U.S. Department
of Transportation
Federal Highway Administration

1200 New Jersey Ave., SE
Washington, D.C. 20590

March 13, 2020

In Reply Refer To:
HSST-1 / CC-157

Mr. Kaddo Kothman
Road Systems, Inc.
3616 Howard County Airport
Big Spring, TX 79720

Dear Mr. Kothman:

This letter is in response to your July 20, 2019 request for the Federal Highway Administration (FHWA) to review a roadside safety device, hardware, or system for eligibility for reimbursement under the Federal-aid highway program. This FHWA letter of eligibility is assigned FHWA control number CC-157 and is valid until a subsequent letter is issued by FHWA that expressly references this device.

Decision

The following device is eligible within the length-of-need, with details provided in the form which is attached as an integral part of this letter:

- MBEAT Terminal

Scope of this Letter

To be found eligible for Federal-aid funding, new roadside safety devices should meet the crash test and evaluation criteria contained in the American Association of State Highway and Transportation Officials'(AASHTO) Manual for Assessing Safety Hardware (MASH). However, the FHWA, the Department of Transportation, and the United States Government do not regulate the manufacture of roadside safety devices. Eligibility for reimbursement under the Federal-aid highway program does not establish approval, certification or endorsement of the device for any particular purpose or use.

This letter is not a determination by the FHWA, the Department of Transportation, or the United States Government that a vehicle crash involving the device will result in any particular outcome, nor is it a guarantee of the in-service performance of this device. Proper manufacturing, installation, and maintenance are required in order for this device to function as tested.

This finding of eligibility is limited to the crashworthiness of the system and does not cover other structural features, nor conformity with the Manual on Uniform Traffic Control Devices.

Eligibility for Reimbursement

Based solely on a review of crash test results and certifications submitted by the manufacturer, and the crash test laboratory, FHWA agrees that the device described herein meets the crash test and evaluation criteria of the AASHTO's MASH. Therefore, the device is eligible for reimbursement under the Federal-aid highway program if installed under the range of tested conditions.

Name of system: MBEAT Terminal
Type of system: Terminal
Test Level: MASH Test Level 3 (TL3)
Testing conducted by: KARCO
Date of request: July 20, 2019
Date of final package: August 16, 2019

FHWA concurs with the recommendation of the accredited crash testing laboratory on the attached form.

Full Description of the Eligible Device

The device and supporting documentation, including reports of the crash tests or other testing done, videos of any crash testing, and/or drawings of the device, are described in the attached form.

Notice

This eligibility letter is issued for the subject device as tested. Modifications made to the device are not covered by this letter. Any modifications to this device should be submitted to the user (i.e., state DOT) as per their requirements.

You are expected to supply potential users with sufficient information on design, installation and maintenance requirements to ensure proper performance.

You are expected to certify to potential users that the hardware furnished has the same chemistry, mechanical properties, and geometry as that submitted for review, and that it will meet the test and evaluation criteria of AASHTO's MASH.

Issuance of this letter does not convey property rights of any sort or any exclusive privilege. This letter is based on the premise that information and reports submitted by you are accurate and correct. We reserve the right to modify or revoke this letter if: (1) there are any inaccuracies in the information submitted in support of your request for this letter, (2) the qualification testing was flawed, (3) in-service performance or other information reveals safety problems, (4) the system is significantly different from the version that was crash tested, or (5) any other information indicates that the letter was issued in error or otherwise does not reflect full and complete information about the crashworthiness of the system.

Standard Provisions

- To prevent misunderstanding by others, this letter of eligibility designated as FHWA control number CC-157 shall not be reproduced except in full. This letter and the test documentation upon which it is based are public information. All such letters and documentation may be reviewed upon request.

- This letter shall not be construed as authorization or consent by the FHWA to use, manufacture, or sell any patented system for which the applicant is not the patent holder.

- This FHWA eligibility letter is not an expression of any Agency view, position, or determination of validity, scope, or ownership of any intellectual property rights to a specific device or design. Further, this letter does not impute any distribution or licensing rights to the requester. This FHWA eligibility letter determination is made based solely on the crash-testing information submitted by the requester. The FHWA reserves the right to review and revoke an earlier eligibility determination after receipt of subsequent information related to crash testing.

Sincerely,

Michael S. Griffith

Michael S. Griffith
Director, Office of Safety Technologies
Office of Safety

Enclosures

Request for Federal Aid Reimbursement Eligibility of Highway Safety Hardware

Submitter	Date of Request:	March 12, 2020	◉ New ○ Resubmission
	Name:	Steven Matsusaka	
	Company:	Applus IDIADA KARCO Engineering, LLC.	
	Address:	9270 Holly Road, Adelanto, CA 92301	
	Country:	United States of America	
	To:	Michael S. Griffith, Director FHWA, Office of Safety Technologies	

I request the following devices be considered eligible for reimbursement under the Federal-aid highway program.

Device & Testing Criterion - Enter from right to left starting with Test Level

!-!-!

System Type	Submission Type	Device Name / Variant	Testing Criterion	Test Level
'CC': Crash Cushions, Attenuators, & Terminals	◉ Physical Crash Testing ○ Engineering Analysis	MBEAT Terminal	AASHTO MASH	TL3

By submitting this request for review and evaluation by the Federal Highway Administration, I certify that the product(s) was (were) tested in conformity with the AASHTO Manual for Assessing Safety Hardware and that the evaluation results meet the appropriate evaluation criteria in the MASH.

Individual or Organization responsible for the product:

Contact Name:	Kaddo Kothman	Same as Submitter ☐
Company Name:	Road Systems, Inc.	Same as Submitter ☐
Address:	3616 Howard County Airport, Big Spring, TX 79720	Same as Submitter ☐
Country:	United States of America	Same as Submitter ☐

Enter below all disclosures of financial interests as required by the FHWA `Federal-Aid Reimbursement Eligibility Process for Safety Hardware Devices' document.

Road Systems, Inc. is the manufacturer and marketer of device.

