U.S. Department
of Transportation
Federal Highway Administration

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

December 27, 2016

In Reply Refer To:
HSST-1/CC-126C

Mr. Kaddo Kothman
Road Systems, Inc.
36 161 Howard County Airport
Big Spring, TX 79720

Dear Mr. Kothman:

This letter is in response to the, 2016, request from Balbino Beltran 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-126C and is valid until a subsequent letter is issued by FHWA that expressly references this device.

Decision

The following devices are eligible, with details provided in the form which is attached as an integral part of this letter:

- MSKT- SP-MGS (MASH Sequential Kinking Terminal, Standard Posts, Midwest Guardrail System) with Wood Posts.

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' 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

FHWA previously issued an eligibility letter for the roadside safety system described in your pending request. Your pending request now identifies a modification to that roadside safety system.

The original roadside safety device information is provided here:

Name of system:	MSKT- MASH Sequential Kinking Terminal
Type of system:	W-Beam Guardrail Terminal
Date of original request:	January 20, 2016
Original FHWA eligibility letter:	September 21, 2016
FHWA Control number:	CC-126

The pending modification(s) consists of the following changes:

1. Use of CRT wood posts in post locations 3 through 8.

FHWA concurs with the recommendation of the accredited crash testing laboratory as stated within 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

If a manufacturer makes any modification to any of their roadside safety hardware that has an existing eligibility letter from FHWA, the manufacturer must notify FHWA of such modification with a request for continued eligibility for reimbursement. The notice of all modifications to a device must be accompanied by:

- Significant modifications – For these modifications, crash test results must be submitted with accompanying documentation and videos.
- Non-signification modifications – For these modifications, a statement from the crash test laboratory on the potential effect of the modification on the ability of the device to meet the relevant crash test criteria.

FHWA's determination of continued eligibility for the modified hardware will be based on whether the modified hardware will continue to meet the relevant crash test criteria.

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 the 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 numbers CC-126C 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.

- If the subject device is a patented product it may be considered to be proprietary. If proprietary systems are specified by a highway agency for use on Federal-aid projects: (a) they must be supplied through competitive bidding with equally suitable unpatented items; (b) the highway agency must certify that they are essential for synchronization with the existing highway facilities or that no equally suitable alternative exists; or (c) they must be used for research or for a distinctive type of construction on relatively short sections of road for experimental purposes. Our regulations concerning proprietary products are contained in Title 23, Code of Federal Regulations, Section 635.411.

Sincerely yours,

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:	September 6, 2016	◉ New ○ Resubmission
	Name:	Balbino A. Beltran	
	Company:	KARCO Engineering, LLC.	
	Address:	9270 Holly Road Adelanto, CA 92301	
	Country:	United States	
	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	MSKT 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 Kothmann	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	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.

KARCO Engineering, LLC is an independent research and testing laboratory having no affiliation with any other entity. The company is solely-owned and operated by Mr. Frank D. Richardson and Ms. Jennifer W. Peng (husband and wife) and was established on September 2, 1994. 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 KARCO Engineering 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 Non-Significant

The MSKT-SP-MGS (MASH Sequential Kinking Terminal - Standard Post - Midwest Guardrail System) terminal, as approved in CC-126 dated June 10, 2016, is a W-beam guardrail terminal consisting of an impact head assembly, a breakaway cable anchorage system and a 12.5 ft (3.8 m) end section. The system requires use of 37.5 ft (11.4 m) of standard guardrail downstream mounted on 8-in. (203-mm) deep wood or composite blocks and 6 ft (1.8 m) long W6x9 (or W6x8.5) steel posts. A 9.4 ft (2.9 m) W-beam rail section is required downstream of Post 3 to transition the rail splices to mid-span.

Some States specify the use of wood posts instead of steel posts for their guardrail systems. To accommodate the needs of these States, it is requested that the use of a wood-post version be approved for the MSKT terminal. From an impact standpoint, it is our opinion that the steel-post system is more critical than the wood-post system. Refer to the complete product description for the analysis and reasoning behind this conclusion.

CRASH TESTING

By signature below, the Engineer affiliated with the testing laboratory, agrees in support of this submission that the Modification to Existing Hardware is deemed Non-significant for the device listed above to meet the MASH criteria.

