

# Manual for Assessing Safety Hardware (MASH) Implementation

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# Outline

- ▶ Background on MASH
- ▶ Implementation of MASH – Design Guidelines
- ▶ Items Requiring MASH Testing
- ▶ Items Tested and Implemented
- ▶ Items Not Tested
- ▶ How Design Process Is Affected

# How Are Devices Tested?



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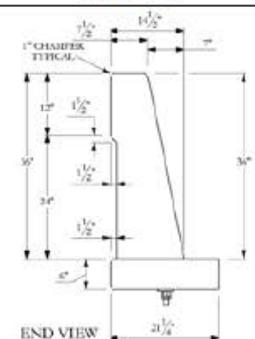
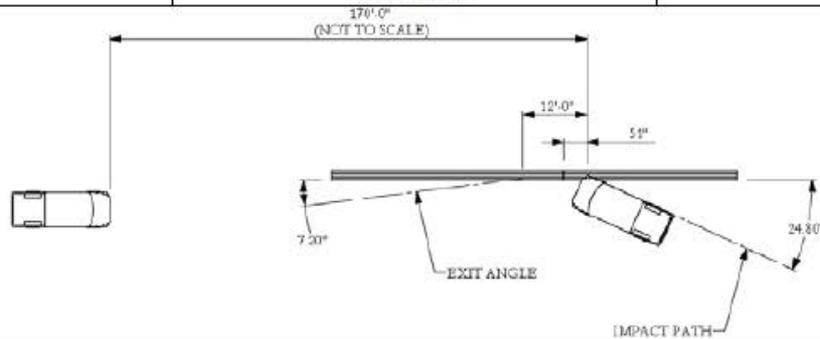
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# What is MASH (Manual for Assessing Safety Hardware)?

- ▶ MASH is the latest set of performance criteria used in crash testing to evaluate safety hardware.
- ▶ Several Test Levels (TL)
  - Test Levels 1–3 includes cars and pickups
  - Test Level 4 includes cars, pickups, and single unit trucks
  - Test Levels 5–6 includes cars, pickups, and tractor trucks

# Background MASH

- ▶ MASH Needed because changes in the vehicle fleet since NCHRP Report 350 criteria were adopted in 1993
- ▶ MASH first edition was published in 2009, but not required.
- ▶ FHWA issued memo issued on January 7, 2016 which laid out the implementation of MASH
- ▶ MASH 2016 second edition required

# Significant changes between NCHRP Report 350 and MASH

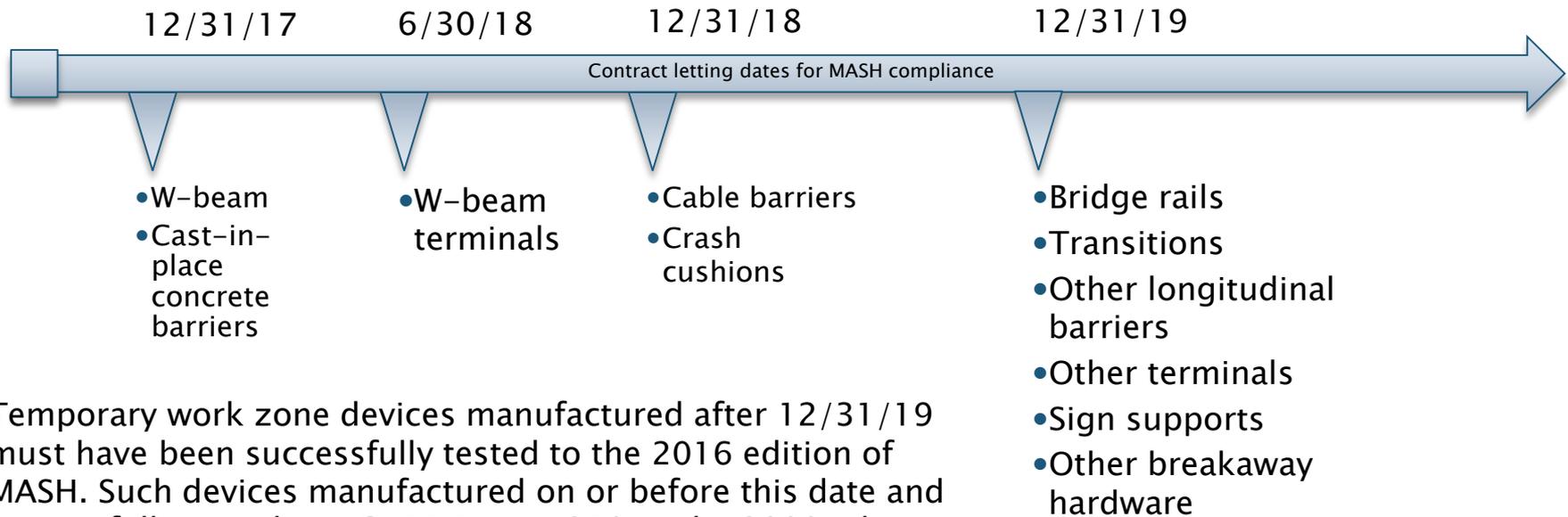
Topic	NCHRP 350	MASH
Small car test vehicle	820C vehicle (1,800 lbs.)	1100C vehicle (2,420 lbs.)
Small car impact angle	20 degrees	25 degrees
Light truck test vehicle: 3/4 ton 2-door to 1/2 ton 4-door	2000P vehicle (4,400 lbs.)	2270P vehicle (5,000 lbs.)
Gating terminals and crash cushion impact angle	15 degrees	5 degrees
Variable message signs and arrow board trailers	No mention	Added to TMA crash test matrix
Support structure and work zone traffic control device testing	Only small car tested	Small car and light truck tested
Windshield damage criteria	Subjective/Qualitative	Objective/Quantitative
Vehicle rebound in crash cushion tests	None	Required

# Compliance Timeline

## FHWA Memo

NCHRP  
Report 350

MASH



- Temporary work zone devices manufactured after 12/31/19 must have been successfully tested to the 2016 edition of MASH. Such devices manufactured on or before this date and successfully tested to NCHRP Report 350 or the 2009 edition of MASH, may continue to be used through their normal service life.