Applus IDIADA KARCO Engineering, LLC (IDIADA KARCO) is an independent research and testing laboratory having no affiliation with any other entity. IDIADA KARCO is actively Involved In data acquisition and compliance/certification testing for a variety of government agencies and equipment manufacturers. The principals and staff of IDIADA KARCO have no past or present financial, contractual or organizational interest in any company or entity directly or indirectly related to the products that KARCO tests. If any financial interest should arise, other than receiving fees for testing, reporting, etc., with respect to any project, the company will provide, In writing, a full and immediate disclosure to the FHWA.

PRODUCT DESCRIPTION

(•) New Hardware or Significant Modification ( ) Modification to Existing Hardware

The MBEAT terminal is a box-beam guardrail terminal consisting of: an impact head assembly, an end terminal rail section, and a breakaway cable anchorage system with a ground strut. The terminal has a total length of 11 ft 11.3125 in. (3.6 m) from the nose of the impact head to the end of the terminal. The total as-tested installation length was 168.3 ft. (51.3 m).

The impact head assembly consists of: a front impact plate, a mandrel tube that inserts into the energy absorbing tube, and a tapered mandrel. The front impact plate has a dimension of 20.0 in. x 20.0 in. (508 mm x 508 mm) with 2.0 in. (51 mm) wide protruded edges. The mandrel tube is fabricated from a 46.0 in. (1.2 m) long section of 4.5 in. x 4.5 in. x 0.1875 in. (114 mm x 114 mm x 4.8 mm) tube and welded to the back of the impact plate on one end. The other end of the mandrel tube is inserted into the end terminal rail for a distance of approximately 22.0 in. (560 mm). A tapered mandrel with cross sectional dimension increasing from 4.5 in. x 4.5 in. (114 mm x 114 mm) to a maximum of 6.6 in. x 6.6 in. (168 mm x 168 mm) is welded to the mandrel tube upstream of the end terminal rail. Note that the inside dimensions of the box-beam rail are 5.75 in. x 5.75 in. (146 mm x 146 mm).

The end terminal rail is a 9 ft 10.75 in. (3.0 m) long section of 6.0 in. x 6.0 in. x 0.125 in. (152-mm x 152-mm x 3.2 mm) box-beam rail. A 0.25 in. (6.4 mm) deep 45° notch is cut into each of the four corners of the box-beam at the upstream end. Two (2) 2.5 in. x 2.5 in. x 0.25 in. (63.5 mm x 63.5 mm x 6.4 mm) angles are welded 2.0 in. (50 mm) upstream from the downstream end of the tube for connection to the standard box-beam rail section. Two (2) special splice plates are used to connect the end terminal rail to the standard 6 in. x 6 in. x 0.1875 in. (152 mm x 152 mm x 4.8 mm) box-beam rail. A cable anchor bracket for one end of the anchor cable is welded to the bottom of the rail in the middle. The cable anchor bracket consists of a 0.5 in. (12.7-mm) thick plate with a 1.125 in. (29 mm) diameter hole for the cable anchor and reinforced with gussets.

The breakaway cable anchorage system consists of: a breakaway end post (Post 1) and a hinged Post 2 connected with a ground strut, a cable anchorage assembly, and an angled bracket welded to the bottom of the box-beam rail. The end post has a 2.4 ft (0.7 m) long top portion constructed of 6.0 in. x 6.0 in. x 0.125 in. (152 mm x 152 mm x 3.2 mm) steel tube and a 6.0 ft (1.8 m) long bottom section constructed of W6 x 15 (W152 x 22.4) steel I-beam. The top and bottom sections are pinned together by a 0.625 in. (16 mm) diameter bolt and nut. A post-breaker is bolted to the end post on the traffic side.

Post 2 consists of one 2.8 ft (0.9 m) long top portion and a 6.0 ft (1.8 m) long bottom portion, both fabricated from W6 x 9 (W152 x 13.4) steel I-beam and pinned together by a 0.75 in. (19 mm) diameter bolt and nut. Posts 1 and 2 are spaced 6.25 ft (1.9 m) apart and connected with a ground strut. All subsequent posts from Post 3 on are standard 5 ft. 4 in. (1.6 m) long S3 x 5.7 (S75 x 8.5) steel weak posts with a standard spacing of 6.0 ft. (1.8 m).

The upstream end of the cable anchor is attached to Post 1 through a 0.625 in. (16 mm) thick, 8.0 in. (203 mm) square steel bearing plate. The downstream end of the cable anchor is attached to an angled bracket welded to the bottom of the box-beam rail. The ground strut is mounted to a second 0.625 in. (16 mm) bolt through Post 1 and by the 0.75 in. (19 mm) hinge bolt in Post 2.

Test Chronology and Design Modifications:

Test 3-30 was conducted on 05/01/18.

Tests 3-31, 32, 33, 34, 35, and 37 were conducted from 05/14/18 through 07/11/18 with two design modifications made to the original system: a retention plate was added at post 2 and the post breaker was lengthened. Complete details on these design modifications are included in Attachment A to this submission.

CRASH TESTING

By signature below, the Engineer affiliated with the testing laboratory, agrees in support of this submission that all of the critical and relevant crash tests for this device listed above were conducted to meet the MASH test criteria. The Engineer has determined that no other crash tests are necessary to determine the device meets the MASH criteria.

Engineer Name:	Steven Matsusaka	
Engineer Signature:	Steven Matsusaka Digitally signed by Steven Matsusaka DN: cn=Steven Matsusaka, email=steven.matsusaka@idiada.com, c=US Date: 2020.03.12 13:16:22 -07'00'	
Address:	9270 Holly Road, Adelanto, CA 92301	Same as Submitter ☒
Country:	United States of America	Same as Submitter ☒

A brief description of each crash test and its result:

Required Test Number	Narrative Description	Evaluation Results
3-30 (1100C)	IDIADA KARCO Test No. P38087-01. An 1100C (2,425 lb) passenger car impacting the terminal end-on at a nominal impact speed and angle of 100 km/h (62.2 mph) and 0°, respectively, with the quarter point of the vehicle aligned with the centerline of the nose of the terminal. This test is primarily intended to evaluate occupant risk and vehicle trajectory criteria. The test vehicle, a 2012 Hyundai Accent 4-door sedan weighing 2,415.1 lbs (1,095.5 kg), impacted the MBEAT Terminal at an impact speed and angle of 59.73 mph (96.12 km/h) and 0.4°, respectively. The vehicle forced the impact head down the box beam rail until the vehicle's forward motion was arrested at a point between posts 3 and 4. The vehicle then yawed clockwise before coming to rest 45.4 ft. (13.8 m) downstream and 27.2 ft. (8.3 m) left from its position at the initial point of contact with the system. The test vehicle sustained damage to its front end with negligible occupant compartment deformation. The vehicle remained upright throughout the impact event. The test article was damaged from post 1 through post 3 with approximately 14.7 ft. (4.5 m) bursting during the event. The Occupant Impact Velocities (OIV) and ridedown accelerations are within the recommended limits. The MBEAT terminal passed all evaluation criteria for Test 3-30.	PASS

