



U.S. Department
of Transportation

**Federal Highway
Administration**

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

October 3, 2016

In Reply Refer To:
HSST-1/CC-130

Mr. Kaddo Kothmann
Road Systems, Inc.
3616 Howard County Airport
Big Spring, Texas 79720

Dear Mr. Kothmann:

This letter is in response to your July 29, 2016 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-130 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:

- 350 SKT Terminal with MASH SKT Impact Head

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) or the National Cooperative Highway Research Program (NCHRP) Report 350. 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 NCHRP Report 350. Therefore, the device is eligible for reimbursement under the Federal-aid highway program if installed under the range of tested conditions.

| | |
|------------------------------|--|
| Name of system: | 350 SKT Terminal with MASH SKT Impact Head |
| Type of system: | W-Beam Guardrail extruder terminal |
| Test Level: | NCHRP Report 350 Test Level 3 (TL3) |
| Testing conducted by: | KARCO, Inc. |
| Dates of request: | December 22, 2015, revised July 29, 2016 |
| Date initially acknowledged: | December 31, 2015 and August 23, 2016 |
| Date of completed package: | September 1, 2016 |

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 number CC-130 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,

A handwritten signature in blue ink that reads "Michael S. Griffith". The signature is written in a cursive, flowing style.

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: | July 29, 2016 | <input checked="" type="radio"/> New <input type="radio"/> 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 | <input type="radio"/> Physical Crash Testing <input checked="" type="radio"/> Engineering Analysis | 350 SKT Terminal with MASH SKT Impact Head | NCHRP Report 350 | 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 NCHRP Report 350 (Report 350) and that the evaluation results meet the appropriate evaluation criteria in the Report 350.

Individual or Organization responsible for the product:

| | | |
|---|---|--|
| Contact Name: | Kaddo Kothmann | Same as Submitter <input type="checkbox"/> |
| Company Name: | Road Systems, Inc. | Same as Submitter <input type="checkbox"/> |
| Address: | 3616 Howard County Airport Big Spring, TX 79720 | Same as Submitter <input type="checkbox"/> |
| Country: | United States | Same as Submitter <input type="checkbox"/> |
| Enter below all disclosures of financial interests as required by the FHWA 'Federal-Aid Reimbursement Eligibility Process for Safety Hardware Devices' document. | | |
| Road Systems is the manufacturer and marketer of device. | | |
| <p>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.</p> <p>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.</p> | | |

PRODUCT DESCRIPTION

| | | |
|---|--|---|
| <input type="radio"/> New Hardware or Significant Modification | <input checked="" type="radio"/> Modification to Existing Hardware | <input type="radio"/> Non-Significant |
| <p>The modification under evaluation is the replacement of the existing 350-SKT impact head by the new MSKT impact head on existing 350-SKT terminal systems. Given the continuing use of the 350 SKT systems for the foreseeable future and the need for repair parts into the future, having a single impact head that is approved for all systems will minimize maintenance inventory and potential liability for the States. Refer to Appendix B for engineering analysis and component testing.</p> <p style="text-align: center;">CRASH TESTING</p> <p>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.</p> | | |
| Engineer Name: | Balbino A. Beltran | |
| Engineer Signature: | <div style="display: flex; justify-content: space-between; align-items: center;"> <div style="text-align: center;"> <p style="font-size: 1.2em; margin: 0;">Balbino A. Beltran</p> </div> <div style="font-size: 0.8em; margin: 0;"> Digitally signed by Balbino A. Beltran DN: cn=Balbino A. Beltran, o=KARCO Engineering, LLC., ou, email=abeltran@karco.com, c=US Date: 2016.08.01 18:46:48 -07'00' </div> </div> | |
| Address: | 9270 Holly Road, Adelanto, CA. 92301 | Same as Submitter <input checked="" type="checkbox"/> |
| Country: | United States | Same as Submitter <input checked="" type="checkbox"/> |