# Implementation Timeline by NDDOT – 2018 Construction

- ▶ NDDOT Implemented MASH using the Design Guidelines(Section I-06)

## Resources

- [Design Guidelines \(Section I-06\) - For projects constructed in 2018 and beyond](#) PDF 
- [Design Guidelines \(Section I-06\) - For projects constructed in 2017](#) PDF 
- [Reference and Forms](#)
- [Plan Preparation Guide](#)
- [Standard Drawings](#)

- ▶ Plans to include MASH for projects bid in October 2017 and later
- ▶ Implement MASH when items are available

# Design Guidelines

## Roadway Improvement Strategies

Safety	Safety issues will be identified and addressed as part of the Statewide Safety Program. Safety features will remain as they exist unless a need is identified. Safety hardware that is not in compliance with NCHRP Report 350 performance criteria will be upgraded to be in compliance with MASH* performance criteria. Existing guardrail that is in compliance with NCHRP Report 350 except for rail height, may be reset to correct rail height for compliance with NCHRP Report 350.
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*\* If safety hardware is not available for MASH performance criteria, safety hardware shall instead be required to be in compliance with NCHRP Report 350 performance criteria.*

- ▶ Minor Rehab & Structural Improvement
  - Changed minimum from NCHRP Report 230 to NCHRP Report 350
  - Upgrade to MASH if not in conformity to NCHRP Report 350

Safety	Safety hardware will be in compliance with MASH* performance criteria.
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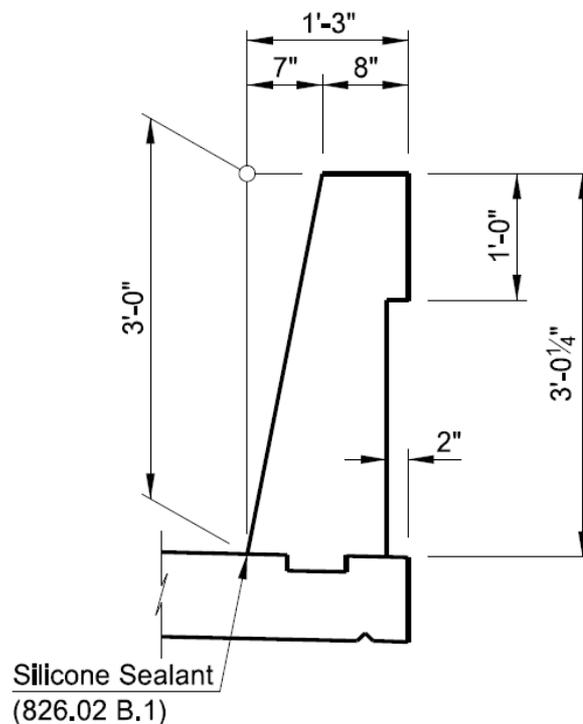
*\* If safety hardware is not available for MASH performance criteria, safety hardware shall instead be required to be in compliance with NCHRP Report 350 performance criteria.*

- ▶ Major Rehab & New/Reconstruction
  - Changed minimum from NCHRP Report 350 to MASH
- ▶ If safety hardware is not available for MASH performance criteria, use NCHRP Report 350 minimum.

# Design Guidelines

## Bridge Improvement Strategies

- ▶ New or Reconstruction category
  - Use MASH TL-4
  - Texas Single Slope Bridge Rail

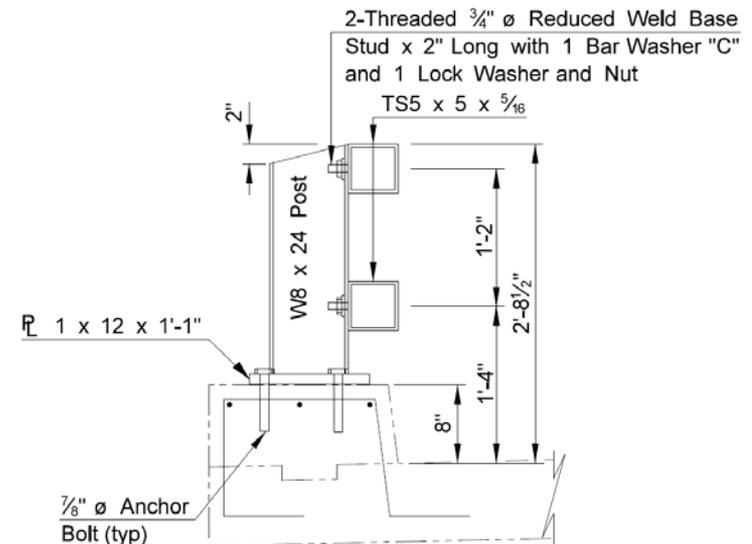
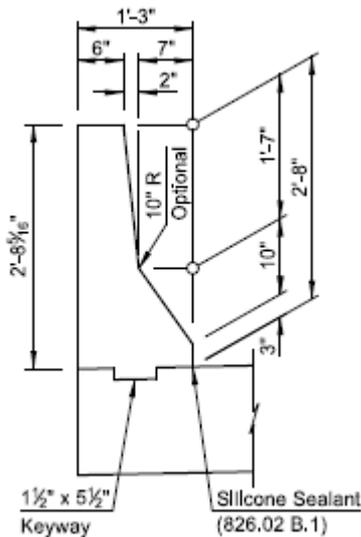