Required Test Number	Narrative Description	Evaluation Results
3-31 (2270P)	IDIADA KARCO Test No. P38088-01. A 2270P (5,000 lb) pickup truck impacting the terminal end-on at a nominal impact speed and angle of 100 km/h (62.2 mph) and 0°, respectively, with the centerline of the vehicle aligned with the centerline of the nose of the terminal. This test is primarily intended to evaluate occupant risk and vehicle trajectory criteria. The test vehicle, a 2013 RAM 1500 4-door pickup truck, with a test inertial mass of 5,001.1 lbs (2,268.5 kg), impacted the MBEAT Terminal at an impact speed and angle of 62.52 mph (100.61 km/h) and 0.1°, respectively. The vehicle forced the impact head down the length of the box beam before being brought to a stop 27.4 ft, (8.4 m) downstream and 0.3 ft. (0.1 m) left from its position at the initial point of contact with the system. The test vehicle sustained damage to its front end with negligible occupant compartment deformation. The test vehicle remained upright and did not leave its lane. The test article was damaged from post 1 through post 4 with approximately 27.9 ft, (8.5 m) of the box beam bursting during the event. The Occupant Impact Velocities (OIV) and ridedown accelerations were within the recommended limits. The MBEAT terminal passed all evaluation criteria for Test 3-31. The test was conducted with the design modifications detailed in Attachment A.	PASS

3-32 (1100C)	IDIADA KARCO Test No. P38089-02. An 1100C (2,425 lb) passenger car impacting the terminal end-on at a nominal impact speed and angle of 100 km/h (62.2 mph) and 5°, respectively, with the centerline of the vehicle aligned with the centerline of the nose of the terminal. This test is primarily intended to evaluate occupant risk and vehicle trajectory criteria. The test vehicle, a 2014 Hyundai Accent 4-door sedan weighing 2,428.4 (1,101.5 kg), impacted the MBEAT Terminal at an impact speed and angle of 61.37 mph (98.76 km/h) and 6.0°, respectively. The vehicle forced the impact head down the length of the box beams until the reaching the second box beam, at which point the impact head began to rotate about its yaw axis. As the impact head rotated, the vehicle gated through the system and the vehicle's A-pillar impacted the box beam rail. The test vehicle came to rest 31.9 ft. (9.7 m) downstream and 6.2 ft. (1.9 m) right from its position at the initial point of contact with the system. The test vehicle sustained damage concentrated to its front end. The vehicle's left front fender, left A-pillar, and left side windshield were also damaged. The test vehicle remained upright throughout the impact event. The test article received damaged from post 1 through post 5. The first box beam rail burst and the second box beam rail was torn on its non-traffic side. The Occupant Impact Velocities (OIV) and ridedown accelerations were within the recommended limits. The MBEAT terminal passed all evaluation criteria for Test 3-32. The test was conducted with the design modifications detailed in Attachment A.	PASS

3-33 (2270P)	IDIADA KARCO Test No. P38104-01. A 2270P (5,000 lb) pickup truck impacting the terminal end-on at a nominal impact speed and angle of 100 km/h (62.2 mph) and 5°, respectively, with the centerline of the vehicle aligned with the centerline of the nose of the terminal. This test is primarily intended to evaluate occupant risk and vehicle trajectory criteria. The test vehicle, a 2012 RAM 1500 4-door pickup truck weighing 4,978.0 lbs (2,258.0 kg), impacted the MBEAT Terminal at an impact speed and angle of 63.60 mph (102.35 km/h) and 4.8°, respectively. The test vehicle forced the impact head down the length of the box beam before being brought to a stop 25.2 ft. (7.7 m) downstream and 2.6 ft. (0.8 m) right from its position at the initial point of contact with the system. The test vehicle sustained damage concentrated to its front end with negligible occupant compartment deformation. The test vehicle remained upright and did not leave its lane. The test article was damaged from post 1 through post 6. Approximately 20.0 ft. (6.1 m) of box beam burst and the third beam kinked at post 6. The front face of the impact head was also damaged. The Occupant Impact Velocities (OIV) and ridedown accelerations were within the recommended limits. The MBEAT terminal passed all evaluation criteria for Test 3-33. The test was conducted with the design modifications detailed in Attachment A.	PASS

3-34 (1100C)	IDIADA KARCO Test No. P38105-01. An 1100C (2,425 lb) passenger car impacting the terminal at a nominal impact speed and angle of 100 km/h (62.2 mph) and 15°, respectively, with the corner of the vehicle bumper aligned with the critical impact point (CIP) of the length of need (LON) of the terminal. This test is primarily intended to evaluate occupant risk and vehicle trajectory criteria. The test vehicle, a 2013 Hyundai Accent 4-door sedan weighing 2,438.3 lbs (1,106.0 kg), impacted the MBEAT Terminal 32.0 in. (813 mm) downstream from post 1 at an impact speed and angle of 62.59 mph (100.73 km/h) and 15.1°, respectively. The vehicle was contained and redirected by the terminal and box beam before separating from the article near post 6 and coming to rest 200.7 ft. (61.2 m) downstream and 17.5 ft. (5.3 m) left from its position at the initial point of contact with the system. The vehicle remained upright and stable throughout the impact event and did not leave its lane. The test vehicle sustained damage concentrated to its right front side with negligible occupant compartment deformation. The test article was damaged from post 1 through post 5. The Occupant Impact Velocities (OIV) and ridedown accelerations were within the recommended limits. The MBEAT terminal passed all evaluation criteria for Test 3-34. The test was conducted with the design modifications detailed in Attachment A.	PASS

