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FINAL SUMMARY REPORT

CONTRACT #DTFH61-92-C-00036

Design, Construction and Maintenance of Highway Safety Features and Appurtenances

Written by

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October, 1998

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DESIGN, CONSTRUCTION and MAINTENANCE OF HIGHWAY SAFETY FEATURES AND APPRUTENANCES

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INTRODUCTION

This report summarizes the accomplishments, significant findings, planned efforts and problems identified for a study entitled "Design, Construction and Maintenance of Highway Safety Appurtenances". The objective of this project as defined in the scope of work, was to develop a users's guide and training course on the design, construction, and maintenance of highway safety appurtenances and features, The course was to consist of 3-1/2 days of total course material which could be used as individual modules to structure one, two, or three day training courses. The modules were to be structured in 30-minute to 90-minute stand-alone units which could be presented separately or arranged to provide for the specific training requirements of individual agencies. Upon completion of a training module, each participant was to be able to:

- Have a practical understanding of the particular highway feature or safety appurtenance addressed, including a knowledge of why they are used, when and where they shall be used and what actions (appropriate to the design, construction, or maintenance)are important to ensure they function correctly.

- Be able to recognize common substandard or potentially hazardous highway appurtenances and features.

- Be able to develop alternatives to eliminate, correct , enhance, or mitigate any unsatisfactory safety and operational characteristics of existing or proposed safety appurtenances or highway features.

SUMMARY OF PROJECT ACTIVITIES

The following is a discussion of the tasks, activities, and results of the project efforts.

Task A - Information Gathering

This task involved obtaining information on 28 different topics ranging from the clear zone concept to breakaway utility poles. This information was obtained from technical papers unpublished project reports, FHWA memos, crash test results, and contacts with manufacturers. Requested information included data on the schematics of proprietary and non-proprietary devices.

Task B - Training Course Outline

A training course outline and resource reference summary, for each of the 28 modules, was developed and submitted to FHWA for review and approval.

Task C - Develop Course Materials

The course materials for the project was to consist of, 1) Users Guide, 2) Instructors Manual, 3) visual aids, 4) workshop materials, and 5) video tapes. The draft Users Guide was developed by following the outline approved by FHWA. This outline included the module designations and descriptions that are summarized in Table 1.

One concern expressed by the Principal Investigator (PI), concurred with by the Contracting Offices Technical Representative (COTR), was the amount of repetition present in the manual. This was due to the contract requirement that each module be able to be presented by itself. The duplication was increased when the comments resulting from the FHWA review were addressed. For example, the distinction between the definition of crash cushions and end treatments is not clear resulting in the ability of properly using some crash cushions as end treatments. The result was a discussion of crash cushions in the end treatment module and of end treatments in the crash cushion module.

Approval of the draft Users Guide by the FHWA resulted in the development of the Instructors Manual, presentation materials and scripts for use in developing the training course video. The video was intended to provide standalone video-based instruction on a total of ten videos approximately 30 minutes in length. The video story boards were developed by combining modules of similar topics together. The module combination used to develop the video story boards is presented as Table 2.

Task D - Pilot Presentations.

The first of two pilot presentations was presented on November 13 through 16, 1995 in Sterling, Virginia. The course was attended by 42 participants from the FHWA, State Government, and private contractors. A debriefing conducted on November 17, 1995 resulted in the following conclusions.

- The course and Users Guide were developed to the organizational structure and content requested in the contract and by the FHWA reviews of draft material.
- Review of the course material by the pilot course participants indicated that the material would be restructured to better flow with logical grouping of topics/.
- The majority of modules, initially designated for design information, should be modified to include construction, installation, and maintenance concerns.

These conclusions resulted in modifications to the training materials including abandoning the concept of stand alone modules, and reorganizing the manual into six chapters.

Table 1 - Summary of training modules and topics.

Module	Description
A	Introduction to barriers and crash cushions.
B	Rigid barrier systems
C	Design orientated W-beam strong post system.
D	Maintenance and construction of W-beam strong post barrier system.
E	W-beam weak post barrier system.
F	Thrie beam barrier system.
G	Cable barrier systems.
H	Aesthetic barrier systems.
I	Commercially available terminals.
J	Commercially available barrier systems.
K	Crashworthy bridge rails and transitions.
L	Identification of substandard bridge rails and guardrail transitions to bridge rails.
M	Crash cushions - sand barrels and Connecticut systems.
N	Commercial crash cushions.
O	Wide medial treatments, barrier envelopes, curved barrier sections and other methods for protection large areas.
P	Introduction to breakaway systems.
Q	Design orientated single mount sign supports.
R	Design orientated multiple mount sign supports.
S	Maintenance and construction of single sign supports.
T	Maintenance and construction of multiple mount sign supports.,
U	Crash tested light supports.
V	Breakaway utility poles.
W	Crashworthy mail boxes.
X	Safety considerations when designing and locating traffic signal supports.
Y	Introduction to traversable terrain features.
Z	Traversable and nontraversable ditches and backslopes.
AA	Traversable and nontraversable drainage features.
BB	Safety considerations of landscaping and vegetation control.

Table 2 - Summary of video story board organization.

Video	Module	Description
1	A	Introduction to barriers and crash cushions.
2	B C D E F	Rigid barrier systems Design orientated W-beam strong post system. Maintenance and construction of W-beam strong post barrier system W-beam weak post barrier system Thrie beam barrier system.
3	G H	Cable barrier systems. Aesthetic barrier systems
4	I J M N	Commercially available terminals. Commercially available barrier systems Crash cushions - sand barrels and Connecticut systems. Commercial crash cushions.
5	K L	Crashworthy bridge rails and transitions. Identification of substandard bridge rails and guardrail transitions to bridge rails.
6	O BB	Wide medial treatments, barrier envelopes, curved barrier sections and other methods for protection large areas. Safety considerations of landscaping and vegetation control.
7	P Q R	Introduction to breakaway systems. Design orientated single mount sign supports Design orientated multiple mount sign supports
8	S T	Maintenance and construction of single sign supports. Maintenance and construction of multiple mount sign supports.
9	U V W X	Crash tested light supports. Breakaway utility poles Crashworthy mail boxes Safety considerations when designing and locating traffic signal supports
10	Y Z AA	Introduction to traversable terrain features. Traversable and nontraversable ditches and backslopes. Traversable and nontraversable drainage features.

The six chapters were developed by performing the following changes.

Chapter 1 - Introduction to the Safe Roadside Concept.

The introduction was expanded to give a history of the clear roadside concept accident statistics, and evolution of the testing procedure. This included moving some testing procedures for the different device types from the individual modules up to the introduction.

Chapter 2 - Design of Highway Safety Features.

Modules NEW, Y, Z, AA, BB, A and P were moved to follow the introduction. Module BB, on vegetation concerns, was placed in this chapter since it is a concern to all agencies. The order of appearance of modules A and P were interchanged since chapter 2 deals with breakaway designs. This built logical order in the manual that helped the reader who did not take the course. Module A was modified to cover barrier systems and terminals in general terms with the more detailed information in module A moved to new sections in chapters 3 and 4. The NEW section was titled DESIGN OF LONGITUDINAL BARRIERS and included some of the detailed information previously in module A, a description of barrier design concerns, and examples of length of need determination.

Chapter 3 - Breakaway Designs

Modules Q, R, S, T, U, V, W, and X were the next groupings of modules. Where appropriate the discussion on these modules was expanded to include a discussion on the specific maintenance concerns of individual devices.

Chapter 4 - Longitudinal Barrier Systems

Modules B, C+F, D, E+G, O, H, and J were contained in this chapter. Combining the strong post W-beam and thrie-beam (C+F) and the weak post W-beam and cable barrier (E+G) reduced some duplication and made the manual more concise. Maintenance concerns and information on the concerns for the proper construction of each system were included with the discussion of each device. The proprietary devices were reviewed to provide a neutral discussion of their advantages and disadvantages.

Chapter 5 - Terminals and Crash Cushions

NEW, C, I, and M+N were included as the next chapter, The portions of C which pertain to the design of terminals were moved to this section. Maintenance and construction concerns were included with maintenance check lists in an appendix. The construction concerns were obtained from the manufacturers, principally from their installation guidelines, and included only the major points that were stressed in the guidelines. The manufacturers were contacted to obtain this information. A new section was titled *Design of Terminals and Crash Cushions* and included information from module A pertaining to crash cushion design and portions of M and N. The proprietary rigid barriers were reviewed to provide a neutral discussion of their advantages and disadvantages.

Chapter 6 - Bridge Barriers

Modules K and L comprise the last chapter. Information was expanded on the inspection of substandard bridge transitions.

The second pilot was conducted on August 27 through 29, 1996 in Madison, Wisconsin. It was presented using the revised Users Guide, Instructors Manual, and presentation material. There were 42 participants including 10 FHWA, 29 State Government , and 2 private sector individuals. The acceptance of the training materials by the participants was very favorable. The result was to finalize the training materials.