A brief description of each crash test and its result:

| Required Test Number | Narrative Description | Evaluation Results |
|----------------------|--|---|
| 3-30 (820C) | <p>KARCO Test No. P35127-01. An 820C (1,800 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 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.</p> <p>This 3-30 test was conducted with a 350 SKT-SP MGS steel-post guardrail system, SKT-SP-MGS-MS3000, with a MASH SKT impact head at a mounting height of 32 in. (813 mm).</p> <p>The test vehicle, a 2000 Chevrolet Metro 3-door hatchback weighing 1,819.9 lb (825.5 kg), impacted the 350 SKT terminal head-on at an impact speed and angle of 60.64 mph (97.59 km/h) and 0.5 degree, respectively. The vehicle pushed the impact head down the length of the guardrail past Post 4, at which point the kinking process stopped and the rail began to buckle between posts 4 and 5. The vehicle rotated counter-clockwise before separating from the article towards the traffic side at an exit angle of 21.0 degrees. The vehicle came to rest 49.9 ft (15.2 m) forward and 22.5 ft (6.9 m) right of the point of initial impact. The test vehicle sustained moderate damage to the front end with no occupant compartment penetration or deformation. The vehicle remained upright during and after the impact event. The test article received extensive damage from post 1 through post 4. The Occupant Impact Velocities (OIV) and ridedown accelerations are within the recommended limits. In summary, the 350 SKT terminal with a MASH SKT impact head passed all evaluation criteria for Test 3-30.</p> | Modification has no effect on crashworthiness |

| Required Test Number | Narrative Description | Evaluation Results |
|----------------------|--|---|
| 3-30 (820C) | <p>KARCO Test No. P35226-01. An 820C (1,800 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 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.</p> <p>This 3-30 test was conducted with a 350 SKT MGS wood-post guardrail system, SKT-W-MGS8-MS3000, with a MASH SKT impact head at a mounting height of 32 in. (813 mm).</p> <p>The test vehicle, a 1997 Geo Metro 3-door hatchback weighing 1,795.8 lb (814.5 kg), impacted the SKT terminal head-on at impact speed and angle of 60.53 mph (97.42 km/h) and 0.2 degree, respectively. The vehicle pushed the impact head down the length of the guardrail past Post 4 and the extruded section of the rail contacted Post 5. The kinking process stopped at about Post 5 and the vehicle rotated counter-clockwise before separating from the article toward the traffic side. The vehicle came to rest 33.1 ft (10.1 m) forward and 4.1 ft (1.2 m) right of its position at the point of initial impact. The test vehicle sustained moderate damage to the front end with no occupant compartment penetration or deformation. The vehicle remained upright and did not leave its lane. The test article received extensive damage from post 1 through post 5. The Occupant Impact Velocities (OIV) and ridedown accelerations are within the recommended limits. In summary, the 350 SKT terminal with the MASH SKT impact head passed all evaluation criteria for Test 3-30.</p> | Modification has no effect on crashworthiness |

| | | |
|--------------|--|---|
| 3-31 (2000P) | <p>KARCO Test No. P35225-01. A 2000P (4,400 lb) pickup truck 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 occupant risk and vehicle trajectory criteria.</p> <p>This test was conducted with a 350 SKT-SP Metric steel-post guardrail system, SKT-SP-S-MS3000, with a MASH SKT impact head at a mounting height of 27-5/8 in. (702 mm).</p> <p>The test vehicle, a 2000 Chevrolet Silverado 2500 2-door pickup truck weighing 4,460.9 lbs (2,023.5 kg), impacted the 350 SKT terminal head-on at impact speed and angle of 62.00 mph (99.78 km/h) and 0.5 degree, respectively. The vehicle pushed the impact head down the length of the guardrail past Post 8. The kinking process stopped some time between Post 7 and 8. The vehicle remained in contact with the impact head until the vehicle came to rest 41.4 ft (12.6 m) forward and 0.3 ft (0.1 m) left of the point of initial impact. The test vehicle sustained moderate damage to the front end with no occupant compartment penetration or deformation. The vehicle remained upright and did not leave its lane. The test article received extensive damage from Post 1 through Post 8. The Occupant Impact Velocities (OIV) and ridedown accelerations are within the recommended limits. In summary, the 350 SKT terminal with a MASH SKT impact head passed all evaluation criteria for Test 3-31.</p> | Modification has no effect on crashworthiness |
| 3-32 (820C) | <p>NCHRP 350 Test Designation No. 3-32. An 820C (1,800 lb) passenger car impacting the terminal end-on at a nominal impact speed and angle of 100 km/h (62.2 mph) and 15 degrees, respectively, with the center line of the vehicle aligned with the center line of the nose of the terminal.</p> <p>For the evaluation of replacing the 350 impact head with the MASH impact head, this head-on angle crash test (Test 3-32) is, in our opinion, non-critical and not necessary for this specific evaluation. The rationale for our opinion is presented in Attachment B.</p> | Non-Relevant Test, not conducted |
| S3-32 (700C) | Test not necessary for component testing. | Non-Relevant Test, not conducted |