Engineer Name:	Balbino A. Beltran	
Engineer Signature:	Balbino A. Beltran Digitally signed by Balbino A. Beltran DN: cn=Balbino A. Beltran, o=KARCO Engineering, LLC., ou, email=abeltran@karco.com, c=US Date: 2016.09.06 18:23:00 -07'00'	
Address:	9270 Holly Road Adelanto, CA 92301	Same as Submitter ☒
Country:	United States	Same as Submitter ☒

A brief description of each crash test and its result:

Required Test Number	Narrative Description	Evaluation Results
3-30 (1100C)	KARCO Test No. P35125-01. 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 degrees, respectively, with the quarter point of the vehicle aligned with the center line of the nose of the terminal. This test is primarily intended to evaluate occupant risk and vehicle trajectory criteria. The test vehicle, a 2009 Kia Rio 4-door sedan weighing 2,390.9 lb (1,084.5 kg), impacted the MASH SKT terminal head on at impact speed and angle of 61.54 mph (99.05 km/h) and 0.9 degree, respectively. The vehicle pushed the impact head down the length of the guardrail past the fifth post, at which point the rail began to buckle and the vehicle began to yaw counter-clockwise until it impacted the rail at the bend before coming to a stop next to the rail on the traffic side. The test vehicle sustained moderate damage to the front end with no occupant compartment deformation. The vehicle remained upright without excessive roll or pitch. The test article was extensively damage from Post 1 through Post 5 and the rail wrapped around Post 6. The Occupant Impact Velocities (OIV) and ridedown accelerations are within the recommended limits. The MSKT-SP-MGS terminal passed all evaluation criteria for Test 3-30.	Modification has no effect on crashworthiness

Required Test Number	Narrative Description	Evaluation Results
3-31 (2270P)	KARCO Test No. P34149-01. 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 degrees, 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 occupant risk and vehicle trajectory criteria. The test vehicle, a 2008 Dodge Ram 4-door pickup truck, with a test inertial mass weighing 4,896.4 lb (2,221 kg). impacted the MASH SKT terminal head-on at impact speed and angle of 62.33 mph (100.31 km/h) and 0.4 degrees, respectively. The vehicle pushed the impact head down the length of the guardrail past Post 8 and came to rest 50.5 ft (15.4 m) from the point of initial impact The test vehicle sustained moderate damage to the front end with no occupant compartment deformation. The vehicle remained upright and stable. The test article was extensively damaged from Post 1 through Post 8. The Occupant Impact Velocities (OIV) and ridedown accelerations are within the recommended limits. The MSKT-SP terminal passed all evaluation criteria for Test 3-31.	Modification has no effect on crashworthiness

3-32 (1100C)	KARCO Test No. P35025-01. 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 5 degrees, 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 occupant risk and vehicle trajectory criteria. The test vehicle, a 2010 Kia Rio 4-door sedan weighing 2,457.0 lb (1,114.5 kg), impacted the MASH SKT terminal head-on at impact speed and angle of 61.47 mph (98.93 km/h) and 4.4 degrees, respectively. The vehicle pushed the impact head down the length of the guardrail past the fifth post, at which point the vehicle mounted the guardrail. Upon dismounting the rail, the vehicle proceeded forward and to the left and remained upright throughout the impact sequence. The test vehicle sustained moderate damage to the front and left side with no occupant compartment deformation. The vehicle remained upright and stable. The test article was extensively damaged from Post 1 through Post 5. The Occupant Impact Velocities (OIV) and ridedown accelerations are within the recommended limits. The MSKT-SP-MGS terminal passed all evaluation criteria for Test 3-32.	Modification has no effect on crashworthiness

3-33 (2270P)	KARCO Test No. P34149-04 . 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 degrees, 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 occupant risk and vehicle trajectory criteria. The test vehicle, a 2008 Dodge Ram 4-door pickup truck weighing 4,895.3 lb (2,220.5 kg), impacted the MASH SKT terminal head-on at an impact speed and angle of 62.74 mph (100.97 km/h) and 5.7 degrees, respectively. The vehicle pushed the impact head down the guardrail past the fifth post at which point the vehicle mounted the guardrail in a controlled manner without excessive deceleration and proceeded forward. The vehicle then impacted Post 6 before separating from the guardrail. The vehicle impacted the test article again between Posts 23 and 24. The vehicle sustained moderate damage at the front and left side and deformations to the occupant compartment were negligible. The vehicle remained upright and stable. The test article was extensively damaged from Posts 1 through Post 6. Post 7 was not impacted, but separated from the guardrail as a result of the rail buckling. The Occupant Impact Velocities (OIV) and ridedown accelerations are within the recommended limits. The MSKT-SP terminal passed all evaluation criteria for Test 3-33.	Modification has no effect on crashworthiness

