# LTAP Transportation Technology Transfer Center


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*Spokesperson Decade of Action for Road Safety 2011-2020*

Assuming that a barrier is needed and is properly designed and installed,

# WHAT IS THE BEST WAY TO TERMINATE A STRONG-POST W-BEAM GUARDRAIL OR CONCRETE BARRIER?

# Terminal Design and Warrants



- Minimize injury to vehicle occupants in the event of a crash into the end of the guardrail
- Crashworthy terminals MUST be used on the National Highway System
- Recommended for use on all public roads

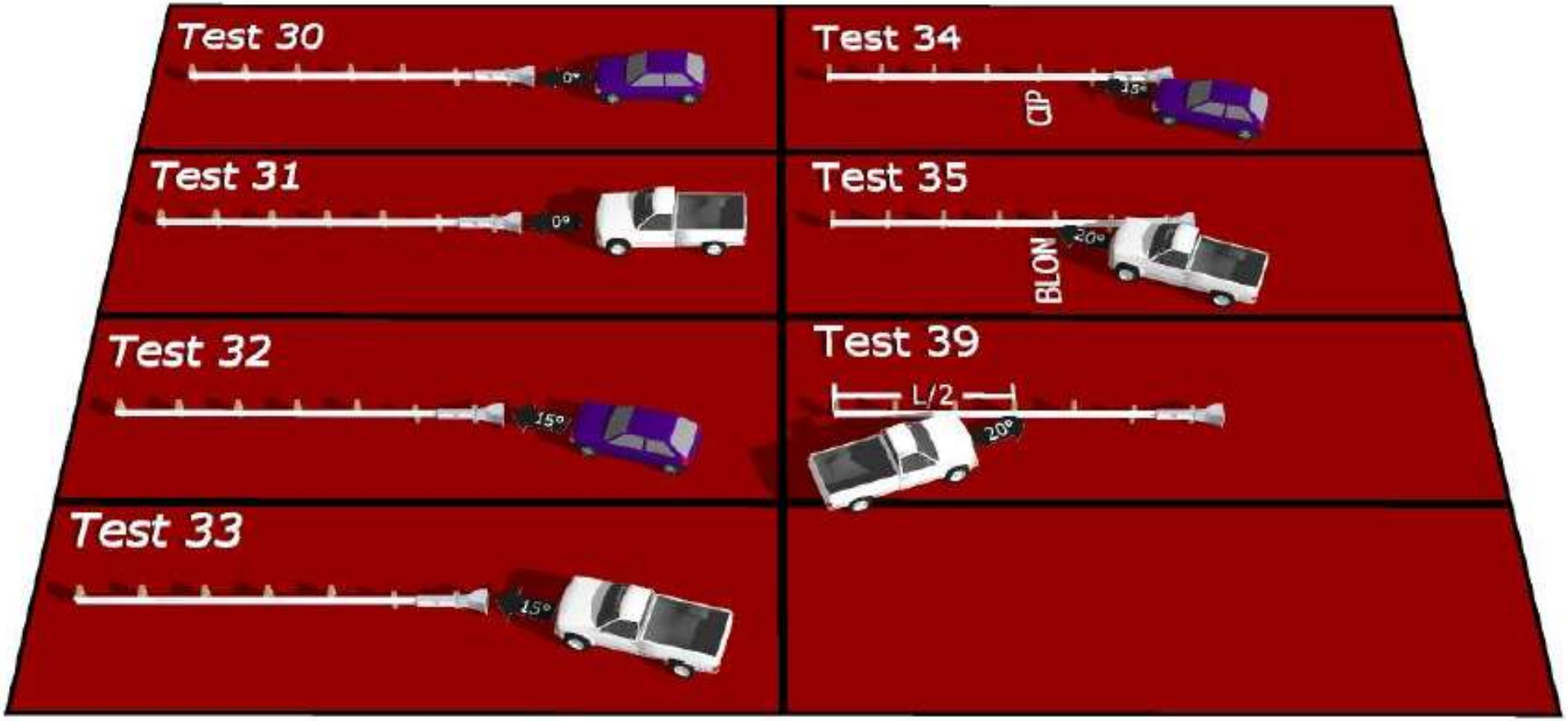
# 1. Performance Requirements



- Gradually decelerates vehicle to a stop or redirects it when impacting end-on
- Safely redirecting vehicle that impacts side of device, at mid-length and near the nose
- Test levels w/ 1.8k car and 4.4k pick-up
  - TL-1: 30 mph
  - TL-2: 45 mph
  - TL-3: 60 mph

# NCHRP 350 Test Matrix End Terminals





# Terminal Crash Tests

FHWA 8-11

1. An offset head-on impact with a small car
2. A head-on impact with a pickup truck
3. A 15-degree angle hit at the end of the terminal with the small car and the truck

# Terminal Crash Tests

FHWA 12-14

4. A “critical impact point” hit, usually at the second post, with the small car impacting at 20 degrees
5. A strength test with the pickup truck to determine the point at which the guardrail will contain and redirect the vehicle
6. A reverse direction impact if the terminal will be used where it can be struck by opposing traffic

# 2. End Treatments Characteristics



1. Able to perform under head-on and side impacts with no penetration in passenger compartment
2. Used to shield traffic on one direction
3. Essential if barrier is within clear zone or in an area likely to be struck
4. Should not spear, vault, or roll a vehicle
5. Must be properly anchored

# Strut and Cable Anchor



- Helps to develop the full tensile strength of the W-beam rail element when hit along its side
  - Typically occurs at the third pole
  - Allows the vehicle to be contained and redirected

# Selection of Appropriate W-beam Terminals



- Based on specific site locations
  - Flat angle impacts are possible
  - Terrain behind and adjacent to barrier allow vehicle to reach the shielded object
  - Terrain behind and adjacent to barrier itself can cause serious occupant injuries

- Options
  - Increase the length of the barrier
  - Use an energy-absorption terminal

# Importance of Selecting and Installing Terminals

# CHARACTERISTICS OF W-BEAM END TREATMENTS

# Common W-beam Terminals






1. Buried in backslope
2. Non-energy absorbing
3. Energy absorbing

# Unacceptable W-beam Terminals





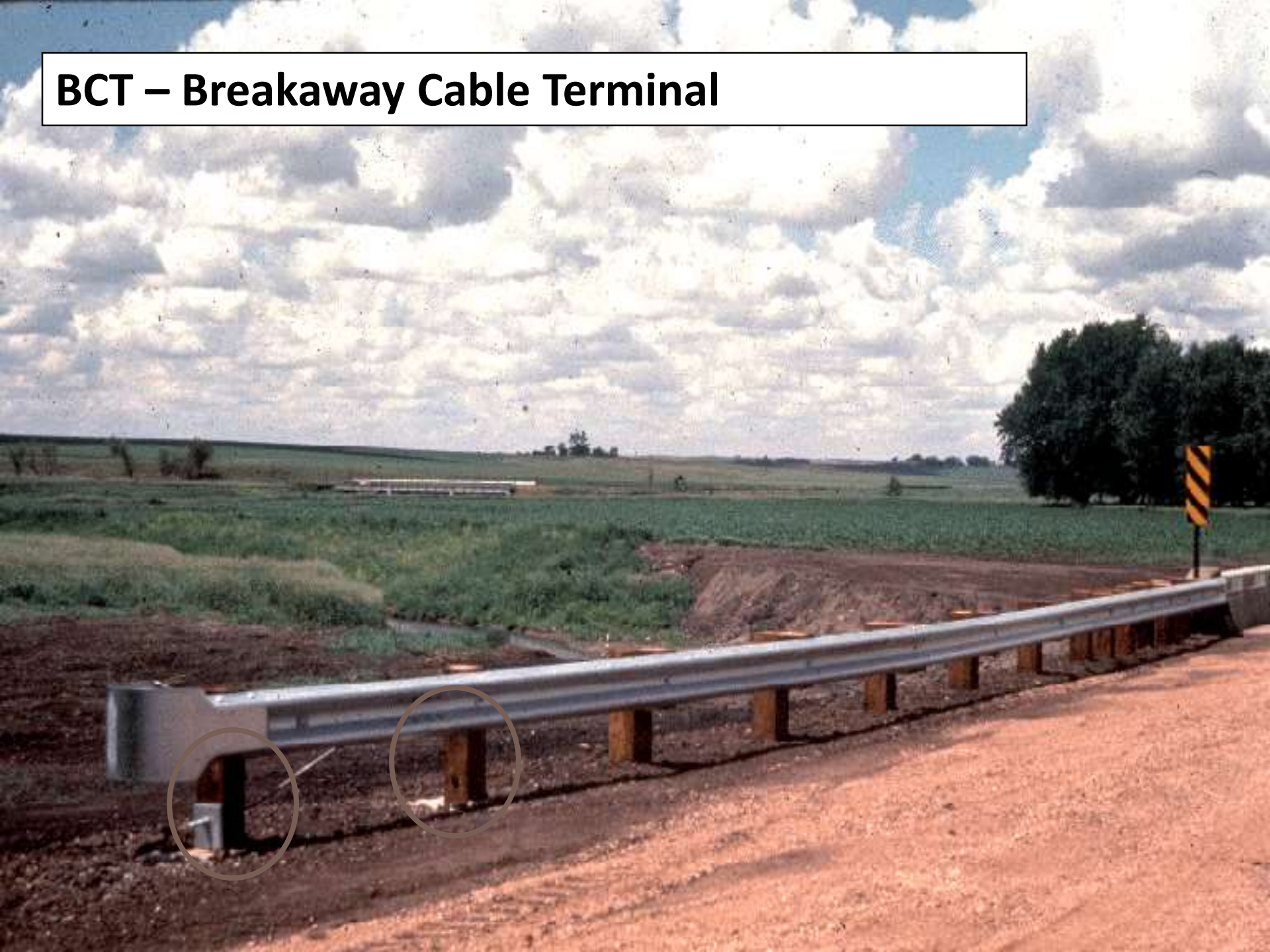
1. Blunt end
2. Fish-tail
3. Turn-down
4. BCT

# Turndown Guardrail



- Terminal turned down into the ground to prevent spearing but may cause vehicles to roll over
- Critical on high-speed, high-volume highways
- Rollovers are the most severe type of roadside crashes

# BCT – Breakaway Cable Terminal



**MELT -** Modified Eccentric Loader Terminal

# Buried-in Backslope Terminal



- Backslope becomes an extension of the barrier and a motorist cannot physically get behind the terminal
- Eliminates the exposed end of the guardrail and the possibility of a true end-on hit
- Provides full shielding for the hazard

# Barrier Anchored in Backslope



- Height of the guardrail is maintained until the ditch flow line
- Guardrail is flared into the backslope
- Add rubrail for W-beam installation
- Guardrail is anchored in the backslope
- Slope into the face of the rail should be 1V:4H or flatter
- Ideal backslope is nearly vertical

# Buried-in Backslope Terminal



- Successfully tested behind 10:1, 6:1, and 4:1 foreslopes
- Length of need begins at the point where the W-beam remains at full height in relation to the roadway shoulder, usually at the point where the barrier crosses the ditch line
- When distance from the ground to the bottom of the W-beam exceeds approximately 18 inches, a rubrail must be added to minimize wheel snagging on the support posts

# Buried-In-Backslope

# Improper Buried Terminals

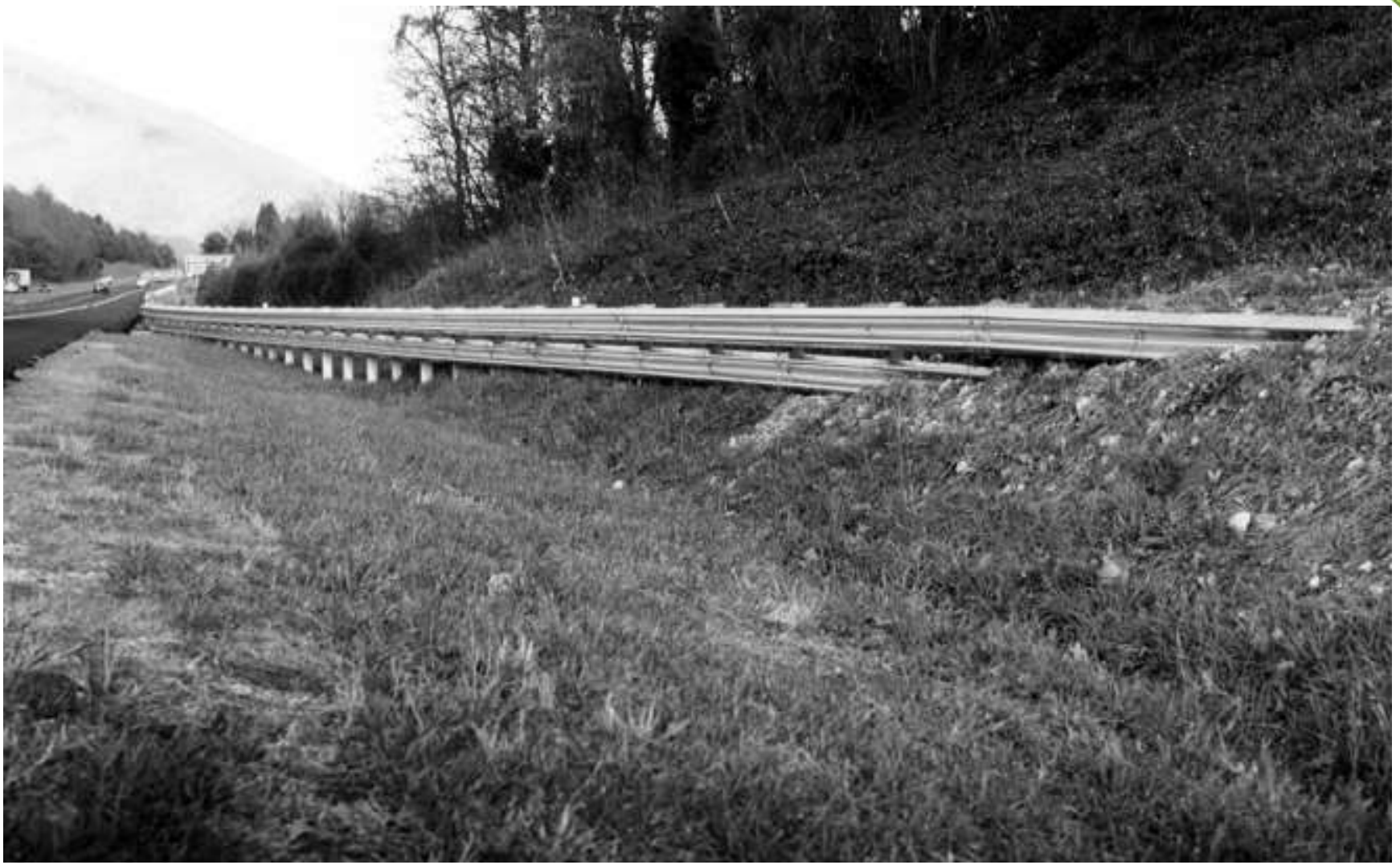


# Effect of Foreslope



# Effect of Backslope

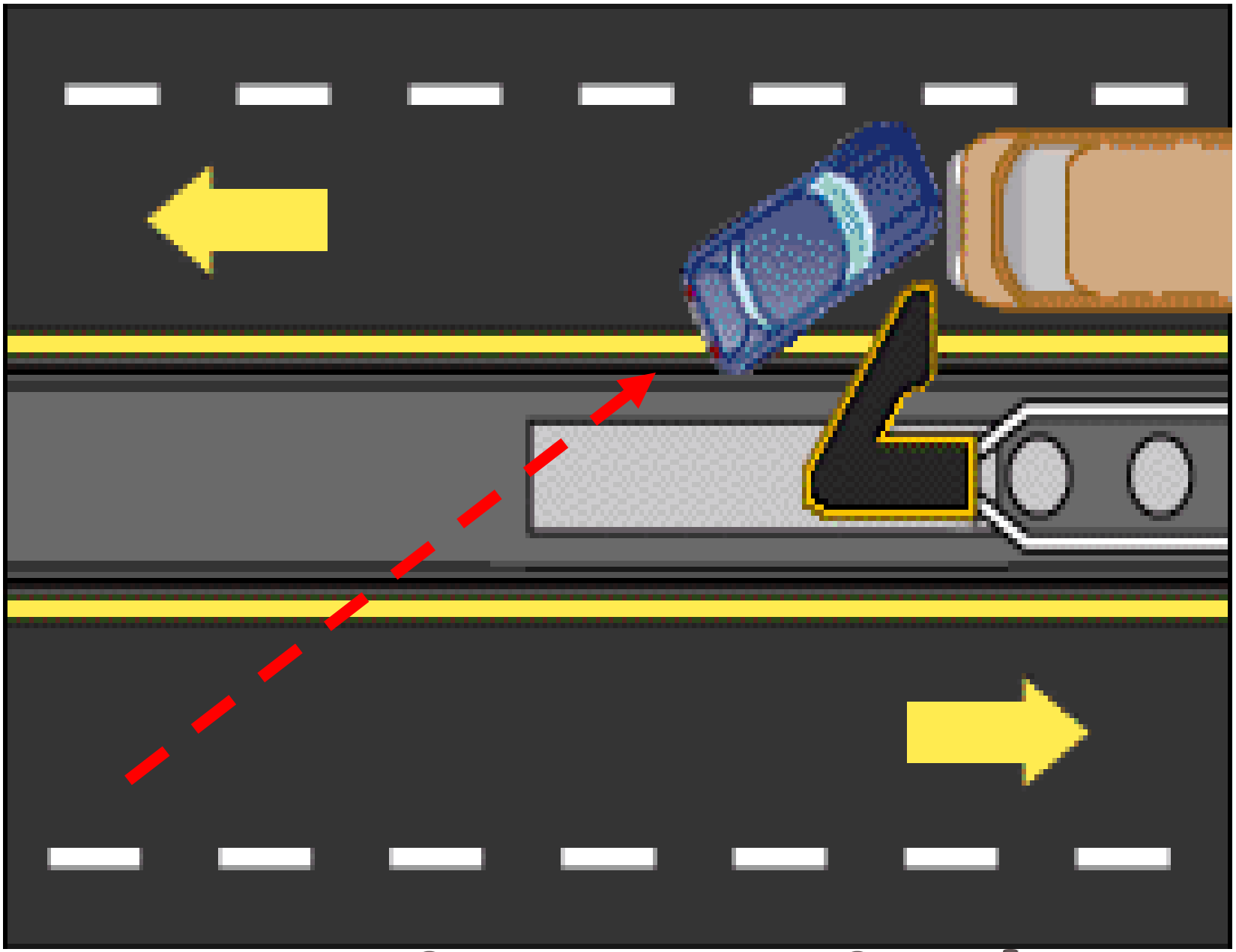




# End Treatment Types



1. Gating
   - Allows a vehicle impacting at or near the nose at an angle of 15 degrees or greater to pass thought the device
   - Length of need of rail starts at 12.5 ft from impact head
   - Suggested a traversable area of 75-ft (beyond terminal) by 20-ft (behind terminal)
2. Non-gating – capable of redirecting along its entire length