| | | |
|--------------|---|----------------------------------|
| 3-33 (2000P) | <p>NCHRP 350 Test Designation 3-33. A 2000P (4,400 lb) pickup truck impacting the terminal end-on at a nominal impact speed and angle of 100 km/h (62.2 mph) and 15 degrees, respectively, with the center line of the vehicle aligned with the center line of the nose of the terminal.</p> <p>For the evaluation of replacing the 350 impact head with the MASH impact head, this head-on angle crash test (Test 3-33) is, in our opinion, non-critical and not necessary for this specific evaluation. The rationale for our opinion is presented in Attachment B.</p> | Non-Relevant Test, not conducted |
| 3-34 (820C) | <p>NCHRP 350 Test Designation No. 3-34. An 820C (1,800 lb) passenger car impacting the terminal at a nominal impact speed and angle of 100 km/h (62.2 mph) 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.</p> <p>Since the modification under evaluation involves only the replacement of the impact head, it would have no effect on this CIP redirection test 3-34. Thus, this test is considered irrelevant and excluded from the crash test matrix.</p> | Non-Relevant Test, not conducted |
| S3-34 (700C) | Test not necessary for component testing. | Non-Relevant Test, not conducted |
| 3-35 (2000P) | <p>NCHRP 350 Test designation No. 3-35. A 2000P (4,400 lb) pickup truck impacting the terminal at a nominal impact speed and angle of 100 km/h (62.2 mph) and 20 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.</p> <p>Since the modification under evaluation involves only the replacement of the impact head, it would have no effect on this LON redirection test 3-35. Thus, this test is considered irrelevant and excluded from the crash test matrix.</p> | Non-Relevant Test, not conducted |
| 3-36 (820C) | Test not relevant for component testing. | Non-Relevant Test, not conducted |
| S3-36 (700C) | Test not relevant for component testing. | Non-Relevant Test, not conducted |
| 3-37 (2000P) | Test not relevant for component testing. | Non-Relevant Test, not conducted |
| 3-38 (2000P) | Test not relevant for component testing. | Non-Relevant Test, not conducted |

| | | |
|--------------|---|----------------------------------|
| 3-39 (2000P) | <p>NCHRP 350 Test Designation 3-39. A 2000P (4,400 lb) pickup truck impacting the terminal at a nominal impact speed and angle of 62.2 mph (100 km/h) and 20 degrees, respectively, at the 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.</p> <p>Since the modification under evaluation involves only the replacement of the impact head, it would have no effect on this reverse direction test 3-39. Thus, this test is considered irrelevant and excluded from the crash test matrix.</p> | Non-Relevant Test, not conducted |
| 3-40 (2000P) | Test not relevant for component testing. | Non-Relevant Test, not conducted |
| S3-40 (700C) | Test not relevant for component testing. | Non-Relevant Test, not conducted |
| 3-41 (2000P) | Test not relevant for component testing. | Non-Relevant Test, not conducted |
| 3-42 (820C) | Test not relevant for component testing. | Non-Relevant Test, not conducted |
| S3-42 (700C) | Test not relevant for component testing. | Non-Relevant Test, not conducted |
| 3-43 (2000P) | Test not relevant for component testing. | Non-Relevant Test, not conducted |
| 3-44 (2000P) | Test not relevant for component testing. | 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 | <small>Digitally signed by Balbino A. Beltran DN: cn=Balbino A. Beltran, o=KARCO Engineering, LLC., ou, email=abeltran@karco.com, c=US Date: 2016.08.01 18:47:16 -0700</small> |
| Address: | 9270 Holly Road, Adelanto, CA. 92301 | Same as Submitter <input checked="" type="checkbox"/> |
| Country: | United States | Same as Submitter <input checked="" type="checkbox"/> |
| Accreditation Certificate Number and Dates of current Accreditation period : | TL-371, December 18, 2015 through December 18, 2017 | |

Submitter Signature*:

Balbino A. BeltranDigitally signed by Balbino A. Beltran
DN: cn=Balbino A. Beltran, o=KARCO Engineering, LLC., ou, email=abeltran@karco.com, c=US
Date: 2016.08.01 18:47:53 -0700