The video story boards and a voice pattern tape were forwarded to FHWA for review on April 5, 1995. No response was received from this review and no subsequent changes to reflect the comments of the first pilot course were performed. The draft video story boards are attached as appendix B.

Task E - Final Course Material

A summary of the final course material is presented as Appendix A. Appendix S is a course planning form that was forwarded to locations interested in hosting a training course. The final course materials consisted of the following:

- Users Guide that has 925 pages of technical material including 332 computer generated CADD drawings.

- Instructors Manual consisting of 1436 35 mm slides, 40 transparencies and 9 workshops. The Instructors Manual contains breakout sessions providing the nuts and bolts procedure of installing proprietary and non-proprietary hardware.

- Appendices in the Users Guide that can be used to inspect safety hardware, and to select appropriate bridge rails, sign supports, longitudinal barriers and crash cushions.

The course material was updated during July 1997 to reflect changes in the NCHRP 350 testing of devices and new safety hardware.

Task F - Course Presentations

Courses have been conducted at locations presented in Table 3.

Table 3 - Locations training course was presented.

Location	Course Date	Number of participants
San Antonio, TX	September 17 to 18, 1997	25
Bridgeport, NB	February 17 to 18, 1998	28
Dover, DE	March 10 to 12, 1998	47
Fredericksburg, VA	March 17 to 18, 1998	38
Columbia, SC	April 20 to 24, 1998	40
Cheyenne, WY	May 19 to 21, 1998	37
Ft. Lauderdale, FL	May 27 to 29, 1998	40
Phoenix, AZ	June 8 to 11, 1998	126
Newington, CN	September 15 to 17, 1998	36

RECOMMENDATIONS

1. The final training material was much larger in volume than initially planned and reflected in the contract. The volume of material was large due to number of available safety appurtenances and the subsequent expansion of the project scope. The size of the course does not lend itself to the development of training videos as originally planned. The course would benefit greatly from the development of approximately 10 short , 10 minute videos keyed to the particular subject matter of selected chapter sections. The sections that would benefit most from videos include:

- Introduction: A brief documentary of severe crashes due to impacts with fixed objects, severe side slope, blunt cross slope, fence top tail entering the vehicle, guardrail penetration, and sign penetration. Images of vehicle damage and fatality/severity rate will emphasize the importance of proper roadside design.

- Separate 10 minute videos with crash test results on

  - Parallel and cross slope design.
  - Longitudinal barrier design and end treatments.
  - Crash cushions.
  - Single and multiple sign supports.
  - Bridge railings.
  - Transition designs.

- Drainage ditch and inlet design.
- Breakaway utility poles.
- Mailbox and light supports.

2. There is continued interest in presenting this training course. At the time of contract end the following agencies had scheduled or were in the process of scheduling a course.

Table 4 - Potential training course locations.

Location	Initial Course Date
Iowa	NA
Illinois	February 2 to 5, 1998
Puerto Rico	NA
Texas (Houston)	Na
Texas (Austin)	October 20 to 21, 1998
Ohio	NA
Washington	December 9 to 11, 1998
Arizona (#2)	November 10 to 13, 1998

3. The Users Guide consistently receives comments on the fact that it is the best and most comprehensive resource document available on highway safety appurtenances. The roadway safety environment is, however, constantly changing. To maintain the value of the Users Guide it must be updated at least annually, If it is not updated then it will become obsolete. One update since the initial publication has already been performed. Another update will be released by January, 1999. FHWA should consider awarding a maintenance contract to ensure that the manual remains current. The PI is developing the January 1999 update through a volunteer effort.

Appendix A - Course Overview and Planning Form

NHI COURSE #38034 OVERVIEW AND PLANNING FORM

This training course addresses concepts of traffic safety related to roadway and roadside features that can prevent the occurrence of a traffic accident, and reduce the severity of an accident should one occur. It presents current information on crash worthy longitudinal barriers, crash cushions, bridge rails, transitions, end terminals, sign posts, luminaire supports, utility poles and other topics related to improving traffic safety.

The objectives of the course are to provide design, construction and maintenance personnel information on roadway and roadside safety needs and the safety performance of rigid, semi rigid, and flexible longitudinal barriers, crash cushions, sign supports, breakaway utility poles, luminaire supports, mailboxes, drainage features, and bridge railings. Upon course completion the participants will be able to:

1. Identify advantages and disadvantages of different types of longitudinal barriers and crash cushions.
2. Identify NCHRP 350 tested safety appurtenances.
3. Have a practical understanding of highway safety appurtenances, including a knowledge of why they are used, when and where they should be used, and what is necessary to ensure they function correctly.
4. Design the placement of, and determine the length of need for, longitudinal barriers.
5. Know the proper installation, construction, and maintenance procedures for both proprietary and non-proprietary longitudinal barriers, terminals, transitions, crash cushions, bridge railings and sign supports.
6. Recognize substandard or potentially hazardous highway appurtenances and features.
7. Develop alternatives to eliminate, correct, or mitigate unsatisfactory operational characteristics of existing safety devices. The purpose of the course is to provide design, construction and maintenance personnel information on roadway and roadside safety needs and the safety performance of highway safety features. The objectives of the manual are to enable the reader to:

The training course can consist of from 1 to 4-1/2 days of instruction and be structured primarily for designers, or for construction\maintenance personnel. Please complete the bottom of this sheet and use the attached summary to select those sessions that are of primary interest. It is suggested that the course include the kickoff and sessions 1.1, 2.1 through 2.6 to establish the course framework. The other sessions can be selected individually or you can specify your training needs by category; such as strong post longitudinal barriers, bridge barriers, utility poles, etc. If the category is specified then necessary companion sessions will be selected that maintains the desired time frame.

<u>PLEASE REQUEST THAT THE PARTICIPANTS BRING A CALCULATOR TO THE TRAINING COURSE.</u>

Name:______________________________ Telephone # ____________________

Host Agency:______________________________________

Estimated Number of Participants:

____________ Designers ____________ Sign Crew ____________ Barrier Crew

Return to: Brian L. Bowman, Ph.D, P.E., Auburn University, Harbert Engineering Center, Auburn, AL 36849 TEL: 334/844-6262 FAX: 334/844-6290

SUMMARY OF TRAINING COURSE CONTENT

	DESCRIPTION	ESTIMATED LECTURE TIME (MINUTES)	WORKSHOP ESTIMATED TIME (MINUTES)
	KICKOFF Welcome to the training course by a Host Agency Representative, overview of the course, establishment of training hours, lunch time and introduction of the speakers and participants.	30	
1.1	**1 INTRODUCTION TO THE SAFE ROADSIDE CONCEPT** Background: An introduction to predominant roadside safety hazards and effective countermeasures. Also included in the introduction are: accident statistics, evolution of roadside safety, NCHRP 350 testing procedures, FHWA procedures for barrier acceptance, out of date installations, and steps to increase roadside safety.	30	
2.1	**2 DESIGN OF HIGHWAY SAFETY FEATURES** Clear Zone Concept : Definition, description, history, and examples of the acceptable clear zone as defined by AASHTO for various geometric situations.	45 plus 45 min for workshop	group workshop 45 min (usually combined with 2.2)
2.2	Traversable and Non-Traversable Ditches and Backslopes: Describes the hazard areas of ditches, where ditches are acceptable, and alternatives to using ditches to remove water.	30 plus 30 min for workshop	group workshop 30 min (usually combined with 2.1)
2.3	Overview of Traffic Barriers: Describes roadside barriers, terminals, and transitions, and defines characteristics such as redirecting capability and pocketing, which are used to classify the barriers.	45	
2.4	Performance Requirements of Barriers: Testing procedures, such as vehicle weight, speed, and angle of impact, which are used to classify a barrier or bridge rail, and the performance levels by which barriers and bridge rails are evaluated.	20	
2.5	Barrier Selection Guidelines: Lists selection criteria, with brief descriptions, that should be considered in determining the barrier system that provides the required degree of shielding at the lowest cost.	20	

	DESCRIPTION	ESTIMATED LECTURE TIME (MINUTES)	WORKSHOP ESTIMATED TIME (MINUTES)
2.6	Design of Longitudinal Barriers: Definition of barrier design elements and discussion of the factors that must be considered in barrier layout. Examples of calculating length of need for longitudinal barriers.	60	group workshop (60 min)
2.7	Design of Crash Cushions: Outlines places of need, methods of operation, evaluation, and selection of FHWA approved crash cushions.	45	
2.8	Design of Bridge Rails and Transitions: Differences between bridge rails and roadside barriers; bridge rail performance levels and crash test criteria, and bridge rail selection. Examples of determining appropriate performance levels and barrier types.	45	group workshop (30 min)
2.9	Design of Traversable and Non-Traversable Drainage Features: Design concerns associated with curbs, pipes, culverts, headwalls, and drop inlets. Recommendations on the location, design, and maintenance of these features for increased safety.	60	good/poor practice slide example workshop (15 min)
2.10	Construction and Maintenance of Drainage Features: Construction of drainage features and their maintenance needs including inspection checklists for ditches, drainage structures, and intakes.	30	
2.11	Safety Considerations of Landscaping and Vegetation Control: Compares advantages and disadvantages of landscaping along highways. Importance of properly maintaining vegetation, and impact of vegetation in different geometric situations.	30	
3.1	**3 BREAKAWAY DESIGNS** Introduction to Breakaway Systems: Options available to engineers for providing safe designs of traffic signs, roadway illumination, utility service, and postal delivery hardware placed within the right-of-way.	60	
3.2	Design Orientated Single Mount Sign Supports: Situations in which signs require single support systems, and the most widely used approved sign support systems.	60	
3.3	Design Orientated Multiple Mount Sign Support: Differences between single and multiple mount sign supports. The most widely used approved multiple sign support systems.	30	