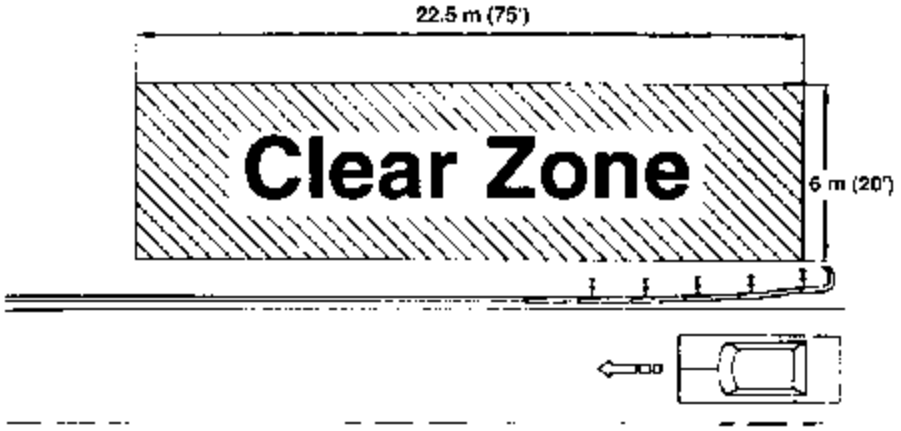


# Gating Terminal

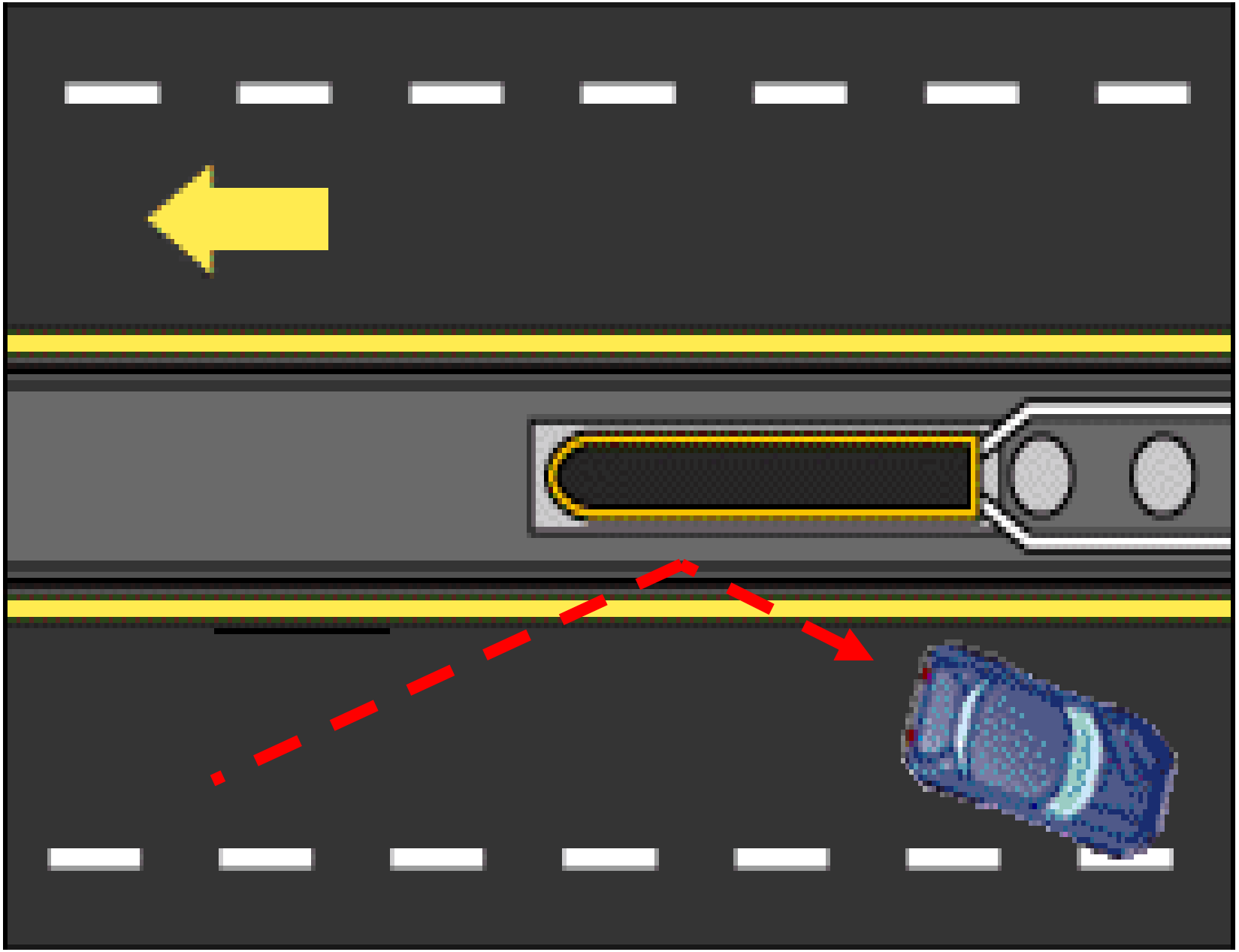
# FHWA Guidelines on Gating



- FHWA recommends a minimum clear zone for gating terminals
  - 75 X 20 feet
  - Clear of trees, poles, drop-offs, oncoming traffic




- Terminals for median applications requires bi-directional capability when using double-faced guardrails
- Non-gating terminals should always be used for narrow medians



# Non-gating Terminal

# Non-Energy Absorbing Terminals



- Allow an un-braked vehicle to travel over 150 feet behind and parallel to the rail
- Rail is designed to separate from the posts, or collapse, minimizing the chances that it will intrude into the passenger compartment
- Vehicle speed is not significantly reduced

# Non-Energy Absorbing Terminal

# Non-Energy Absorbing Terminal



# Non-Energy Absorbing Terminals



# Non-Energy Absorbing Terminals



# Energy Absorbing Terminals



- Have the ability to stop head-on vehicles in relatively short distances, in about 50 feet

# Flared Terminal

# Non-flared Terminal

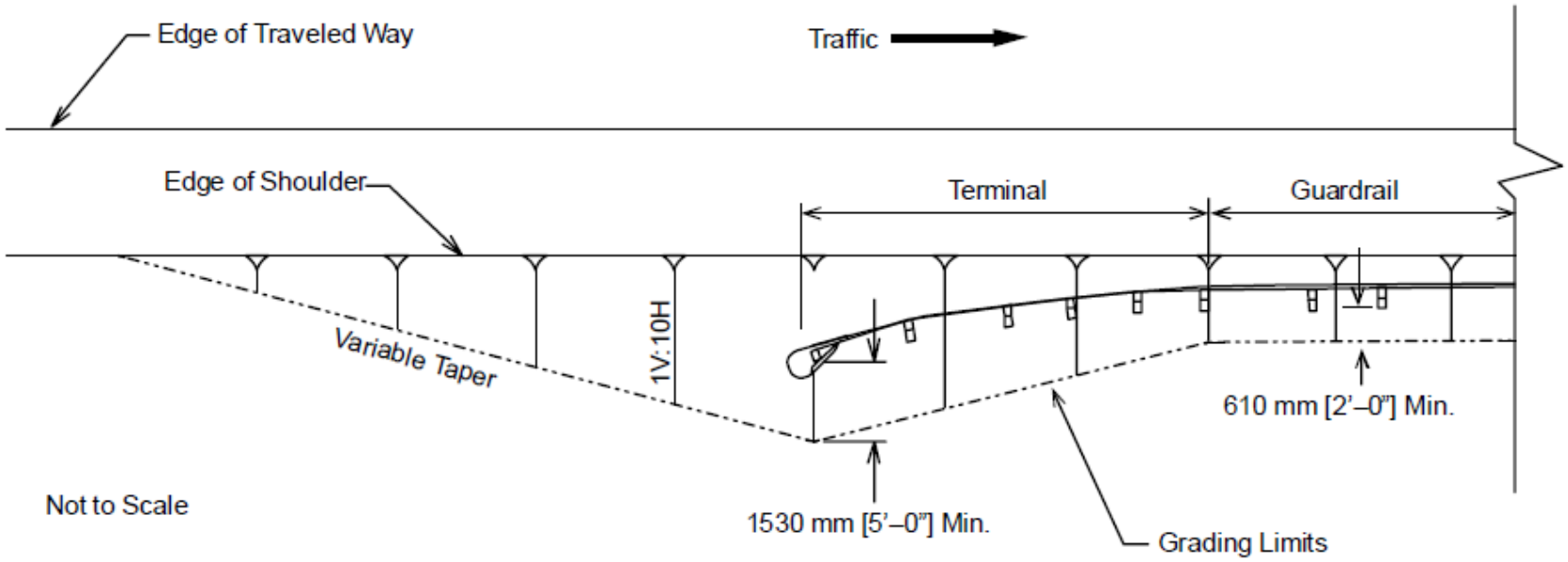


- Terminals are flared away from the traveled way which creates an offset from the tangent guardrail

- Used where the widening to provide the offset for a flared terminal is not practical

# Grading for Flared End Treatment
## (Figure 8-2, 2011 RDG)

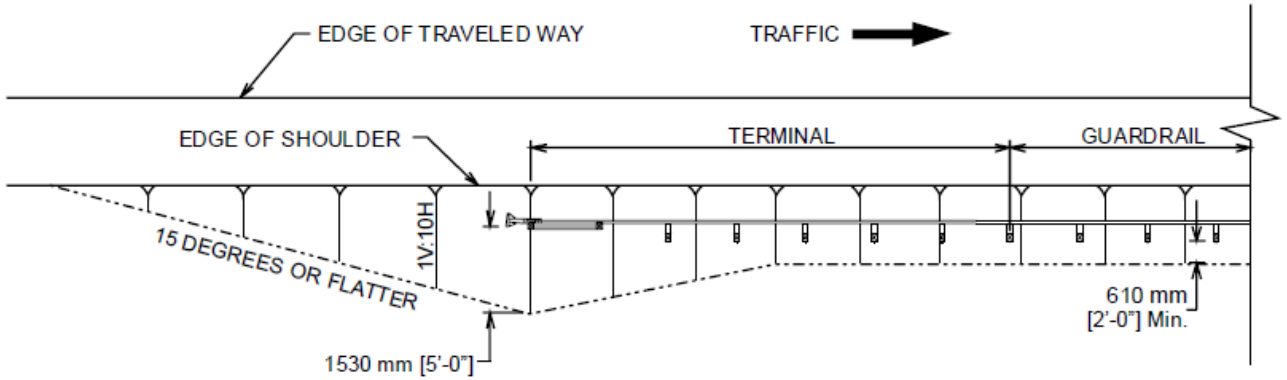




# Grading for Tangent Guardrail Terminal

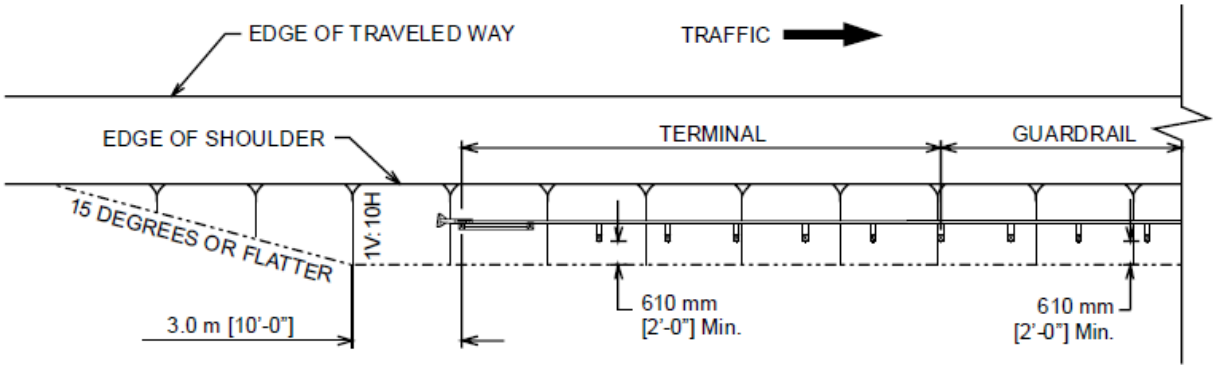
## (Figure 8-3 2011 RDG)






PREFERRED GRADING

NOT TO SCALE




ALTERNATIVE GRADING

Note: The preferred grading layout should be used when practical. However, if necessary because of site limitations, the alternative grading layout may be used when upgrading an existing terminal.

# Installation of Terminal Systems



- Special Attention:
  - Terminal Selection
  - Layout
- Installation:
  - To Manufacturers' Specifications
  - State Design Standards
- Site Grading:
  - In Advance: Essentially Flat
  - Behind and Beyond: Must Accommodate Gating Vehicles

2:50
3:40

# AVAILABLE W-BEAM GUARDRAIL TERMINALS

# End Treatments



| System | NCHRP Report 350 Test Level | System Width | System Length |
|---|---|---|---|
| Three-Strand Cable Terminal | TL-3 | 1.2 m [4.0 ft] Flare | N/A |
| Wyoming Box Beam End Terminal (WYBET-350) | TL-3 | 0.6 m [2 ft] | 15.2 m [50 ft] |
| Barrier Anchored in Backslope | TL-3 | N/A | N/A |
| Eccentric Loader Terminal (ELT) | TL-3 | 0.5 m [1.6 ft] plus 1.2 m [4 ft] Flare | 11.4 m [37.5 ft] |
| Slotted Rail Terminal (SRT-350) | TL-3 | 0.5 m [1.6 ft] plus 1.2 m [4 ft] Flare<br>or<br>0.5 m [1.6 ft] plus 0.9 m [3 ft] Flare | 11.4 m [37.5 ft] |
| REGENT | TL-3 | 0.5 m [1.6 ft] plus 1.3 m [4.3 ft] Flare | 11.4 m [37.5 ft] |

# End Treatments



| System | NCHRP Report 350 Test Level | System Width | System Length |
|---|---|---|---|
| Vermont Low-Speed, W-Beam Guardrail End Terminal | TL-2 | 1.5 m [4.9 ft] | 3.4 m [11.15 ft] |
| Flared Energy-Absorbing Terminal (FLEAT) | TL-2 | 0.5 m [1.6 ft] plus 0.51 m – 0.81 m [1.7 ft – 2.7 ft] Flare | 7.62 m [25 ft] |
| | TL-3 | 0.5 m [1.6 ft] plus 0.76 m – 1.2 m [2.5 ft – 4 ft] Flare | 11.4 m [37.5 ft] |
| Beam-Eating Steel Terminal (BEST) | TL-3 | 0.5 m [1.6 ft] | 11.4 m [37.5 ft] or 15.2 m [50 ft] |
| Extruder Terminal (ET-2000) | TL-3 | 0.5 m [1.6 ft] | 11.4 m [37.5 ft] or 15.2 m [50 ft] |
| Sequential Kinking Terminal (SKT-350) | TL-3 | 0.5 m [1.6 ft] | 15.2 m [50 ft] |
| QuadTrend-350 | TL-3 | 0.46 m [1.5 ft] | 6.1 m [20 ft] |
| NEAT | TL-2 | 0.57 m [1.9 ft] | 2.957 m [9.7 ft] |
| Sloped Concrete End Treatment | N/A | 0.6 m [2 ft] | 6 m to 12 m [20 ft to 40 ft] |

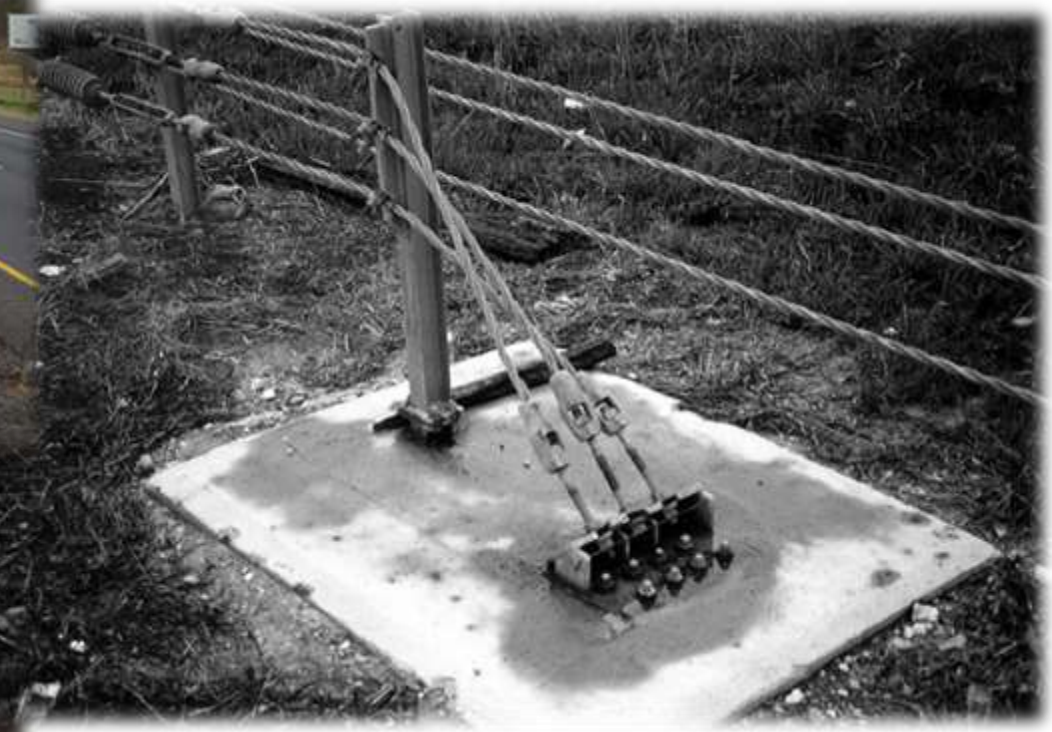
# Terminals for Cable Barrier Systems
## (Table 8-1 2011 RDG)



| Terminal | Test Level (TL) | FHWA Acceptance Letter | System Designation | Manufacturer | Reference Section |
|---|---|---|---|---|---|
| Three-Strand Cable Terminal | 3 | CC-63 | SEC01 | Generic | 8.3.5.1 |
| Terminals for High-Tension Cable Barriers | 3 | CC-76 | SEC07a | Trinity Highway Products, LLC (CASS), and Nucor Steel Marion, Inc. (NU-CABLE) | 8.3.5.2 |
| | 3 | CC-86<br>CC-86A<br>CC-86B | SEC07b | Brifen USA, Inc. | |
| | 3 | CC-92<br>CC-92A | Not posted | Gibraltar Cable Barrier Systems, L.P. | |
| | 3 | CC-98 | SEC07c | Barrier Systems, Inc. | |
| | 3 | CC-93<br>CC-93A | Not posted | Gregory Industries, Inc. (SAFENCE) | |

# Cable Barrier Terminal





**TL-3 & TL-4**

# Terminals for Box-Beam Guardrail Systems (Table 8-4 2011 RDG)



| Terminal | NCHRP Report 350 Test Level | FHWA Acceptance Letter | System Designation | Manufacturer | Reference Section |
|---|---|---|---|---|---|
| Wyoming Box-Beam End Terminal (WY-BET™) | 3 | CC-60<br>CC-60A | SEB03<br>SEB04 Median | Trinity Highway Products, LLC | 8.3.7.1 |
| Bursting Energy Absorbing Terminal (BEAT™) and (BEAT-MT™) | 3 | CC-69<br>CC-69A | SEB05<br>SEB06 Median | Road Systems, Inc. | 8.3.7.2 |

# Wyoming Box Beam Terminal WY-BET



- Oversized outer tube that telescopes over the standard box-beam rail element
- Includes a nosepiece welded to a short box beam
- Installed parallel to roadway or with 1:10 flare rate
- Head is typically reusable after a design impact

**SPECIFICATIONS**

WY-BET™

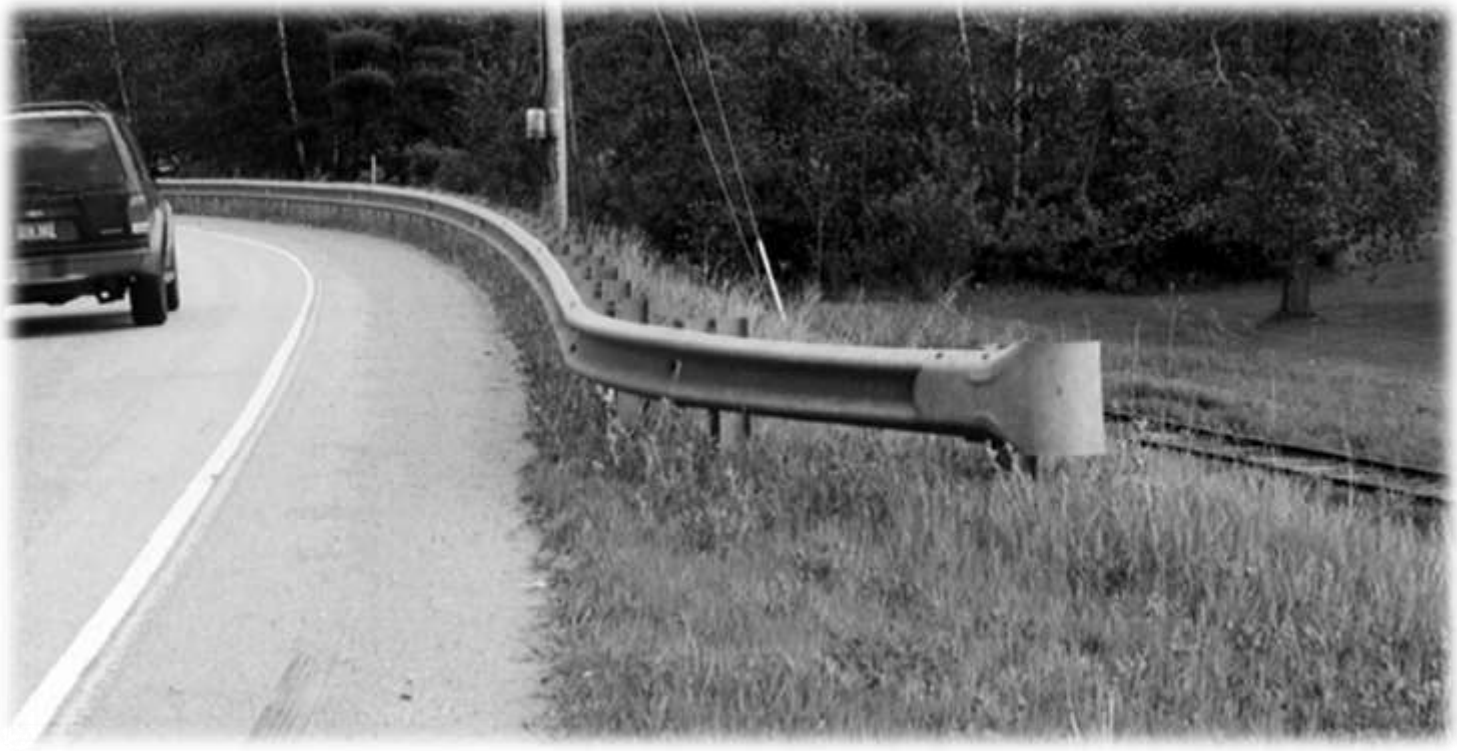
- Length: 50' 0" (15.24 m)
- Post Spacing: 6' (1.83 m)
- Shoulder and median options