Submit Form

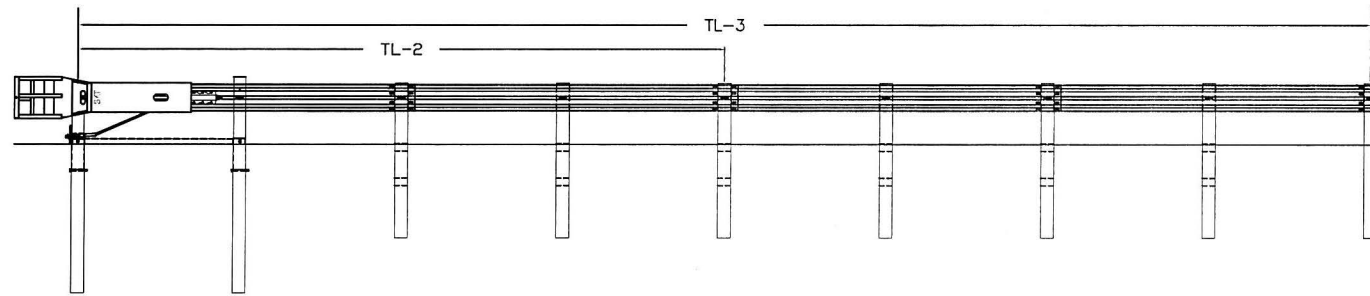
ATTACHMENTS

Attach to this form:

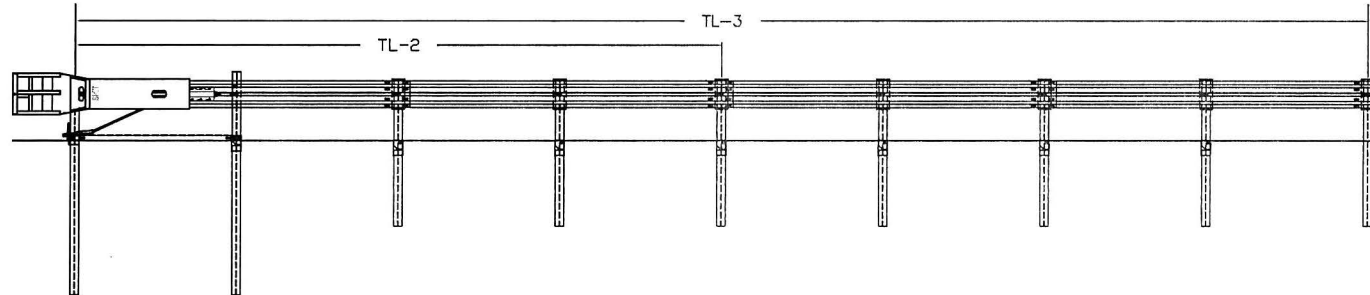
- 1) Additional disclosures of related financial interest as indicated above.
- 2) A copy of the full test report, video, and a Test Data Summary Sheet for each test conducted in support of this request.
- 3) A drawing or drawings of the device(s) that conform to the Task Force-13 Drawing Specifications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

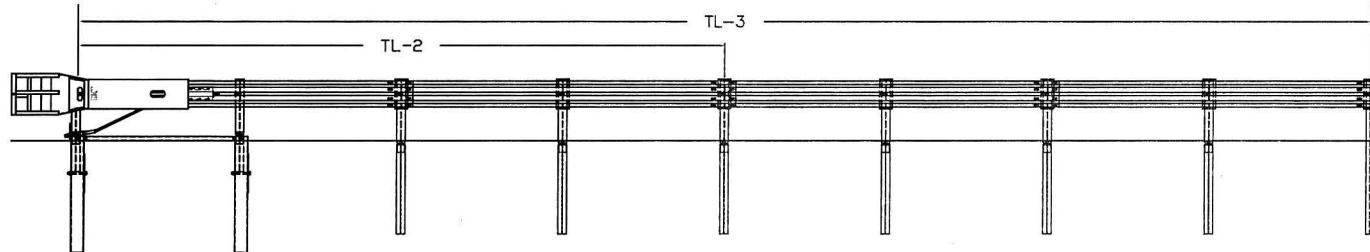
| Eligibility Letter | | |
|--------------------|------|-----------|
| Number | Date | Key Words |
| | | |