3-35 (2270P)	IDIADA KARCO Test No. P38086-03. A 2270P (5,000 lb) pickup truck impacting the terminal at a nominal impact speed and angle of 100 km/h (62.2 mph) and 25°, respectively, with the corner of the vehicle bumper aligned with the beginning of the LON of the terminal. This test is primarily intended to evaluate structural adequacy and vehicle trajectory criteria. The test vehicle, a 2012 RAM 1500 4-door pickup truck weighing 5,003.3 lbs (2,269.5 kg), impacted the MBEAT Terminal 2.0 in. (51 mm) upstream of post 3 at an impact speed and angle of 65.31 mph (105.11 km/h) and 24.8°, respectively. The vehicle was contained and redirected by the terminal and box beam, exiting the system approximately 1.24 s after impact. After exiting, the vehicle impacted the system a second time before coming to rest 126.4 ft. (38.5 m) downstream and 2.1 ft. (0.6 m) right from its position at the initial point of contact with the system. The vehicle remained upright and did not leave its lane throughout the impact event. The test vehicle sustained damage concentrated to its right front end with negligible occupant compartment deformation. The test article was damaged from post 1 through post 11. The Occupant Impact Velocities (OIV) and ridedown accelerations were within the recommended limits. The MBEAT terminal passed all evaluation criteria for Test 3-35. The test was conducted with the design modifications detailed in Attachment A.	PASS
3-36 (2270P)	MASH Test Designation 3-36. A 2270P (5,000 lb) pickup truck impacting the terminal at a nominal Impact speed and angle of 100 km/h (62 mph) and 25°, respectively, with the corner of the vehicle bumper aligned with the critical Impact point (CIP) with respect to the transition to the stiff barrier or backup structure. This test is primarily intended to evaluate the performance of the terminal when connected to a stiff barrier or a backup structure. As a box beam terminal, the MBEAT Terminal is designed to attach to box beam barriers. Transitions to alternative barriers downstream of the terminal will require case-by-case evaluation.	Non-Relevant Test, not conducted

3-37 (2270P)	IDIADA KARCO Test No. P38163-01. An 1100C (2,425 lb) passenger car impacting the terminal at a nominal impact speed and angle of 100 km/h (62.2 mph) and 25°, respectively, at Post 3 in the reverse direction. This test is intended to evaluate the performance of a terminal for a "reverse" hit. The test vehicle, a 2015 Kia Rio 4-door sedan weighing 2,405.2 lbs (1,091.0 kg), impacted the MBEAT Terminal 2.3 in. (58 mm) upstream of post 3 at an impact speed and angle of 62.04 mph (99.84 km/h) and 25.6°, respectively. The test vehicle impacted post 2, post 1, and the impact head before gating through and exiting the system at a velocity of 35.30 mph (56.81 km/h). The test vehicle came to rest 103.1 ft. (31.4 m) downstream and 43.8 ft. (13.4 m) right from its position at the initial point of contact with the system. The vehicle remained upright and stable throughout the impact event. The test vehicle sustained damage concentrated the front end and right front side and minimal occupant compartment deformations. The test article was damaged from post 1 through post 3. he Occupant Impact Velocities (OIV) and ridedown accelerations were within the recommended limits. The MBEAT terminal passed all evaluation criteria for Test 3-37. The test was conducted with the design modifications detailed in Attachment A.	PASS
3-38 (1500A)	MASH Test Designation 3-38. A1500A (3,307 lb) passenger car impacting the terminal end-on at a nominal impact speed and angle of 100 km/h (62.2 mph) and 0°, respectively, with the center line of the vehicle aligned with the center line of the nose of the terminal. This test is primarily intended to evaluate the performance of the staged attenuator/ terminal when impacted by a mid-size vehicle. The MBEAT Terminal is not a staged device, because the force required to move the Impact head down the rail does not change.	Non-Relevant Test, not conducted
3-40 (1100C)	Test for non-redirective crash cushion, not applicable for terminals	Non-Relevant Test, not conducted
3-41 (2270P)	Test for non-redirective crash cushion, not applicable for terminals	Non-Relevant Test, not conducted
3-42 (1100C)	Test for non-redirective crash cushion, not applicable for terminals	Non-Relevant Test, not conducted
3-43 (2270P)	Test for non-redirective crash cushion, not applicable for terminals	Non-Relevant Test, not conducted

3-44 (2270P)	Test for non-redirective crash cushion, not applicable for terminals	Non-Relevant Test, not conducted
3-45 (1500A)	Test for non-redirective crash cushion, not applicable for terminals	Non-Relevant Test, not conducted

Full Scale Crash Testing was done in compliance with MASH by the following accredited crash test laboratory (cite the laboratory's accreditation status as noted in the crash test reports.):

Laboratory Name:	Applus IDIADA KARCO Engineering, LLC.	
Laboratory Signature:	Steven Matsusaka Digitally signed by Steven Matsusaka DN: cn=Steven Matsusaka, email=steven.matsusaka@idiada.com, c=US Date: 2020.03.12 13:16:39 -07'00'	
Address:	9270 Holly Road, Adelanto, CA 92301	Same as Submitter ☒
Country:	United States of America	Same as Submitter ☒
Accreditation Certificate Number and Dates of current Accreditation period :	TL 371: July 1, 2019 - July 1, 2022	

Submitter Signature*: Steven Matsusaka Digitally signed by Steven Matsusaka DN: cn=Steven Matsusaka, email=steven.matsusaka@idiada.com, c=US Date: 2020.03.12 13:16:52 -07'00'

Submit Form

ATTACHMENTS

Attach to this form:

1) Additional disclosures of related financial interest as indicated above.
2) A copy of the full test report, video, and a Test Data Summary Sheet for each test conducted in support of this request.
3) A drawing or drawings of the device(s) that conform to the Task Force-13 Drawing Specifications [Hardware Guide Drawing Standards]. For proprietary products, a single isometric line drawing is usually acceptable to illustrate the product, with detailed specifications, intended use, and contact information provided on the reverse. Additional drawings (not in TF-13 format) showing details that are relevant to understanding the dimensions and performance of the device should also be submitted to facilitate our review.

