in a single crash test. See MASH 2016, Section A2.2.4, p 136, for additional discussion, which includes the following: "Note that many testing agencies impact two work-zone traffic control devices in a single run. The devices are placed to impact opposite quarter points of the front of the vehicle. Device spacing is selected such that the first device is usually completely disengaged from the test vehicle before it strikes the second device. In some cases, the first device does not disengage or it produces sufficient damage that it is impossible to determine the extent of windshield damage for the second device. In these situations, the second device should be retested."

May 2018 #12. Is rear window damage (e.g., due to a tall breakaway or work zone device) cause for failure of a test?

Currently, there are no defined criteria for rear window damage in MASH. Until additional research is conducted, no penetration of any element of the test article through the rear window is allowed. Deformation and/or shattering of the rear window is acceptable if within intrusion limits. A detailed description of the events surrounding the deformation and/or shattering event must be provided by the testing facility.

May 2018 #13. Is floor board penetration or tearing (e.g., from sign stand legs, cable posts, frangible sign supports, etc.) cause for failure of a test?

A separation of floor board seams is allowable under MASH criteria, however because cutting or tearing of the floor board by the test article is evidence of penetration, it is cause for failure. Until additional research is conducted, no penetration of any element of the test article through the floor board is allowed. See MASH 2016, Section 5.2.2, p 106, which states, "…a seam separation by itself is not considered a test failure unless (1) a component of the safety device protrudes through the opening or (2) the deformation limit of 12 in. is exceeded."

May 2018 #14. May breakaway slip bases, frangible couplings, and similarly-defined breakaway devices that have been successfully tested in strong soil be mounted in or on paved surfaces?

Testing conducted with posts driven into strong soil is considered equivalent to testing conducted with posts driven into a combination of asphalt pavement and strong soil. However, devices securely attached to concrete pavement and devices driven into weak soil must be tested separately.

May 2018 #15. Are devices known as "Category 4" devices under NCHRP 350 (such as portable, changeable-message sign (PCMS) trailers, temporary traffic signals, and camera trailers) exempt from crash testing?

MASH contains crash testing criteria for devices previously known as "Category 4" devices. See MASH 2016, Section 2.2.3, p 36, "Truck- and Trailer-Mounted Attenuators and Portable Work-Zone Traffic Control Trailers." The AASHTO/FHWA Joint Implementation Agreement states that temporary work zone devices manufactured after December 31, 2019, must have been successfully tested to the 2016 edition of MASH.

May 2018 #16. How long may portable concrete barriers and "Category 4" devices, such as trailer-mounted arrow boards, variable message signs, etc., meeting NCHRP Report 350 crash test criteria remain in use?

As stated in the AASHTO/FHWA Joint Implementation Agreement for MASH, "Temporary work zone devices, including portable barriers, manufactured after December 31, 2019, must have been successfully tested to the 2016 edition of MASH. Such devices manufactured on or before this date, and successfully tested to NCHRP Report 350 or the 2009 edition of MASH, may continue to be used throughout their normal service lives." Temporary work zone devices include, but are not limited to, all devices that were known as "Category 4" devices under NCHRP 350, including truck- and trailer-mounted attenuators. Note that individual transportation agencies/facility owners may opt to specify MASH-compliant devices sooner than stated in the joint implementation agreement.

May 2018 #17. Who determines the "service life" for NCHRP Report 350-compliant work zone devices?

The owner-agency determines the service life of a work zone device. Decisions may be based on the use of a standard device lifetime, compliance with functional and/or visibility guidelines, or some other method.

May 2018 #18. Must individual barricade units that have been successfully crash-tested as stand-alone devices be retested if they are to be connected and used as longitudinal channelizers?

Yes. If a device is to be used for a different purpose, it needs to be tested for that purpose. See MASH 2016, Section 2.2.4.1, p 40, which states, "For systems intended to be used as stand-alone barricades, the device should be tested as a barricade. For systems designed as positive barriers, it should be crash tested as a permanent or temporary barrier as presented in Section 2.2.1. For longitudinal channelizers, or any channelizing device incorporating individual elements that are connected to form a continuous unit, these systems are considered a separate class of hardware with different testing and evaluation guidelines, as described in Section 2.2.4.2 under tests 90 and 91."

May 2018 #19. Do surface and road markers need to be tested to MASH?

There are no criteria for testing surface and road markers in MASH.