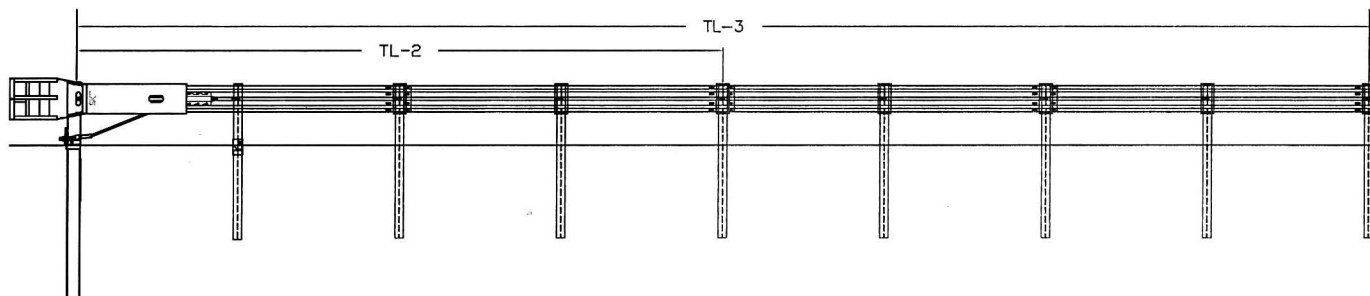
Wood Post Systems
 (2, 4, or 8 Tubes)
 Rail Height 28" - *31"
 * Blocks may be 8" or 12" Deep



Hinged/Plug Welded System
 Posts 3-8 May be Hinged or
 Plug Welded
 Rail Height 28" - *31"
 * Blocks may be 8" or 12" Deep



Plug Welded System
 (2, 4, or 8 Tubes)
 Rail Height 28" - *31"
 * Blocks may be 8" or 12" Deep



SP Steel Post
 Rail Height 28" - *31"
 * Blocks may be 8" or 12" Deep

END PANELS

12'-6" for 28" through 30" rail heights
 25' for 28" through 30" rail heights
 12'-6" for 31" rail heights (a)
 15'-7 1/2" for 31" rail heights (b)

SECOND RAIL

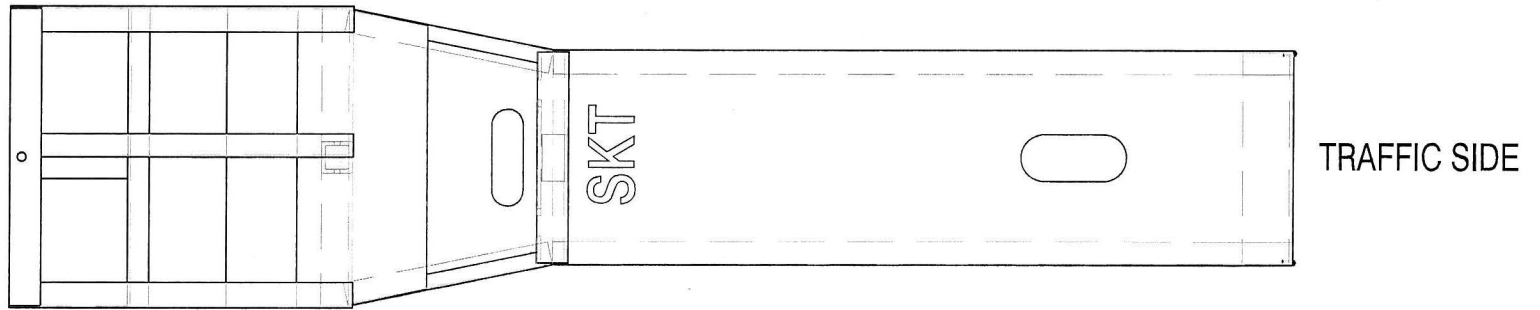
12'-6" for 28" through 30" rail heights
 25' for 28" through 30" rail heights
 (a) 9'-4 1/2" for 31" rail heights
 (a) 15'-7 1/2" for 31" rail heights
 (b) 12'-6" for 31" rail heights