# Design Guidelines

## Bridge Improvement Strategies

### ► Rehabilitation category

- Bridge rail remains if it meets NCHRP Report 350 TL-3
- Jersey Barrier meets MASH TL-3
- Alaska Two-Tube meets NCHRP 350 TL-4



# Design Guidelines

## Bridge Improvement Strategies

- ▶ Rehabilitation category
  - If bridge rail does not meet NCHRP Report 350 TL-3, upgrade to MASH TL-3 or higher
  - Do not remove a portion of deck to upgrade to MASH
  - If MASH TL-3 or higher is not available, upgrade to meet NCHRP Report 350 TL-3

# Design Guidelines – Bridge Rail

- ▶ Bridge Rail Retrofit to MASH is currently not available
  - Alaska Two-tube bridge rail to be tested for MASH TL-4



# AASHTO LRFD

- ▶ MASH loads have not been published in AASHTO LRFD yet
- ▶ Currently designing for MASH which exceeds NCRHP Report 350

	Included in AASHTO LRFD	New
	Barrier Height 32 in.	Barrier Height 36 in.
Design Forces and Designations	NCRHP Report 350 TL-4	MASH TL-4
$F_t$ Lateral (kip)	54	67.2
$F_L$ Long. (kip)	18	21.6
$F_v$ Vertical (kip)	18	37.8
$L_t$ and $L_L$ (ft)	3.5	4
$H_e$ (in.)	32	25.1

# Items Requiring MASH Testing

- ▶ Guardrail
- ▶ Bridge Rail
- ▶ Attenuation Devices / Crash Cushions
- ▶ Sign Supports
- ▶ Breakaway Light and Traffic Signal Standards
- ▶ Temporary Barriers
- ▶ Traffic Control Devices

# Items Tested and Implemented

- ▶ Guardrail
- ▶ Bridge Rail
- ▶ Attenuation Devices / Crash Cushions

# Guardrail

- ▶ Longitudinal section
- ▶ Transition
- ▶ End Terminals

# Guardrail Longitudinal Section

- ▶ Midwest Guardrail System (MGS)
  - Will be NDDOT standard W-beam guardrail
  - 31” high instead of 28”
  - Splices are mid span not at the post
- ▶ 3 Cable (low tension)
  - Only meets NCHRP 350

# Guardrail Transition

- ▶ Connects MGS guardrail to bridge rail
  - To concrete jersey barrier
  - To concrete Texas single slope barrier
  - To concrete safety shape transition

# Guardrail Terminals

- ▶ Flared guardrail
- ▶ Non-flared guardrail

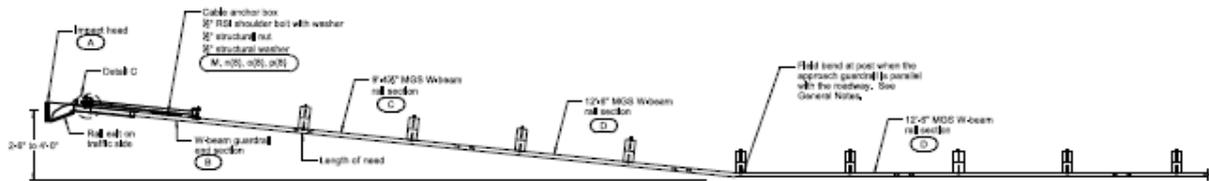
# Guardrail Terminals

- ▶ Flared guardrail
  - MGS FLEAT

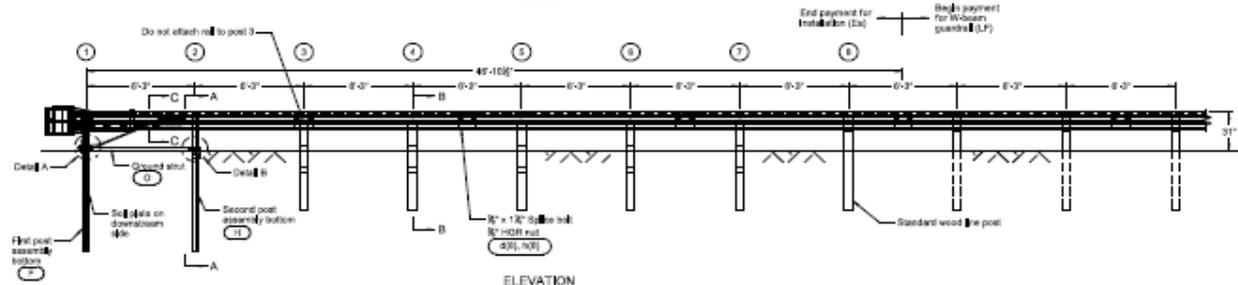
# MGS FLEAT

## MGS FLARED ENERGY ABSORBING TERMINAL - WOOD POST

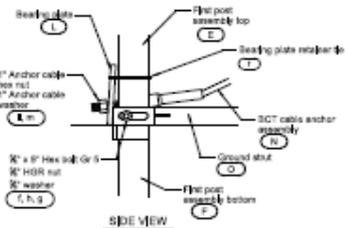
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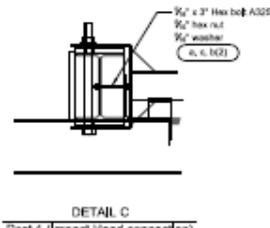
PLAN