# Vermont Low-speed w/ Guardrail



- Non-proprietary
- Impact speeds < 45 mph
- W-beam shop bent

**TL-2**



# Terminals for W-Beam Guardrail Systems (Table 8-2 2011 RDG)



| Terminal | Test Level (TL) | FHWA Acceptance Letter | System Designation | Manufacturer | Reference Section |
|---|---|---|---|---|---|
| **Buried-in-Backslope Terminal (Section 8.3.6.1)** | | | | | |
| Buried-in-Backslope Terminal | 3 | CC-53<br>CC-53A | Not Posted | Generic | 8.3.6.1 |
| **Flared Terminals (Section 8.3.6.2)** | | | | | |
| Eccentric Loader Terminal (ELT) | 3 | CC-56<br>CC-56A | Not Posted | Generic | 8.3.6.2.1 |
| Modified Eccentric Loader Terminal (MELT) | 2 | CC-84 | SEW05 | Generic | 8.3.6.2.2 |
| Flared Energy-Absorbing Terminal (FLEAT™) | 2 and 3 | CC-46A, B, and C | SEW14a to b | Road Systems, Inc. | 8.3.6.2.3 |
| | 2 | CC-61B and C<br>CC-88 | | | |
| Slotted Rail Terminal (SRT-350™) | 3 | CC-31<br>CC-31A<br>CC-72<br>CC-100 | SEW12<br>SEW11 | Trinity Highway Products, LLC | 8.3.6.2.4 |
| X-Tension™ Guardrail End Terminal | 3 | CC-91<br>CC-102 | Not Posted | Barrier Systems, Inc. | 8.3.6.2.5 |

# Eccentric Loader Terminal ELT



- Developed to improve BCT
- Steel lever nose inside corrugated steel pipe
- A 4-ft offset to the end post

TL-3

# Slotted Rail Terminal SRT-350



# Slotted Rail Terminal SRT-350



- Gating, non-energy absorbing, flared end terminal
  - 6-Post - 2 steel breakaway posts, 4 wood CRT posts, straight-line flare
  - 8-Post - 2 tube sleeves/wood posts, 6 wood CRT posts, parabolic flare
- Slots reduce buckling strength


**SPECIFICATIONS**

SRT-350™

- Offset: 3'0" to 4'0" (915-1220 mm)
- Length: 37' 6" (11.43 m)
- Length of need: 12'6" (3.81 m) from the end of the terminal (at the 3rd post)
- Parabolic or straight flare options

# REGENT-C



- Gating, non-energy absorbing treatment
- W-beam head slider
- Rail elements pre-crushed

# Terminal for W-Beam Guardrail Systems



**Table 8-2. Terminals for W-Beam Guardrail Systems**

| Terminal | Test Level (TL) | FHWA Acceptance Letter | System Designation | Manufacturer | Reference Section |
|---|---|---|---|---|---|
| **787-mm [31-in.] Height Terminals (Section 8.3.6.4)** | | | | | |
| FLEAT™ | 3 | CC-88<br>CC-96 | SEW15 | Road Systems, Inc. | 8.3.6.2.3 |
| SRT-350™ | 3 | CC-100 | Not Posted | Trinity Highway Products, LLC | 8.3.6.2.4 |
| SKT-350™ and SKT-LITE | 3 | CC-88<br>CC-96 | SEW18a to b | Road Systems, Inc. | 8.3.6.3.2 |
| ET-Plus™ | 3 | CC-94<br>CC-94A | Not Posted | Trinity Highway Products, LLC | 8.3.6.3.1 |

# Flared Energy-Absorbing Terminal FLEAT

11:20



- Proprietary, gating, energy absorbing treatment
- W-beam, impact head, weakened posts
- Rolls beam into loop

TL-2

TL-3

# Extruder Terminal ET-PLUS



**TL-2,3**

# Extruder Terminal ET-PLUS



- Energy-absorbing end treatment
- Cable-anchored system utilizing standard guardrail components
- Flattens the W-beam rail and shoots it away from the car and driver
- As the rail curls away from the vehicle toward the roadside, energy is absorbed
- Head is sometimes reusable after design impact

**SPECIFICATIONS**

ET-PLUS™

- Offset: 0 to 2' (0-610 mm)
- Length: 25" (7.62 m), 37' 6" (11.43 m) or 50' 0" (15.24 m)
- Post Spacing: 6'-3" (1905 mm)
- Length of need: 12'6" (3.81 m)

# Terminals for W-Beam Guardrail Systems



| Terminal | Test Level (TL) | FHWA Acceptance Letter | System Designation | Manufacturer | Reference Section |
|---|---|---|---|---|---|
| **Flared Terminals (Section 8.3.6.2)** | | | | | |
| Eccentric Loader Terminal (ELT) | 3 | CC-56<br>CC-56A | Not Posted | Generic | 8.3.6.2.1 |
| Modified Eccentric Loader Terminal (MELT) | 2 | CC-84 | SEW05 | Generic | 8.3.6.2.2 |
| Flared Energy-Absorbing Terminal (FLEAT™) | 2 and 3 | CC-46A, B, and C | SEW14a to b | Road Systems, Inc. | 8.3.6.2.3 |
| | 2 | CC-61B and C<br>CC-88 | | | |
| Slotted Rail Terminal (SRT-350™) | 3 | CC-31<br>CC-31A<br>CC-72<br>CC-100 | SEW12<br>SEW11 | Trinity Highway Products, LLC | 8.3.6.2.4 |
| X-Tension™ Guardrail End Terminal | 3 | CC-91<br>CC-102 | Not Posted | Barrier Systems, Inc. | 8.3.6.2.5 |

# X-Tension Guardrail Terminal



# X-Tension Guardrail Terminal



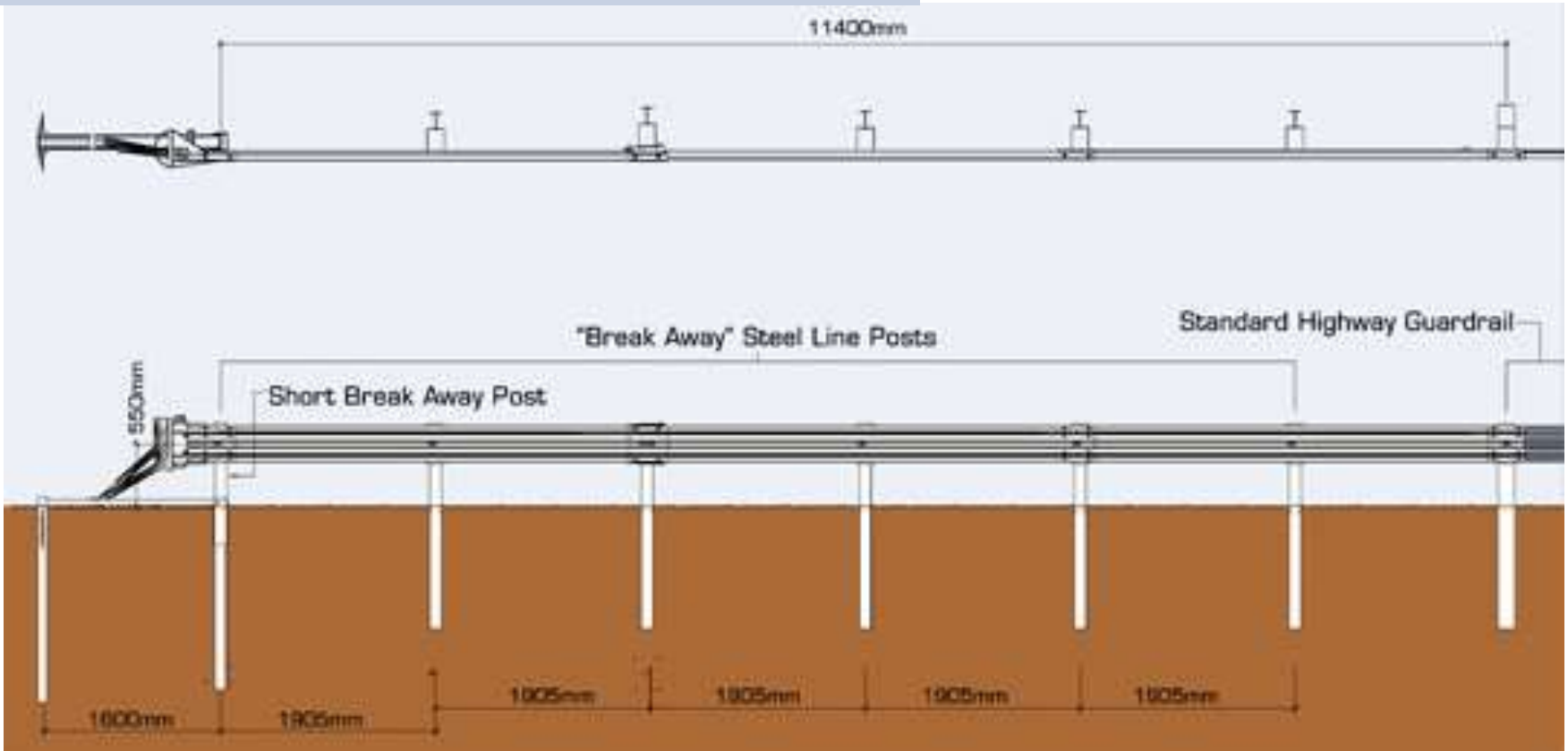

- Fully re-directive, non-gating W-beam terminal
- Tension-based energy-absorbing terminal
- Consists of impact head with brake bar inside, slider assembly and bracket, cable anchor bracket, foundation anchor, breakaway posts and 3 standard W-bam rails
- Maximum deflection = 38 in

# X-Tension Guardrail Terminal



**Material Characteristics:**

- Length of need starts at post #1 -37 feet (11.4m)
- Max flare - 16 inches (400mm) over 3 lengths of rail
- Height to top of rail - 28 inches (710mm)



# X-Tension™ End Treatments



**Non-flared Installation**

**Median Installation**

**Flared Installation**

# QUESTIONS & REVIEW

# Module 4 Review

1. Why are there only three test levels for terminals and crash cushions and why is the highest test speed only 100 km/h (62.2 mph) when many highways have speed limits of 65 mph or more?

a. It is not usually practical to design these features for trucks
b. It may not be possible to design economically for higher speeds
c. Actual impact speeds may often be less than operating speeds due to braking
d. All of the above

# Module 4 Review

2. The best way to identify currently accepted terminals and crash cushions is:

a. Ask a manufacturer
b. Refer to the AASHTO RDG
c. Check out FHWA's Report 350 Hardware web site

# Module 4 Review

3. What does the cable anchorage on w-beam do ?

a. In a side hit near the end, the cable transfers the tension in the w-beam to the ground so the rail remains intact and the impacting vehicle is redirected towards the roadway
b. In an end hit, the cable is released when the end post breaks so the terminal can be pushed out of the way of the impacting vehicle as the vehicle proceeds behind the terminal
c. Both of the above

# Module 4 Review

4. An energy-absorbing terminal will generally be a better choice than a non-energy absorbing terminal.

True or False?

# Module 4 Review

5. Proper site grading near terminals is essential for good crash performance.

True or False?

# 6. Compare The End Treatments



# 7. Compare The End Treatments




# 8. Compare The End Treatments



# 9. Adequate End Treatment?



# 10. Adequate End Treatment?



# 11. Adequate End Treatment?


1/4 MILE

# CHARACTERISTICS OF CRASH CUSHIONS / IMPACT ATTENUATORS

# Crash Cushions



- Gradually decelerates vehicle to a stop, in a relatively short distance
- Shield fixed objects on either side of roadway
- Shield end of median barrier or fixed object on gore area
- Protection of highway work zones
- Absorb impact energy at a controlled rate
  - Kinetic energy
  - Transfer of momentum

# Selection Criteria and Guidelines



- Each system has own unique physical and functional characteristics
- Once it is decided that a shield is needed
  - Site characteristics
  - Structural and safety characteristics of systems
  - Cost
  - Maintenance requirements

# Structural and Safety Characteristics



1. Impact decelerations
2. Redirection capabilities
3. Anchorage and support requirements
4. Debris produced by impact

# Placement Recommendations



- Tested at flat, level surface
- Vehicle should strike at normal height
- Curbs should not be built near cushions
- Most attenuator systems must be placed on hard, smooth pad or surface
- Delineate system to make it more noticeable to drivers

# Barrier Anchored in Backslope



# Sloped Concrete End Treatment

0:48



- Includes taper
- Used for impact speeds < 40 mph
- Locations where barrier is flared out
- Used in sites with ROW constraints
- **DOES NOT MEET NCHRP 350**


Carolina
Ave. Los Angeles
Aeropuerto
Pte T Moscoso
Ave Laguna
2.5


Gulf


# AVAILABLE CONCRETE BARRIER TERMINALS AND CRASH ATTENUATORS

# Cushions Types



## Kinetic Energy

- Plastically deformable materials
- Crushing of front end dissipates impact energy
- Rigid back-up or support is needed

## Transfer of Momentum

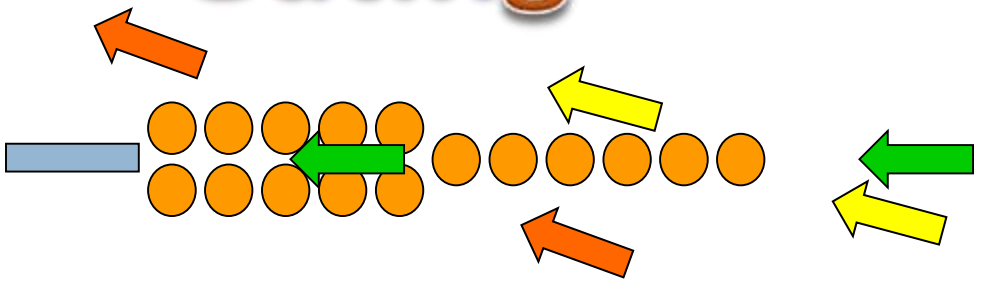
- Inertial barrier
- Expendable mass of material (sand)
- No rigid support needed
- Analytically determined design

**TL-2 & TL-3**

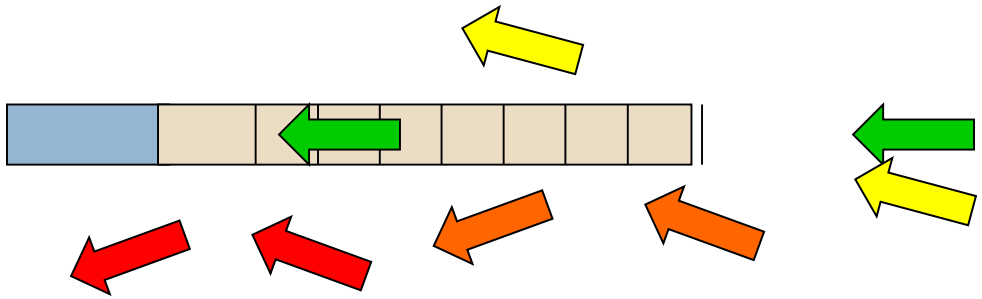
# Cushions Types



## Gating



## Non-gating



# Crash Cushions



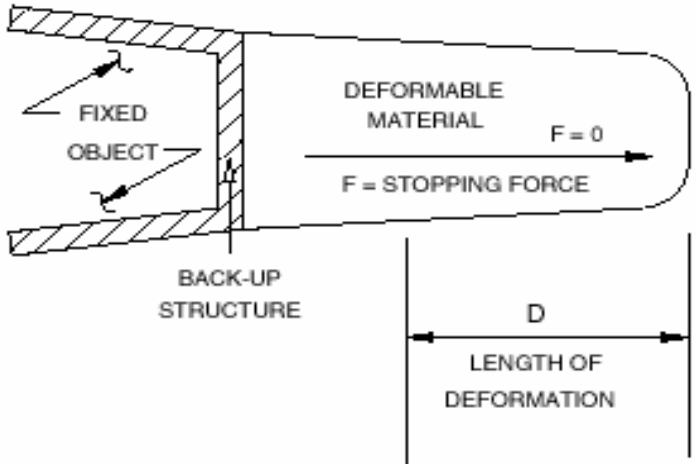
| System | NCHRP Report 350 Test Level | System Width | System Length |
|---|---|---|---|
| Advanced Dynamic Impact Extension Module (ADIEM II) | TL-3 | 0.7 m [2.3 ft] | 9.1 m [30 ft] |
| Brakemaster 350 | TL-3 | 0.64 m [2.1 ft] | 9.6 m [31.5 ft] |
| Crash Cushion Attenuating Terminal (CAT) | TL-3 | 0.7 m [2.3 ft] | 9.5 m [31 ft] |
| Bullnose Guardrail System | TL-3 | 4.5 m [14.8 ft] | 20 m [65 ft] |
| ABSORB 350 | TL-2 | 0.6 m [2 ft] | 5.2 m [17 ft] |
| | TL-3 | 0.6 m [2 ft] | 9.7 m [32 ft] |
| | TL-3 | 0.6 m [2 ft] | 8.3 m [27 ft] |
| QuadGuard Family | | | |
| — QuadGuard | | | |
| 3-bay unit | TL-2 | 0.6 m [2 ft] | 4.0 m [13 ft] |
| 6-bay unit | TL-3 | 0.76 m [2.5 ft] | 6.74 m [22 ft] |
| — QuadGuard Wide | | | |
| 3-bay unit | TL-2 | up to 2.29 m [7.5 ft] | 4.0 m [13 ft] |
| 6-bay unit | TL-3 | up to 2.29 m [7.5 ft] | 6.74 m [22 ft] |
| — QuadGuard LMC | | | |
| 11-bay unit | TL-3 | 1.2 m [4 ft], 1.75 m [5.7 ft], or 2.29 m [7.5 ft] | 10.16 m [33.33 ft] |
| — QuadGuard Elite | | | |
| 7-bay unit | TL-2 | 0.6 m to 2.29 m [2 ft to 7.5 ft] | 7.26 m [23.8 ft] |
| 9-bay unit | TL-3 | 0.6 m to 2.29 m [2 ft to 7.5 ft] | 10.82 m [35.5 ft] |

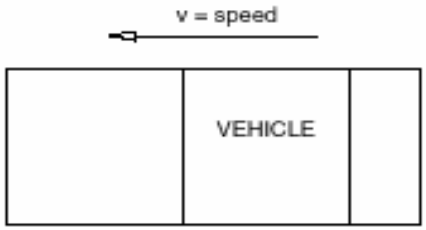
# Crash Cushions



| System | NCHRP Report 350 Test Level | System Width | System Length |
|---|---|---|---|
| Trinity Attenuating Crash Cushion (TRACC) | TL-3 | 0.8 m [2.6 ft] | 6.4 m [21 ft] plus 0.6 m [2 ft] back-up |
| Reusable Energy-Absorbing Crash Terminal (REACT 350) | | | |
| 4-cylinder array | TL-2 | 0.9 m [3 ft] | 4.0 m [13.1 ft] |
| 9-cylinder array | TL-3 | 0.9 m [3 ft] | 9.35 m [30.7 ft] |
| Narrow Connecticut Impact Attenuation System (NCIAS) | TL-3 | 0.9 m [3 ft] | 7.3 m [24 ft] |
| Sand-Filled Barrels (2-Column Array) | | | |
| — Fitch | TL-3 | 2.0 m [6.6 ft] | Varies |
| — Energite | TL-3 | 2.0 m [6.6 ft] | Varies |
| — TrafFix | TL-3 | 2.0 m [6.6 ft] | Varies |
| Gravel Bed Attenuator | N/A | N/A | N/A |
| Dragnet | N/A | N/A | N/A |
| Water Twister Vehicle Arresting System (VAS) | N/A | N/A | N/A |