	DESCRIPTION	ESTIMATED LECTURE TIME (MINUTES)	WORKSHOP ESTIMATED TIME (MINUTES)
3.4	Maintenance and Construction of Single Sign Supports: Methods of installation, placement, and maintenance of single sign supports.	60	
3.5	Maintenance and Construction of Multi-Mount Sign Supports: Methods of installation, placement, and maintenance of multiple mount supports.	60	
3.6	Maintenance of Traffic Sign Panels and Posts: Sign vandalism problems including destruction, mutilation, and theft, with possible solutions and maintenance suggestions. Repair and replacement guidelines are also included for different sign types.	30	
3.7	Breakaway Utility Poles: Advantages of using breakaway utility poles in situations where other options are not available, available designs of breakaway systems, and tips for system selection.	30	breakaway AD-IV-S construction (15 min)
3.8	Crashworthy Mailbox Supports: Mailbox hazards and the need for their proper design, placement, and installation.	30	
3.9	Safety Considerations when Designing and Locating Traffic Signal Supports and Controller Boxes: Considerations required when installing traffic signals and control boxes.	30	
3.10	Crash Tested Light Supports: Advantages and disadvantages of the different types of materials available for use as light supports. Methods of designing and installing light support foundations, bases, and wiring systems. Guidelines for construction of lighting installations.	45	good/poor practice slide example workshop (15 min)
	4 LONGITUDINAL BARRIER SYSTEMS		
4.1	Rigid Barrier Systems: A listing of the various types of concrete barriers and discussion of their performance capabilities. Highway design parameters which must be met to ensure proper barrier performances. Barrier selection, inspection, and evaluation.	60	
4.2	Strong Post W-Beam and Thrie-Beam Barriers: Historical development of W-beam and thrie-beam barriers and a discussion of their design and performance differences. Approved end treatments and transitions available for use. Selection and design considerations.	60	good/poor practice slide example workshop (15 min)

	DESCRIPTION	ESTIMATED LECTURE TIME (MINUTES)	WORKSHOP ESTIMATED TIME (MINUTES)
4.3	Construction and Maintenance of Semi-Rigid Systems: Details concerning layout, construction, and maintenance of strong post W-Beam and thrie-beam guardrails, transitions, and terminals.	60	
4.4	Weak Post Barrier Systems: Construction and maintenance of flexible systems including weak post W-beam, weak post thrie-beams and cable systems.	45	group workshop (30 min)
4.5	Treatment of Wide Medians, Barrier Envelopes, Curved Barrier Sections, and Other Methods of Protecting Large Areas: Methods of treating wide roadside areas that can pose as safety hazards.	30	
4.6	Aesthetic and Lower Service Level Barrier Systems: Traffic barriers that provide impact performance comparable to conventional barrier systems with visual qualities to complement aesthetically sensitive environments.	60	
4.7	Commercially Available Barrier Systems: Discusses configuration and dimensions of available commercial barrier systems. *Workshops are selective by device type, pertain to construction and installation, and require approximately 15 minutes each.*	20 plus selected workshops	Barrier Gate Triton Guardian (variable time)
	5 TERMINALS AND CRASH CUSHIONS	15	
5.1	Introduction to Terminals and Crash Cushions: Introduction to the need for proper end treatments and the principles by which these treatments operate.		
5.2	Construction and Maintenance of Terminals: Construction and maintenance of various types of terminals, both proprietary and non-proprietary, available for use W-beam and/or thrie-beam end treatments. Includes installation and maintenance checklists. *Workshops are selective by device type, pertain to construction and installation, and require approximately 15 minutes each.*	45 plus selected workshops	TERMINALS MELT BEST 350 SKT 350 ET2000 SENTRE SRT TREND FLEAT REGENT (variable time)

	DESCRIPTION	ESTIMATED LECTURE TIME (MINUTES)	WORKSHOP ESTIMATED TIME (MINUTES)
5.3	Construction and Maintenance of Crash Cushions and Sand Barrels: Description, construction, maintenance, and product check lists of crash cushions, sand barrels, truck-mounted attenuators, and positive intrusion protection. *Workshops are selective by device type, pertain to construction and installation, and require approximately 15 minutes each.*	45 plus selected workshops	ADIEM Brakemaster CAT Cushionwall GREAT QuadGuard LMA NEAT REACT 350 Sand Barrels MPS-350III (variable time)
	6 BRIDGE BARRIERS		
6.1	Crashworthy Bridge Railings: Dimensions and overall geometry of bridge railing systems.	60	
6.2	Transitions To Bridge Rail and Between Barrier Systems: Guardrail to bridge railings transitions.	45	
6.3	Identification of Deficient Bridge Rail Systems: Improper designs of bridge railings, corrective measures, and retrofit designs.	45	good/poor practice slide example workshop 20 min

Appendix B - Original Video Story Boards

VIDEO STORYBOARD - 1
(Module A)
INTRODUCTION TO BARRIER SYSTEMS, CRASH CUSHIONS AND BRIDGE RAILS

Left column is narration, - right column describes video scene.
Captions for video footage are in caps and are boxed.

Material in parenthesis ( ) is comment or explanation.
Material in brackets [ ] identifies existing video footage.
✓ - indicated footage to be obtained from existing presentation quality video.
✓✓ - indicated footage to be obtained from existing crash test videos.
* - indicates new footage to be obtained.
@ - indicates possible use of existing photographs.

NARRATIVE	**VIDEO 1** **V 1**
A basic philosophy of highway design is that every reasonable effort should be made to keep motorists on the roadway. Pavement marking, raised pavement markers, roadway edge lines, traffic signing and texturized shoulders are devices used, in conjunction with good geometric design to help the motorist safely drive his vehicle.	* View good section of interstate roadway with pavement markings, edge lines, traffic signing, texturized shoulders, horizontal curve invisible. INTRODUCTION TO BARRIER SYSTEMS, CRASH CUSHIONS AND BRIDGE RAILS (Include all opening credits, etc.)

NARRATIVE	**VIDEO 1** **V 2**
However, in spite of careful attention to the geometric design of the roadway and the application of such safety features as pavement markings, signs and signals, and roadway lighting, vehicles continue to leave the roadway for a number of reasons. A second basic philosophy of highway design is that the roadside should be as forgiving as reasonably possible to provide errant vehicles an opportunity to recover; and either stop safely, or return to the roadway, or if that isn't possible, to reduce the severity of the resulting accident as much as possible.	*@ Accident scene.

NARRATIVE	VIDEO 1 V 3
Well-defined guidelines for the treatment of roadside features to reduce the risk of a collision, given that a vehicle departs the roadway, have been developed since the 1960's. Recommended design options are discussed in the 1989 American Association of State Highway and Transportation Officials (AASHTO) Roadside Design Guide, which lists the following options in the order in which they are normally considered.	*@ Close-up of RDG text.

NARRATIVE	VIDEO 1 V 4
- Remove the obstacle or redesign it so it can be traversed safely.	*@ Traversable culvert end.

NARRATIVE	VIDEO 1 V 5
- Relocate the obstacle to a point where it is less likely to be struck.	*@ Sign on overpass or sign located on far upslope.

NARRATIVE	VIDEO 1 V 6
- Reduce impact severity by using an appropriate breakaway device.	*@ Device with frangible couplings.

NARRATIVE	VIDEO 1 V 7
- Redirect the vehicle by shielding the obstacle with a longitudinal traffic barrier and/or crash cushion.	*@ Longitudinal barrier or crash cushion.

NARRATIVE	VIDEO 1 V 8
- Delineate the obstacle if the above alternatives are not appropriate.	*@ Bridge pier with hazard marker.

NARRATIVE	VIDEO 1 V 9
OVERVIEW OF TRAFFIC BARRIERS The "Roadside Design Guide" defines traffic barriers as devices used to prevent a vehicle from striking a more severe obstacle or feature located on the roadside or in the median, or to prevent a median crossover accident. Traffic barriers are typically classified by their primary function as follows: - Roadside barrier - a longitudinal barrier used to shield roadside obstacles or non-traversable terrain features, or occasionally to protect pedestrians or bystanders from vehicle traffic.	*@ Roadside barrier.