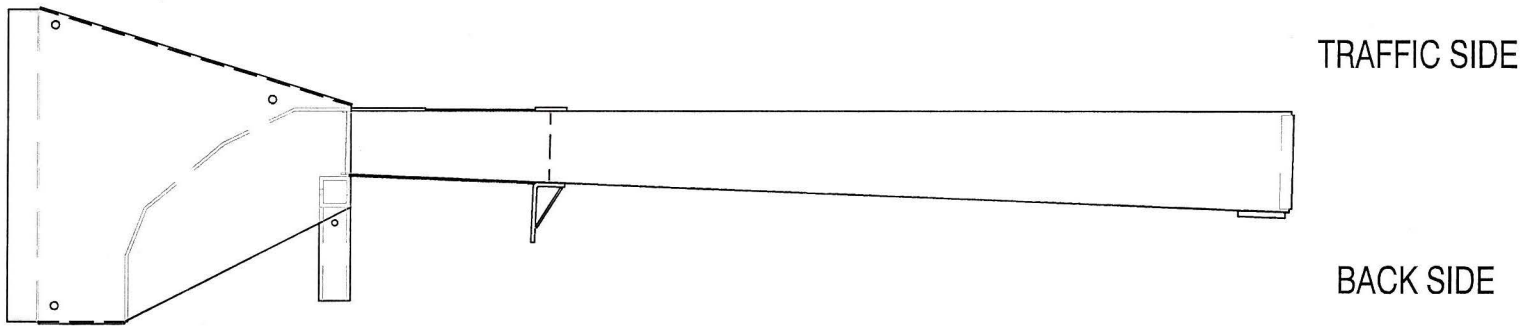
MSKT Impact Head
 Applicability for
 NCHRP 350 Terminals

Drawing Name: MSKT Replacement
 Scale: None

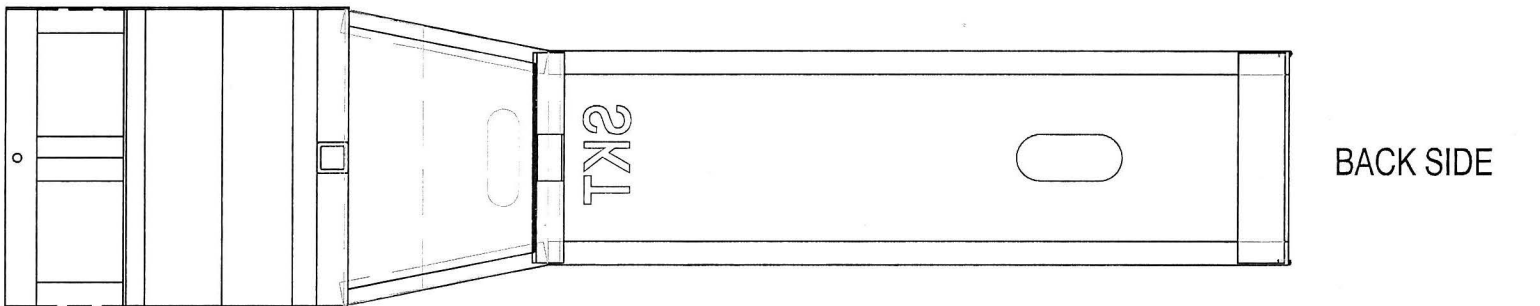
| | |
|--------|----------|
| Sheet: | 1 |
| Date: | 08/30/16 |
| By: | JRR |
| Rev: | 0 |



TRAFFIC SIDE



TRAFFIC SIDE



BACK SIDE

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

MASH SKT
 IMPACT HEAD

Sheet:

1

Date:

02/15/15

Drawing Name:

MS3000

Scale:

NONE

By:

JRR

Rev:

ATTACHMENT B

350 SKT TERMINAL SYSTEMS WITH MASH SKT IMPACT HEAD CRASH TEST MATRIX

INTRODUCTION

A new MSKT terminal has been successfully crash tested under the MASH guidelines and will be submitted to FHWA for review within the next few weeks. With the introduction of the MSKT terminal, the State DOTs will be faced with the problem of maintaining inventory of two different impact heads and training their personnel to use one impact head for installation and a differing one for maintenance/repair operations. Given that there are in excess of 200,000 350-SKT terminals in service it would be ideal if all future installations, as well as repairs of 350-SKT terminals, could use the same MSKT impact head. The objective of this series of full-scale crash tests is to demonstrate the satisfactory impact performance of replacing the current 350-SKT impact head with the MSKT impact head for all new and repaired 350-SKT terminal systems.

While the new MSKT impact head offers significant safety improvements, having met all MASH testing criteria, it is very similar to the 350-SKT impact head in terms of the dimensions of the deflector plate and layout of the feed chute. While these changes could be considered minor in terms of performance, Road Systems, Inc., citing the significance of this change to the market, asked that the performance of MSKT heads on existing 350-SKT systems be confirmed with full-scale testing.