# Kinetic Energy Principle

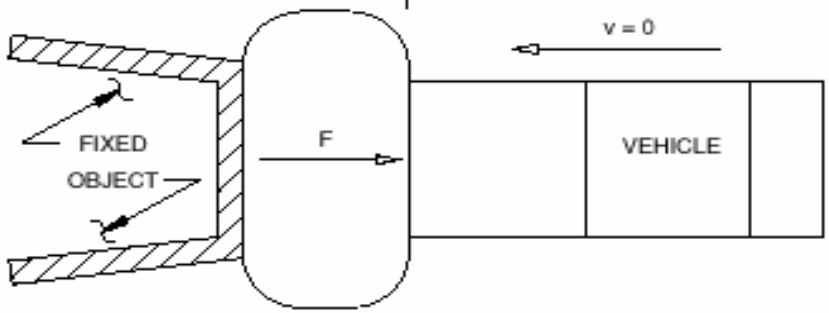



m = vehicle mass

KINETIC ENERGY OF VEHICLE = $\frac{mv^2}{2}$

BEFORE IMPACT




ENERGY ABSORBED BY CRASH CUSHION = FD

$FD = \frac{mv^2}{2}$

AFTER IMPACT

# Terminals for Median W-Beam Guardrail Systems (Table 8-3 2011 RDG)



**Table 8-3. Terminals for Median W-Beam Guardrail Systems**

| Terminal | NCHRP Report 350 Test Level (TL) | FHWA Acceptance Letter | System Designation | Manufacturer | Reference Section |
|---|---|---|---|---|---|
| Brakemaster® 350 | 3 | CC-41 | SEW06 | Energy Absorption Systems, Inc. | 8,3,6,5,1 |
| Crash Cushion Attenuating Terminal (CAT-350™) | 3 | CC-33<br>CC-33A | SEW08 | Trinity Highway Products, LLC | 8,3,6,5,2 |
| FLEAT Median Terminal (FLEAT-MT™) | 3 | CC-46D | SEW16 | Road Systems, Inc, | 8,3,6,5,3 |
| X-Tension™ Median Attenuator System (X-MAS) | 3 | CC-91<br>CC-102 | Not Posted | Barrier Systems, Inc. | 8,3,6,5,4 |

# Brakemaster 350

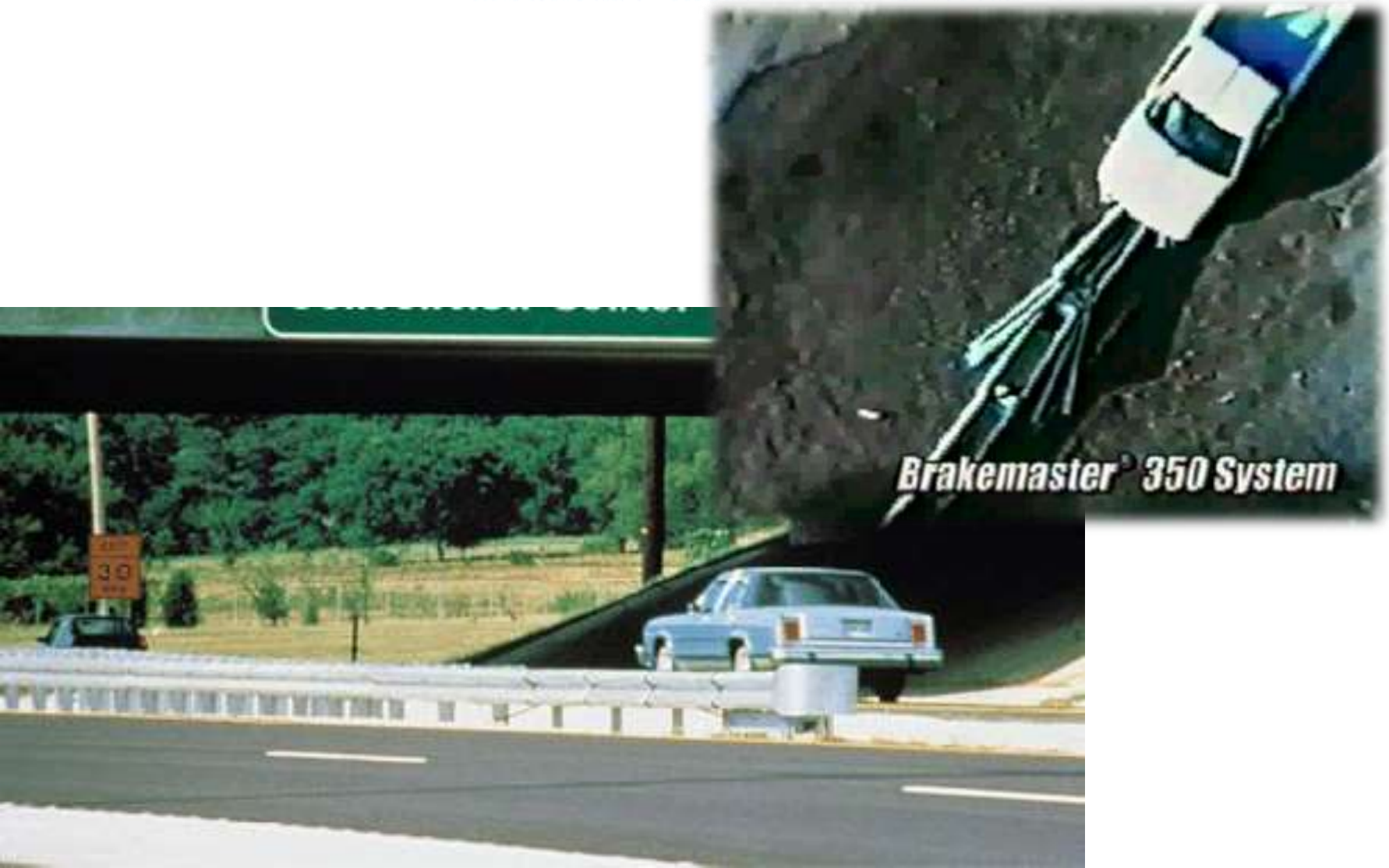


- W-beam wide median gating terminal
- Cushion for narrow objects
- W-beams telescope back
- Anchor absorbs energy
- Redirecting capability
- Does not need paved pad


***Low frequency impact areas***

# Brakemaster 350

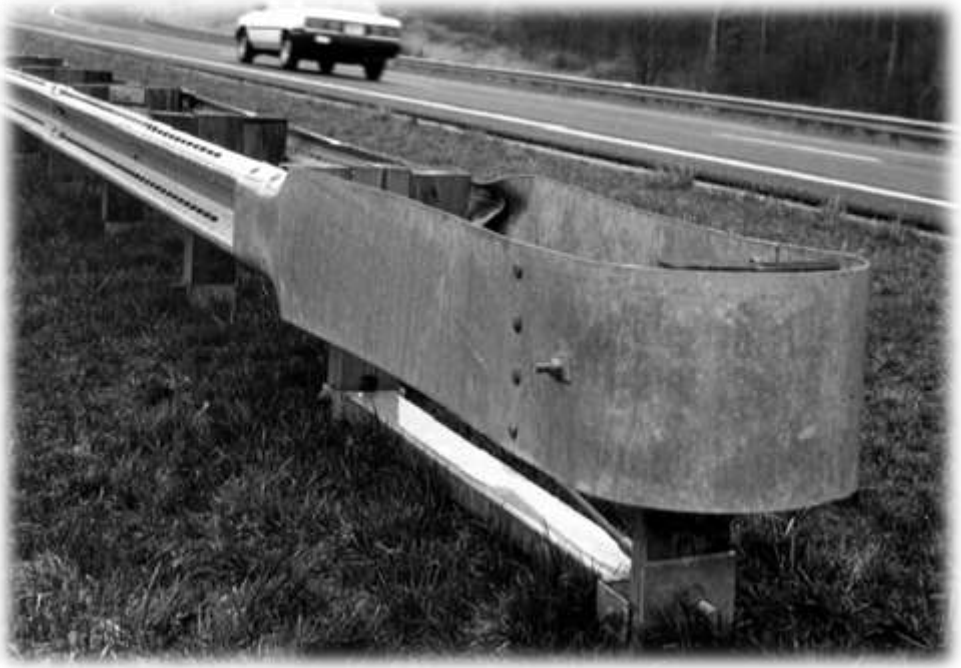




# Cushion Attenuating Terminal CAT



- Energy-absorbing median or shoulder attenuator
- Cushion for narrow objects or terminal for W-beam barrier
- Slotted W-beams telescope back
- Redirecting capability
- Non-flared



3:00

TL-3

# Sacrificial Crash Cushion

## (Table 8-5 2011 RDG)



| Crash Cushion | Test Level | FHWA Acceptance Letter | System Designation | Manufacturer | Reference Section |
|---|---|---|---|---|---|
| BEAT-BP™ | 3 | CC-69C | SC112 | Road Systems, Inc. | 8.4.2.1.5 |
| QuadTrend® 350 | 3 | CC-49 | SET02 | Energy Absorption Systems, Inc. | 8.4.2.1.6 |
| Narrow Connecticut Impact Attenuation System (NCIAS) | 3 | CC-58<br>CC-77 | SCI08 | Generic | 8.4.2.1.7 |

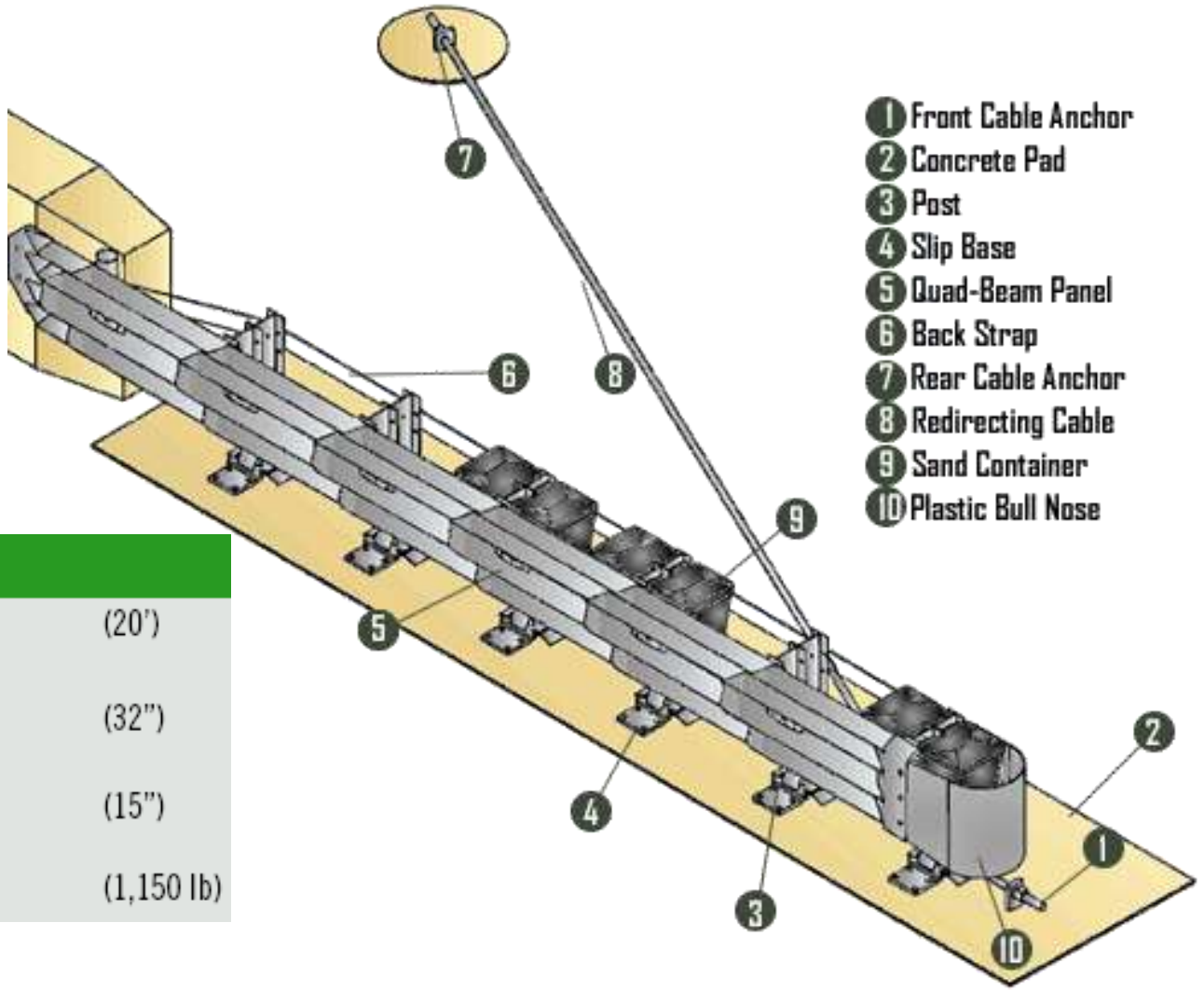
# QuadTrend-350



- Proprietary, gating re-directive terminal
- Consists of Quad-Beam TM panels, slip bases, tension strap, redirective cable and sand-filled boxes
- No transition segment needed for concrete barriers or railings

# QuadTrend-350






| SPECIFICATIONS | | |
|---|---|---|
| Length | 6.1 m | (20') |
| Height | 813 mm | (32") |
| Width | 380 mm | (15") |
| Weight | 522 kg | (1,150 lb) |

# Narrow Connecticut Impact Attenuation System NCIAS



- Non-proprietary
- Eight steel cylinders with two wire tension cables on each side
- Each cylinder is 3-ft wide and 4-ft tall
- Last four cylinders reinforced

*Susceptible to reverse direction impacts*

# Reusable Crash Cushions

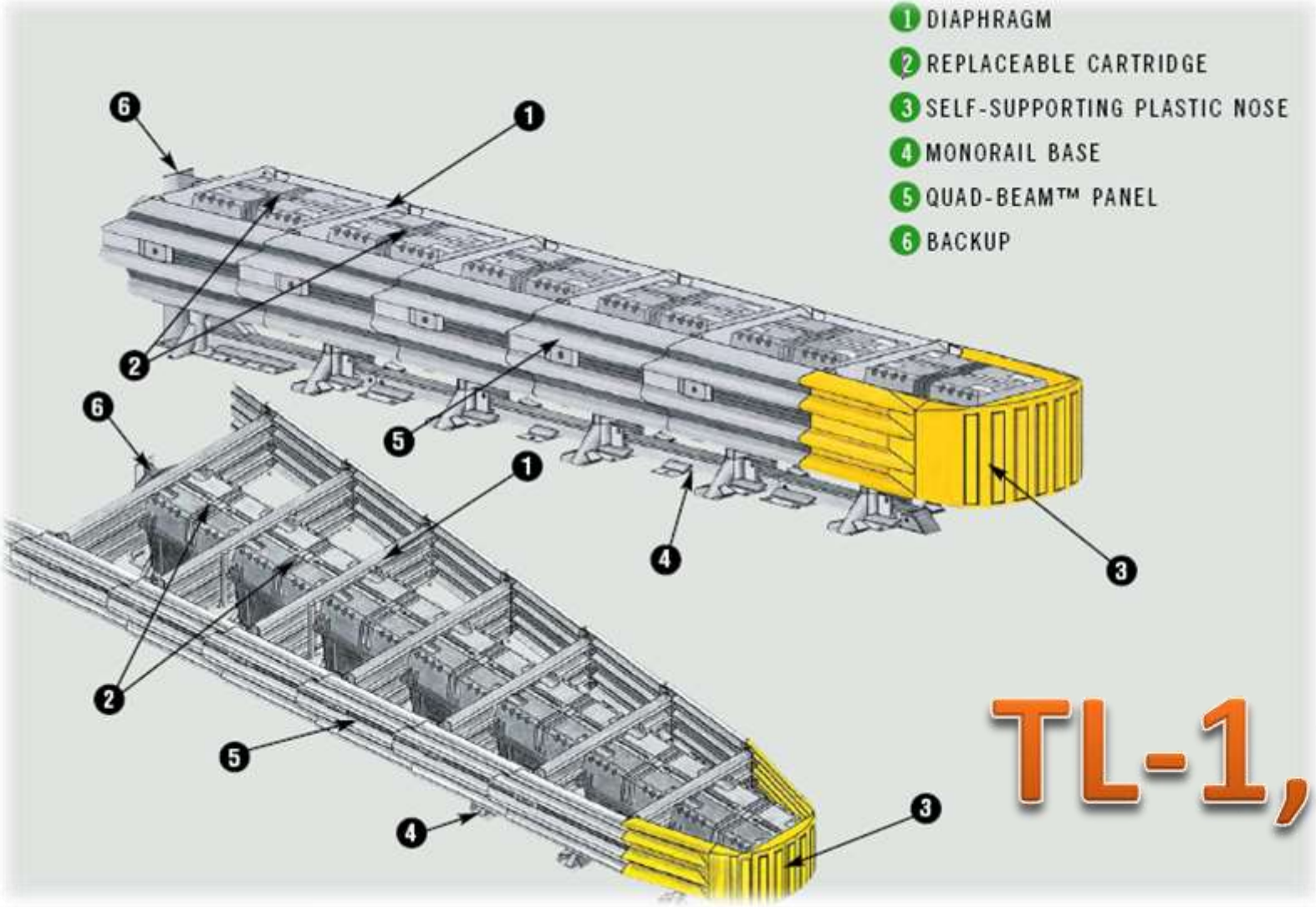
## (Table 8-6 2011 RDG)



| Crash Cushion | Test Level (TL) | FHWA Acceptance Letter | System Designation | Manufacturer | Reference Section |
|---|---|---|---|---|---|
| QuadGuard® Family<br>QuadGuard<br>3-bay unit<br>6-bay unit<br>QuadGuard Wide<br>QuadGuard HS | 2<br>3 | CC-35<br>B to H<br>CC-42, 42A<br>and CC-45 | SCT02A to D | Energy Absorption Systems, Inc. | 8.4.2.2.1 |
| Universal TAU-II Family® | 2<br>3 | CC-75<br>A, B, and C | SCT01A and B | Barrier Systems, Inc. | 8.4.2.2.2 |
| Trinity Attenuating Crash Cushion (TRACC) Family<br>TRAC™<br>FASTRACC™<br>SHORTRACC™<br>WIDETRACC™ | 2 and 3 | CC-54<br>A thru H | Not Posted | Trinity Highway Products, LLC | 8.4.2.2.3 |
| QUEST® | 3 | CC-87 | Not Posted | Energy Absorption Systems, Inc. | 8.4.2.2.4 |

# QuadGuard Crash Cushion Family





# QuadGuard System



- Re-directive, non-gating  crash cushion
- Consists of crushable, energy-absorbing cartridges surrounded by a framework of steel Quad-Beam panels
- During head-on impacts, the system telescopes rearward and crushes to absorb the energy of impact
- High 80% reusability after most design impacts