NARRATIVE	VIDEO 1 V 10
- Median barrier - a longitudinal barrier used to prevent an errant vehicle from crossing the highway median.	*@ Median barrier.

NARRATIVE	VIDEO 1 V 11
- Bridge railing - a longitudinal barrier whose primary function is to prevent an errant vehicle from going over the side of the bridge structure.	*@ Bridge railing.

NARRATIVE	VIDEO 1 V 12
- Crash cushion - an impact attenuator device that prevents an errant vehicle from impacting fixed object hazards by gradually decelerating the vehicle to a safe stop or redirecting the vehicle away from the hazard.	*@ Crash cushion.

NARRATIVE	VIDEO 1 V 13
These broad categories, while commonly used, do not adequately describe their intended use or limitations. The categories appear quite different because they distinguish between longitudinal barriers, and crash cushions for example. The problem, however, is that systems within categories may be quite different, while systems between categories may be very similar.	- ROADSIDE BARRIER - MEDIAN BARRIER - BRIDGE RAILING - CRASH CUSHION *@ (Screen can be split into quadrants with wording over example of each device or a collage of devices with wording blocked in center.)

NARRATIVE	VIDEO 1 V 14
Cable guardrail and concrete safety shapes are both categorized as longitudinal barriers but they differ significantly in their performance and situations in which each should be used.	*@ Split screen view of cable guardrail and concrete safety shape.

NARRATIVE	VIDEO 1 V 15
Alternatively some crash cushions have a redirecting ability that results in their performance as a longitudinal barrier for side impacts and as a crash cushion for head-on impacts. To understand the performance characteristics of highway safety appurtenances it is useful to review the terms used in defining their abilities and application areas.	*@ Split screen view of crash cushions, one without skirts one with skirts.

NARRATIVE	VIDEO 1 V 16
Redirecting Capability A redirecting system will redirect an impacting vehicle away from a fixed object when the system is struck on the side.	✓✓ Crash testing footage of redirective system. REDIRECTIVE

NARRATIVE	VIDEO 1 V 17
If a vehicle strikes a nonredirective system at an angel it will continue in nearly the same direction until it impacts a fixed object, another vehicle or comes to a stop.	✓✓ Crash testing footage of nonredirective system. NONREDIRECTIVE

NARRATIVE	VIDEO 1 V 18
Site conditions will dictate whether a redirective or nonredirective system is required. If a redirective system is required a further determination will be if it is necessary to have redirectional capabilities for one direction (unidirectional)	* View of traffic passing unidirectional crash cushion. UNIDIRECTIONAL

NARRATIVE	VIDEO 1 V 19
or both directions (bidirectional).	* View of traffic passing bidirectional crash cushion at gore area. BIDIRECTIONAL

NARRATIVE	VIDEO 1 V 20
Gating Capability When a gating system is struck at an angle on the front (system nose) it allows the vehicle to pass through in the same general direction of travel.	✓✓ Crash testing of gating system. GATING

NARRATIVE	VIDEO 1 V 21
If the safety device is nongating, it will bring the impacting vehicle to a controlled stop.	✓✓ Crash testing of nongating system. NONGATING

NARRATIVE	VIDEO 1 V 22
The decision to allow gating depends on whether the length-of-need has been used for the longitudinal barrier. If the length-of-need has been established then the end treatment could allow gating without being hazardous.	* View of location with gating system installed.

NARRATIVE	VIDEO 1 V 23
If the length-of-need has not been established then the system should not be allowed to gate. Similarly gating should not be allowed if the site characteristics indicate that an impacting vehicle would be at high risk due to a secondary impact or by encroaching into opposing traffic lanes.	* View of location with nongating system installed.

NARRATIVE	VIDEO 1 V 24
Pocketing occurs when the stiffness of two redirective barriers is so different that the impacting vehicle deflects the softer barrier and impacts the end of the strong barrier. Pocketing is a concern, for example, at the transition of W-beam to bridge rail. The stiffness and deflection characteristics of sequential barrier systems should be determined and a proper transition used to reduce the potential of pocketing.	✓✓ Scene of improper transition to bridge rail with crash test showing effects of pocketing. POCKETING

NARRATIVE	VIDEO 1 V 25
Vehicle Intrusion The trajectory and final resting position of a vehicle after impact is a critical factor in safety performance. Intrusion characteristics of safety devices can result in a high probability of secondary impacts with fixed objects or adjacent traffic. The intrusion characteristics of systems vary considerably. Some systems bring an impacting vehicle to a controlled stop within the barrier area. Other systems allow the vehicle to exit at a steep angle into adjacent traffic, deflect the barrier sufficiently to encroach into opposing traffic lanes or to deflect sufficiently to permit impact with the fixed object it was installed to shield. The lateral deflection characteristics must be known for proper appurtenance selection and installation.	✓✓ Crash test of vehicle impacting barrier and also fixed object. INTRUSION

NARRATIVE	VIDEO 1 V 26
Capacity The capacity of a system refers to the test or performance level that the safety appurtenance successfully passed during the crash testing. Testing documentation. and the approval process is being reported in a format that is useful to designers. Designers can select a system based on its ability to absorb or redirect at least some specified level of kinetic energy, such as a 2040 kg vehicle at 100 km/h and 25 degrees. The capacity of a system is often dependent upon a specified length, width, attachments or anchoring options. These options should be clearly understood, and compatible with site conditions, before selecting any safety appurtenance. The majority of manufacturers provide design services for commercially available safety appurtenances.	✓✓ Crash test of large vehicle impacting longitudinal barrier. CAPACITY

NARRATIVE	VIDEO 1 V 27
Now that we have established that there are both similarities and differences between longitudinal barriers, bridge rails and crash cushions, lets review each one. Longitudinal barriers, whether placed on the roadside or median, separate traffic from hazards by operating as either a tension system, strong beam system or rigid wall system. Some longitudinal barriers operate by a combination of these systems.	LONGITUDINAL BARRIERS - TENSION - STRONG BEAM - RIGID WALL * Split screen with W-beam, concrete safety shape, median and roadside applications.

NARRATIVE	VIDEO 1 V 28
Tension systems are barrier systems that resist impact through the development of tension in the rail element. As the rail is deflected laterally by the impacting vehicle, large tensile forces build up, and the lateral component of those forces redirect the vehicle. Tension anchors are required at each end of the barrier to resist the rail tension. Tension systems are frequently referred to as "flexible systems" because they provide the most lateral "give" on impact. Barriers in this category include cable barriers.	*@ View of cable barrier with close-up of tension anchor. (Video scenes AV28, AV29, and AV30 could be arranged on one screen.) TENSION SYSTEMS

NARRATIVE	VIDEO 1 V 29
Weak post W-beam	*@ View of weak post W-beam.

NARRATIVE	VIDEO 1 V 30
and weak post thrie-beam.	*@ View of weak-post thrie-beam.

NARRATIVE	VIDEO 1 V 31
Strong beam systems are the most widely used barrier systems. They redirect vehicles primarily through beam action. Relatively strong rails act as beams to transfer impact loads to closely spaced posts, which in turn transfer the loads to the ground. Tensile forces in the rail also contribute to their effectiveness to some extent and end anchors are used for many strong beam barriers. Strong beam systems undergo much less lateral impact deflection, and are frequently referred to as "semi-rigid" systems. Barriers in this category include strong post W-beam and	*@ View of strong-post W-beam. (Video scenes AV31, AV32, and AV33 could be arranged on one screen.) STRONG BEAM

NARRATIVE	VIDEO 1 V 32
strong post thrie-beam	*@ View of strong-post thrie-beam.

NARRATIVE	VIDEO 1 V 33
and steel backed timber guardrail.	*@ View of steel backed timber guardrail.

NARRATIVE	VIDEO 1 V 34
Descriptions of longitudinal barriers frequently use the terms "strong post" and "weak post" to describe them. As the names imply there is a difference in the post size but also frequently spaced 3810 mm between post - strong post systems at 1905 between posts.	*@ (Split screen with strong post on one side, weak post on the other.) STRONG POST WEAK POST

NARRATIVE	VIDEO 1 V 35
Rigid wall barriers resist impact loads by transferring impact loads directly into the ground, either with or without the use of a footing. Some of these barriers resist impact through the inertial resistance of the massive barrier section, and by sliding resistance of the barrier across the roadway surface. As the name implies, barriers in this category experience little or no lateral deflection upon impact. A number of different shapes are used on the traffic face of rigid barriers to absorb impact energy by partially lifting the vehicle, and to control the post-impact behavior of the vehicle. Barriers in this category include concrete safety shape and vertical concrete barriers, stone masonry walls, and various proprietary barriers.	*@ View of concrete safety shape. (Video scenes AV35, AV36, and AV37 could be arranged on one screen.) RIGID WALL

NARRATIVE	VIDEO 1 V 36
Vertical concrete barriers	*@ View of vertical barrier.

NARRATIVE	VIDEO 1 V 37
and concrete aesthetic barriers.	*@ View of concrete aesthetic barrier.