3-34 (1100C)	KARCO Test No. P35126-01. An 1100C (2,425 lb) passenger car impacting the terminal at a nominal impact speed and angle of 62.2 mph (100 km/h) and 15 degrees, 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 2010 Kia Rio 4-door sedan weighing 2,436.1 lb (1,105.0 kg), impacted the downstream end of the impact head between Posts 1 and 2 at impact speed and angle of 61.37 mph (98.77 km/h) and 15.3 degrees, respectively. The vehicle was contained and redirected by the guardrail before separating from the test article near Post 6 at a velocity of 27.7 mph and an exit angle of 17.0 degrees and proceeded downstream adjacent to the guardrail. The vehicle remained upright and stable throughout the impact sequence. The test vehicle sustained moderate damage to the front right side with no occupant compartment deformation. The test article was extensively damaged from Post 1 through Post 5. The Occupant Impact Velocities (OIV) and ridedown accelerations are within the recommended limits. The MSKT-SP-MGS terminal passed all evaluation criteria for Test 3-34.	Modification has no effect on crashworthiness

3-35 (2270P)	KARCO Test No. P35103-01. 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 degrees, respectively, with the corner of the vehicle bumper aligned with the beginning of the length-of-need (LON) of the terminal. This test is primarily intended to evaluate structural adequacy and vehicle trajectory criteria. The test vehicle, a 2011 Dodge Ram 4-door pickup truck weighing 4,942.6 lb (2,242.0 kg), impacted the guardrail at Post 3, the beginning of length-of-need, at impact speed and angle of 62.36 mph (100.36 km/h) and 26 degrees, respectively. The vehicle was contained and redirected by the guardrail before separating from the test article near Post 9 at a velocity of 32.75 mph (52.71 km/h) and an exit angle of 34.93 degrees and proceeded downstream adjacent to the guardrail on the traffic side. The vehicle then veered back toward the guardrail and impacted Post 20 before coming to rest at Post 26. The vehicle remained upright and stable throughout the impact sequence. The test vehicle sustained moderate damage to the front right side with no occupant compartment deformation. The test article was extensively damaged from Post 1 through Post 9. The maximum static lateral deformation was 30.2 in (768 mm) between Posts 5 and 6. The Occupant Impact Velocities (OIV) and ridedown accelerations are within the recommended limits. The MSKT-SP-MGS terminal passed all evaluation criteria for Test 3-35.	Modification has no effect on crashworthiness
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 degrees, 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 W-beam guardrail terminal, the MSKT-SP-MGS terminal is designed to attach to W-beam barrier, transitions to alternative barriers downstream of the terminal will require case-by-case evaluation.	Non-Relevant Test, not conducted

3-37 (2270P)	Test No. P35025-02. A 2270P (5,000 lb) pickup truck impacting the terminal at a nominal impact speed and angle of 62.2 mph (100 km/h) and 25 degrees, respectively, midpoint between the nose and the end of the terminal in the reverse direction. This test is intended to evaluate the performance of a terminal for a "reverse" hit. Successful testing of other cable anchor systems with the 1100C indicates that the 2270P is more critical with the concern of override and interaction with the terminal head. The test vehicle, a 2009 Dodge Ram 4-door pickup truck weighing 4,964.7 lb (2,252.0 kg), impacted the guardrail at Post 3 with an impact speed and angle of 63.13 mph (101.6 km/h) and 24.9 degrees, respectively. The vehicle impacted Post 2, the back side of the impact head, and then Post 1 before separating from the test article at an angle of 13.37 degrees clockwise from its original path. The vehicle sustained moderate front end damage with no deformation to the occupant compartment. The test article received extensive damage between Posts 1 and 2. The impact head was forced off the rail element and the cable anchor assembly was separated from the guardrail. The Occupant Impact Velocities (OIV) and ridedown accelerations are within the recommended limits. The MSKT-SP-MGS terminal passed all evaluation criteria for Test 3-37.	Modification has no effect on crashworthiness
3-38 (1500A)	MASH Test Designation 3-38. A 1500A (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 degree, 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 MSKT-SP-MGS terminal is not a staged device, because the force required to move the impact head down the rail does not change. The 3-30 test with the 1100C vehicle makes this test unnecessary.	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