# QuadGuard System

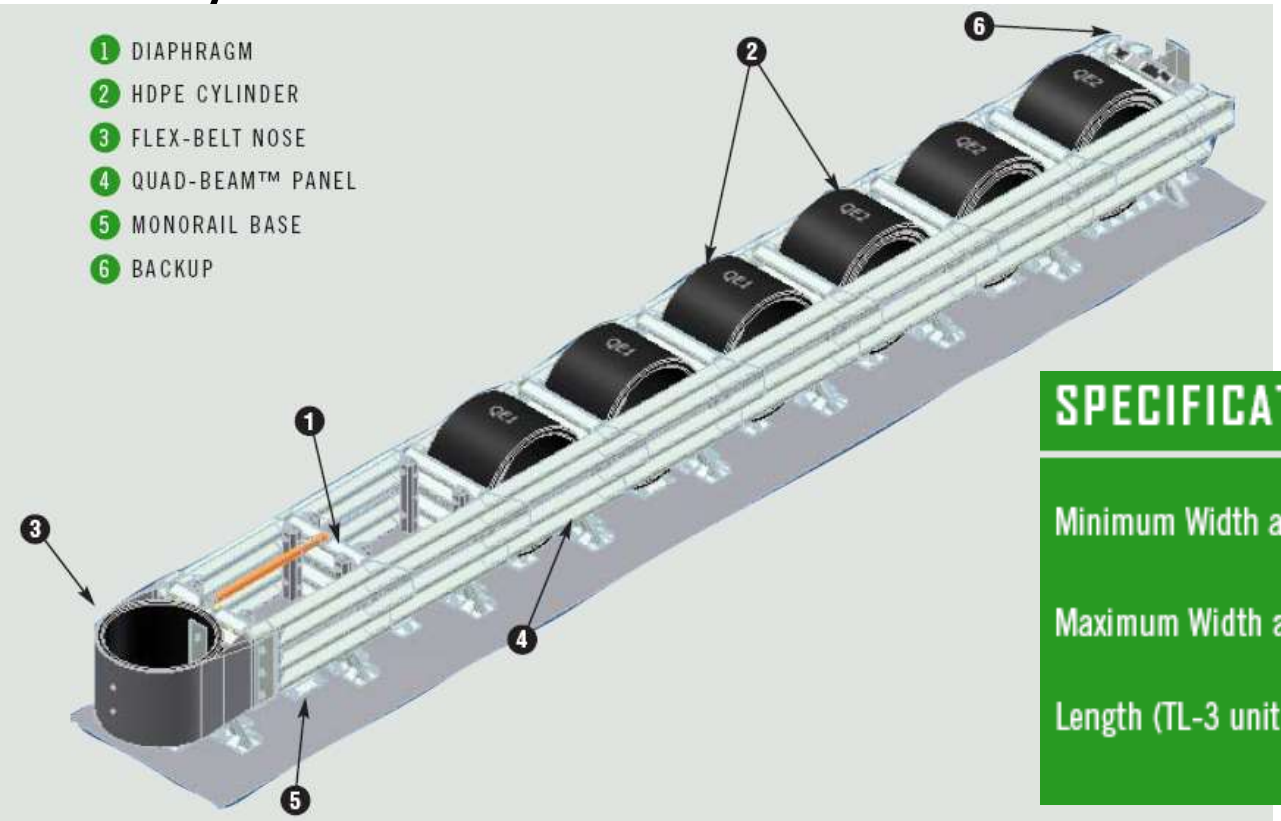


- Crash cushion for hazards ranging in width from 610 mm to 910 mm (24" to 36")
- Length of the system
  - 9 bays needed for locations up to 70 mph
  - 6 bays (21 ft) needed for locations with ≥ 45 mph
  - 3 bays for locations with ≤ 40 mph
- Lifting brackets allow easy repositioning as a complete unit
- Monorail base eliminates the need for anchoring chains and tension cable

# QuadGuard Elite System



- Reusable cylinders for applications with above average impact frequency
- System is 99-100% reusable after a design impact




**TL-2,3**

| SPECIFICATIONS | | |
|---|---|---|
| Minimum Width at Backup | 610.0 mm | (2') |
| Maximum Width at Backup | 2.4 m | (96") |
| Length (TL-3 unit) | 8.0 m | (26' 6") |

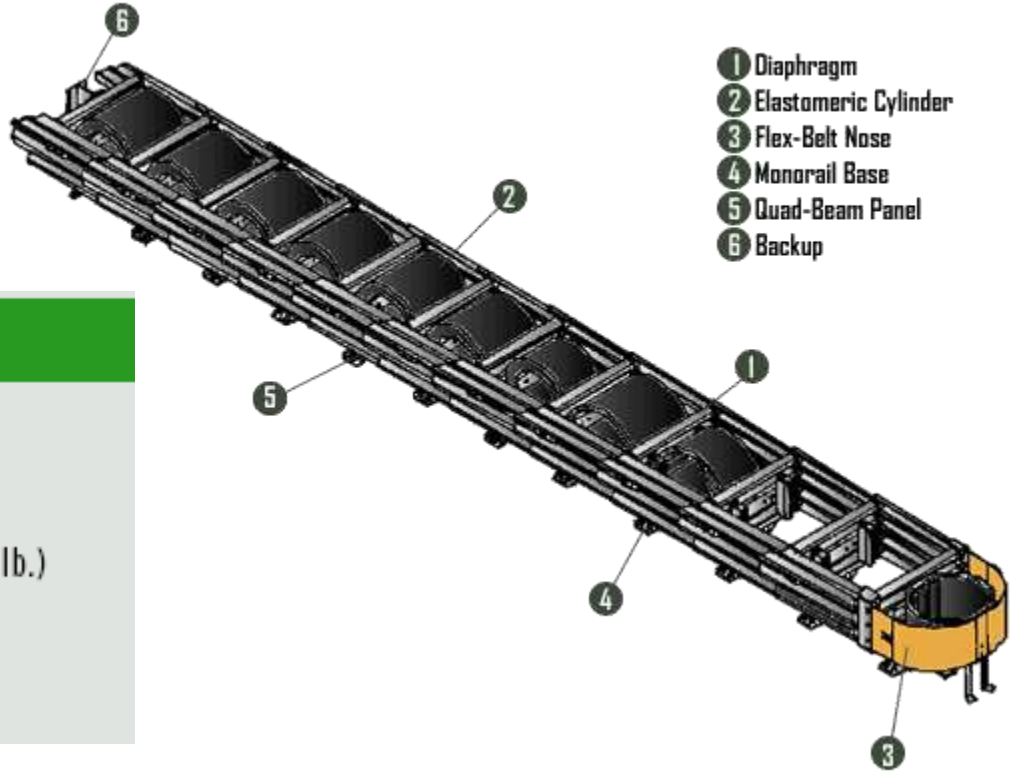
# QuadGuard LMC System



- Elastomeric cylinders surrounded by triple-corrugated steel diaphragms and Quad-Beam panels
- System is 100% reusable after design impact

## TL-3

| SPECIFICATIONS | | |
|---|---|---|
| Width at Backup | 914 mm | (3') |
| Weight (typical 11 bay unit) | 3900 kg | (8500 lb.) |
| Length (typical 11 bay unit) | 10 m | (31') |



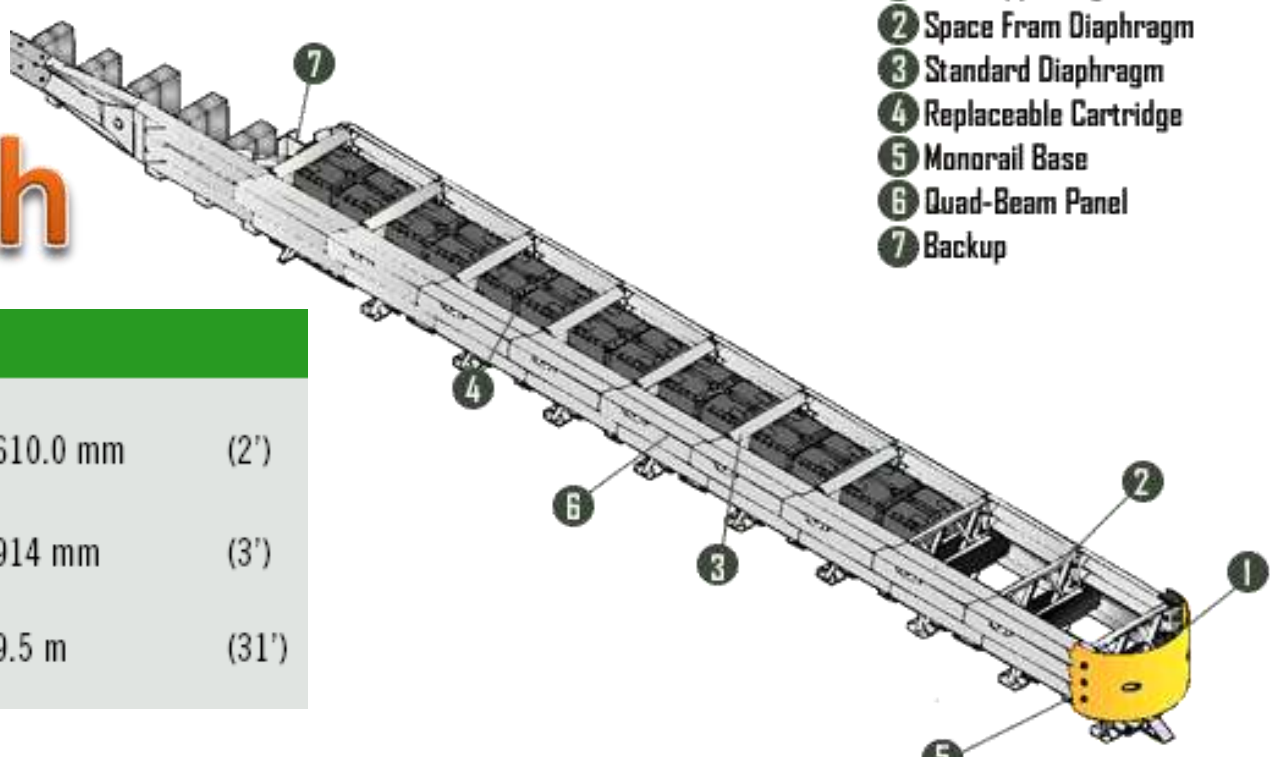
# QuadGuard HS (High Speed) System



- System is 60-70% reusable after design impact
- Shields hazards up to 3 ft wide

**TL-3**

**70 mph**




| SPECIFICATIONS | | |
|---|---|---|
| Minimum Width at Backup | 610.0 mm | (2') |
| Maximum Width at Backup | 914 mm | (3') |
| Length (typical 6-bay unit) | 9.5 m | (31') |

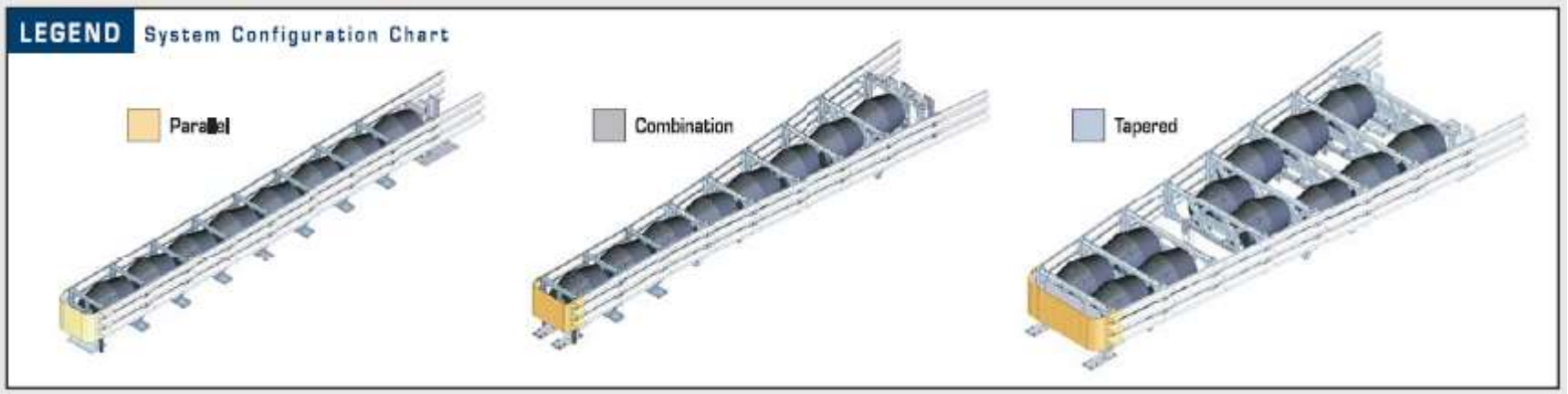
# Universal TAU Cushion Family



# Universal TAU Cushion Family

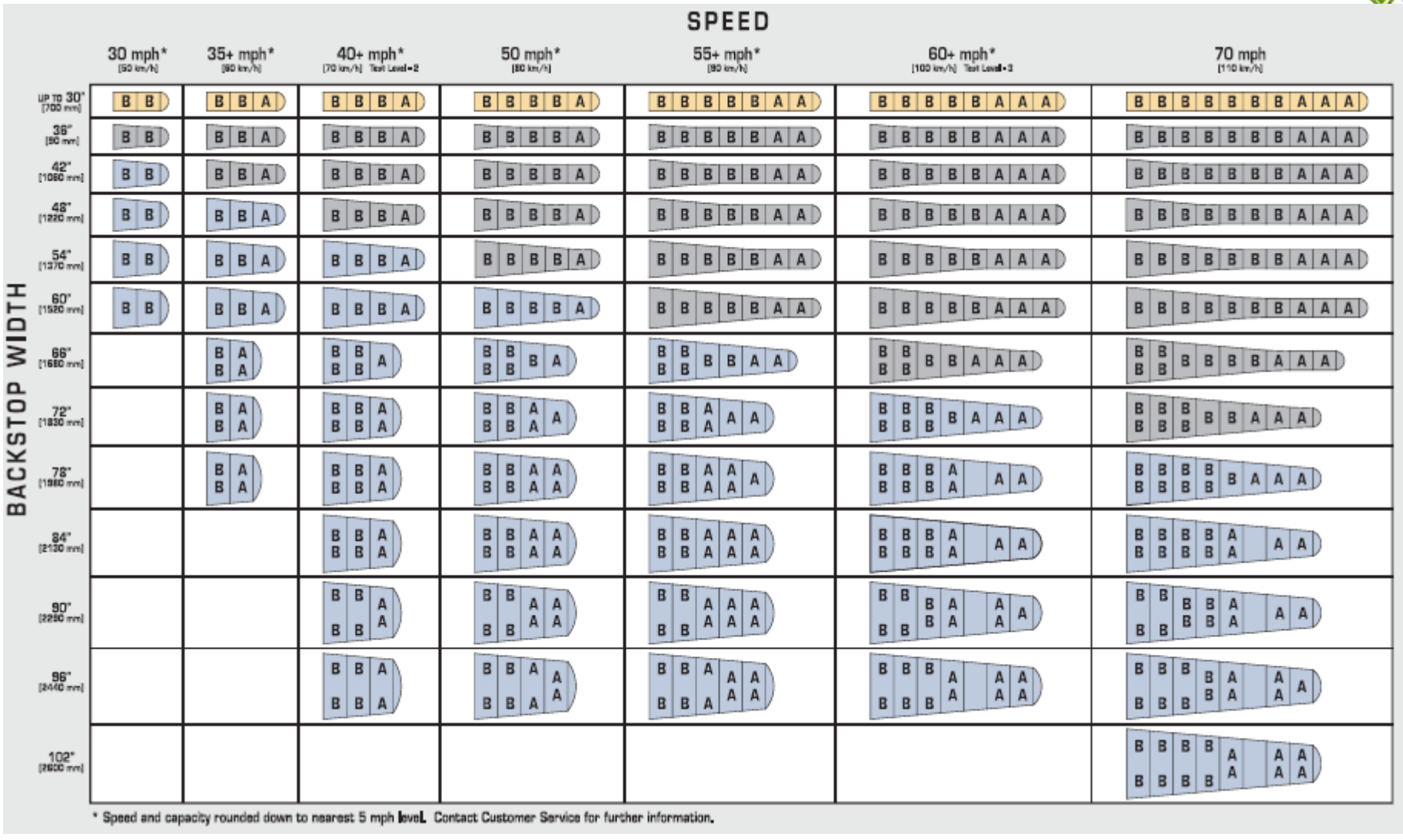


- Redirective, non-gating cushion
- Open arquitecture with energy absorbing cartridges and high-strength Thrie beam panels
- No rails or tracks
- Narrow (30 in) and wide hazards (up to 8.5 ft)



# Universal TAU Configurations





# Typical Applications



# Trinity Attenuating Crash Cushion TRACC Family



- Redirective, non-gating crash cushions
- End treatment with guidance tracks
- Impact sled cut the metal plates on impact
- W-beam slides backward
- No cartridges or boxes

**TL-2,3**

# Trinity Attenuating Crash Cushion TRACC Family



## SPECIFICATIONS

TRACC™

**TL-3**

- 21'-3" (6.5m)
- 24" Wide (610 mm)
- 3200 Lbs (1451 kg)

SHORTRACC™

**TL-2**

- 14' - 3" (4.3 m)
- 24" Wide (610 mm)
- 2200 Lbs (998 kg)

## SPECIFICATIONS

FASTRACC™

**TL-3**

**70 mph**

- 26' (7.9 m)
- 24" Wide (610 mm)
- 4000 Lbs (1814 kg)

WIDETRACC™(*standard wide system)

- 21' Long (6.4 m)
- 58" Wide Standard (1.47 m)
- 3825 Lbs (1735 kg)

***Can be customized to protect any width.**

# Trinity Attenuating Crash Cushion TRACC Family





# QUEST System Crash Cushion

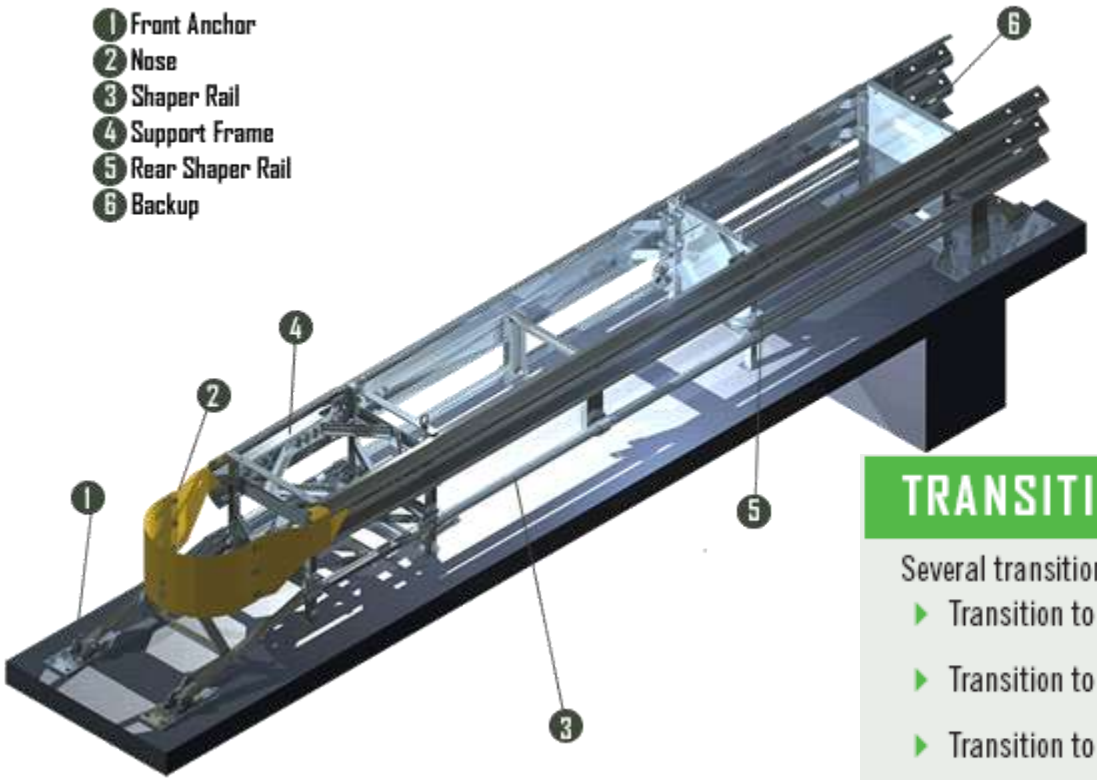


- Redirective, non-gating W-beam fender panels
- Supported by diaphragms
- Integrated trigger mechanism at the nose that releases a front assembly during impacts to absorb the energy of impact

# QUEST System Crash Cushion



- Protects hazard widths ranging from 24”-36”
- Driveable pile anchoring system for installations in soil or asphalt




## TRANSITION OPTIONS

Several transition panels are available for the QUEST System, including:

- Transition to New Jersey Safety Barrier
- Transition to W-Beam
- Transition to Concrete Median Barrier