TESTING PARAMETERS

May 2018 #20. If a door opens during a crash test, is that cause for failure of a test?

Until additional research on this topic is conducted, a door opening during a crash test is not considered cause for test failure in and of itself; however, penetration of the test article and/or intrusion limits must be verified. If one or more doors open during a crash test, the test facility must document the level of intrusion and whether it exceeds the appropriate MASH criteria.

May 2018 #21. How are vehicle override and underride determined?

Override of a barrier is considered to occur if, after traveling over the uppermost element of the barrier, any part of the test vehicle touches down on the far side (i.e., non-traffic side) of the barrier. Regarding underride, until additional research is conducted, the following guidance may be used: underride is considered to occur if the vehicle comes to rest beyond the initial traffic face of the barrier and no structural member of the barrier remains in contact with a side element of the test vehicle.

BARRIERS

May 2018 #22. Which MASH 2009-compliant barriers need to be re-evaluated to MASH 2016?

Cable barriers and terminals that were tested successfully to MASH 2009 criteria will require additional review to determine if supplemental testing is required to meet MASH 2016 criteria.

May 2018 #23. Do MASH-compliant, crashworthy, concrete barriers or concrete bridge railings that are constructed taller, wider, or stronger need to be re-tested?

The geometry and strength of the concrete barrier (and, in the case of bridge rail, its connections) need to be considered to determine its crashworthiness. As barriers get taller, impact loads increase because more of the vehicle is being engaged with the barrier. Thus, if a MASH-compliant, crashworthy, concrete barrier or bridge rail is intended to be constructed taller, then a strength calculation needs to be completed to determine if the higher load anticipated during a crash will be accommodated. If the calculated load cannot be accommodated, then additional internal reinforcement may be necessary. If the same MASH-compliant barrier is constructed wider or stronger, there is no need for a barrier strength calculation. See the *AASHTO LRFD Bridge Design Specifications* and your state's bridge design specifications for additional information on the strength calculation.

May 2018 #24. Does a crashworthy bridge railing/concrete barrier need to be retested when the rebar details are adjusted to match an agency's typical bridge deck or foundation reinforcement pattern?

If the strength of the barrier and the strength of the connections are the same or greater (determined by a strength calculation) and the shape of the barrier has not changed, then no retesting is required. See the *AASHTO LRFD Bridge Design Specifications* or your state's bridge design specifications for additional information on the strength calculation.

May 2018 #25. Do safety shape, single slope, constant slope, and vertical concrete barriers or bridge rails meeting NCHRP Report 350 TL-5 and TL-6 crash test criteria also meet MASH TL-5 and TL-6 crash test criteria?

If a solid, cast-in-place concrete barrier or bridge rail (such as a safety shape, single slope, constant slope, or vertical shape), with no potential snagging elements on top, has been successfully tested to NCHRP Report 350 criteria for TL-5 or TL-6, then that barrier may be considered equivalent to MASH 2016 TL-5 or TL-6 criteria. Additional information may be found in the following NCHRP research reports: *MASH Equivalency of NCHRP Report 350-Approved Bridge Railings* and *Evaluation of Existing Roadside Safety Hardware Using Updated Criteria*.

May 2018 #26. May MASH-compliant, crashworthy w-beam, box beam, and cable barriers be used with reduced post spacing (to reduce design deflection) without the need for additional crash testing?

The crash test matrix in MASH for cable barrier provides guidance on the appropriate range of post spacings for testing (i.e., which tests should use wider or narrower spacing). For semi-rigid barriers, including w-beam and box beam, additional evaluation to MASH criteria is required if post spacing is reduced.

May 2018 #27. Do MASH TL-3-compliant devices automatically meet MASH TL-1 and TL-2?

Yes. Devices meeting MASH TL-3 crash test criteria can be considered for use as MASH TL-1 and TL-2 devices.

May 2018 #28. May crash cushions be connected to concrete barriers using previously-crash-tested guardrail-to-bridge-rail transition hardware?

This configuration needs to be evaluated to MASH 2016 criteria. Owner-agencies may approve different combinations based on testing and/or engineering analysis.

May 2018 #29. How should road closure nets be tested?

There is currently no MASH test matrix for these devices. Until additional research is conducted, owner-agencies may work with researchers and/or test facilities to develop a testing matrix that evaluates the range of a system's parameters, including varying lengths. Any test matrices developed through research will be considered by AASHTO for future inclusion in MASH.