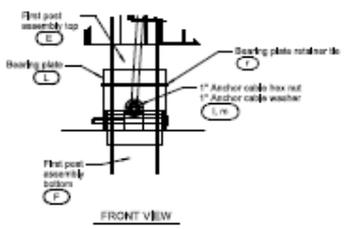
ELEVATION



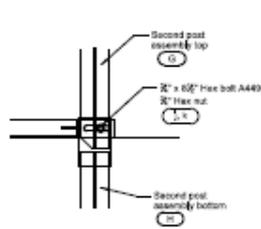
SIDE VIEW



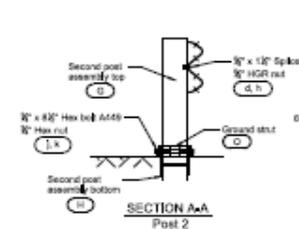
DETAIL C  
Post 1 (Impact Head connection)



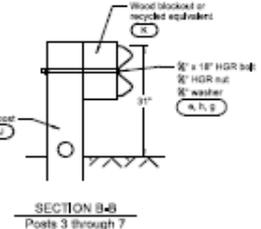
FRONT VIEW



DETAIL B  
Post 2



SECTION A-A  
Post 2



SECTION B-B  
Posts 3 through 7

- GENERAL NOTES:**
- Wood posts are required with the Flared Energy Absorbing Terminal except posts 1 and 2.
  - Order for all bolts, nuts, cable assemblies, cable anchors, and bearing plates.
  - Flare the Flared Energy Absorbing Terminal when the approach guardrail is parallel with the roadway. When the approach guardrail is flared at 15:1 to 10:1, ensure the Flared Energy Absorbing Terminal has only the flare side of the guardrail. When the guardrail flare is between 10:1 and 7:1, square the Flared Energy Absorbing Terminal to be turned parallel to the roadway.
  - Ensure the lower section of the posts do not protrude more than 4" above the ground (measured along a 5° cone). No grinding may be necessary to meet this requirement.
  - Install the lower section of the flared posts without the upper post attached. If the post is placed in a drilled hole, the hole diameter must be completed to prevent soil from.
  - The breakaway cable assembly must be tied. Use a locking device (like pins or channel lock pins) to prevent cables from sliding when flaring into.
  - \*Use nut the wood closely to the rectangular wood posts. Use two 25 penny galvanized nails.

ITEM	ITEM NO.	BILL OF MATERIALS	QTY
A	P000	IMPACT HEAD	1
B	01133	W-BEAM GUARDRAIL END SECTION 12 Ga	1
C	01205	2-410' MGS W-BEAM RAIL SECTION 12 Ga	1
D	01204	12-4' MGS W-BEAM RAIL SECTION 12 Ga	2
E	LHP1A	FIRST POST ASSEMBLY TOP	1
F	HP1B	FIRST POST ASSEMBLY BOTTOM	1
G	LHP2A	SECOND POST ASSEMBLY TOP	1
H	HP2B	SECOND POST ASSEMBLY BOTTOM	1
J	LHP7	WOOD CRT POST	5
K	1975	WOOD BLOCKOUT OR RECYCLE EQUIVALENT	5
L	E750	BEARING PLATE	1
M	S700	CABLE ANCHOR BOX	1
N	E770	30T CABLE ANCHOR ASSEMBLY	1
O	S780	GROUND STRUT HENGE POST	1

HARDWARE			
a	B516030A	3/2" x 3" HEX BOLT A325	2
b	W6516	3/2" WASHER	4
c	N6516	3/2" HEX NUT	2
d	B89122	3/2" Dia x 12" SPLICE BOLT	35
e	B551802	3/2" Dia x 18" HGR BOLT	5
f	B38300A	3/2" Dia x 9" HEX BOLT GRD 5	1
g	W660	3/2" WASHER	7
h	N650	3/2" HGR NUT	39
i	B34084A	3/2" Dia x 6 1/2" HEX BOLT GRD A440	1
k	N630	3/2" Dia HEX NUT	1
l	N150	1" ANCHOR CABLE HEX NUT	2
m	W150	1" ANCHOR CABLE WASHER	2
n	S212A	3/2" R30 SHOULDER BOLT WITH WASHER	8
o	N212A	3/2" STRUCTURAL NUT	8
p	W212A	3/2" STRUCTURAL WASHER	8
r	CT1338T	BEARING PLATE RETAINER TB	1

NOTE: Standard wood tie post, block and associated hardware not included in Bill of Materials Table.