Selection of Test System

There are numerous approved configurations of 350-SKT terminal system, thus it is necessary to select the most critical systems for use in evaluation of the performance of the MSKT impact head. To evaluate the broadest range of conditions there are four primary factors: 1) post configuration, 2) system height, 3) rail configuration and 4) block out depth.

1) Post Configuration:

Road Systems, Inc. offers several steel hinged post systems along with a system utilizing standard W6x9 line posts at and downstream of Post #3. Breakaway or hinged posts are designed to break away at given force levels for predictable breakaway behavior, thus it is well understood that standard steel line posts pose more of a risk. Since standard steel line posts do not break away, there is greater potential for adverse effects on occupant safety and vehicle kinematics. The fewer breakaway posts a terminal system has, the more critical it is from a performance standpoint. The steel-post 350-SKT standard post (SP) system has only two breakaway posts followed by standard steel line posts from Post #3 on and therefore it is considered the most critical among the approved steel-post systems.

There are also approved wood-post 350-SKT systems with differing numbers of BCT and CRT posts. These systems are comprised of two foundation tube anchors connected with a strut followed by a series of either BCT or CRT posts downstream. Downstream of the anchor, CRT posts that are directly embedded in soil have a higher propensity to rotate than a BCT posts in foundation tubes. This rotation of the CRT posts upon impact may destabilize a small passenger car (820C) and adversely affect the

resulting vehicle trajectory. Therefore a system with CRT posts from Post #3 on was considered to be the most critical case.

2) System Height:

Existing 350-SKT systems have been approved for system heights ranging from 27-5/8 in. (702 mm) to 32 in. (813 mm). The highest and lowest extremes were selected to demonstrate the effectiveness of using MSKT impact heads on existing 350-SKT systems for all rail heights. Systems with the 27-5/8 in. (702 mm) rail height have been shown to be critical for pickup truck crash tests since they increase the potential for the pickup truck to override the impact head and rail. In contrast, 32 in. (813 mm) rail height systems have been shown to be more critical for small car crash tests since they increase the potential for the vehicle to underide the impact head and rail. Thus, a rail height of 32 in. (813 mm) was used for the small car crash tests while a rail height of 27-5/8 in. (702 mm) was used for the pickup truck crash test.

3) Rail Configuration:

The 350-SKT system has a variety of approved options for the location of the first splice. Increased force is required to feed spliced sections through the impact head. Therefore, the closer this location is to the upstream end of the system, the more critical its impact on performance is. Thus, all tests were conducted with the initial rail splice at Post #3, the most upstream location in the approved 350-SKT systems.

4) Block Depth:

Both 8-in. (203-mm) and 12-in. (305-mm) blocks have been approved for specific 350-SKT systems. The depth of the blocks has been shown to have negligible impact in head-on and head-on angle tests; however, in redirection tests the 8-in. (203 mm) block has been shown to have a higher potential for tires of the vehicle to contact and snag on the posts. Thus, in keeping with the philosophy of testing the most critical systems, all tests were conducted with 8-in. (203-mm) blocks.

Selection of Crash Test Matrix

Three crash tests were conducted to evaluate the impact performance of the MSKT impact head when used with the 350-SKT terminal systems:

1. Test 3-30. An 820-kg (1800-lb) passenger car impacting the terminal head-on with a one-quarter offset at a speed and angle of 100 km/h (62.2 mph) and 0 degree. The test system was selected to be a steel-post 350-SKT standard post (SP) system with a rail height of 32 in. (813 mm).
2. Test 3-31. A 2000-kg (4400-lb) pickup truck impacting the terminal head-on at a speed and angle of 100 km/h (62.2 mph) and 0 degree. The test system is selected to be a steel-post 350-SKT standard post (SP) system with a rail height of 27-5/8 in. (702 mm).
3. Test 3-30. An 820-kg (1800-lb) passenger car impacting the terminal head-on with a one-quarter offset at a speed and angle of 100 km/h (62.2 mph) and 0 degree. The test system is selected to be a wood-post 350-SKT system with a rail height of 32 in. (813 mm).

NCHRP 350 guidelines specify up to seven crash tests to evaluate a guardrail terminal system. Since the modification under evaluation involves only the replacement of the impact head, only those tests that are potentially affected by changing the impact head were considered (Tests 3-30, 3-31, 3-32 and 3-33).