FHWA Official Business Only:

Eligibility Letter		
Number	Date	Key Words

MASH 2016 Test 3-30 Summary

0.000 s 0.050 s 0.250 s 0.400 s 0.900 s

GENERAL INFORMATION	
Test Agency	KARCO Engineering, LLC.
KARCO Test No.	P38087-01
Test Designation	3-30
Test Date	05/01/18
TEST ARTICLE	
Name / Model	MBEAT
Type	Box Beam End Terminal
Installation Length	168.3 ft. (51.3 m)
Terminal Length	11.9 ft. (3.6 m)
Road Surface	Medium to Fine Silty Soil
TEST VEHICLE	
Type / Designation	1100C
Year, Make, and Model	2012 Hyundai Accent
Curb Mass	2,486.8 lbs (1,128.0 kg)
Test Inertial Mass	2,486.8 lbs (1,128.0 kg)
Gross Static Mass	2,415.1 lbs (1,095.5 kg)

Impact Conditions	
Impact Velocity	59.73 mph (96.12 km/h)
Impact Angle	0.4°
Location / Orientation	17.0 in. (432 mm) Offset
Kinetic Energy	288.0 kip-ft (390.5 kJ)
Exit Conditions	
Exit Velocity	10.1 mph (16.3 km/h)
Exit Angle	76.8°
Final Vehicle Position	45.4 ft. (13.8 m) Downstream 27.2 ft. (8.3 m) Left
Exit Box Criteria Met	N/A
Vehicle Snagging	Satisfactory
Vehicle Pocketing	Satisfactory
Vehicle Stability	Satisfactory
Maximum Roll Angle	5.9 °
Maximum Pitch Angle	-6.5 °
Maximum Yaw Angle	137.4 °

Occupant Risk	
Longitudinal OIV	27.2 ft/s (8.3 m/s)
Lateral OIV	0.7 ft/s (0.2 m/s)
Longitudinal RA	-9.9 g
Lateral RA	3.9 g
THIV	27.6 ft/s (8.4 m/s)
PHD	10.4 g
ASI	0.74
Test Article Deflections	
Static	2.3 ft (0.7 m)
Dynamic	9.7 ft (3.0 m)
Working Width	10.2 ft (3.1 m)
Debris Field	78.7 ft. (24.0 m) Downstream 25.3 ft. (7.7 m) Right
Vehicle Damage	
Vehicle Damage Scale	12FDEW2
CDC	12-FD-3
Maximum Intrusion	0.7 in. (18 mm)

Figure 4 Summary of Test 3-30

MASH 2016 Test 3-31 Summary

0.000 s 0.050 s 0.125 s 0.350 s 0.900 s

GENERAL INFORMATION	
Test Agency	KARCO Engineering, LLC.
KARCO Test No	P38088-01
Test Designation	3-31
Test Date	05/15/18
TEST ARTICLE	
Name / Model	MBEAT
Type	Box Beam Terminal
Installation Length	168.3 ft. (51.3 m)
Terminal Length	11.9 ft. (3.6 m)
Road Surface	Medium to Fine Silty Soil
TEST VEHICLE	
Type / Designation	2270P
Year, Make, and Model	2013 RAM 1500
Curb Mass	5,035.3 lbs (2,284.0 kg)
Test Inertial Mass	5,001.1 lbs (2,268.5 kg)
Gross Static Mass	5,001.1 lbs (2,268.5 kg)

Impact Conditions	
Impact Velocity	62.52 mph (100.61 km/h)
Impact Angle	0.1°
Location / Orientation	0.5 in. (13 mm) Left of CL
Kinetic Energy	653.4 kip-ft (885.9 kJ)
Exit Conditions	
Exit Velocity	N/A
Exit Angle	N/A
Final Vehicle Position	27.4 ft. (8.4 m) Downstream 0.3 ft. (0.1 m) Left
Exit Box Criteria Met	N/A
Vehicle Snagging	Satisfactory
Vehicle Pocketing	Satisfactory
Vehicle Stability	Satisfactory
Maximum Roll Angle	4.1 °
Maximum Pitch Angle	1.7 °
Maximum Yaw Angle	-2.7 °

Occupant Risk	
Longitudinal OIV	25.3 ft/s (7.7 m/s)
Lateral OIV	0.7 ft/s (0.2 m/s)
Longitudinal RA	-17.8 g
Lateral RA	-2.2 g
THIV	25.3 ft/s (7.7 m/s)
PHD	17.9 g
ASI	0.84
Test Article Deflections	
Static	N/A
Dynamic	N/A
Working Width	2.2 ft. (0.7 m)
Debris Field	135.0 ft. (41.1 m) Downstream 8.1 ft. (2.5 m) Right
Vehicle Damage	
Vehicle Damage Scale	12FDEW2
CDC	12-FD-4
Maximum Intrusion	0.4 in. (10 mm)

Figure 4 Summary of Test 3-31

MASH 2016 Test 3-32 Summary

0.000 s 0.125 s 0.300 s 0.700 s 1.800 s

GENERAL INFORMATION

Test Agency	KARCO Engineering, LLC.
KARCO Test No	P38089-02
Test Designation	3-32
Test Date	05/15/18

TEST ARTICLE

Name / Model	MBEAT
Type	Box Beam Terminal
Installation Length	168.3 ft. (51.3 m)
Terminal Length	11.9 ft. (3.6 m)
Road Surface	Medium to Fine Silty Soil

TEST VEHICLE

Type / Designation	1100C
Year, Make, and Model	2014 Hyundai Accent
Curb Mass	2,485.7 lbs (1,127.5 kg)
Test Inertial Mass	2,428.4 lbs (1,101.5 kg)
Gross Static Mass	2,595.9 lbs (1,177.5 kg)

Impact Conditions

Impact Velocity	61.37 mph (98.77 km/h)
Impact Angle	6.0°
Location / Orientation	1.9 in. (48 mm) From Center
Kinetic Energy	305.7 kip-ft (414.5 kJ)

Exit Conditions

Exit Velocity	N/A
Exit Angle	N/A
Final Vehicle Position	31.9 ft. (9.7 m) Downstream 6.2 ft. (1.9 m) Right
Exit Box Criteria Met	N/A
Vehicle Snagging	None
Vehicle Pocketing	None
Vehicle Stability	Satisfactory
Maximum Roll Angle	5.0 °
Maximum Pitch Angle	8.8 °
Maximum Yaw Angle	-23.1 °