NARRATIVE	VIDEO 1 V 38
Bridge Railings Bridge railings are used to prevent a vehicle from running off the edge of a bridge or culvert. While roadside and median barriers transfer impact loads to the ground through posts or end anchors, bridge rails transfer impact loads to the bridge deck. Although some railings may undergo slight deflections on impact, most bridge railing are essentially rigid, and have virtually no deflection when impacted by an errant vehicle. Bridge railings are generally one of three types: - Post and beam railings consist of strong beams supported by strong posts attached to the top or side of the deck. While posts and beams are most often metal or reinforced concrete, wood posts and rails are also used.	*@ View of post and beam railing. (Video scenes AV38, AV39, and AV40 could be arranged on one screen.) BRIDGE RAILINGS

NARRATIVE	VIDEO 1 V 39
- Solid parapet rigid walls generally constructed of concrete, frequently employing a concrete safety shape, are frequently used as bridge rails. Rigid metal parapets, also employing the safety shape, may be used where reduced weight on the structure is a consideration.	*@ View of solid parapet wall.

NARRATIVE	VIDEO 1 V 40
- Combination railings consist of metal or concrete post and beams which are attached to the top of solid parapet railings to reduce weight and cost, or to provide an open view from the bridge.	*@ View of combination railing.

NARRATIVE	VIDEO 1 V 41
- Bridges located in areas with pedestrian or bicycle activity frequently have raised sidewalks across the bridge. Such bridges may require a traffic railing, separating the traffic lanes from the sidewalk, and a pedestrian railing between the sidewalk and bridge edge. The pedestrian railing has a higher height than the traffic railing. It is installed to improve the comfort and safety of pedestrians and bicyclists with a potential for falling over their railings.	*@ View of traffic and pedestrian railing.

NARRATIVE	VIDEO 1 V 42
CRASH CUSHIONS Also called impact attenuators, these protective devices prevent errant vehicles from impacting fixed object hazards either by gradually decelerating the vehicle, or by directing the vehicle away from the hazard. They are ideally suited for situations where longitudinal barriers cannot be effectively used to shield objects that cannot otherwise be removed, relocated, or made breakaway. Although a limited number of generic designs are available, most crash cushions are proprietary designs developed and marketed by private industry.	*@ (Views of sand barrels, Connecticut system, hydro cells, and ADIEM.) CRASH CUSHIONS

NARRATIVE	VIDEO 1 V 43
Crash cushions protect occupants of impacting vehicles by providing a controlled stop using one of two principles: <u>Kinetic Energy Principle</u> The energy absorption modules of the crash cushion are crushed -- plastic deformation -- with the product of the applied force and crush distance equal to the decrease in kinetic energy of the impacting vehicle. These devices require a back-up support or foundation system to resist the impact force.	✓✓ Crash test footage of Connecticut System.

NARRATIVE	VIDEO 1 V 44
Conservation of Momentum Principle The momentum of the vehicle is transferred to an expendable mass in the crash cushion, typically sand. As the combined mass of the vehicle and expendable mass increases, the velocity decreases. These devices require no back-up support of foundation, since the energy of the vehicle is transferred to other masses rather than absorbed.	✓✓ Crash test footage of sand barrier.

NARRATIVE	VIDEO 1 V 45
PERFORMANCE REQUIREMENTS Roadside barriers may be subjected to a wide range of impacts by errant vehicles, and in return, traffic barriers provide a wide range of protection to the occupants of impacting vehicles. An important consideration in the selection and design of any roadside feature is to determine the level of impact severity for which it is desirable to provide protection, and to determine an appropriate level of protection to be provided by the feature.	*@ View of freeway traffic with large truck volumes and concrete safety shape. PERFORMANCE REQUIREMENTS

NARRATIVE	VIDEO 1 V 46
It has become increasingly recognized that different roadways present different requirements in terms of the levels of impact severity for which it is desirable, or practical, to provide protection. Accordingly, criteria now widely used for the evaluation of roadside barriers consider a range of performance levels.	* View of nice rural roadway, few vehicles horizontal curve.

NARRATIVE	VIDEO 1 V 47
NCHRP Report 350 "Recommended Procedures for the Safety Performance Evaluation of Highway Features", provides testing procedures and performance requirements for barriers. These performance requirements are called test levels and range from level 1 to level 6.	* View of someone holding NCHRP 350 or of cover.

NARRATIVE	VIDEO 1 V 48
NCHRP 350 does not provide guidance on the applicability of the test levels to roadway or traffic characteristics. Rather, it is left to the owner agencies to determine which of the test levels is most appropriate for a feature's intended applications. Most roadside barriers now in common use were developed to provide adequate strength to resist impact by full-size sedans (typically 2040 kg) impacting at 100 km/h and 25 degrees, while providing adequate protection for the occupants of small sedans (typically 820 to 1020 kg) impacting at 100 km/h and 15 to 20 degrees. This is test level 3 and is generally considered appropriate for wide spread use.	* View of strong- post guardrail.

NARRATIVE	VIDEO 1 V 49
Test levels 1 and 2 may be used for roadways with lower speeds and volumes such as local streets and highways, local and collector roads, and some work zone applications.	* View of park roadway with low level barrier

NARRATIVE	VIDEO 1 V 50
Test levels 4 thru 6 may be suitable for highways carrying high volumes of trucks, and where consequences of barrier penetration may be particularly severe. unlike the AASHTO Guide Specifications, which match performance levels to roadway and traffic characteristics. Research proposed to start in 1995, under the National Cooperative Highway Research Program, will develop guidelines to aid user agencies in the selection of appropriate roadside safety features to match traffic and highway characteristics.	* View of tall wall concrete median application.

NARRATIVE	VIDEO 1 V 51
The "Guide Specifications for Bridge Railings," published in 1989 by AASHTO, introduced the concept of multiple performance levels and the requirement that future bridge railing designs be crash tested to confirm that they meet the requirements of a specified performance level. The multiple performance level concept allows for the selection of a bridge railing based on site-specific conditions. Although penetration of any railing by a vehicle is potentially hazardous to its occupants,	* View of rural road bridge drop off into creek.

NARRATIVE	VIDEO 1 V 52
there are bridge locations where vehicle penetration could be particularly hazardous to others as well. The multiple performance level approach considers design speed, average daily traffic (ADT), traffic mix, roadway design characteristics and the presence of vulnerable elements beneath the bridge.	*@ View of bridge or elevated freeway ramp with buildings or heavy traffic beneath.

NARRATIVE	VIDEO 1 V 53
Performance level 1 is the lowest level bridge rail designed to contain and redirect passenger cars, light trucks and vans. This level provides the opportunity to install low-cost bridge railings on low-speed, low volume roadways and high performance bridge railings on truck routes if site conditions warrant such treatment.	*@ View of performance level 1 railing on rural road.

NARRATIVE	VIDEO 1 V 54
Performance levels 2 and 3 The ability to contain and redirect larger vehicles, as required, is dependent upon the railings strength, effective height and shape of the railing face. The required strength may be as high as 1.4 million Kilopascals for a 36,200 kg tractor-trailer striking the railing at 80 km/h at an angle of 15 degrees.	*@ View of performance levels 2 and 3 bridge railings.

NARRATIVE	VIDEO 1 V 55
Roadside safety hardware and terrain features that must be placed within the roadside clear zone adjacent to the travelled way of National Highway System (NHS) routes are required by FHWA to be of a crashworthy design.	* Scenes of approved guardrail and bridge railings.

NARRATIVE	VIDEO 1 V 56
As a service to hardware developers and manufacturers, highway agencies, and others in the highway industry, FHWA's Office of Engineering reviews crash test documentation and issues letters of acceptance for crashworthy features and hardware.	* Views of a collage of FHWA acceptance letters.

NARRATIVE	VIDEO 1 V 57
While FHWA's acceptance qualifies a device for use on NHS roadways, it is still up to the owner agency to determine which qualifying devices are most suitable for their particular application. Other devices that have not been accepted by FHWA's Office of Engineering may also be acceptable for use, and when adequate documentation is available to demonstrate compliance with the NCHRP Report 350 criteria, an agency may obtain approval for use of such devices on an NHS roadway directly from their FHWA Division Office.	* View of office crew inspecting prints.

NARRATIVE	VIDEO 1 V 58
A clear understanding of the performance criteria discussed in the previous section is essential for a highway engineer to determine the level of protection that is desirable from a safety feature, and the basis for determining whether a device can, in actual practice, provide that protection. An equally basic question that must be addressed in roadside safety design is whether or not any safety feature should be employed at a given location, and if so, which of the available safety treatments or features is the "best" choice. Improper design, such as this inadequate flare rate	*@ View of wrong flare rate.

NARRATIVE	VIDEO 1 V 59
or this improper height.	*@ View of improper guardrail height.
NARRATIVE	**VIDEO 1 V 60**
Installing where not needed or beyond the length of need.	*@ View of guardrail installed where not needed.
NARRATIVE	**VIDEO 1 V 61**
Placing too close to the hazard can all result in increase in accident frequency	*@ View of placement too close to hazard.