# Low-Maintanance and/or Self Restoring Crash Cushions (Table 8-7 2011 RDG)



| Crash Cushion | Test Level | FHWA Acceptance Letter | System Designation | Manufacturer | Reference Section |
|---|---|---|---|---|---|
| Compressor | 3 | CC-95 | Not Posted | Traffix Devices | 8.4.2.3.1 |
| EASI-CELL | 1 | CC-71 | SCI 15 | Energy Absorption Systems, Inc, | 8.4.2.3.2 |
| Hybrid Energy Absorbing Reusable Terminal (HEART™) | 3 | CC-89 | Not Posted | Trinity Highway Products, LLC | 8.4.2.3.3 |
| QuadGuard Elite<br>7-bay unit<br>8-bay unit<br>9-bay unit | 2<br>3<br>3 | CC-57<br>CC-57A<br>CC-57B | SCT02e | Energy Absorption Systems, Inc, | 8.4.2.3.4 |
| QuadGuard LMC<br>11-bay unit | 3 | CC-43 | SCT02f | Energy Absorption Systems, Inc. | 8.4.2.3.5 |
| Reusable Energy Absorbing Crash Terminal (REACT 350®)<br>4-cylinder array<br>9-cylinder array | 2<br>3 | CC-26,A-I<br>CC-60,A-B,<br>CC-73,A-C | SCI16a-b | Energy Absorption Systems, Inc. | 8.4.2.3.6 |
| Smart Cushion Innovations (SCI)<br>SCI-70GM<br>SCI-100GM | 2<br>3 | CC-85 A and B | SCI17a and b | SCI Products, Inc. | 8.4.2.3.7 |

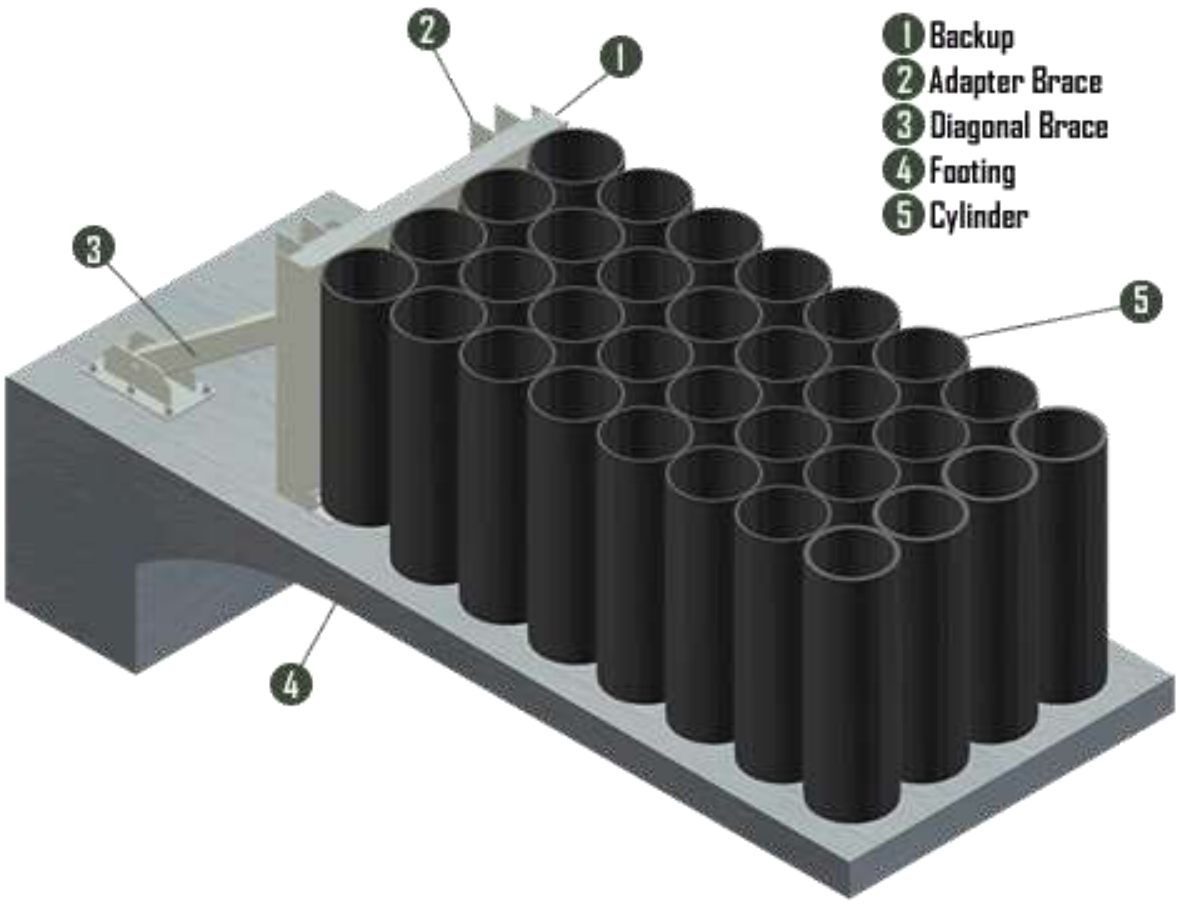
# EASICELL Cluster Crash Cushion System



- Interconnected high density polyethylene plastic cylinders
- Non-redirective, multi-angle impact protection
- Cylinders fits against the hazard or a concrete transition from the hazard
- During an impact, the reusable plastic cylinders compress to maximize energy absorption
- Can be customized to fit specific applications

# EASICELL Cluster Crash Cushion System






- system will self restore
- after most design lateral impacts, typically regaining up to
- 90% of its original shape and capacity

# Hybrid Energy Absorbing Reusable Terminal (HEART)



**SPECIFICATIONS**

HEART™

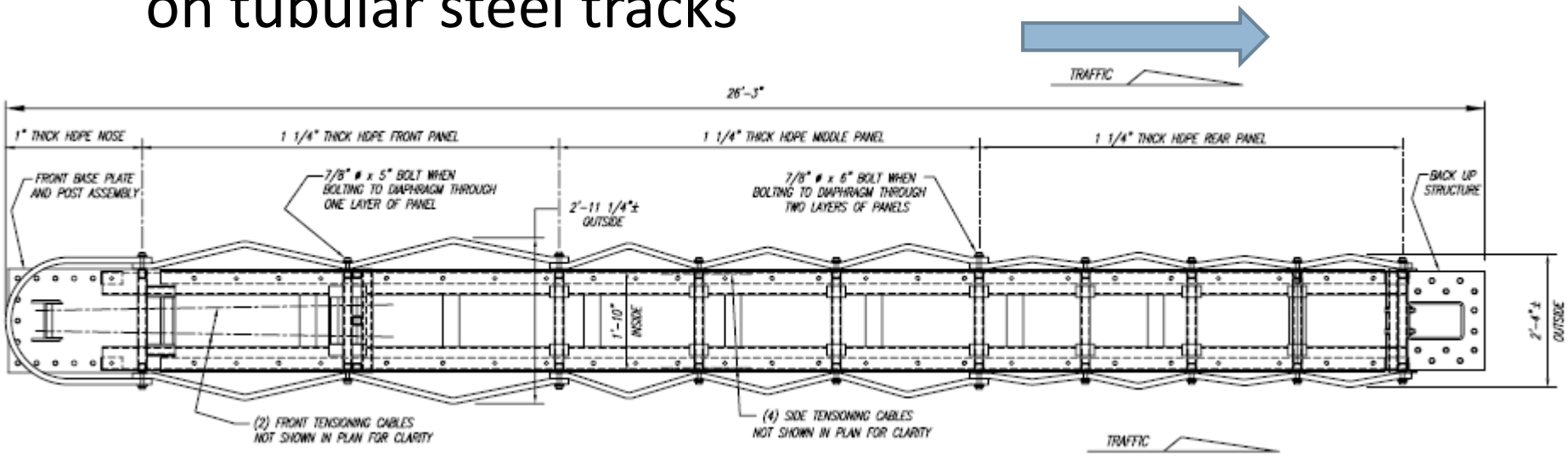
- 26' Long
- 32" High
- 25" - 27" Wide at the diaphragms with a maximum width of 36" between diaphragms 3 and 4.
- 2700 Lbs

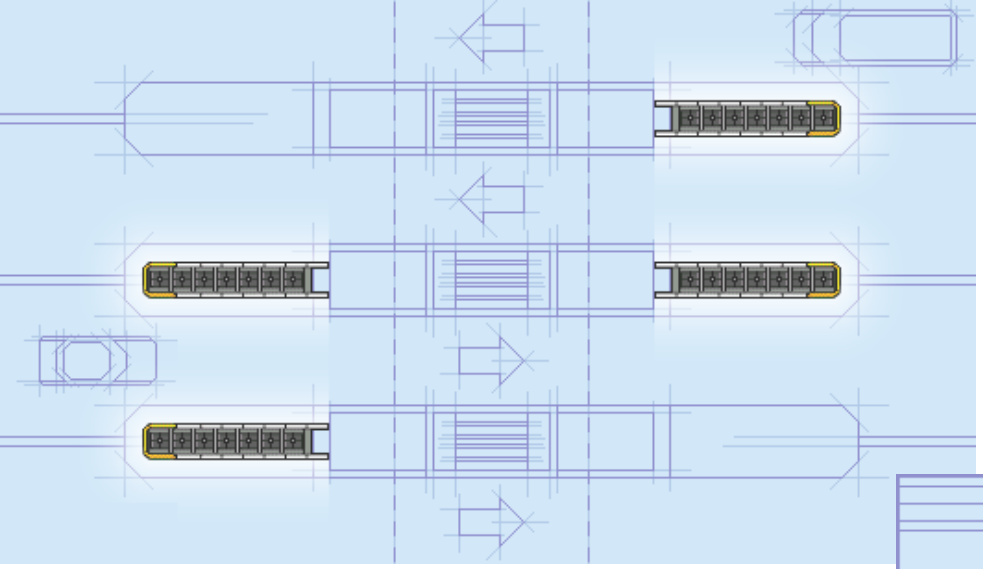
**TL-3**

# Hybrid Energy Absorbing Reusable Terminal (HEART)



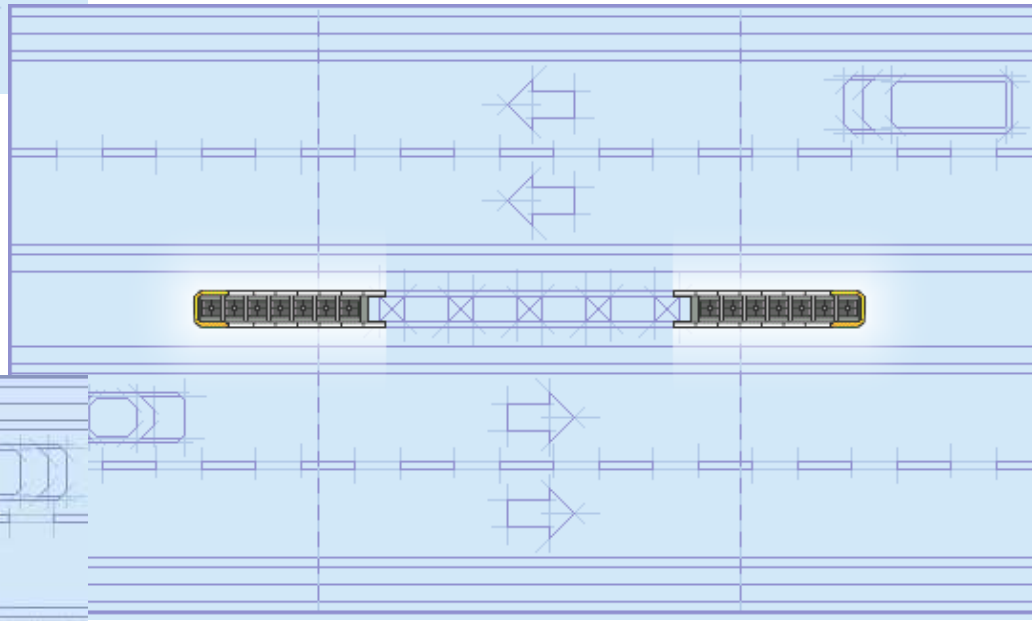
- Reusable, restorable, non-gating and re-directive crash cushion
- High Molecular Weight/High Density Polyethylene side panels and a rounded frontal nose piece, which are connected to steel diaphragms mounted on tubular steel tracks

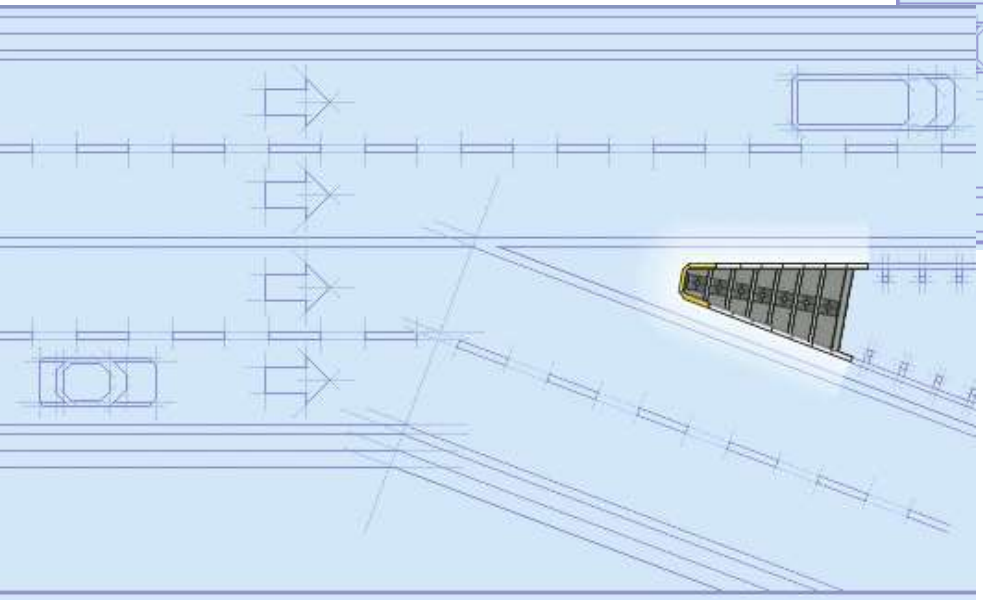




# Toll Plazas

# Median Bridge





# Gore Areas

# Reusable Energy-Absorbing Crash Terminal REACT 350

6:15



# Reusable Energy-Absorbing Crash Terminal REACT 350

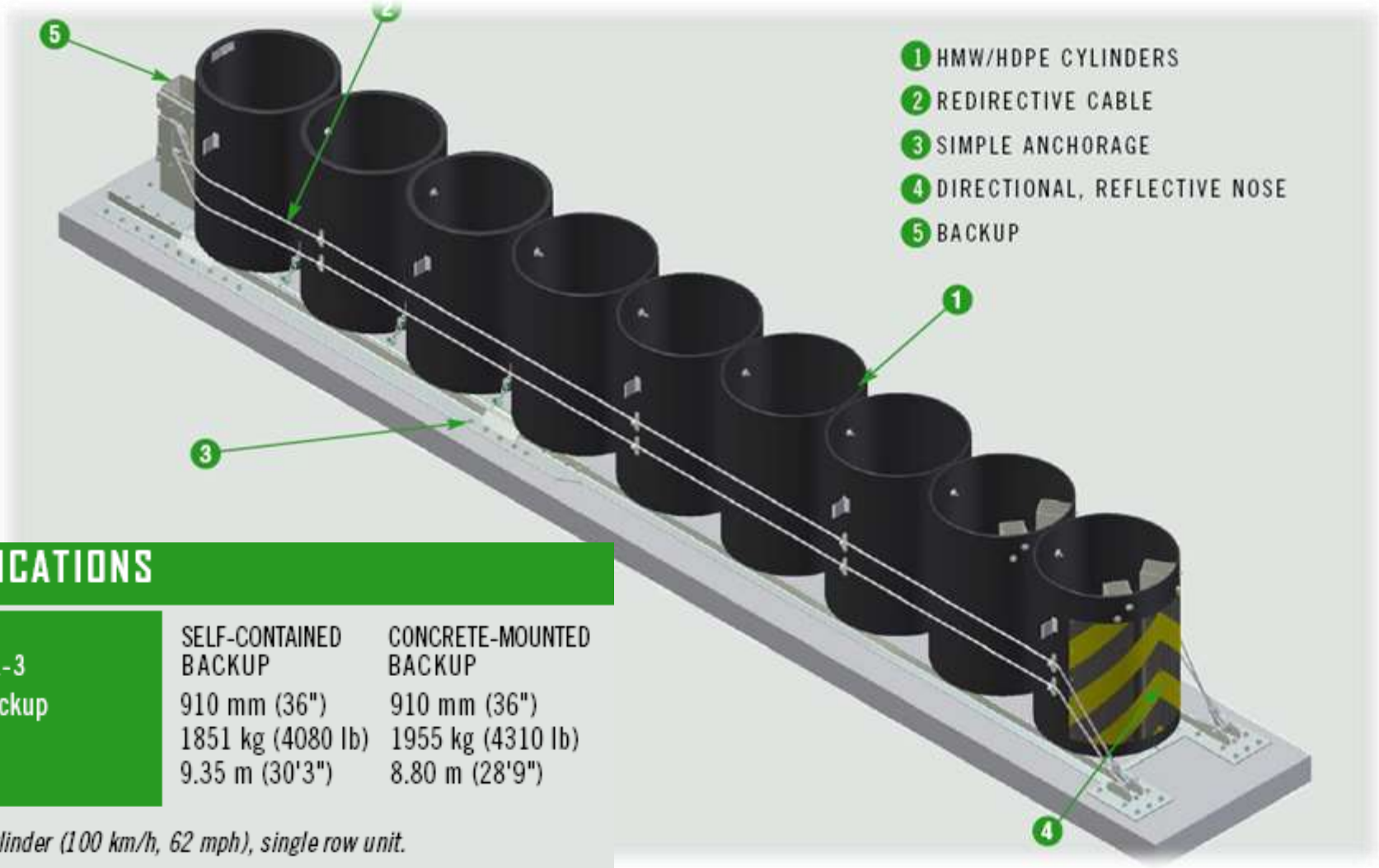


- High-density polyethylene plastic cylinders 3-ft wide atop steel skid rails for head-on hits
- Two steel wire ropes redirect side angle hits
- Can be designed for speeds from 25 - 75 mph
- Regains up to 90% of its original design deceleration capability after design impact
  - TL-2: four cylinders
  - TL-3: nine cylinders

**TL-1,2,3**

# Reusable Energy-Absorbing Crash Terminal REACT 350





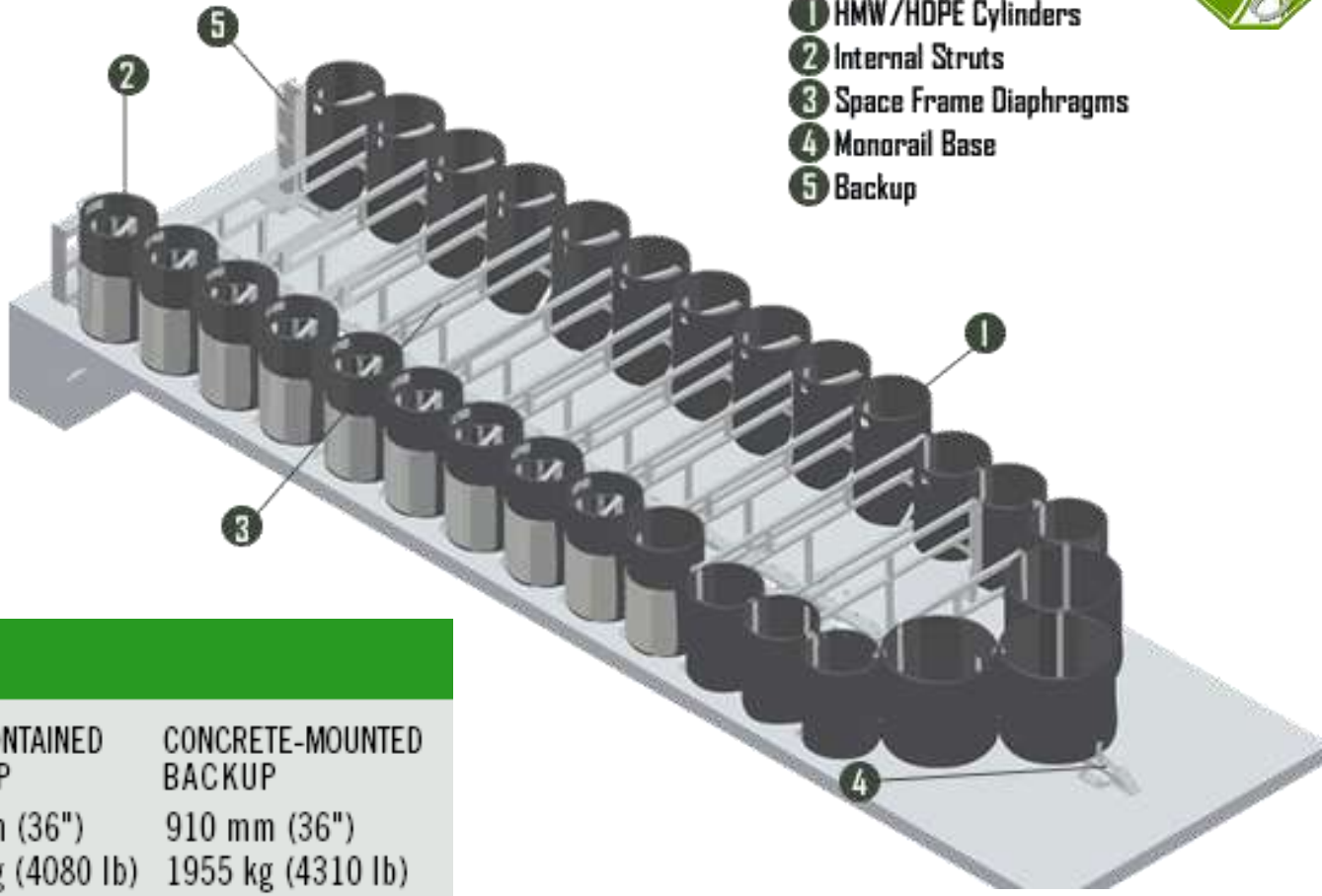

## SPECIFICATIONS

| 36 INCH TL-3 | SELF-CONTAINED BACKUP | CONCRETE-MOUNTED BACKUP |
|---|---|---|
| Width at Backup | 910 mm (36") | 910 mm (36") |
| *Weight | 1851 kg (4080 lb) | 1955 kg (4310 lb) |
| *Length | 9.35 m (30'3") | 8.80 m (28'9") |

*Typical 9-cylinder (100 km/h, 62 mph), single row unit.