Tests 3-32 and 3-33 were determined to be unnecessary, given the similarity of the MSKT and the 350-SKT impact heads. The geometry and force levels of the two impact heads are nearly identical and the original Test 3-32 of the 350 SKT terminal (Test SBD-5)⁽¹⁾, clearly demonstrates (Figures 1&2) that because of the 15 degree initial impact angle, the vehicle gates behind the guardrail before the buckled rail or the elbow would pose a hazard to the vehicle.

It is also to be noted that the MSKT terminal has successfully passed Test 3-32 and 3-33 under MASH criteria with an impact angle of 5 degrees, cited in the report⁽²⁾ by the AASHTO-FHWA Joint Task Force on Guardrail Terminal Crash Analysis as a critical performance criteria for compression terminals.

References

1. Strybos, J. W., and Mayer, J. B., "Full-Scale Crash Evaluation of A Sequential Kinking Terminal (SKT-350)," Southwest Research Institute, San Antonio, Texas, March 1997.
2. "Safety Analysis of Extruding W-Beam Guardrail Terminal Crashes," Report by Joint AASHTO-FHWA Task Force on Guardrail Terminal Crash Analysis, Washington, D. C., September 2015.

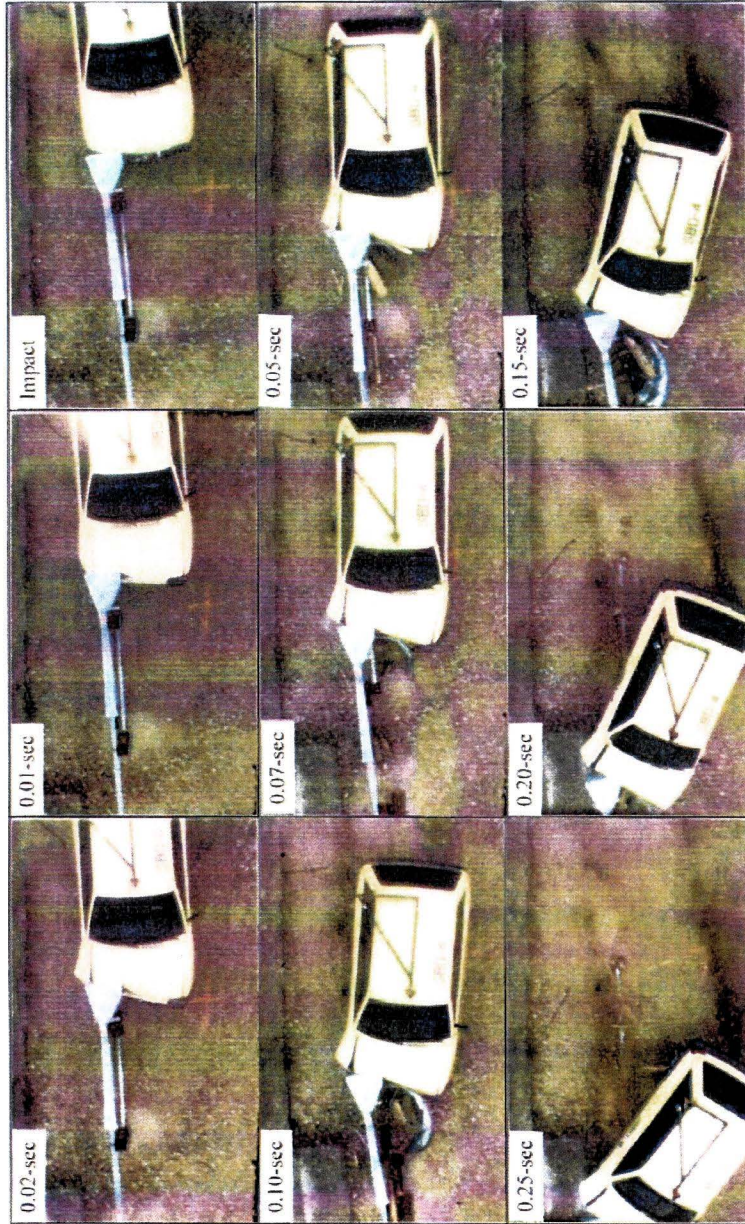


Figure 1. Sequential Photographs - Test SBD-4

Figure 1. Sequential Overhead Photographs 350 SKT Test 3-32.



Figure 7. Sequential Photographs - Test SBD-4 (continued)

Figure 2. Sequential Photographs 350 SKT Test 3-32.