Testing Laboratory's signature concurs that these modifications are considered Non-Significant.		
Laboratory Name:	KARCO Engineering, INC	
Laboratory Signature:	Balbino A. Beltran — Digitally signed by Balbino A. Beltran DN: cn=Balbino A. Beltran, o=KARCO Engineering, LLC., ou, email=abeltran@karco.com, c=US Date: 2016.09.06 18:23:26 -07'00'	
Address:	9270 Holly Road Adelanto, CA 92301	Same as Submitter ☒
Country:	United States	Same as Submitter ☒
Accreditation Certificate Number and Dates of current Accreditation period :	TL-371; December 18, 2015 through December 18, 2017	

Submitter Signature*:Balbino A. Beltran — Digitally signed by Balbino A. Beltran DN: cn=Balbino A. Beltran, o=KARCO Engineering, LLC., ou, email=abeltran@karco.com, c=US Date: 2016.09.06 18:23:44 -07'00'

Submit Form

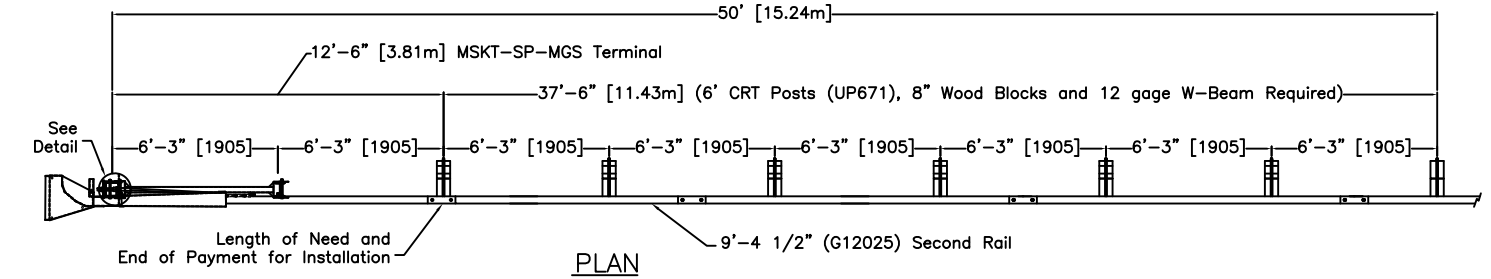
ATTACHMENTS

Attach to this form:

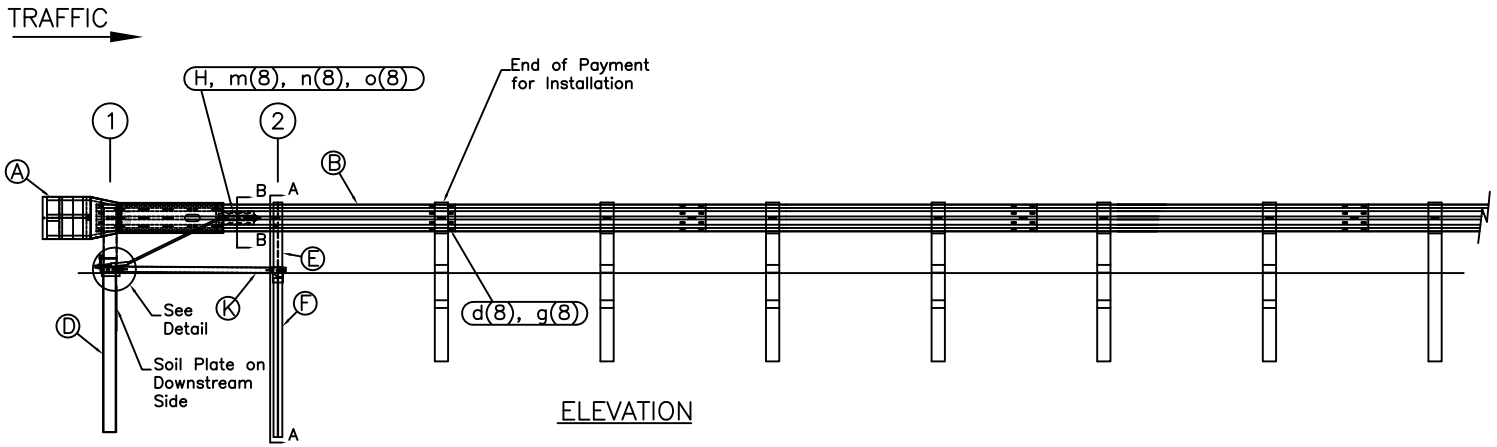
1) Additional disclosures of related financial interest as indicated above.
2) A copy of the full test report, video, and a Test Data Summary Sheet for each test conducted in support of this request.
3) A drawing or drawings of the device(s) that conform to the Task Force-13 Drawing Specifications [Hardware 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



