Introduction to MASH Crash Testing

The Manual for Assessing Safety Hardware (or MASH) was developed to provide uniform guidelines for crash testing highway roadside safety devices, and to recommend evaluation criteria for crash test results. This section provides an introduction to and condensed discussion of

- MASH crash tests,
- crash test levels,
- crash test matrices, and
- evaluation criteria.

Crash Test Development

Crash test development requires a combination of worst case, or most critical, conditions and practicality. Test parameters such as vehicle, impact speed, and impact angle, as well as point of impact are selected to represent the worst case or most critical conditions. At the same time, test parameters must also allow for development of roadside safety devices to be cost effective and provide a high level of safety without being unreasonably expensive. The goal is to select vehicle masses, impact speeds, impact angles and impact points that will result in a high percentage of possible conditions. To that end, devices aren't designed to handle all possible conditions.

The combination of 85th percentile impact speed, 85th percentile impact angle, and 5th and 95th percentile vehicle weights is considered to be worst practical conditions. Investigation of run-off-the-road (ROR) crashes on high speed roadways indicates an impact speed of 62 mph and impact angle of 25 degrees approximate the 85th percentile of real world impacts. Lower impact speeds are used for lower test levels. Lower impact angles and speeds are used for large trucks due to reduced cornering capabilities and generally lower operating speeds.

Lower impact angles are also used for devices such as end terminals, crash cushions, and truck mounted attenuators since they are designed primarily for end on impacts. Crash testing on these devices has shown low angle impacts are more likely to result in serious injuries than are high angle impacts.

Impact locations are selected so they will most likely represent critical conditions that will produce a test failure. These are referred to as critical impact points (CIPs).

Numerous crash tests have been developed to evaluate roadside safety devices. Some of the devices included in this section are:

- Longitudinal barriers such as steel beam guardrail, cable barrier rail, and concrete barrier rail.
- Terminals such as end terminals and crash cushions.
- Work zone traffic control devices.
- Support structures and breakaway utility poles.

A variety of crash tests have been developed for each type of these devices.

Crash Tests

The Department relies on two facilities to perform and evaluate crash tests for non-proprietary devices: The Midwest Roadside Safety Facility (MwRSF) located at the University of Nebraska, and the Texas A&M Transportation Institute (TTI) located at Texas A&M University. Proprietary products generally rely on other testing facilities. However, on occasion they will rely on MwRSF and TTI.

> Crash tests are conducted under ideal conditions. Installations should replicate the testing conditions to the extent possible. Crash tests don't account for spinning vehicles or vehicles sliding sideways.

The text that follows is a breakdown of tests by type of roadside safety device.

Longitudinal Barriers

Semi-rigid (steel beam) and rigid (concrete): 10, 11, 20 (optional), 21, and 22.

Cable: 10, 11, 13, 14, 15, 16, 17, 18, 20 (optional), 21, and 22.

Test 10

Small car impacting at a 25 degree angle. This is a test of the ability of a barrier to redirect a vehicle. Concerns are under-ride, wheel snag, rollover, and head slap. For cable, an additional concern is damage to the A-pillar, windshield, and roof.

Test 11

Light truck impacting at a 25 degree angle. This is a maximum strength test to evaluate performance when impacted by a light truck or SUV. Rollover is also a concern with taller profile vehicles. For cable, an additional concern is damage to the A-pillar, windshield, and roof.

Test 12

Single unit (TL-4), tractor-van trailer (TL-5), or tractor-tank trailer (TL-6) impacting at a 15 degree angle. This test evaluates the strength of a barrier in containing and redirecting heavy trucks.

Test 13

Pickup truck impacting a cable barrier placed beyond the foreslope slope break point at a 25 degree angle. The test evaluates the ability of the barrier to contain and redirect light trucks and SUVs to evaluate the performance of the barrier impacted by a tall, high mass vehicle with a high bumper trajectory (relative to the ground surface).

Test 14

Small car impacting a cable barrier placed beyond the foreslope slope break point at a 25 degree angle. The test evaluates the ability of the barrier to contain and redirect a small car without instabilities and/or rollover.

Test 15

Small car impacting a cable barrier placed anywhere in a median ditch at a 25 degree angle. The test evaluates the ability of the barrier to contain and redirect a small car without under-riding the barrier and without components penetrating the vehicle and/or excessive deformation of the roof, A-pillar, or windshield.