# Reusable Energy-Absorbing Crash Terminal REACT 350 Wide






## SPECIFICATIONS

| 36 INCH TL-3 | SELF-CONTAINED BACKUP | CONCRETE-MOUNTED BACKUP |
|---|---|---|
| Width at Backup | 910 mm (36") | 910 mm (36") |
| *Weight | 1851 kg (4080 lb) | 1955 kg (4310 lb) |
| *Length | 9.35 m (30'3") | 8.80 m (28'9") |

*Typical 9-cylinder (100 km/h, 62 mph), single row unit.*

# Sacrificial Crash Cushions

## (Table 8-5 2011 RDG)



| Crash Cushion | Test Level | FHWA Acceptance Letter | System Designation | Manufacturer | Reference Section |
|---|---|---|---|---|---|
| Thrie-Beam Bullnose Guardrail System | 3 | CC-68 | SET03 | Generic | 8.4.2.1.1 |
| ABSORB 350® | 3<br>2 | CC-66, A and B | SCI11 | Barrier Systems, Inc. | 8.4.2.1.2 |
| Advanced Dynamic Impact Extension Module (ADIEM™) | 3 | CC-38 | SCI09 | Trinity Highway Products, LLC | 8.4.2.1.3 |
| BEAT-SSCC™ | 3 | CC-69B, D, and E | SC113A-B | Road Systems, Inc. | 8.4.2.1.4 |

# ABSORB 350 Crash Cushion



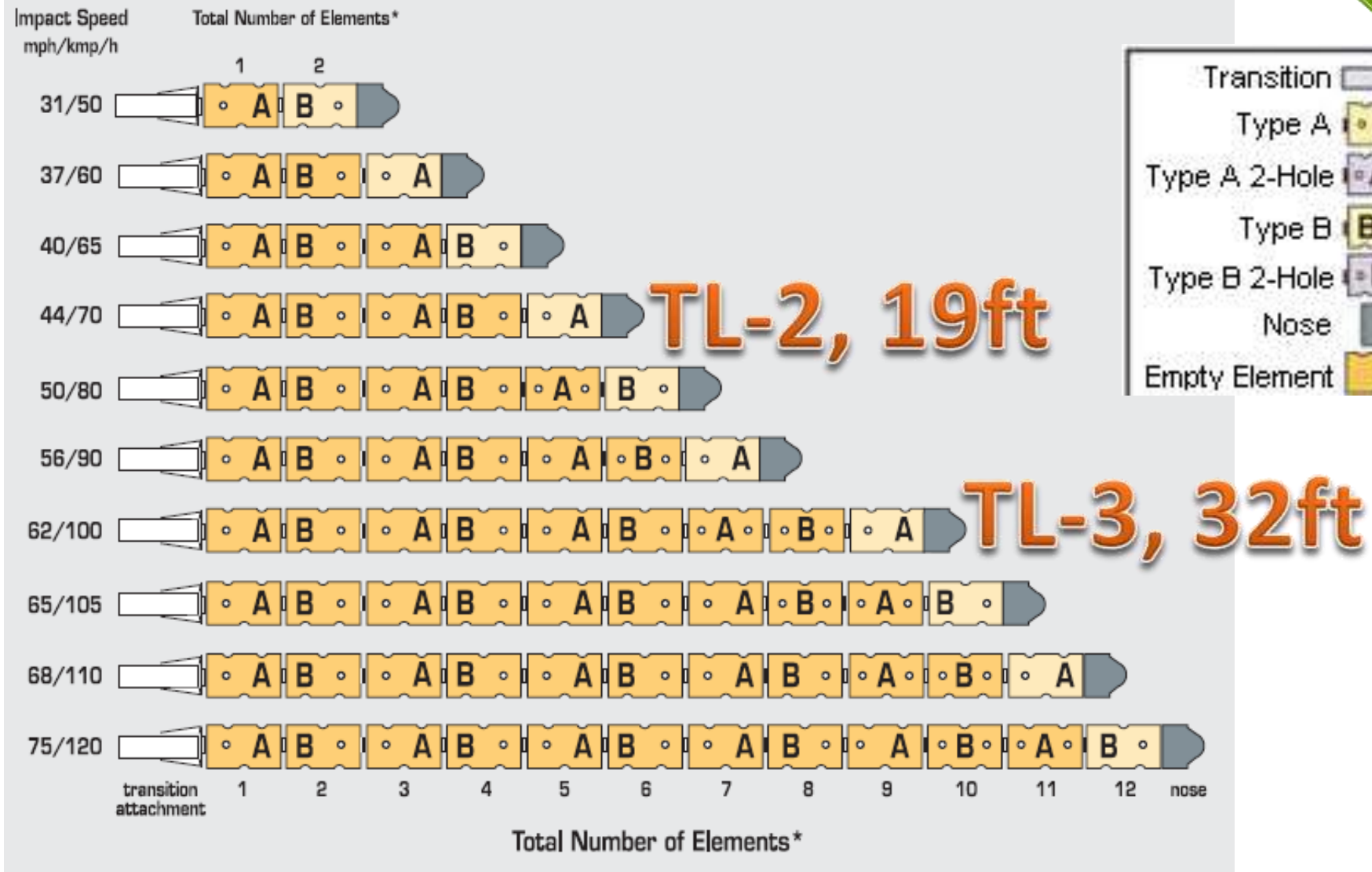
# ABSORB 350 Crash Cushion



- Non -redirective, gating and energy absorbing device
- Water-filled Polyethylene containers
- Protects end of concrete walls
- Do not need anchorage or foundation
- Temporary and permanent applications

# ABSORB 350 Configurations





# Non-redirective Energy-Absorbing Terminal - NEAT



- Narrow and with less than 10 ft in length aluminum cartridge
- Impact protection for speeds up to 43 mph
- Shield end of concrete safety shape or Quickchange Barrier system
- Easy installation
- Work zone application

**TL-2**

# Advanced Dynamic Impact Extension Module ADIEM II

0:30



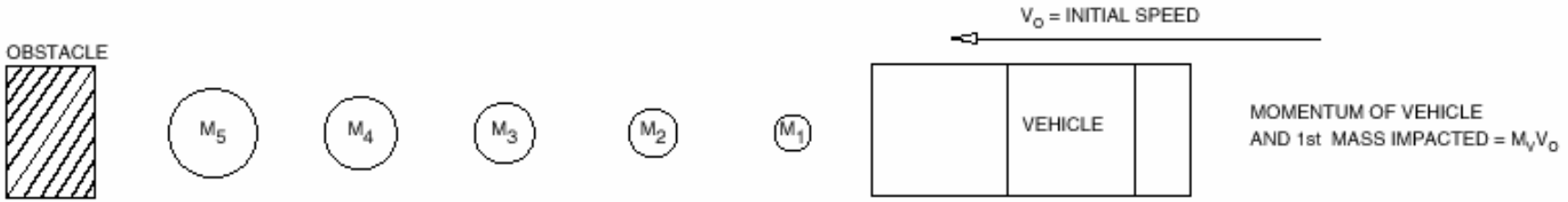
- Used at the end of concrete barrier
- Made of 10 perlite concrete, lightweight crushable modules
- Mounted on a 30-ft long base structure of standard concrete (Re-directive capability at 15’ from nose)

**Susceptible to weather**

**TL-3**

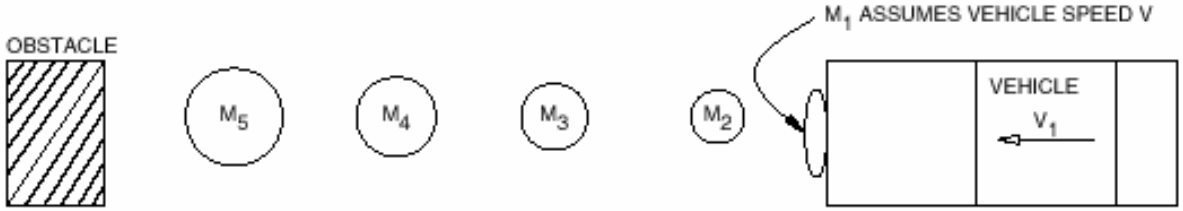
# Principle of Conservation of Momentum






BEFORE IMPACT

$$M_V \cdot V_O = \left(M_V + M_{S_1}\right) \cdot V_1$$




AFTER IMPACT

MOMENTUM BEFORE IMPACT = MOMENTUM AFTER IMPACT

$$V_n = \frac{M_V \cdot V_{n-1}}{M_V + M_n}$$

**Final speed about 10 mph**

# Sand-Filled Barrels



- Transfer of momentum principle, non-redirective
- No support is needed
- Standard modules from 0.2 up to 2.1kip
- Wide hazards in low-frequency impact areas
- Barrel weight is determined by its place within the array

**TL-3***

* Approved for specific barrel array

# Barrels Use



- Can safely decelerate vehicles ranging in weight from 1,810 to 4,410 lb and traveling at speeds up to 70 mph during head-on impacts
- Low initial cost and requires no assembly
- Does not redirect errant vehicles away from the hazard during angle impacts
- It should not be used if frequent angle impacts are expected

•Breaks up during impact

•Impacts close to corner

# Crash Cushions for Large Vehicles



- All previously shown cushions are not designed for heavy vehicles
- Gravel bed attenuator is still the most suitable velocity attenuating design

# Inertial Cushion Types



1. Fitch
2. Energite
3. TrafFix Devices Big Sandy Barrels

*Sand density of 100 lb/ft$^3$*

*No sand on sacks*

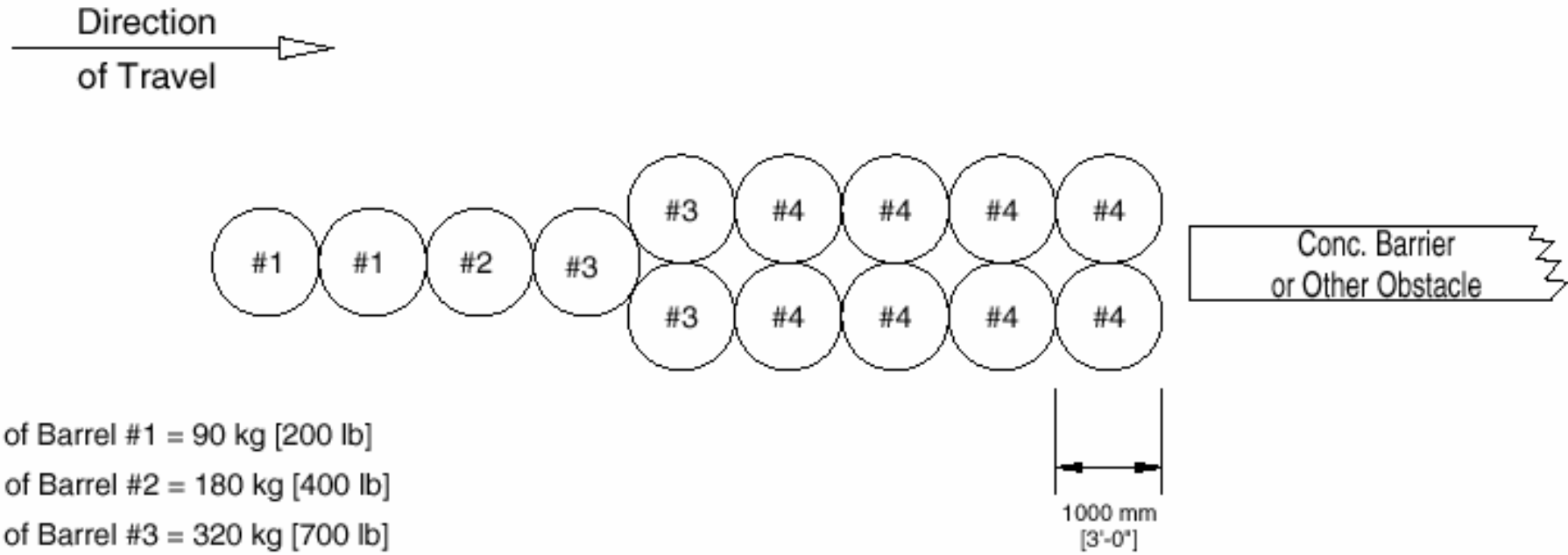
## Fitch System

## ENERGITE SYSTEM

## TrafFix System

# Design of Barrel System






Mass of Barrel #1 = 90 kg [200 lb]

Mass of Barrel #2 = 180 kg [400 lb]

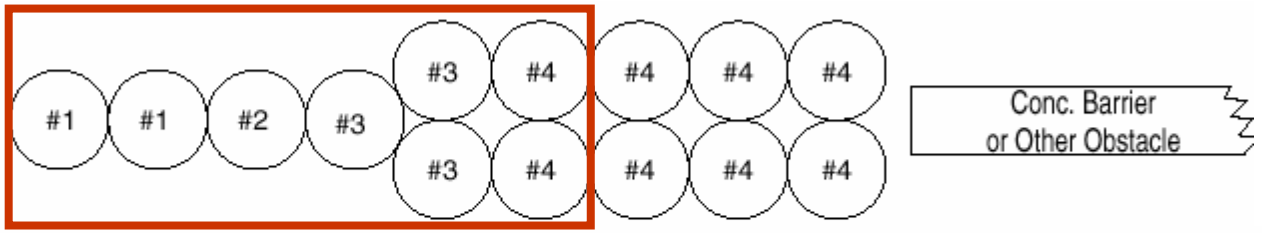
Mass of Barrel #3 = 320 kg [700 lb]

Mass of Barrel #4 = 640 kg [1400 lb]

Design Velocity = 100 km/h (27.8 m/s) [60 mph (88.0 ft/s)]

# Design of Barrel System

60 mph



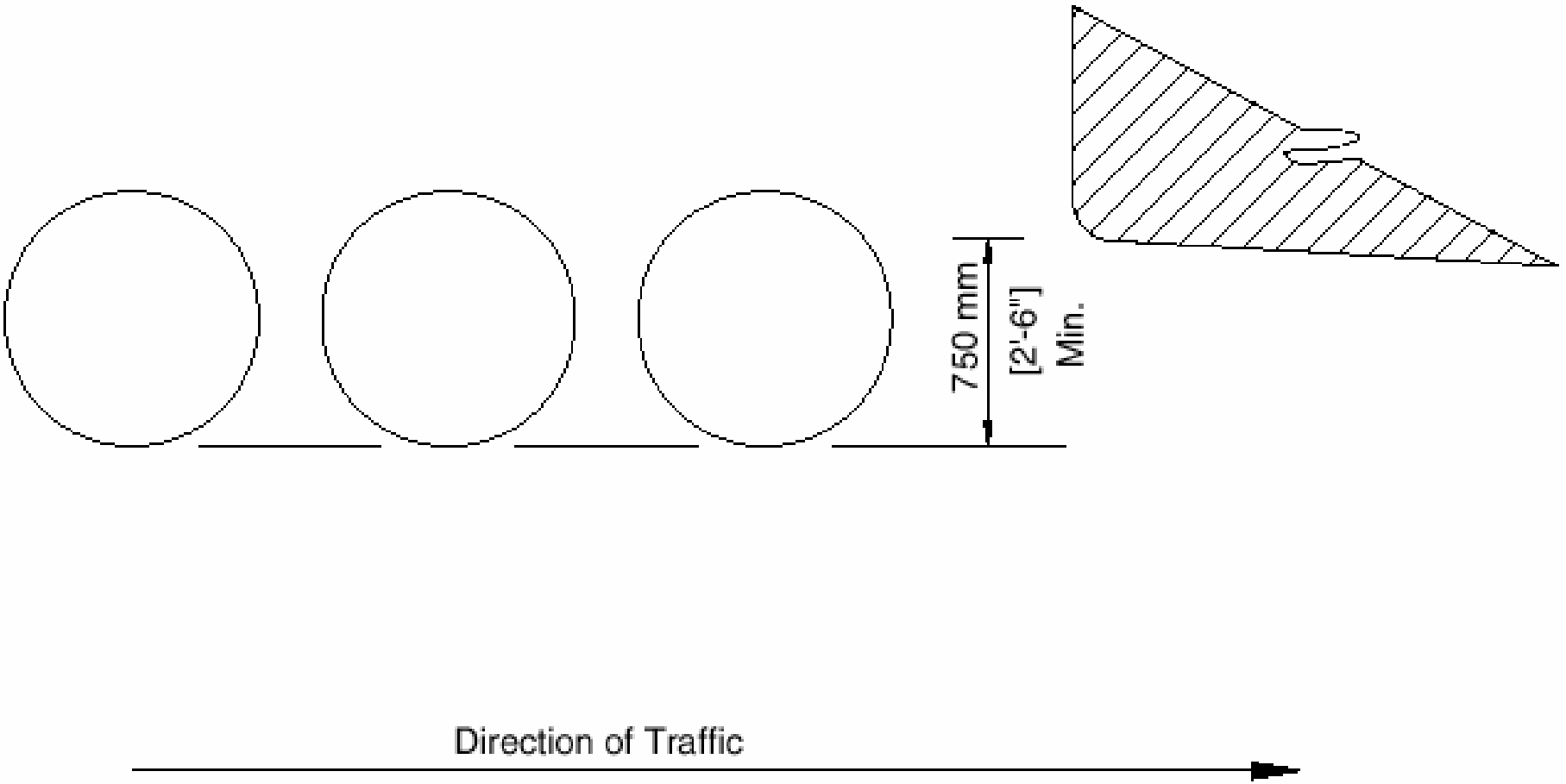

| | 1,800 lb Vehicle | | | | 4,400 lb Vehicle | | | |
|---|---|---|---|---|---|---|---|---|
| | $M_1$ [lb] | $V_O$ [ft/s] | $V_1$ [ft/s] | G | t [s] | $V_O$ [ft/s] | $V_1$ [ft/s] | G | t [s] |
| Fila 1 | 200 | 88.0 | 79.2 54 mph | | 0.036 | 88.0 | 84.3 | 3.34 | 0.035 |
| Fila 2 | 200 | 79.2 | 71.3 48 mph | | 0.040 | 84.3 | 25.5 | 3.06 | 0.036 |
| Fila 3 | 400 | 71.3 | 58.3 40 mph | | 0.046 | 80.7 | 74.1 | 5.27 | 0.039 |
| Fila 4 | 700 | 58.3 | 42.0 29 mph | | 0.060 | 74.1 | 64.1 | 7.13 | 0.043 |
| Fila 5 | 1400 | 42.0 | 23.6 16 mph | | 0.091 | 64.1 | 48.9 | 8.90 | 0.053 |
| Fila 6 | 2800 | 23.6 | 9.2 6 mph | | 0.183 | 48.9 | 30.1 | 7.67 | 0.076 |
| | 2800 | | | | | 30.1 | 18.6 | 2.92 | 0.123 |
| | 2800 | | | | | 18.6 | 11.5* | 1.11 | 0.200 |

Notes:

*At this point, the vehicle is traveling at less than 15 km/h [10 mph] and is stopped by the "bulldozing" action of the vehicle rolling through sand and one additional row of heavy containers.