NARRATIVE	VIDEO 1 V 62
or improper device operation resulting in accidents that can be as severe as if no safety device was installed.	✓✓ Crash scene of guardrail intruding into passenger compartment.

NARRATIVE	VIDEO 1 V 63
So one of the first decisions is should a safety be installed or not.	*@ View of unprotected bridge abutment with -- IS SAFETY DEVICE WARRANTED?

NARRATIVE	VIDEO 1 V 64
One of the first decisions that must be made is whether to install any device at all. Generally if the location will be safer with the device than without it then it should be installed. Safer? Well what is the probability of it being impacted? What is the potential severity of impact?	*@ View of traffic on roadway. <u>IMPACT</u> - PROBABILITY - SEVERITY

NARRATIVE	VIDEO 1 V 65
The probability of a vehicle impacting a fixed object is determined from the design speed, side slopes and traffic volumes. The "Roadside Design Guide" provides extensive guidelines on selecting appropriate clear zone widths. These clear zone widths are determined by comparing the probability of a roadside accident and the associated costs. Wide traversable roadside areas such as this provide adequate area for an errant vehicle to either recover control or come safely to a stop. If such an area meets the clear zone requirements of the "Roadway Design Guide", and is free of obstacles, then it requires no longitudinal barrier.	* Scenes of obstacle free, flat slope, clear zones.

NARRATIVE	VIDEO 1 V 66
Fixed objects placed within the clear zone should either be of breakaway design	*@ Scene of breakaway sign supports.

NARRATIVE	VIDEO 1 V 67
or shielded with a longitudinal barrier	*@ Scene of longitudinal barrier at bridge column.

NARRATIVE	VIDEO 1 V 68
or other appropriate and approved safety device.	*@ Scene of crash cushions.

NARRATIVE	VIDEO 1 V 69
Areas such as this, which have sufficient clear zone should not have barriers installed. The barrier itself is a fixed object and is intended to reduce severity. The installation of practically all types of safety appurtenance will increase accident frequency since they occupy space that could be used for vehicle recovery.	*@ Scene of guardrail installed where not required.

NARRATIVE	VIDEO 1 V 70
Barrier warrants are typically based on the premise that a barrier should be installed if a collision with the barrier is likely to be less severe than a collision with the roadside hazard. Based on subjective analysis, experience, and accident studies, recommended warrants for the use of roadside barriers have been developed by a number of agencies, and are frequently used to determine the need for both roadside and median barriers, and for crash cushions. Considering the severity of vehicles departing an unprotected edge, bridge railings are typically provided for all bridges.	*@ Scene of unprotected bridge abutment.

NARRATIVE	VIDEO 1 V 71
Studies of the relative severity of roadside encroachments on embankments versus impacts with roadside barriers have been used to develop severity warrant. These warrants consider only the severity associated with the embankment itself, and other obstacles on or at the bottom of the embankment must be considered separately. The "Roadside Design Guide" provides recommended barrier warrants for nontraversable and fixed object hazards. These warrants, are applicable to roadside barriers. They may also be used to determine the need for a crash cushion where roadway geometry makes it impossible to shield the hazard using a longitudinal barrier.	*@ Scene of deep drop off into water or of crash cushions.

NARRATIVE	VIDEO 1 V 72
Benefit/Cost Analysis While severity-based warrants call for the installation of a barrier when the consequences of a vehicle contacting the hazard are considered to be more severe than contact with the barrier, this method does not consider the likelihood that a roadside encroachment will occur, and does not consider the total costs of the shielded versus the unshielded conditions. Recent advances in the development of barrier warrants use benefit/cost analysis methodology to compare the costs and benefits of the shielded and unshielded conditions. Barrier costs associated with installation, maintenance, and accident costs are compared to similar costs for the unshielded hazard.	*@ Scene of guardrail accident BENEFIT/COST ANALYSIS

NARRATIVE	VIDEO 1 V 73
Median barriers are used to prevent accidents resulting from median crossings, and severity-based warrants are based on consideration of median width and traffic volume. These two factors determine the probability of a vehicle crossing the median and intruding into the opposing traffic lanes. Warrants often used to determine the need for median barriers are also contained in the "Roadside Design Guide".	*@ (Scenes of different median barriers on split screen.) MEDIAN BARRIERS

NARRATIVE	VIDEO 1 V 74
A wide variety of barriers are available to serve most roadside safety needs, and the designer is faced with selecting the individual barrier that provides the best level of protection, at the lowest overall cost, and with the fewest objectionable characteristics. Selection considerations for individual barrier systems are depended upon the operational characteristics, installation needs and space requirements of each device.	*@ Collage of different median barrier types with imposed. BARRIER SELECTION GUIDELINES

NARRATIVE	VIDEO 1 V 75
The following are site characteristics that should be known prior to device selection. Designers may want to modify these concerns to adequately define consideration which are necessary in their area for proper appurtenance selection.	*@ Collage of different hazards requiring various types of safety appurtenances.

NARRATIVE	VIDEO 1 V 76
Hazard width and height. The width, height and type of hazard being shielded provides information necessary to determine attachment options and transition designs. For example the width of the hazard is a factor in determining the length of need for roadside barriers.	*@ Scene of massive roadside obstacle.
NARRATIVE	**VIDEO 1 V 77**
While other devices require a solid backup structure to operate properly.	*@ Scene of crash barrels requiring solid backup.
NARRATIVE	**VIDEO 1 V 78**
Hazard proximity to traffic. The distances of the hazard from the lane line and to opposing traffic lanes are restrictions on lateral space that will influence proper system selection. There must be sufficient clearance between the device and traffic lane to not adversely affect driving behavior and sufficient deflection distance between the device and obstacle.	*@ Scene of roadside barrier in front of luminaries.

NARRATIVE	VIDEO 1 V 79
Available maintenance space. If maintenance space is restricted there will be an increase in overall system safety and system maintenance costs. Restricted maintenance space exposes maintenance crews to personal safety risks, requires costly traffic controls, and results in traffic congestion during maintenance operations. There are significant differences between different appurtenance systems for both routine and post collision maintenance activities.	* Scene of maintenance crew working on median guardrail.
NARRATIVE	**VIDEO 1 V 80**
Surface conditions and anchoring options. There anchoring options of the different systems vary considerably. It is necessary to know the soil characteristics, type of subbase, the strength of portland cement concrete or asphaltic concrete, deck or no-deck application and cross slopes for proper system selection. Knowledge of the presence and location of drainage features, expansion joints and other surface features should be known.	* Scene of crash cushions on bridge deck.
NARRATIVE	**VIDEO 1 V 81**
Probable impact speed. The probable impact speed is one operational variable that determines the required system capacity. This estimate can often be improved by consulting the local traffic engineer.	* Scene of traffic.

NARRATIVE	VIDEO 1 V 82
Impact frequency. The traffic volume and site geometrics, such as the outside of horizontal curves, can be used to provide an insight into the frequency of impact. For new installations this estimate can be enhanced by the experience at sites with similar ADT, geometric and speed characteristics. Estimates of impact frequency at existing sites can be obtained by inspecting accident history and conversations with the local maintenance crews.	*@ Scene of horizontal curve guardrail with numerous of impact marks.

NARRATIVE	VIDEO 1 V 83
Unidirectional or bidirectional traffic. The selected appurtenance must have the capability of handling impacts probable for the site conditions. The direction of traffic in the vicinity along with other site geometrics will help determine such key system requirements as unidirectional or bidirectional needs, redirection, and gating characteristics.	*@ Scene of narrow median barrier.

NARRATIVE	VIDEO 1 V 84
Many highway agencies have developed policies for the types of barriers to be used for specific situations, and application of these polices frequently results in acceptable levels of roadside safety at reasonable overall costs. However, even when agency policies prescribe the use of certain barrier types, designers need to be aware of the wide range of barrier choices available, and the criteria that may influence their selection. When a situation deviates from the agency's standard conditions, those criteria should be reviewed to confirm that the barrier selected is in fact the best solution for the situation. In many cases the final selection is a trade-off between cost and impact performance. In such cases, a benefit/cost analysis as discussed in the previous section may be a useful approach to determining the "best", or at least the most cost-effective system.	*@ Collage of frequent movement between barrier types.

NARRATIVE	VIDEO 1 V 85
After the decision to install a barrier is made; and the type of barrier is selected, the layout of the barrier installation must be determined. Factors that must be considered include: lateral offset from the pavement edge, terrain effects, flare rate, and length of need. These issues are discussed in some depth in the individual barrier modules, and an introduction is provided here.	* Crew installing barrier. PLACEMENT RECOMMENDATIONS

NARRATIVE	VIDEO 1 V 86
It is desirable to place barriers as far from the edge of the traveled way as conditions permit. Drivers tend to react adversely to objects placed too close to the edge of pavement by slowing unnecessarily or by steering away.	*@ View of roadside barrier with arrow going from lane edge to roadside. LATERAL OFFSET

NARRATIVE	VIDEO 1 V 87
The distance away from the road beyond which roadside features do not cause such a reaction is termed the shy line offset. It is considered desirable to place all roadside features beyond the shy line offset, and to the extent possible, to maintain a uniform minimum offset.	*@ View of roadway with guardrail and line showing shy line offset.