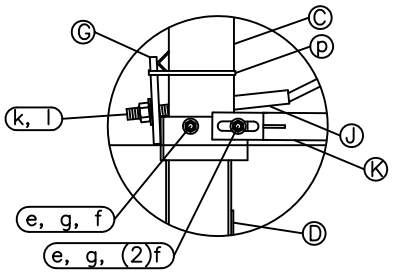
PLAN



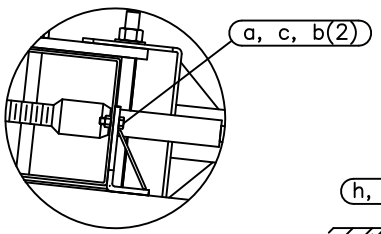
ELEVATION

ITEM	QTY	BILL OF MATERIALS	ITEM NO.
A	1	IMPACT HEAD	MS3000
B	1	W-BEAM GUARDRAIL END SECTION, 12 Ga.	SF1303
C	1	FIRST POST TOP (6X6X$\frac{1}{8}$" Tube)	MTPHP1A
D	1	FIRST POST BOTTOM (6' W6X15)	MTPHP1B
E	1	SECOND POST ASSEMBLY TOP	UHP2A
F	1	SECOND POST ASSEMBLY BOTTOM	HP2B
G	1	BEARING PLATE	E750
H	1	CABLE ANCHOR BOX	S760
J	1	BCT CABLE ANCHOR ASSEMBLY	E770
K	1	STRUT	MS785
HARDWARE (ALL DIMENSIONS IN INCHES)			
a	2	5/16 x 1 HEX BOLT GRD 5	B5160104A
b	4	5/16 WASHER	W0516
c	2	5/16 HEX NUT	N0516
d	9	5/8 Dia. x 1 1/4 SPLICE BOLT (POST #2)	B580122
e	2	5/8 Dia. x 9 HEX BOLT GRD 5	B580904A
f	3	5/8 WASHER	W050
g	11	5/8 Dia. H.G.R NUT	N050
h	1	3/4 Dia. x 8 1/2 HEX BOLT GRD A449	B340854A
j	1	3/4 Dia. HEX NUT	N030
k	2	1 ANCHOR CABLE HEX NUT	N100
l	2	1 ANCHOR CABLE WASHER	W100
m	8	1/2 RSI SHOULDER BOLT W/WASHER	SB12A
n	8	1/2 STRUCTURAL NUT	N012A
o	8	1/2 STRUCTURAL WASHER	W012A
p	1	BEARING PLATE RETAINER TIE	CT-100ST

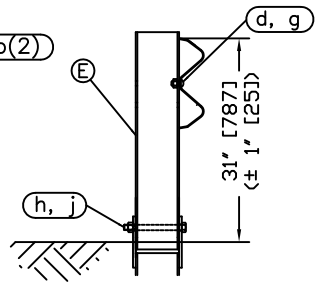
GENERAL NOTES:
1. All bolts, nuts, cable assemblies, cable anchors and bearing plates shall be galvanized.
2. The lower sections of the Posts 1&2 shall not protrude more than 4 in [100] above the ground (measured along a 5' [1.5m] cord). Site grading may be necessary to meet this requirement.
3. The lower section of the hinged post should not be driven with the upper post attached. If the post is placed in a drilled hole, the backfill material must be satisfactorily compacted to prevent settlement.
4. When competent rock is encountered, a 12" [300] Ø post hole, 20 in. [500] deep cored into the rock surface may be used if approved by the engineer for Posts 1 and/or 2. Granular material will be placed in the bottom of the hole, approximately 2.5" [60] deep to provide drainage. The first and/or second post can be field cut to length, placed in the hole and backfilled with suitable backfill. The soil plate may be trimmed if required.
5. The breakaway cable assembly must be taut. A locking device (vice grips or channel lock pliers) should be used to prevent the cable from twisting when tightening nuts.