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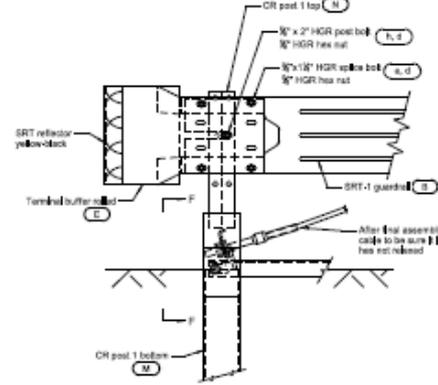
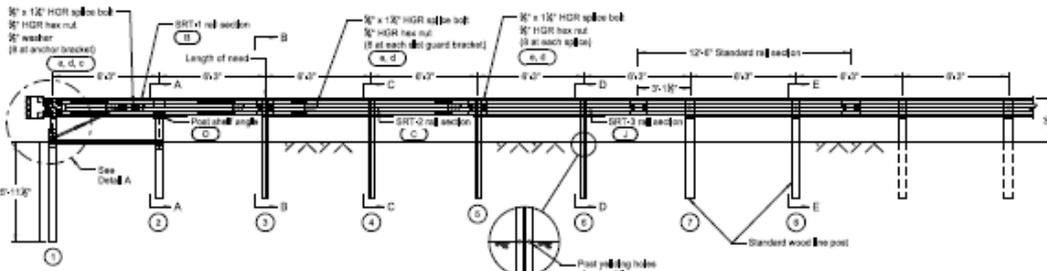
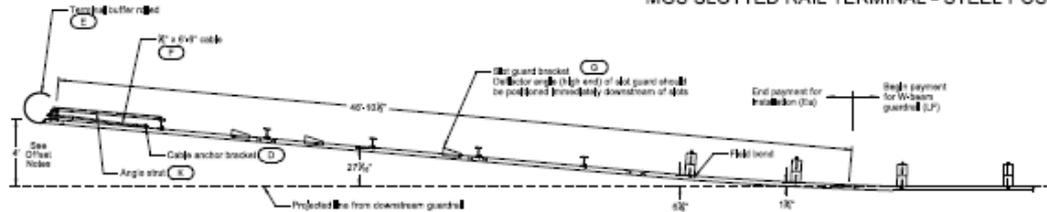
# Guardrail Terminals

- ▶ Flared guardrail
  - MGS FLEAT
- ▶ Non-Flared guardrail
  - MGS Slotted Rail Terminal (MGS SRT)

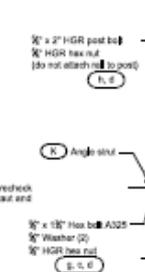
# MGS SRT

## MGS SLOTTED RAIL TERMINAL - STEEL POST

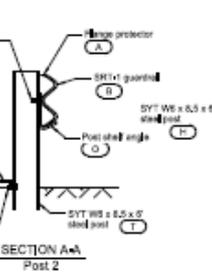
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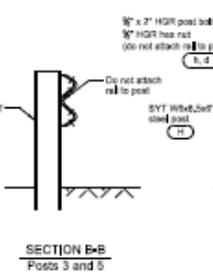
DETAIL B  
Posts 3 through 6



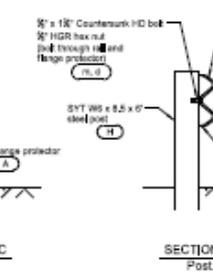
SECTION A-A  
Post 2



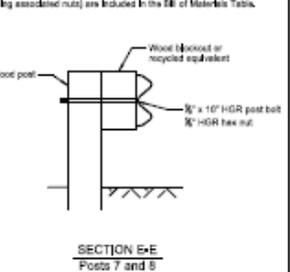
SECTION B-B  
Posts 3 and 5



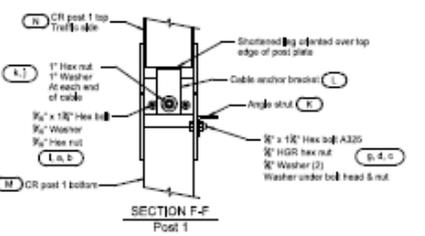
SECTION C-C  
Post 4



SECTION D-D  
Post 6



SECTION E-E  
Posts 7 and 8



SECTION F-F  
Post 1

**GENERAL NOTES:**

1. **Colorcode** all bolts, nuts, cable connections, cable anchors, locking plates, end guards, struts, nuts, plates and tubes and end plates.
2. The backaway cable assembly must be taut. A locking device (like pins or channel lock pliers) should be used to prevent cable from backing when tightening nuts.
3. For each **Installation**, the curb must end prior to post 7, where the curb is extended beyond post 7, the **Slotted Rail Terminal** can not be used. Use a straight end treatment at the end of the slotted guarded rail in place at the face of the curb.
4. For details not shown, see the manufacturer's **Installation manual**.
5. The **Slotted Rail Terminal** is only to be used as an end terminal when a minimum length of 175 feet, including the length of the end terminal, can be provided in absence of these objects.

**OFFSET NOTES:**

1. Post offset dimensions are given to the center of the traffic face of posts, except for posts 7 and 8 where dimensions are to the center of the traffic face of the slab.
2. Guardrail between posts 1-7 is on a straight line line.
3. Install the **Slotted Rail Terminal** with a 4' clearance for a straight or flared guardrail installation.

ITEM	ITEM NO.	BILL OF MATERIALS	QTY
A	70	12\"/>	
B	300	12\"/>	
C	300	12\"/>	
D	700A	CABLE ANCHOR BRACKET	1
E	907G	TERMINAL BUFFER ROLLED	1
F	30500	1/2\"/>	
G	66650	SLOT GUARD BRACKET	4
H	193000	SYT W6x6.5 6\"/>	
J	109070	120-45\"/>	
K	338750	ANGLE STRUT 3\"/>	
L	398000	CABLE ANCHOR BRACKET (POST 1)	1
M	34552A	CR POST 1 BOTTOM WRYS	1
N	34553A	CR POST 1 TOP WRYS	1
O	34554G	POST SHELF ANGLE (POST 2)	1

HARDWARE		
a	32450	1/2\"/>
b	32450	1/2\"/>
c	32000	1/2\"/>
d	32450	1/2\"/>
e	33600	1/2\"/>
f	33800	1/2\"/>
g	32910	1/2\"/>
h	34000	1/2\"/>
i	38600	1\"/>
k	38100	1\"/>
l	42110	1/2\"/>
m	44190	1/2\"/>

NOTE: Standard rail section and standard wood tie posts (including the blocks and associated hardware) not included in Bill of Materials Table. All tie bolts (including associated nuts) are included in the Bill of Materials Table.