Test 16

Small car leaving roadway at a 25 degree angle, traveling through a median ditch and up the backslope (foreslope for opposing traffic), then impacting a cable barrier placed on the backslope. Small cars traveling through a ditch can impact the barrier at a higher angle and velocity, and/or become airborne. These can result vehicle instability causing excessive vehicle deformations and/or penetrations, vehicle instability, rollover, and/or overriding the barrier. This test evaluates the ability of the barrier to contain and redirect a vehicle passing through the median and up a backslope before impacting the barrier.

Test 17

Mid-size passenger sedan impacting at a 25 degree angle. This test evaluates a cable barrier's ability to contain and redirect the vehicle by preventing the vehicle penetrating the barrier. The barrier is placed to maximize the potential for the front of the vehicle to penetrate between adjacent cables. Component penetration into the passenger compartment and deformations of the A-pillar, windshield, and roof are evaluated.

Test 18

Pickup truck leaving roadway at a 25 degree angle, traveling through a median ditch and up the backslope (foreslope for opposing traffic), then impacting a cable barrier placed on the backslope. Pickup trucks traveling through a ditch can impact the barrier at a higher angle and velocity, and/or become airborne. These can result vehicle instability causing excessive vehicle deformations and/or penetrations, vehicle instability, rollover, and/or overriding the barrier. This test evaluates the ability of the barrier to contain and redirect the vehicle passing through a median and up a backslope before impacting the barrier.

Test 20 (Optional)

This test is run to evaluate occupant risk and post-impact trajectory in a transition area. This test is run if there is a concern with impact performance of the system when impacted by a small car at a 25 degree angle.

Test 21

This test is run to evaluate occupant risk and post-impact trajectory in a transition area. This test is run if there is a concern with impact performance of the system when impacted by a pickup truck at a 25 degree angle.

Test 22

This test is run to evaluate occupant risk and post-impact trajectory in a transition area. This test is run if there is a concern with impact performance of the system when impacted by a single unit vehicle, a tractor-van trailer, or a tractor-tank trailer at a 15 degree angle.

Terminals

Guardrail end terminals (gating and non-gating): 30, 31, 32, 33, 34, 35, 36, 37a, 37b, 38.

Crash Cushions

- Redirective: 30, 31, 32, 33, 34, 35, 36, 37a, 37b, 38.
- Non-redirective: 40, 41, 42, 43, 44, 45.

Test 30

Small car impacting at a 0 degree angle and offset ¼ of the car width from the center of the car. This test is run to evaluate vehicle stability. Of particular importance is the potential for vehicle rotation. Tire interaction with rails and/or other components, such as anchors, is another important consideration.

Test 31

Pickup truck impacting at a 0 degree angle at center of the truck. This test is run to evaluate the capability of the device to stop the truck safely and in a controlled manner. For gating systems, this test also evaluates occupant risk and vehicle path after impact.

Test 32

Small car impacting at the center of the car at a 5 to15 degree (gating) or 15 degree (non-gating) impact angle. This test evaluates occupant risk and vehicle path after impact. For gating redirective systems, impact angle is chosen to maximize impact velocity and ridedown acceleration.

Test 33

Pickup truck impacting at the center of the truck at a 5 to 15 degree (gating) or 15 degree (non-gating) angle. This test evaluates occupant risk and vehicle path after impact. For gating redirective systems, impact angle is chosen to maximize impact velocity and ridedown acceleration.

Test 34

Small car impacting at the center of the car at a 15 degree angle. The impact occurs at the point where the device changes from gating or capturing to redirecting. This test evaluates occupant risk and vehicle path after impact.

Test 35

Pickup truck impacting at the center of the truck at a 25 degree angle. The impact point is at the beginning of the length of need for the system (see Section 8B-6 for more on length of need). This is the point where a device changes from gating or capturing to redirecting. For a non-gating crash cushion, this point is located near the nose of the cushion.

Test 36

Pickup truck impacting the critical impact point (CIP) of a transition at a 25 degree angle. This transition is located at the point where a terminal or redirective crash cushion attaches to a rigid barrier or other very stiff feature.

Test 37a

Pickup truck impacting at the center of the truck at a 25 degree angle. This test evaluates a reverse direction impact on a terminal or crash cushion. This test should be run for devices that could be placed in the clear zone for opposing traffic. For crash cushions that lap the panels against opposing traffic, the CIP is selected to maximize the potential to snag on the last lapped panel. Some crash cushions feature a transition that tapers down from the width of the crash cushion to the width of the barrier to which it attaches. In those cases, the CIP is chosen so the impact is on the barrier or the tapered section of the transition, maximizing the potential for snagging.