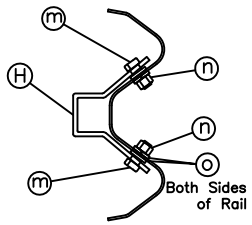
Post #1 Connection Detail



Impact Head Connection Detail



SECTION A-A
Post #2



SECTION B-B
Anchor Bracket

RSI
Road Systems, Inc.
Big Spring, TX
Phone: 432-263-2435
or Phone: 330-346-0721

MSKT-MGS-W Terminal Test Level 3

Sheet:	Date:	By:
1	08/05/16	JRR

Drawing Name:	Scale:	Rev:
MSKT-MGS-W	None	0

Wood-Post MSKT System Product Description

The MSKT-SP-MGS (MASH Sequential Kinking Terminal - Standard Post - Midwest Guardrail System) terminal, as approved in CC-126 dated June 10, 2016, is a W-beam guardrail terminal consisting of an impact head assembly, a breakaway cable anchorage system and a 12.5 ft (3.8 m) end section. The system requires use of 37.5 ft (11.4 m) of standard guardrail downstream mounted on 8-in. (203-mm) deep wood or composite blocks and 6 ft (1.8 m) long W6x9 (or W6x8.5) steel posts. A 9.4 ft (2.9 m) W-beam rail section is required downstream of Post 3 to transition the rail splices to mid-span.

Some States specify the use of wood posts instead of steel posts for their guardrail systems. To accommodate the needs of these States, it is requested that the use of a wood-post version be approved for the MSKT terminal.

Figure 1 shows a schematic drawing of the wood-post MSKT terminal. The wood-post system uses the same SP anchorage system, i.e., the same steel posts 1 and 2 with a ground strut, as the steel-post system. Posts 3 through 8 are CRT (Controlled Release Terminal) wood posts, and standard wood line posts are used from post 9 and beyond. Other than the posts, the other components of both MSKT systems are the same.

Both wood-post and steel-post systems have been successfully used in the field over the years and there has not been any problems identified with either system. For example, both steel-post and wood-post SKT and FLEAT terminals have been deployed in the field with excellent in-service records. Actually, from an impact standpoint, it is our opinion that the steel-post system is more critical than the wood-post system. The analysis and reasoning for this conclusion is presented as follows.

For head-on impacts (Test Designation 30, 31, 32, and 33), both steel-post and wood-post systems should perform the same from the initial point of impact up to post 3 since both systems use the same steel Posts 1 and 2 with a ground strut anchorage system. From Post 3 through Post 8, the wood-post system is, in our opinion, more consistent and predictable than the steel-post system. The wooden CRT posts are designed to break away at a given force level when impacted in a longitudinal direction. In comparison, the standard steel line posts are simply pushed down when impacted in a longitudinal direction to allow for vehicle to pass over the bent posts. Thus, there is more debris on the ground in the path of the vehicle for the steel-post system, which could potentially cause the vehicle to roll and yaw. Thus, we believe that the wood-post system would perform in a more consistent and predictable manner than the steel-post system for head-on and shallow angle impacts.

Two similar small-car, head-on tests (Test 3-30) were conducted on a NCHRP 350 SKT terminal with a MSKT impact head, one for a steel-post system (KARCO Test Report no. TR-P35127-01) and one for a wood-post system (KARCO Test Report no. TR-P35226-01) to demonstrate that the MSKT impact head can be used interchangeably on a NCHRP 350 SKT terminal. These test results were submitted previously to FHWA for review. While the tests were conducted under NCHRP 350 guidelines and not MASH guidelines, they nonetheless provide a direct comparison in the impact performance of steel-post versus wood-post systems. Videos of these two crash tests show that the vehicle kinematics are similar for both systems initially through Posts 1 and 2, which are breakaway posts. However, from Post 3 on, the wood-post system, with the wood CRT posts, has a smoother and more controlled vehicle kinematics than the steel-post system, with standard steel line posts. This observation is supported by the test results as

summarized in the following table. Note that the occupant risk factors, i.e., flail space velocities and ridedown accelerations, are similar for both systems. The most significant differences are that the steel-post system has significantly higher maximum roll angle (25.3 deg. v. 13.3 deg.) and maximum pitch angle (49.7 deg. v. 9.7 deg.) than the wood-post system. In summary, under almost identical test conditions, the wood-post system has smoother and more controlled vehicle kinematics than the steel-post system using the MSKT impact head while exhibiting similar occupant impact severity in terms of flail space velocity and ridedown acceleration.