Occupant Risk

Longitudinal OIV	29.2 ft/s (8.9 m/s)
Lateral OIV	1.0 ft/s (0.3 m/s)
Longitudinal RA	-17.1 g
Lateral RA	4.3 g
THIV	29.2 ft/s (8.9 m/s)
PHD	17.3 g
ASI	1.05

Test Article Deflections

Static	2.5 ft. (0.8 m)
Dynamic	7.1 ft. (2.2 m)
Working Width	12.8 ft. (3.9 m)
Debris Field	30.9 ft. (9.4 m) Downstream 12.8 ft. (3.9 m) Right

Vehicle Damage

Vehicle Damage Scale	12-FD-5
CDC	12FDEW3
Maximum Intrusion	0.6 in. (15 mm)

Figure 4 Summary of Test 3-32

MASH 2016 Test 3-33 Summary

0.000 s 0.150 s 0.250 s 0.550 s 1.100 s

GENERAL INFORMATION	
Test Agency	KARCO Engineering, LLC.
KARCO Test No	P38104-01
Test Designation	3-33
Test Date	07/05/18
TEST ARTICLE	
Name / Model	MBEAT
Type	Box Beam Terminal
Installation Length	168.3 ft. (51.3 m)
Terminal Length	11.9 ft. (3.6 m)
Road Surface	Medium to Fine Silty Soil
TEST VEHICLE	
Type / Designation	2270P
Year, Make, and Model	2012 RAM 1500
Curb Mass	4,905.2 lbs (2,225.0 kg)
Test Inertial Mass	4,978.0 lbs (2,258.0 kg)
Gross Static Mass	4,978.0 lbs (2,258.0 kg)

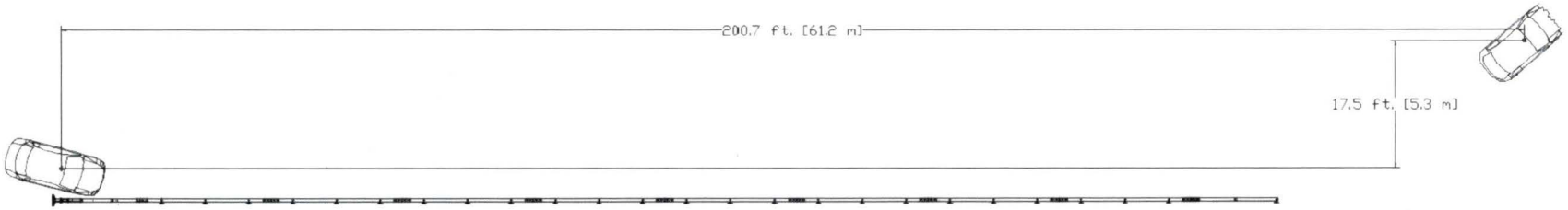
Impact Conditions	
Impact Velocity	63.60 mph (102.35 km/h)
Impact Angle	4.8°
Location / Orientation	2.1 in. (53 mm) Left of CL
Kinetic Energy	673.1 kip-ft (912.6 kJ)
Exit Conditions	
Exit Velocity	N/A
Exit Angle	N/A
Final Vehicle Position	25.2 ft. (7.7 m) Downstream 2.6 ft. (0.8 m) Right
Exit Box Criteria Met	N/A
Vehicle Snagging	None
Vehicle Pocketing	None
Vehicle Stability	Satisfactory
Maximum Roll Angle	4.2 °
Maximum Pitch Angle	4.2 °
Maximum Yaw Angle	-7.8 °

Occupant Risk	
Longitudinal OIV	28.5 ft/s (8.7 m/s)
Lateral OIV	0.7 ft/s (0.2 m/s)
Longitudinal RA	-7.7 g
Lateral RA	-1.3 g
THIV	28.5 ft/s (8.7 m/s)
PHD	7.7 g
ASI	0.61
Test Article Deflections	
Static	2.1 ft. (0.6 m)
Dynamic	9.8 ft. (3.0 m)
Working Width	9.8 ft. (3.0 m)
Debris Field	99.7 ft. (30.4 m) Downstream 3.9 ft. (1.2 m) Right
Vehicle Damage	
Vehicle Damage Scale	12FDEW2
CDC	12-FD-4
Maximum Intrusion	0.3 in. (8 mm)

Figure 4 Summary of Test 3-33

MASH 2016 Test 3-34 Summary

0.600 s 0.350 s 0.225 s 0.050 s 0.000 s



GENERAL INFORMATION	
Test Agency	KARCO Engineering, LLC.
KARCO Test No	P38105-01
Test Designation	3-34
Test Date	07/05/18
TEST ARTICLE	
Name / Model	MBEAT
Type	Box Beam End Terminal
Installation Length	168.3 ft. (51.3 m)
Terminal Length	11.9 ft. (3.6 m)
Road Surface	Medium to Fine Silty Soil
TEST VEHICLE	
Type / Designation	1100C
Year, Make, and Model	2013 Hyundai Accent
Curb Mass	2,390.9 lbs (1,084.5 kg)
Test Inertial Mass	2,438.3 lbs (1,106.0 kg)
Gross Static Mass	2,593.7 lbs (1,176.5 kg)

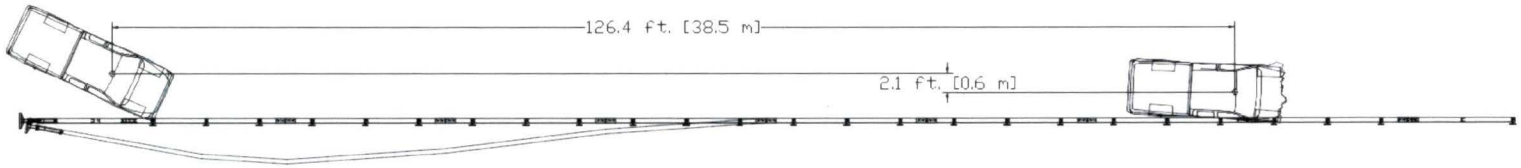
Impact Conditions	
Impact Velocity	62.59 mph (100.73 km/h)
Impact Angle	15.1°
Location / Orientation	32.5 in. (826 mm) from P1
Impact Severity	21.7 kip-ft (29.4 kJ)
Exit Conditions	
Exit Velocity	45.80 mph (73.71 km/h)
Exit Angle	1.9°
Final Vehicle Position	200.7 ft. (61.2 m) Downstream 17.5 ft. (5.3 m) Left
Exit Box Criteria Met	Yes
Vehicle Snagging	None
Vehicle Pocketing	None
Vehicle Stability	Satisfactory
Maximum Roll Angle	10.3 °
Maximum Pitch Angle	3.4 °
Maximum Yaw Angle	-23.0 °