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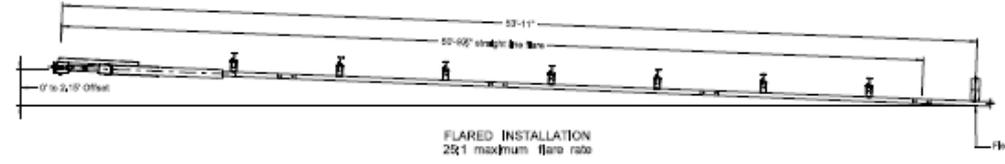
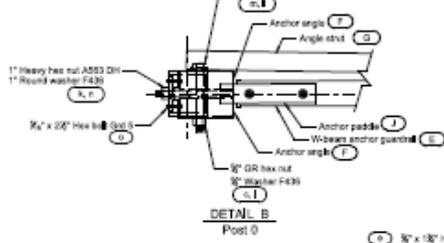
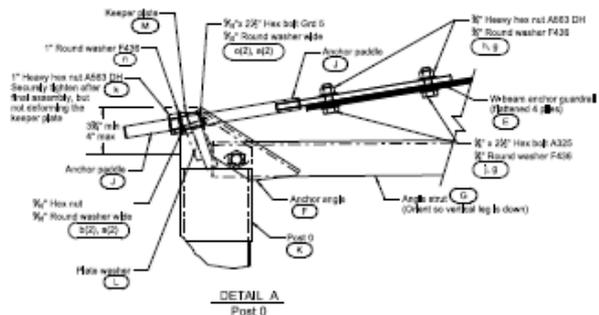
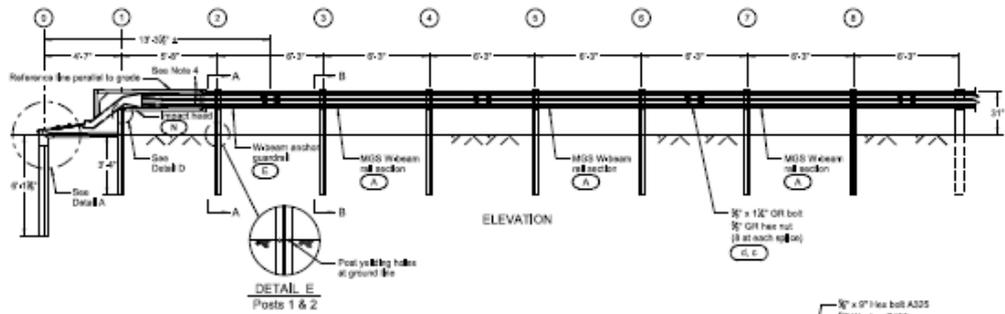
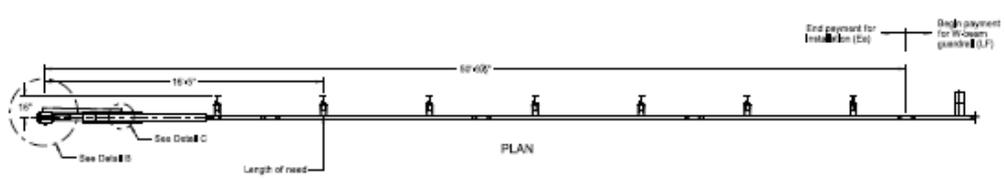
# Guardrail Terminals

- ▶ Flared guardrail
  - MGS FLEAT
- ▶ Non-Flared guardrail
  - MGS Slotted Rail Terminal (MGS SRT)
  - MASH SoftStop End Terminal

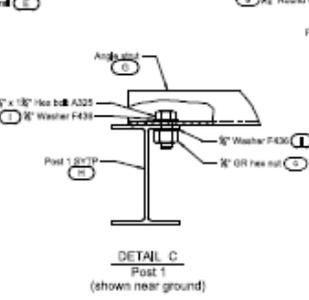
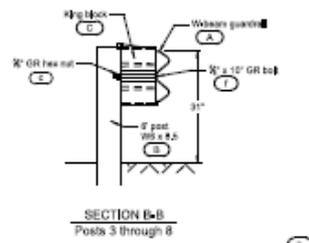
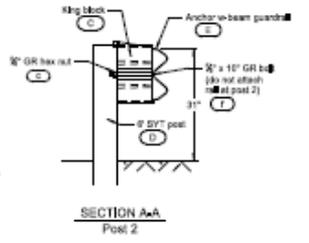
# MASH SOFTSTOP

## MASH SOFTSTOP END TERMINAL - STEEL POST

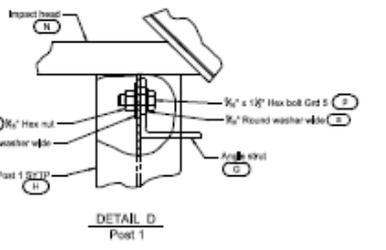
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- GENERAL NOTES:
1. Galvanize all bolts, nuts, cable assemblies, cable anchors, and bearing plates.
  2. The SoftStop can be flared at a rate of 25:1 or flatter.
  3. Do not curve the guardrail within the SoftStop under any circumstances.
  4. It is acceptable to install the SoftStop impact head parallel to the grade line or with an upward slope. See SoftStop assembly manual for specific details.