Test 37b

Small car impacting at the center of the car at a 25 degree angle. This test evaluates a reverse direction impact on a terminal or crash cushion. This test should be run for devices that could be placed in the clear zone for opposing traffic. For crash cushions that lap the panels against opposing traffic, the CIP is selected to maximize the potential to snag on the last lapped panel. For W-beam transitions, Test 37b is typically the critical test with the CIP being where snagging on the anchor cable has the highest potential.

Test 38

Mid-size passenger sedan impacting at the center of the sedan at a 0 degree angle. This test is run to evaluate capability of the device to stop the sedan safely and in a controlled manner. Since Test 31 is run with a heavier vehicle under the same impact conditions, accelerometer data from Test 31 can be used to determine if Test 38 needs to be run. If the data predicts the terminal occupant impact velocity (OIV) and occupant ridedown acceleration (ORA) for the device meet the requirements for the 3,300 pound vehicle (mid-size passenger sedan), MASH recommends not running this test.

Test 40

Small car impacting at a 0 degree angle and offset ¼ of the car width from the center of the car. This test is run to evaluate vehicle stability. Of particular importance is the potential for vehicle rotation. Tire interaction with rails and/or other components, such as anchors, is another important consideration.

Test 41

Pickup truck impacting at the center of the truck at a 0 degree angle and no offset. This test is run to evaluate capability of the device to stop the truck safely and in a controlled manner.

Test 42

Small car impacting at the center of the car at an angle of 5 to 15 degrees. This test evaluates occupant risk and vehicle path after impact. For gating redirective systems, impact angle is chosen to maximize impact velocity and ridedown acceleration.

Test 43

Pickup truck impacting at the center of the truck at an angle of 5 to 15 degrees. This test evaluates occupant risk and vehicle path after impact. For gating redirective systems, impact angle is chosen to maximize impact velocity and ridedown acceleration.

Test 44

Pickup truck impacting at the center of the truck at an angle of 20 degrees. This test evaluates the ability of a non-redirective crash cushion to safely stop a large passenger vehicle (e.g., a 5,000 pound pickup truck) with an impact along the side of the device. The vehicle should remain stable and upright.

Test 45

Mid-size passenger sedan impacting at the center of the sedan at an angle of 0 degrees. This test is run to evaluate capability of the device to stop the sedan safely and in a controlled manner. Since Test 41 is run with a heavier vehicle under the same impact conditions, accelerometer data from Test 41 can be used to determine if Test 45 needs to be run. If the data predicts the terminal occupant impact velocity (OIV) and occupant ridedown acceleration (ORA) for the device meet the requirements for the 3,300 pound vehicle (mid-size passenger sedan), MASH recommends not running this test.

Support Structures

60, 61, and 62.

Test 60

Small car at a determined critical impact angle (CIA). The CIA varies from device to device. This is a low speed test (19 mph) to determine the kinetic energy required to activate a breakaway, fracture, or yielding mechanism in a support. Excessive velocity change, component intrusion into the floor pan, windshield damage, and occupant risk are of most concern.

Test 61

Small car at a determined CIA. The CIA varies from device to device. This is a higher speed test to evaluate velocity change, vehicle instability, component intrusion into the floor pan, windshield damage, and occupant risk.

Test 62

Pickup truck at a determined CIA. The CIA varies from device to device. This is a higher speed test to evaluate velocity change, vehicle instability, component intrusion into the floor pan, windshield damage, and occupant risk.

Work Zone Traffic Control Devices

70, 71, and 72.

Test 70

Small car at a determined critical impact angle (CIA). The CIA varies from device to device. This is a low speed test (19 mph) to determine the ability of a small car to activate a breakaway, fracture, or yielding mechanism in a work zone device. This test is optional for devices weighing less than 220 pounds.

Test 71

Small car at a determined CIA. The CIA varies from device to device. This is a higher speed test to evaluate vehicle instability and component intrusion into the windshield, as well as occupant risk.

Test 72

Pickup truck at a determined CIA. The CIA varies from device to device. This is a higher speed test to evaluate vehicle instability and component intrusion into the windshield, as well as occupant risk.

Breakaway Utility Poles

80, 81, and 82.

Test 80

Small car at a 0 to 25 degree impact angle. This is a low speed test to evaluate the ability of a small car to activate the breakaway mechanism of a pole and to move the pole.