Occupant Risk	
Longitudinal OIV	12.1 ft/s (3.7 m/s)
Lateral OIV	14.4 ft/s (4.4 m/s)
Longitudinal RA	-11.0 g
Lateral RA	-4.9 g
THIV	18.4 ft/s (5.6 m/s)
PHD	11.2 g
ASI	0.52
Test Article Deflections	
Static	1.7 ft. (0.5 m)
Dynamic	2.4 ft. (0.7 m)
Working Width	3.7 ft. (1.1 m)
Debris Field	137.4 ft. (41.9 m) Downstream 35.1 ft. (10.7 m) Left
Vehicle Damage	
Vehicle Damage Scale	01RFEW4
CDC	01-RFQ-5
Maximum Intrusion	0.2 in. (5 mm)

Figure 4 Summary of Test 3-34

MASH 2016 Test 3-35 Summary

0.000 s 0.150 s 0.250 s 0.550 s 0.700 s



GENERAL INFORMATION	
Test Agency	KARCO Engineering, LLC.
KARCO Test No	P38086-03
Test Designation	3-35
Test Date	05/14/18
TEST ARTICLE	
Name / Model	MBEAT
Type	Box Beam Terminal
Installation Length	168.3 ft. (51.3 m)
Terminal Length	11.9 ft. (3.6 m)
Road Surface	Medium to Fine Silty Soil
TEST VEHICLE	
Type / Designation	2270P
Year, Make, and Model	2012 RAM 1500
Curb Mass	4,944.9 lbs (2,243.0 kg)
Test Inertial Mass	5,003.3 lbs (2,269.5 kg)
Gross Static Mass	5,003.3 lbs (2,269.5 kg)

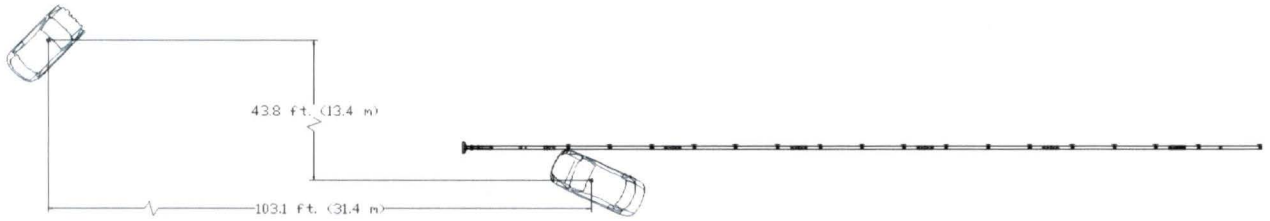
Impact Conditions	
Impact Velocity	65.31 mph (105.11 km/h)
Impact Angle	24.8°
Location / Orientation	2.0 in. (51 mm) Upstream P3
Impact Severity	125.5 kip-ft (170.2 kJ)
Exit Conditions	
Exit Velocity	Out of Camera View
Exit Angle	Out of Camera View
Final Vehicle Position	126.4 ft. (38.5 m) Downstream
	2.1 ft. (0.6 m) Right
Exit Box Criteria Met	Yes
Vehicle Snagging	None
Vehicle Pocketing	None
Vehicle Stability	Satisfactory
Maximum Roll Angle	9.8 °
Maximum Pitch Angle	2.6 °
Maximum Yaw Angle	-32.0 °

Occupant Risk	
Longitudinal OIV	11.5 ft/s (3.5 m/s)
Lateral OIV	9.8 ft/s (3.0 m/s)
Longitudinal RA	-4.4 g
Lateral RA	-4.4 g
THIV	14.4 ft/s (4.4 m/s)
PHD	6.1 g
ASI	0.46
Test Article Deflections	
Static	4.6 ft. (1.4 m)
Dynamic	6.3 ft. (1.9 m)
Working Width	6.8 ft. (2.1 m)
Debris Field	68.7 ft. (20.9 m) Downstream
	7.4 ft. (2.3 m) Left
Vehicle Damage	
Vehicle Damage Scale	01RFEW3
CDC	01-RFQ-4
Maximum Intrusion	0.2 in. (5 mm)

Figure 4 Summary of Test 3-35

MASH 2016 Test 3-37b Summary

0.000 s 0.150 s 0.275 s 0.475 s 0.800 s



GENERAL INFORMATION

Test Agency	KARCO Engineering, LLC.
KARCO Test No	P38163-01
Test Designation	3-37b
Test Date	07/11/18

TEST ARTICLE

Name / Model	MBEAT
Type	Box Beam End Terminal
Installation Length	114.2 ft. (34.8 m)
Terminal Length	11.9 ft. (3.6 m)
Road Surface	Medium to Fine Silty Soil

TEST VEHICLE

Type / Designation	1100C
Year, Make, and Model	2015 Kia Rio
Curb Mass	2,492.3 lbs (1,130.5 kg)
Test Inertial Mass	2,405.2 lbs (1,091.0 kg)
Gross Static Mass	2,572.8 lbs (1,167.0 kg)

Impact Conditions

Impact Velocity	62.04 mph (99.84 km/h)
Impact Angle	25.6°
Location / Orientation	2.3 in. (58 mm) from P3
Impact Severity	57.8 kip-ft (78.3 kJ)

Exit Conditions

Exit Velocity	35.30 mph (56.81 km/h)
Exit Angle	5.1°
Final Vehicle Position	103.1 ft. (31.4 m) Downstream 43.8 ft. (13.4 m) Right
Exit Box Criteria Met	N/A
Vehicle Snagging	None
Vehicle Pocketing	None
Vehicle Stability	Satisfactory
Maximum Roll Angle	-3.2 °
Maximum Pitch Angle	12.5 °
Maximum Yaw Angle	20.7 °