NARRATIVE	VIDEO 1 V 88
However, in the case of long runs of longitudinal barriers, it may not be practical to place the entire length beyond the shy line offset. In such cases, acceptable results can be achieved by gradually tapering it closer to the roadway. In addition to the offset of the barrier, it is important that any changes in offset are accomplished gradually to avoid startling drivers, and to prevent vehicle snagging in the event of impacts in the offset transition area. Recommended shy line offsets are listed in the "Roadside Design Guide".	* Roadside barrier moving closer to pavement edge.

NARRATIVE	VIDEO 1 V 89
Many of the roadside barriers currently in use deflect laterally upon impact, with deflections of 3050 mm or more possible for some barrier systems. A barrier must be placed an appropriate distance in front of a fixed object hazard to prevent snagging by the vehicle during impact.	*@ Scene of guardrail which has deflected into obstacle.

NARRATIVE	VIDEO 1 V 90
Dynamic deflection distances are typically provided as part of the design criteria for individual barrier systems, and these deflection distances are typically stated for 100 km/h, 25 degrees impacts involving full size passenger cars. Where impact conditions are not expected to be as severe, it may be acceptable to reduce the distance between the barrier and the hazard.	*@ Scene of guardrail with graphic arrow between rail and obstacle.

NARRATIVE	VIDEO 1 V 91
In the case of very stiff or rigid barriers, vehicles may roll or tip on impact. This concern is greatest for large trucks and other high-center-of-gravity vehicles which may also climb up the barrier face in addition to rolling. This factor should be considered in determining the position of these barriers, especially where truck traffic is a concern.	✓✓ Crash testing footage of large truck rollover.

NARRATIVE	VIDEO 1 V 92
Of concern in the placement of barriers adjacent to embankments is to guard against the vehicle dropping over the edge and rolling as the barrier deflects. Preventing this requires adequate resistance to post movement through the soil of the embankment. Full scale tests and experience show that a barrier placed at a minimum of 610 mm from the edge of the embankment is generally adequate, and for slopes no steeper than n 2:1, acceptable performance is obtained even for flexible systems such as cable barriers.	*@ Scene of guardrail near embankment with graphic line of 610 mm shown.
NARRATIVE	**VIDEO 1 V 93**
Barriers perform best when impacted by a vehicle with all four wheels on the ground and the suspension components in their normally position. This requires that the surface from the edge of pavement to the barrier be maintained as uniform and level as possible.	*@ Scene of barrier separated from roadway by level terrain. TERRAIN EFFECTS
NARRATIVE	**VIDEO 1 V 94**
Terrain features of special concern include curbs and slopes. Curbs may result in a significant change in bumper height as the vehicle traverses the curb. Placing barriers behind curbs, unless the system is specifically designed and tested in that configuration, such as a curbed bridge railing should be avoided.	✓✓ Crash test with vehicle vaulting on curb.

NARRATIVE	VIDEO 1 V 95
Barrier offsets of 230 mm or less behind the curb are generally not considered to be a concern for vaulting. However, precautions must be taken to ensure the bumper does not underride the rail if full rail height is provided above the curb. This may be accomplished by using a deeper rail section or rub rail, or by setting the rail height relative to the pavement surface in front of the curb.	@ Scene of rub rail.
NARRATIVE	**VIDEO 1 V 96**
Slope changes can result in vehicles impacting higher on the barrier than normal, thus producing vaulting. This is best avoided by limiting slopes in front of barriers to 1:10 or flatter.	*@ Scene of gentle slope in front of barrier.
NARRATIVE	**VIDEO 1 V 97**
A barrier flare is used to adjust the lateral offset. It may be necessary to place a barrier closer or further from the edge of pavement in order to accommodate existing roadway features or to transition to other barriers such as bridge rails.	*@ Scene of barrier moving closer to traveled way. FLARE RATE

NARRATIVE	VIDEO 1 V 98
The flared portion of the barrier can increase the impact angle and thus the impact severity. In addition, impact on the flare may result in higher post-impact departure angles, which can cause greater conflicts with other traffic or roadside features. It is therefore desirable to use flare rates as flat as possible, especially when the flare is within the shy line offset. Suggested maximum flare rates are contained in the "Roadside Design Guide".	@ Scene of proper flare rate.

NARRATIVE	VIDEO 1 V 99
Vehicles typically leave the roadway at flat angles and may travel a considerable distance along the roadside before contacting a hazard or fixed object. For this reason, barriers introduced immediately in front of or just upstream from a roadside hazard may not be totally effective in protecting errant vehicles from impacting the hazard. Determining the required length of need, to ensure that vehicles cannot run behind the barrier to contact the hazard, is an important consideration in barrier design.	@ Scene of long run of guardrail. LENGTH OF NEED

NARRATIVE	VIDEO 1 V 100
Most highway agencies have developed length of need criteria for various roadside features that consider both traffic speed and roadside geometry. a detailed procedure for calculating the required starting point, or "point of need" for a barrier is provided in the "Roadside Design Guide". Factors affecting the point of need include the lateral extent of the hazard to be protected, the required stopping distance for a vehicle to avoid striking the object, and the geometric layout of the barrier including its lateral offset, flare rate, and location that the flare is introduced.	@ Scene of guardrail at wide obstacle on roadside.

NARRATIVE	VIDEO 1 V 101
The Federal Highway Administration has issued a memorandum that requires states to make specific upgrades to obsolete roadside safety hardware and "poor practices" along the National Highway System. The safety upgrades listed in the memorandum are intended to assist states in developing their design and maintenance policies, especially along interstate routes of the National Highway System. Including	* Closure music and mountainous traffic scenes.

NARRATIVE	VIDEO 1 V 102
Replacement of blunt end terminals with crashworthy terminals;	*@ Blunt end terminal.

NARRATIVE	VIDEO 1 V 103
Discontinue the use of turned-down ends on the approach end of roadside or median weak post W-beam barriers on high-speed, high-volume roads;	*@ Turned down terminal.

NARRATIVE	VIDEO 1 V 104
Discontinue the use of Breakaway Cable Terminals on the approach end of barriers on high-speed, high-volume roads;	*@ BCT terminal.

NARRATIVE	VIDEO 1 V 105
Replacement of damaged substandard terminals with crashworthy terminals; and	*@ Damaged terminal.

NARRATIVE	VIDEO 1 V 106
Any remaining unconnected bridge-approach guardrail should be connected by an acceptable transition design within three years.	*@ Unconnected bridge approach transition.

NARRATIVE	VIDEO 1 V 107
By properly designing, installing, and maintaining our highway safety appurtenance we can increase roadway safety while being cost effective. This instructional video introduced the concepts of the general requirements for the selection and placement of safety appurtenances. Further information on the specific requirements of each selected device are required to ensure proper operation.	*@ Scenes of good guardrail, crash cushion said barriers, etc. (or collage of good safety devices--CREDITS.)

VIDEO STORYBOARD - 2
(Modules C, D, E and F)
W-BEAM AND THRIE-BEAM TRAFFIC BARRIERS

Left column is narration, - right column describes video scene.
Captions for video footage are in caps and are boxed.

Material in parenthesis ( ) is comment or explanation.
Material in brackets [ ] identifies existing video footage.

✓ - indicates footage to be obtained from existing presentation quality video.
✓✓ - additional footage to be obtained from existing videos.
* - indicates footage to be obtained.
@ - indicates possible use of existing photographs.

NARRATIVE	VIDEO 2 V 1
	* View of modern 2-lane highway with W-beam roadside barrier - moderate traffic passing by - mix of cars and trucks. W-BEAM AND THRIE-BEAM TRAFFIC BARRIERS (Include all opening credits, etc., during this scene.)

NARRATIVE	VIDEO 2 V 2
Modern highways are designed to ensure that drivers can stay on the roadway.	* Overhead view of busy 4-lane roadway - good pavement markings, clear roadside, good geometry, etc.

NARRATIVE	VIDEO 2 V 3
However, even on modern roadways designed to the highest geometric standards, vehicles occasionally leave the roadway for a number of reasons.	* Overhead view of modern 2-lane (from bridge or embankment) with moderate traffic, high speed.

NARRATIVE	VIDEO 2 V 4
Roadsides of modern highways are kept clear of hazards so that drivers that inadvertently leave the roadway can come to a controlled stop, or return safety to the roadway.	* Overhead view of 4-lane with good roadside and median clearzones -- no hazards.

NARRATIVE	VIDEO 2 V 5
Although the first choice is always to remove potential hazards, or to make them breakaway, traffic barriers can be used to shield roadside hazards that cannot be treated otherwise.	* 2 views of strong-post W-beam guardrail shielding roadside hazard -- fixed object and embankment.