ITEM NO.	ITEM NO.	QTY	DESCRIPTION
A	000011	3	12 / 12'40" / 3'x2' / 5 MGS WEIBeam RAIL SECTION
B	000033	6	6'-0" STEEL POST 106 x 6.5
C	000777	7	RING BLOCK 4" X 7 1/2" X 1-2"
D	015000	1	6'-0" SUTP POST / 6.5 / 31" GR HT
E	015020	1	SFST - ANCHOR GUARDRAIL 12VP
F	015021	2	SFST - ANCHOR ANGLE
G	015022	1	SFST - ANGLE STRUT
H	015023	1	SFST - POST #1 SUTP
J	015024	1	SFST - ANCHOR PADDLE
K	015026	1	SFST - POST #3
L	015028	1	SFST - PLATE WASHER
M	015027	1	SFST - KEEPER PLATE
N	015029	1	SFST - IMPACT HEAD
HARDWARE			
a	000040	6	3/8" ROUND WASHER WIDE
b	000045	3	3/8" HEX NUT
c	000046	41	3/8" GR HEX NUT
d	000060	32	3/8" x 1 1/2" GR BOLT
e	000061	1	3/8" x 1 1/2" HEX BOLT ASSB
f	000062	7	3/8" x 1 1/2" GR BOLT A307
g	000071	4	3/8" ROUND WASHER F436
h	000074	2	3/8" HVY HEX NUT A553 DH
i	000117	2	3/8" x 25/8" HEX BOLT A325
k	000068	1	1" HVY HEX NUT A553 DH
l	004072	4	3/8" WASHER F436
m	004069	1	3/8" x 2" HEX BOLT A325
n	004062	1	1" ROUND WASHER F436
o	100285	2	3/8" x 25/8" HEX BOLT GRD 5
p	100286	1	3/8" x 1 1/2" HEX BOLT GRD 5



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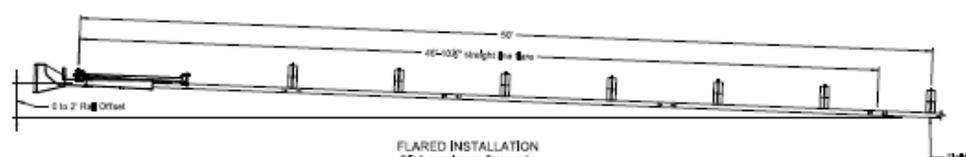
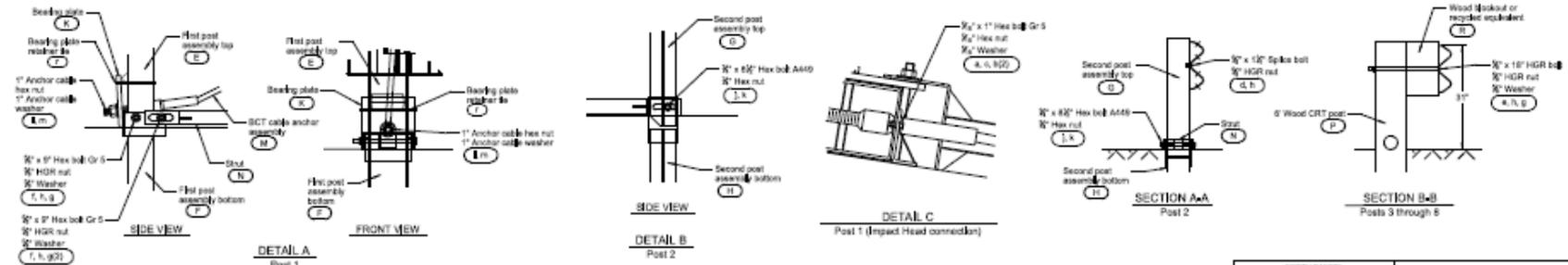
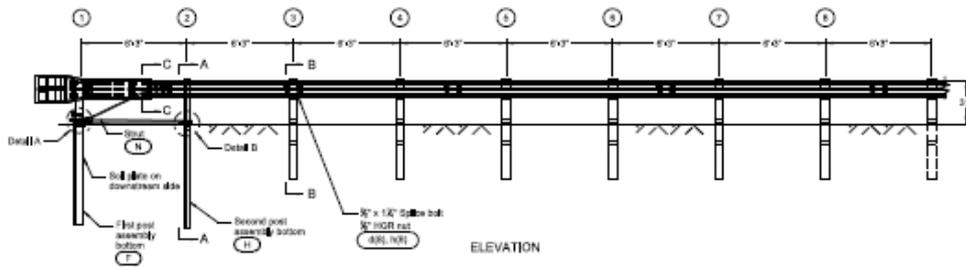
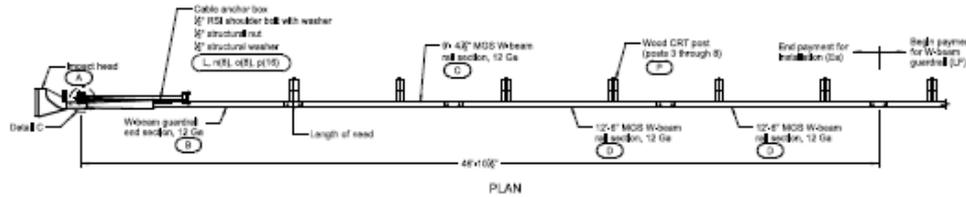
# Guardrail Terminals