Occupant Risk

Longitudinal OIV	31.2 ft/s (9.5 m/s)
Lateral OIV	11.8 ft/s (3.6 m/s)
Longitudinal RA	-13.1 g
Lateral RA	-7.9 g
THIV	33.1 ft/s (10.1 m/s)
PHD	13.2 g
ASI	0.91

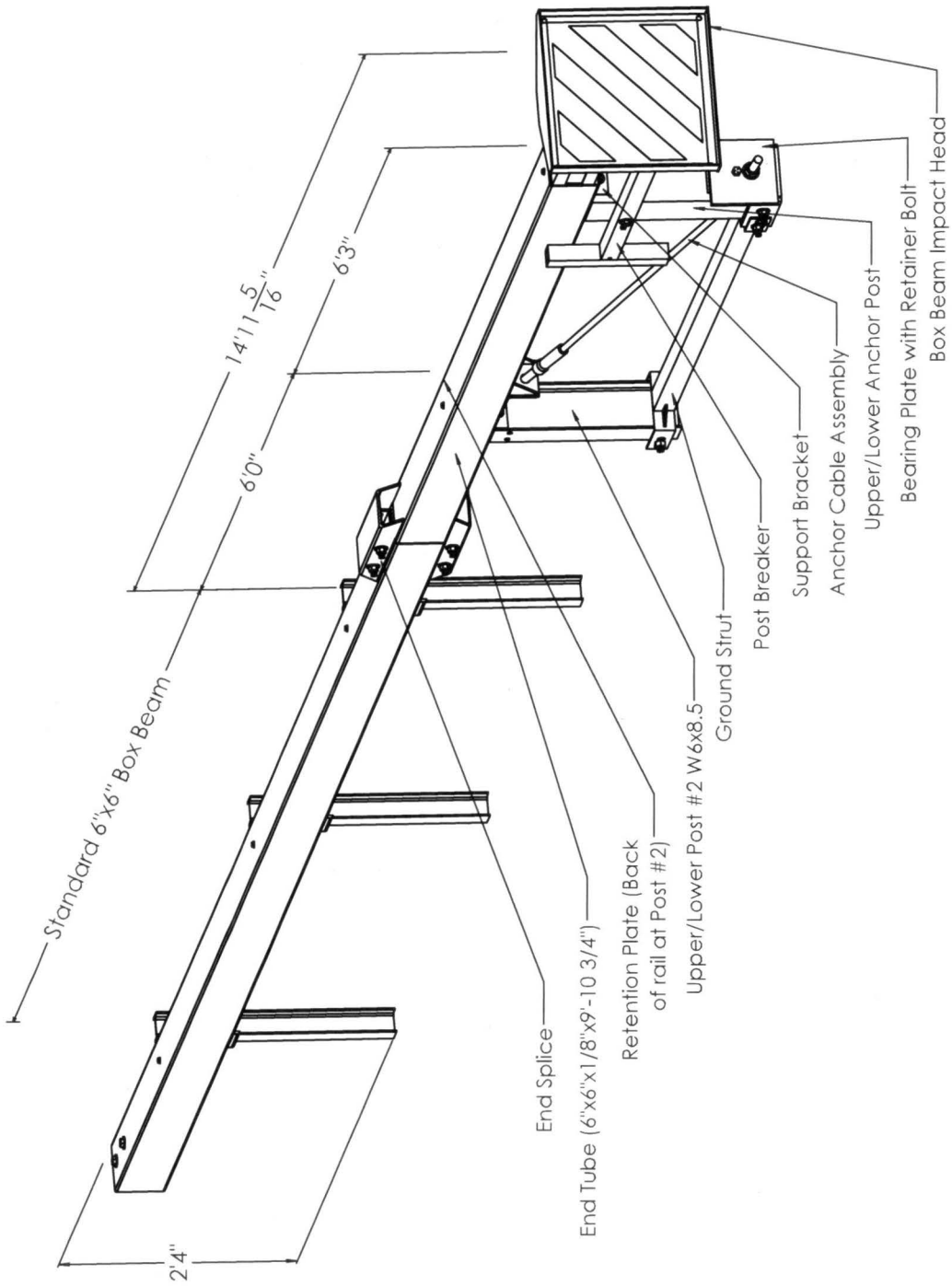
Test Article Deflections

Static	2.7 ft. (0.8 m)
Dynamic	9.1 ft. (2.8 m)
Working Width	10.8 ft. (3.3 m)
Debris Field	78.2 ft. (23.8 m) Downstream 59.4 ft. (18.1 m) Right

Vehicle Damage

Vehicle Damage Scale	01-FD-5
CDC	01FDEW3
Maximum Intrusion	0.5 in. (13 mm)

Figure 4 Summary of Test 3-37b



MBEAT – MASH BEAT – Box Beam System

Road Systems Inc.

SEB05b

SHEET NO.	DATE
1 of 2	10–12–18

INTENDED USE

The M**BEAT** (MASH BEAT) is a roadside energy-absorbing terminal used to protect the ends of 6" x 6" (150 x 150) box beam barriers that has been designed and tested under MASH criteria. It is supported by two steel breakaway end posts connected by a strut and standard 3" x 5.7# (75 x 8.5) I beam weak posts. The MBEAT is approximately 15 feet (4.6m) long and has a rail height of 2'-4" (710 mm). The additional energy absorbing capacity is achieved as the impact head activates the standard downstream box beam sections.

During end-on impacts, the vehicle forces the mandrel portion of the MBEAT impact head into the end of the box beam section causing the tube to burst. The four walls of the tube are then peeled back. The end tube wall thickness is 1/8" (3mm), which is thinner than the 3/16" (5mm) downstream box beam.

The MBEAT is a cable-anchored system. When impacted on the traffic side within the length of need and within design limits, the MBEAT contains and redirects the errant vehicle back toward its original travel path. A gusset plate is welded to the end tube section to anchor the downstream end of the cable. The cable is bolted into place for traffic face redirection impacts. The tension in the cable is released for end-on impacts when breakaway post #1 is fractured.

ACCEPTANCE

FHWA Letter CC-xx, x x, 2018 - MBEAT Test Level 3

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