System	Wood-Post System	Steel-Post System
Impact Speed [km/h (mph)]	97.42 (60.54)	97.59 (60.64)
Impact Angle (°)	0.2	0.5
Impact Severity (kJ)	298.2	303.3
Flail Space Velocity (m/s) - X Direction	7.9	7.8
- Y Direction	0.2	0.0
Ridedown Acceleration (g) - X Direction	-7.8	-8.9
- Y Direction	-3.7	-3.7
Maximum Roll Angle (°)	-13.3	25.3
Maximum Pitch Angle (°)	-9.7	-49.7
Maximum Yaw Angle (°)	158.2	143.9

For redirectional impacts (Test Designation 34 and 35), both steel-post and wood-post systems use the same anchorage system, so the anchorage capacity for both systems would be similar. Thus, any difference in the performance of the two systems in redirectional impacts would be in the lateral resistance of the posts and the interactions between the posts and the rail. The lateral resistance of wood and steel posts have been found to be fairly comparable in various studies over the years based on dynamic testing results. For example, in a recent study by Midwest Roadside Safety Facility [1], a series of bogie tests were conducted on wood and steel posts and the researchers concluded that "*standard steel posts would also provide similar post-soil resistance to 6-in x 8-in. (152-mm x 203-mm) wood posts when installed in level terrain and using 6-ft (1.8-m) long sections.*" In terms of interactions between the posts and the rail, the wood posts also perform better. Steel posts tend to bend and twist while breakaway wood CRT posts would break and split. There is also a potential for the rail to contact the edge or corner of the steel post flanges, resulting in a tear and even rupture to the rail. This would not be a problem for the wood-post system since the wood posts do not present any sharp edges. Also, wheel snagging may be more of a concern for steel-post systems given the bending and twisting of the posts. The satisfactory performance of wood-post guardrail systems in redirectional impacts (Tests 3-10 and 3-11) under MASH guidelines was demonstrated in two series of crash tests conducted on the Midwest Guardrail System (MGS) with Southern yellow pine wood posts and white pine wood posts. [2, 3]

For the reverse direction impact (Test Designation 37), there should not be any difference between the wood-post and steel-post systems, given the point of impact and that Posts 1 and 2 and the ground strut are the same for both systems.

In a September 9, 2015 correspondence between Road Systems, Inc. and FHWA, it was noted that "*Review of the MASH tests of the SKT submitted so far show a significant vehicle lifting and rolling that was not observed in the original SKT testing of 1997. This does not give us confidence that the wood and steel post versions will both meet MASH criteria.*" Interesting enough, this observation actually supports our opinion that the steel-post system is more critical than the wood-post system from an impact performance standpoint. The original testing of the SKT terminal in 1997 used a wood-post system, which seemingly performed better than the current MSKT terminal tested with a steel-post system. While these two series of tests are not directly comparable since one was tested under NCHRP 350 guidelines and the other under MASH guidelines and there are differences between the two systems, it nonetheless provides some interesting observations.

In summary, we believe that the steel-post system is actually more critical than the wood-post system for reasons explained above. Since the MSKT steel-post system successfully passed all MASH evaluation criteria, it is our opinion that the MSKT wood-post system would also satisfy all of the MASH requirements with no problem. Thus, it is requested that the wood-post MSKT terminal be approved.

REFERENCES

1. Homan, D. M., et al, "Investigation and Dynamic Testing of Wood and Steel Posts for MGS on a Wired-Faced MSE Wall," Report TRP-03-231-11, Midwest Roadside Safety Facility, conducted for the Central Federal Lands Highway Division, Lincoln, NE, February 2012.

2. Gutierrez, D.A., et al, "Midwest Guardrail System (MGS) with Southern Yellow Pine Posts," Report TRP-03-272-13, Midwest Roadside Safety Facility, Lincoln, NE, September 2013.

3. Stolle, C.J., et al, "Evaluation of the Midwest Guardrail System (MGS) with White Pine Wood Posts," Report TRP-03-241-11, Midwest Roadside Safety Facility, Lincoln, NE, March 2011.