- ▶ Flared guardrail
  - MGS FLEAT
- ▶ Non-Flared guardrail
  - MGS Slotted Rail Terminal (MGS SRT)
  - MASH SoftStop End Terminal
  - MASH Sequential Kinking Terminal (SKT)

# MASH SKT

## MASH SEQUENTIAL KINKING TERMINAL - WOOD POST

D-764-51



**GENERAL NOTES:**

1. Galvanize all bolts, nuts, cable assemblies, cable anchors, and bearing plates.
2. The MSKT can be flared at a rate of up to 25:1 to prevent the impact head from exceeding its on the skid.
3. Ensure the lower sections of the posts do not protrude more than 4" above the ground (measured along a 5' cord). The grading may be necessary to meet this requirement.
4. Install the lower section of the flanged posts without the upper post attached. If the post is placed in a rigid hole, the backfill material must be compacted to prevent settlement.
5. The breakaway cable assembly must be used. Use a locking device (like glue or channel lock pliers) to prevent the cable from kinking when tightening nuts.
6. The ends of the wood blocks to the rectangular wood posts at post 3 through post 8. Use two 20 penny galvanized nails.

ITEM	ITEM NO.	BILL OF MATERIALS	QTY
A	MS666	IMPACT HEAD	1
B	SF1353	W-BEAM GUARDRAIL END SECTION, 12 Ga	1
C	G12225	6'-42" MGS W-BEAM RAIL SECTION, 12 Ga	1
D	G1223A	12'-0" MGS W-BEAM RAIL SECTION, 12 Ga	2
E	MTPH-1A	FIRST POST ASSEMBLY TOP (6" X 8" X 1/2" Tube)	1
F	MTPH-1B	FIRST POST ASSEMBLY BOTTOM (6" WALK 15)	1
G	LHP2A	SECOND POST ASSEMBLY TOP	1
H	HP25	SECOND POST ASSEMBLY BOTTOM	1
I	S753	BEARING PLATE	1
L	S789	CABLE ANCHOR BOX	1
M	S770	SCT CABLE ANCHOR ASSEMBLY	1
N	MS785	STRUT	1
P	LP971	6" WOOD CRT POST	8
R	PR75	WOOD BLOCKOUT OR RECYCLED EQUIVALENT	8
HARDWARE			
	BS19210A	3/4" x 1" HEX BOLT GR 5	2
	W0616	3/4" WASHER	4
	N0616	3/4" HEX NUT	2
	BS89122	3/4" dia x 18" SPJICE BOLT	33
	BS81802	3/4" dia x 18" HGR BOLT (POSTS 3 THRU 8)	8
	BS83004A	3/4" x 2" HEX BOLT GR 5	2
	W050	3/4" WASHER	9
	N050	3/4" dia HEX NUT	36
	B34384A	3/4" dia x 88" HEX BOLT CRD A499	1
	N030	3/4" dia HEX NUT	1
	N100	1" ANCHOR CABLE HEX NUT	2
	W100	1" ANCHOR CABLE WASHER	2
	BS12A	3/4" RSI SHOULDER BOLT WITH WASHER	8
	N012A	3/4" STRUCTURAL NUT	8
	W012A	3/4" STRUCTURAL WASHER	8
	CT100ST	BEARING PLATE RETAINER TIE	1

NORTH DAKOTA DEPARTMENT OF TRANSPORTATION		This document was originally issued and sealed by Roger Weigel, Registration Number PE-2930, on 7/14/17 and the original document is stored at the North Dakota Department of Transportation
DRAWING		
DATE	REVISION	
	CHANGE	

# Bridge Rail

- ▶ Jersey Shape
  - 32” MASH TL-3 Compliant
- ▶ Texas Single Slope
  - MASH TL-4 Compliant
- ▶ Alaska Two Tube
  - Not tested to MASH TL-4 yet
  - Pooled Fund – Alaska and North Dakota

# Attenuation Devices/ Crash Cushions

- ▶ Manufacturers develop and crash test devices.
- ▶ Several different crash cushions tested and meet MASH.

# Items Not Tested

- ▶ Sign Supports
- ▶ Breakaway Light and Traffic Signal Standards
- ▶ Temporary Barriers
- ▶ Traffic Control Devices

# Sign Supports

- ▶ Nothing tested to match our type of current supports.

# Breakaway Light and Traffic Signal Standards

- ▶ Light standards
- ▶ Type II, V, VI, and VII Traffic Signal Standards

# Temporary Barriers

- ▶ Implementation date – December 31, 2019
- ▶ State Furnished Precast Concrete Median Barriers

# Traffic Control Devices

- ▶ Implementation date – December 31, 2019

# How Design Process is Affected

- ▶ Survey
  - No Change
  
- ▶ Safety Review
  - Design Philosophy
  - Guardrail Height
    - NCHRP 350 (Max=31", Min=26.5")
    - MASH (Max=34", Min=28")
  - Safety Review Templates
  
- ▶ Plan Set

# Standard Drawings

- ▶ D-764-1 thru D-764-32
  - Existing NCHRP 350 standards (15 drawings)
  - Remain in place
- ▶ D-764-38 thru D764-64
  - New MASH standards (13 drawings)

# Summary

- ▶ MASH to be implemented for projects constructed in 2018
- ▶ Implementing items that meet MASH if available
- ▶ Watch for additional items as they meet testing requirements for MASH

# Questions

# Contact Information

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