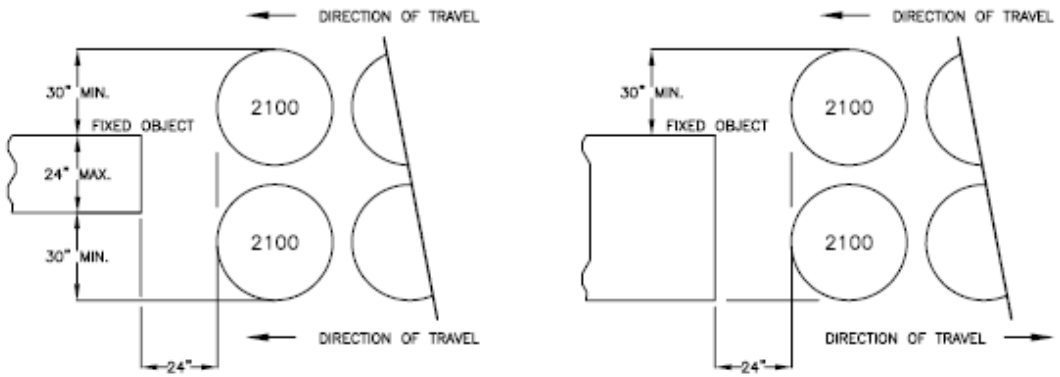
# Location of Barrels Relative to Object



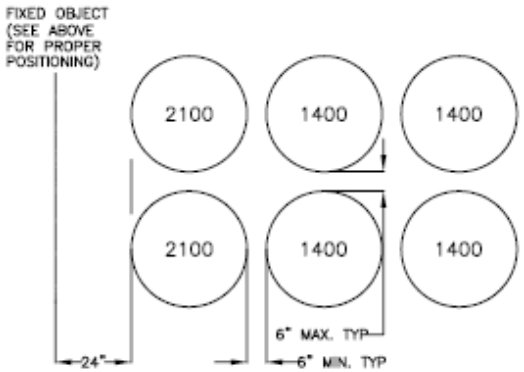


# Barrels Design Charts and Standard Arrays






| REVISIONS | | | | |
|---|---|---|---|---|
| ZONE | REV | DESCRIPTION | DATE | APPROVED |
| | A | INITIAL RELEASE | 7/9/02 | |




THIS DRAWING IS AN EXAMPLE OF A TYPICAL ARRAY PLAN AND SHOULD IN NO WAY OVERRIDE WHAT IS SPECIFIED BY YOUR LOCAL OR STATE TRAFFIC ENGINEER. CONTACT YOUR LOCAL OR STATE TRAFFIC ENGINEER FOR SPECIFIC SITE RECOMMENDATIONS FOR EACH SITUATION.

5. PLACE THE TYPE P MARKER PANEL SO THAT THE BOTTOM OF THE PANEL IS AT THE BOTTOM OF THE MODULE.
4. MASS OF SAND AND OUTLINE OF EACH MODULE SHALL BE PAINTED ON THE SURFACE OF EACH MODULE LOCATION.
3. BIDIRECTIONAL CRASH CUSHION ARRAYS MAY BE ANGLED TOWARD APPROACHING TRAFFIC. AMOUNT OF ANGLE NOT TO EXCEED 10°.
2. EACH MODULE IS TO CONTAIN AMOUNT OF SAND INDICATED. ALL SAND MASSES ARE NOMINAL.
1. (XXX) INDICATES MODULE LOCATION AND MASS OF SAND IN POUNDS (LBS) FOR EACH MODULE. MODULE SPACING IS BASED ON THE GREATER DIAMETER OF THE MODULE.

NOTES: UNLESS OTHERWISE SPECIFIED.

UNLESS OTHERWISE SPECIFIED:
ALL DIMENSIONS ARE IN INCHES.

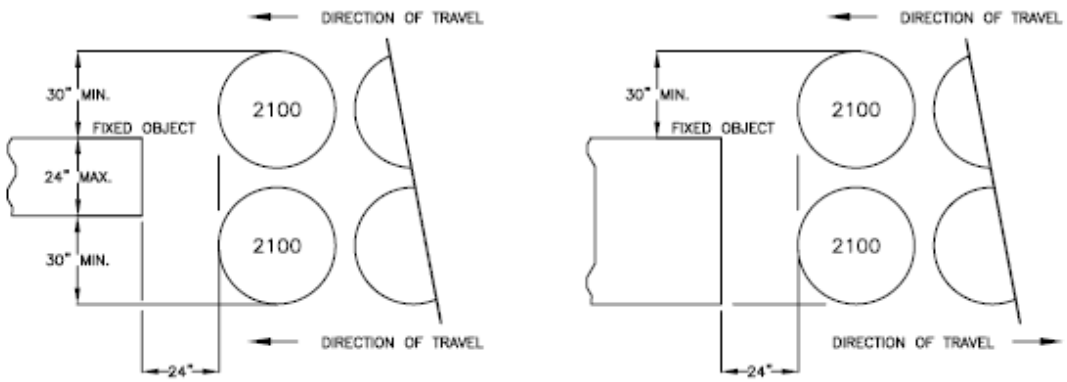
TrafFix Devices Inc.
220 Calle Pintoresco
San Clemente, CA 92672
(949) 361-5663
FAX (949) 361-9205
www.traffixdevices.com

BARREL ARRAY,
25MPH (40 KPH)

| DRAWN BY: | DATE: | SIZE | DWG NO. | REV |
|---|---|---|---|---|
| CHECKED BY: | DATE: | B | BA25 | A |
| APPROVED BY: | DATE: | SCALE NONE | SHEET 1 OF 1 | |

# Barrels Design Charts and Standard Arrays






| REVISIONS | | | | |
|---|---|---|---|---|
| ZONE | REV | DESCRIPTION | DATE | APPROVED |
| | A | INITIAL RELEASE | 7/9/02 | |

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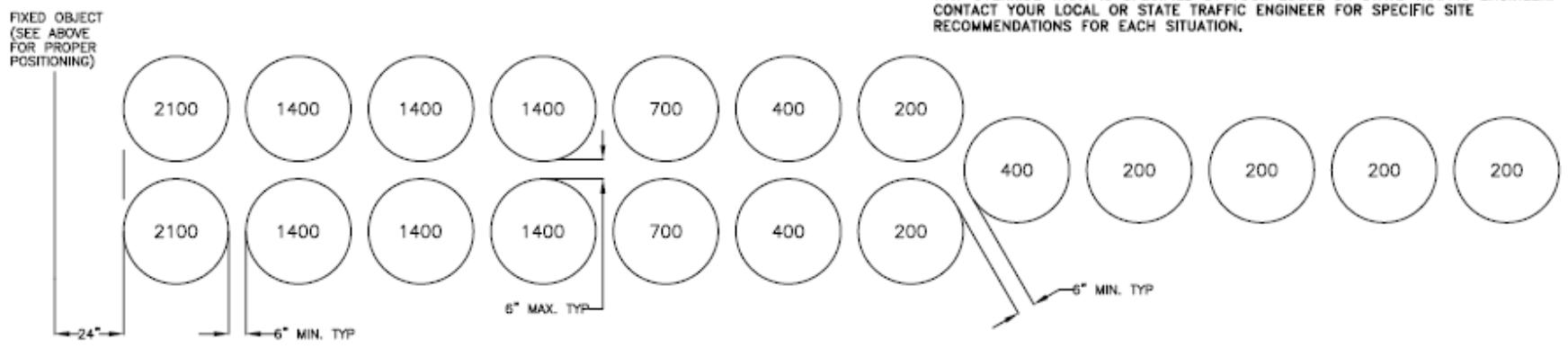


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1. (XXX) INDICATES MODULE LOCATION AND MASS OF SAND IN POUNDS (LBS) FOR EACH MODULE. MODULE SPACING IS BASED ON THE GREATER DIAMETER OF THE MODULE.

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San Clemente, CA 92672
(949) 361-9393
FAX (949) 361-9205
www.traffixdevices.com

BARREL ARRAY,
70 MPH (113 KPH)

| DRAWN BY: | DATE: | SIZE | DWG NO. | REV |
|---|---|---|---|---|
| CHECKED BY: | DATE: | B | BA70 | A |
| APPROVED BY: | DATE: | SCALE NONE | SHEET 1 OF 1 | |


EXIT 20A
63
NORTH
Likelike Hwy
EXIT ONLY
EXIT 20B
Houghtailing
Street
20B
EXIT
SPEED LIMIT
50
MINIMUM
40


ESTE
OESTE
2
2


SALIDA
13


SALIDA
48

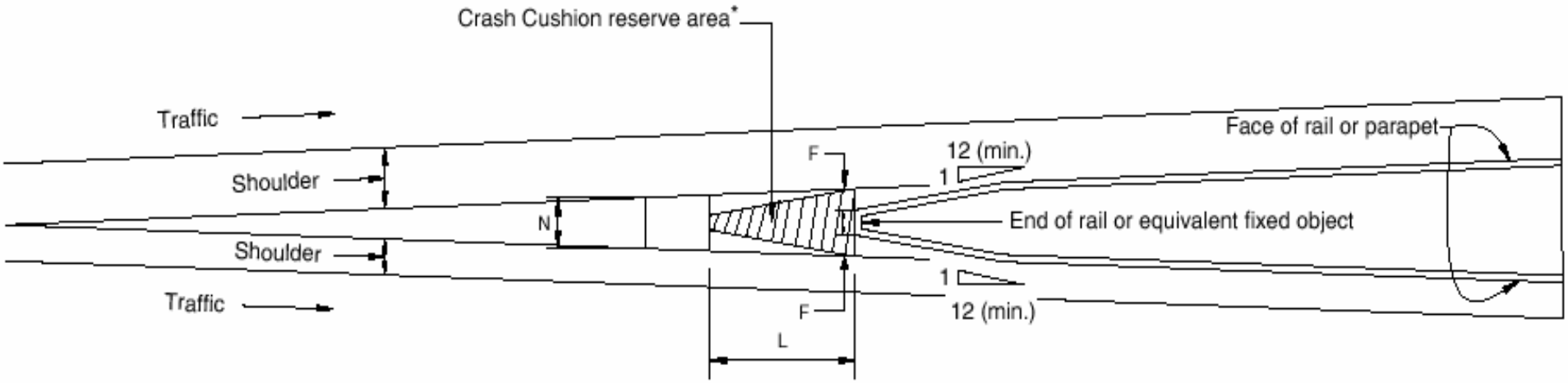

SALIDA 32
OESTE
22
Vega Baja
Arecibo
Mayagüez
2
Vega Alta
Vega Baja


CARRETERA
EN
CONSTRUCCION
ADELANTE


TRABAJO
EN PASO

# *Gore Areas*

# Reserve Areas for Gores




* No curbs, raised pavement, or prows to be built or to remain in the area surrounding or occupied by the crash cushion

*Follow manufacturer specifications*

| Design Speed on Main line [mph] | Dimensions for Crash Cushion, Reserve Area [feet] | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Minimum | | | | | | Preferred | | |
| | Restricted Conditions | | | Unrestricted Conditions | | | | | |
| | N | L | F | N | L | F | N | L | F |
| 30 | 6 | 8 | 2 | 8 | 11 | 3 | 12 | 17 | 4 |
| 50 | 6 | 17 | 2 | 8 | 25 | 3 | 12 | 33 | 4 |
| 70 | 6 | 28 | 2 | 8 | 45 | 3 | 12 | 55 | 4 |
| 80 | 6 | 35 | 2 | 8 | 55 | 3 | 12 | 70 | 4 |


SALIDA
162
TOYOTA

# Gore Area W-Beam “Jointed” Terminal




Ave. De Diego
Puerto Nuevo
SALIDA
5


SALIDA
42B


Carolina
Ave. Los Angeles
Aeropuerto
Pte T Moscoso
Ave Laguna
2.5


SALIDA
27

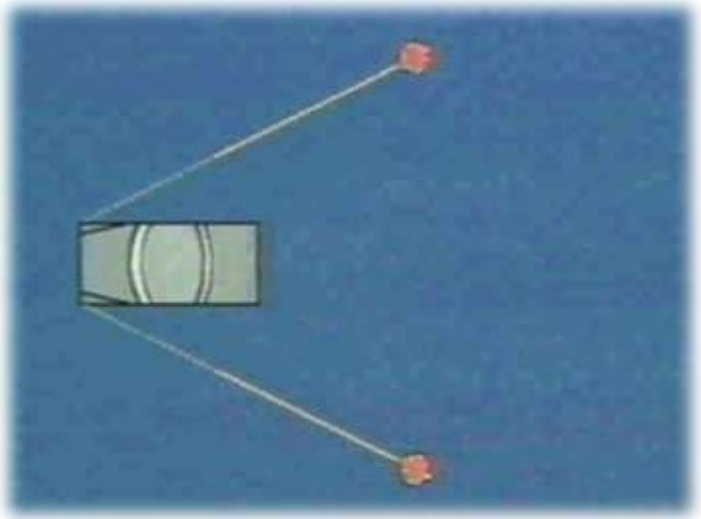

# *DRAGNET System*

# DRAGNET VEHICLE ARRESTING BARRIER System



- Chain link fence or fiber-arresting net
- Stops 4.5 kip car at 60 mph with minimum damage, can stop a heavy vehicles in series
- Span from one to six lanes
- Often reusable and can be repaired after a hit in minutes

*Requires extensive clear area*



# DRAGNET System Applications



1. Median traps - can be applied to any width and adapt to most median contours
2. Single lane or road closing - can be set up in and dismantled in minutes. Anchors can be set in earth, tied to trees or fit over trailer hitches
3. T intersections - can span up to 100 ft with one set of absorbers
4. Drop systems - deployment system vertically drop DRAGNET into an activated position
5. Emergency truck run-off ramps - using a series of nets, can withstand impacts of 80,000 lb. tractor trailers at speeds up to 80 mph

# StopGate Barrier Arm



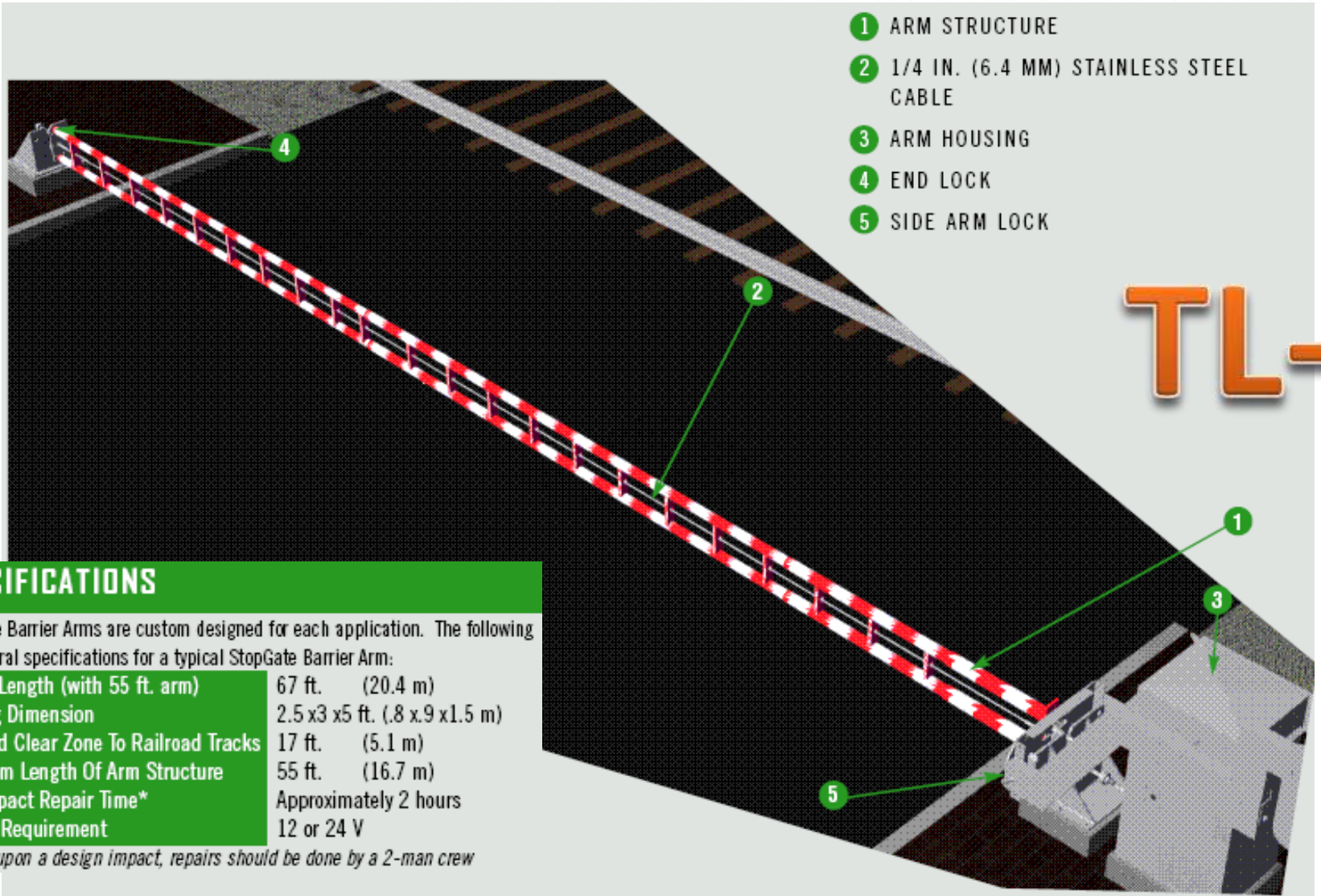
# StopGate Barrier Arm



- Annealed stainless steel cables arresting system laced together into a net-like structure
- Designed to diffuse the kinetic energy of an impacting motor vehicle
- Use to prevent vehicle intrusion onto railroad grade crossings, closed lanes, etc. by vehicles up to 4410 lb traveling at speeds up to 43 mph
- Arm length can be adapted to span up to 55 feet

# StopGate Barrier Arm

PUERTO RICO TRANSPORTATION TECHNOLOGY TRANSFER CENTER




## SPECIFICATIONS

StopGate Barrier Arms are custom designed for each application. The following are general specifications for a typical StopGate Barrier Arm:

| | |
|---|---|
| Overall Length (with 55 ft. arm) | 67 ft. (20.4 m) |
| Housing Dimension | 2.5 x3 x5 ft. (.8 x.9 x1.5 m) |
| Required Clear Zone To Railroad Tracks | 17 ft. (5.1 m) |
| Maximum Length Of Arm Structure | 55 ft. (16.7 m) |
| Post Impact Repair Time* | Approximately 2 hours |
| Voltage Requirement | 12 or 24 V |

**Based upon a design impact, repairs should be done by a 2-man crew*

# General Conclusions



- **All crashworthy terminals are not automatically suitable for use at all locations**
- **A barrier installation can often be extended a moderate distance to shield secondary hazards AND to provide a better location for its terminal**
- **The best choice is ALWAYS to eliminate the need for a barrier whenever practical**

# ¿Is this an Acceptable Crash Attenuator?


## Questions and Review

# Module 4 Review

1. The most important consideration in selecting an appropriate crash cushion design is:

a. Will it shield the hazard effectively
b. Will it contain (or redirect) an impacting vehicle
c. Will it require minimal maintenance

# Module 4 Review

2. Crash cushions will always save lives.

True or False?

# End Treatments and Crash Cushions Manufacturers

Barrier Systems Inc. - http://www.barriersystemsinc.com/

Energy Absorption Systems Inc. - http://www.energyabsorption.com

Highway Safety Corporation - http://www.highwaysafety.net/

Road Systems Inc. - http://www.roadsystems.com/

TrafFix Devices Inc. - http://traffixdevices.com

Trinity Industries Inc. - http://www.highwayguardrail.com/