Test 81 (Test levels 1 and 2)

Small car at a 0 to 25 degree impact angle. This is a high speed test to evaluate the ability of a small car to activate the breakaway mechanism of a pole and to move the pole.

Test 82

Pickup truck at a 0 to 25 degree impact angle. This is a high speed test to evaluate the ability of a heavy passenger vehicle to activate the breakaway mechanism of a pole and to move the pole.

Crash Test Levels

Table 1 from Chapter 1 of MASH provides vehicle types and test conditions for each crash test level.

Table 1: Test Levels (source: Manual for Assessing Safety Hardware, 2016).

test level	test vehicle designation and type	test conditions	
		speed (mph)	angle (degrees)
1	1100C (passenger car) 2270P (pickup truck)	31 31	25 25
2	1100C (passenger car) 2270P (pickup truck)	44 44	25 25
3	1100C (passenger car) 2270P (pickup truck)	62 62	25 25
4	1100C (passenger car) 2270P (pickup truck) 10000S (single unit truck)	62 62 56	25 25 15
5	1100C (passenger car) 2270P (pickup truck) 36000V (tractor-van trailer)	62 62 50	25 25 15
6	1100C (passenger car) 2270P (pickup truck) 36000T (tractor-tank trailer)	62 62 50	25 25 15

The number in the vehicle designation and type is the mass of the vehicle in kilograms. The 1100C is a 2,420 pound vehicle, the 2270P is a 5,000 pound vehicle, the 10000S is a 22,000 pound vehicle, and the 36000 V and 36000T are 79,300 pound vehicles. Another less commonly used vehicle is the 1500A, which is a 3,300 pound mid-size passenger sedan.

Crash Test Matrices

Chapter 2 of MASH provides several crash test matrices. They are too long and numerous to include in this section. The purpose of these matrices is to specify a series of crash tests to evaluate a type of roadside safety device, e.g. longitudinal barriers. The tests are chosen to assess the three dynamic evaluation factors listed below.

Evaluation Criteria

Evaluation criteria consists of 3 dynamic evaluation factors: structural adequacy, occupant risk, and post-impact vehicular response. Table 2 lists all evaluation factors.

Structural Adequacy

Evaluation criteria A, B, and C in Table 2 provide safety evaluation guidelines for structural adequacy. Structural adequacy depends on the intended purpose of a feature and its ability to:

- Redirect a vehicle (e.g. W-beam guardrail or concrete barrier rail),
- Stop a vehicle in a controlled manner (e.g. non-gating terminals and crash cushions), or
- Permit a vehicle to break though the feature (e.g. gating terminals and crash cushions).

The distance an impacting vehicle extends over a barrier or penetrates into a system is referred to as the working width. For steel beam guardrail, this typically exceeds the final position of the rail after impact. Designers should evaluate working width when determining how close to an object a feature may be placed.

When a tall vehicle such as single unit truck, tractor-van trailer, or tractor-tank trailer impacts a barrier, it can lean over creating the potential for impact objects on top of or behind the barrier. The region measured above and behind the face of a barrier system where an impacting vehicle or any major part of the system may extend during an impact is called the zone of intrusion (ZOI). This is discussed in Section 8A-6. ZOI is especially important to consider for features that will protect objects such as sign trusses and bridge piers.

Occupant Risk

Evaluation criteria D through I in Table 2 provide safety evaluation guidelines for occupant risk.

Post-impact Vehicular Response

Evaluation criterion N in Table 2 provides safety evaluation guidelines for post-impact vehicular response. Post-impact vehicular response examines the potential of a vehicle to be involved in a secondary collision with other vehicles and/or other fixed objects. Except for criterion N in Table 2, penetration of the vehicle behind the test article is unacceptable. A smooth redirect of the vehicle is preferred. Excessive pocketing or snagging of the vehicle can result in a high vehicular exit angle or the vehicle spinning out of control. Post-impact behavior that results in the vehicle coming to a stop while still in contact with the barrier is acceptable; however, the stopped vehicle could interfere with oncoming motorists.

Vehicle rebound is a potential with some reusable crash cushions. Testing agencies are required to report this behavior and are to include rebound velocity and point of final rest for the vehicle. This information is crucial if potential installations involve narrow gore areas.

Chronology of Changes to Design Manual Section:

008A-007 Introduction to MASH Crash Testing

1/21/2025	NEW New. Provides an introduction to MASH crash tests and test levels.