NARRATIVE	VIDEO 2 V 6
This video discusses W-beam and thrie-beam traffic barriers. These families of roadside and median barriers are the most widely used barriers in the U.S., and are used in one form or another in virtually all 50 states.	1 - view each of *@ Strong-post W-beam *@ Weak-post W-beam (From New York) *@ Thrie-beam

NARRATIVE	VIDEO 2 V 7
For more than 30 years, W-beam guardrails have been one of the most common types of guardrails used on our nation's roadways.	✓ W-beam guardrail view - Badlands, South Dakota back group. [FHWA thrie beam video.]

NARRATIVE	VIDEO 2 V 8
Strong-post W-beam guardrail are versatile systems that can be used in many types of situations. Every state uses some type of W-beam guardrail system in its state standards.	✓ Roadside W-beam with terminal - traffic passing by. [FHWA thrie beam video.]

NARRATIVE	VIDEO 2 V 9
The typical strong-post guardrail consists of a 10 or 12 gauge W-beam, W 150 x 13 steel posts and blockouts	✓ Backside view - steel post G-4 W-beam barrier showing post, blockout, W-beam. [FHWA thrie beam video.]

NARRATIVE	VIDEO 2 V 10
or 200 mm x 150 mm wood posts and blockouts,	✓ Change to wood post G-4 W-beam similar view. [FHWA thrie beam video.]

NARRATIVE	VIDEO 2 V 11
and an appropriate terminal.	✓ BCT terminal on G-4 W-beam. [FHWA thrie beam video.]

NARRATIVE	VIDEO 2 V 12
Both versions are also available as a median barrier, which adds a second W-beam and blockout on the back side of the post.	* Overhead view of strong-post W-beam median barrier.
NARRATIVE	**VIDEO 2 V 13**
The blockouts are critical to the excellent performance of this barrier. They prevent car wheels from snagging on the strong-posts, and help maintain rail height during impact.	*@ Closeup view of backside of G-4 W-beam showing blockout..
NARRATIVE	**VIDEO 2 V 14**

Strong-post W-beam barriers have been shown to be effective for small cars	✓ Honda Civic crash test on G-4 steel post W-beam. [FHWA thrie beam video.]
NARRATIVE	**VIDEO 2** **V 15**
mid-size cars	✓ Midsize car impact on G-4 steel post W-beam (this scene uses a yellow Chev. Malibu). [FHWA thrie beam video.]
NARRATIVE	**VIDEO 2** **V 16**
and large cars.	✓ Large car impact on G-4 steel post W-beam (this scene uses a white Plymouth). [FHWA thrie beam video.]
NARRATIVE	**VIDEO 2** **V 17**

It has been recognized for some time that these barriers are not nearly as effective for severe impacts involving larger vehicles such as trucks or this school bus. The center of gravity of these larger vehicles is much higher than the 685 mm rail height, and instead of being redirected, they simply roll over onto it.	✓ School bus crash test on G-4 steel post W-beam. Bus rolls over onto barrier. [FHWA thrie beam video.] 20,000 LBS - 60 MPH - 15°
NARRATIVE	**VIDEO 2** **V 18**
Recent tests have also shown that these barriers must not be able to prevent rollovers for severe impacts involving full-size pickup trucks. These vehicles are now used as the standard crash test vehicle, replacing full-size sedans in barrier strength tests.	✓✓ Crash test of G-4 W-beam guardrail with full-size pickup. (Use recent FHWA crash test footage). (Add Appropriate Caption) WEIGHT - SPEED - ANGLE
NARRATIVE	**VIDEO 2** **V 19**
In spite of their limited ability to redirect and contain larger vehicles without overturning, these barriers continue to enjoy wide spread use as a standard service level barrier on American highways.	* W-beam MB-4 median barrier view on busy roadway.

NARRATIVE	VIDEO 2 V 20
These strong post W-beam barriers offer a number of advantages compared to other barriers. The strong posts limit rail deflections to about 900 mm or less for passenger car impacts. This means these barriers can be used to protect fixed objects or embankments located less than 1 meter beyond the edge of the shoulder.	*@ View of W-beam guardrail with large fixed object (sign bridge, etc.) located about 1 meter behind rail.

NARRATIVE	VIDEO 2 V 21
This limited deflection also makes these barriers acceptable for use in medians as narrow as about 2 meters. However, even this limited impact deflection	* View of MB-4 W-beam median barrier in narrow median.

NARRATIVE	VIDEO 2 V 22
makes these W-beam barriers more forgiving than rigid barriers, especially for severe impacts.	*@ View of concrete median barrier in narrow median.

NARRATIVE	VIDEO 2 V 23
While strong-post W-beam barriers are not inexpensive, their costs are more reasonable than some of the higher-performance barriers available.	✓ View of modified thrie-beam roadside barrier. [FHWA thrie beam video.]
NARRATIVE	**VIDEO 2 V 24**
Typical costs for strong-post W-beam roadside barriers typically average about $40 per meter, depending upon local cost variations and the type of post used.	* X-section drawing of W-beam G-4 roadside barrier. [A good drawing is used several times in the FHWA thrie beam video.] $40/M
NARRATIVE	**VIDEO 2 V 25**

The extra rail and blockout ups the cost of typical median barrier to about $55 per meter.	*@ X-section drawing of W-beam MB-4 median barrier. $55/M
NARRATIVE	**VIDEO 2** **V 26**
Depending on the length of barrier run, terminals add from a few dollars to several dollars per meter. The least expensive terminals are only about $500 each, but	*@ View of G-4 W-beam roadside barrier showing backslope buried terminal. $500
NARRATIVE	**VIDEO 2** **V 27**
more expensive terminals costing several times more may be the best choice for some situations.	*@ View of CAT or similar proprietary terminal on W-beam roadside barrier. COST (depends on terminal)

NARRATIVE	VIDEO 2 V 28
Another considerable advantage of strong-post W-beam barriers is their ability to resist moderate impacts with only minor aesthetic damage that does not require a maintenance response.	*@ View of G-4 W-beam guardrail with minor impact damage that does not require maintenance.

NARRATIVE	VIDEO 2 V 29
More sever impacts may require repairs, but even in such cases, the barrier remains serviceable, and it can contain and redirect vehicles until repairs are made.	*@ View of G-4 W-beam guardrail with more sever impact damage - needs maintenance, but still serviceable.

NARRATIVE	VIDEO 2 V 30
Only the most severe impacts, at very high speeds or involving large vehicles, result in damage so serious that the barrier is no longer able to contain and redirect subsequent vehicle impacts.	*@ View of G-4 W-beam guardrail with very severe impact damage (use scene of crash-tested G-4 from near the end of the Mac Ray video if necessary).

NARRATIVE	VIDEO 2 V 31
While most states use some version of the strong-post W-beam barriers, a number of states use a simpler, lower cost W-beam barrier.	* Backside view of weak post W-beam G-2 on roadside with traffic passing by. (from New York)
NARRATIVE	**VIDEO 2 V 32**
This system differs from the strong post system in that it uses weaker posts and no blockouts.	* Close-up view of weak post W-beam G-2 showing post and rail from backside. (from New York)
NARRATIVE	**VIDEO 2 V 33**
Like the strong-post system, this system uses a 12 ga W-beam and either S75 x 8.5 steel posts	*@ Another view (backside) of G-2 weak post W-beam showing steel posts. (from New York)
NARRATIVE	**VIDEO 2 V 34**

NARRATIVE	VIDEO 2
or 140 mm diameter wood posts.	*@ Backside view of G-2 W-beam on wood posts (if not readily available, substitute an isometric drawing). (from New York)
NARRATIVE	**VIDEO 2** **V 35**
Like strong-post W-beam barriers, these weak post barriers can also be used in medians by adding a second W-beam to the back of the posts.	* View of MB-2 weak post W-beam median barrier showing view on both sides. ([from New York)
NARRATIVE	**VIDEO 2** **V 36**
To ensure that the full strength of the weak post is developed in virtually any soil condition, the steel post includes a 200 mm x 600 mm soil resistance plate	*@ Close-up view of steel S75 x 8.5 post out of ground showing soil plate. (from New York)

NARRATIVE	VIDEO 2 V 37
so the post yields uniformly at ground level.	*@ Close-up of steel post yielded at ground level by impact. (from New York)

NARRATIVE	VIDEO 2 V 38
Because these relatively weak posts are intended to yield or break away when impacted, these barriers do not require a blockout.	*@ More close-up views of yielded posted. (from New York)

NARRATIVE	VIDEO 2 V 39
However, on impact, the W-beam rail must separate from the post without being pulled down to the ground. The 8 mm diameter bolt connecting the rail to the post is designed to snap on impact, allowing the rail to remain at full height. In snow areas, a 14 mm shelf bolt helps support the added snow load.	* Close-up view of G-2 steel post W-beam, focusing first on rail connection bolt, then on shelf bolt. (from New York)

NARRATIVE	VIDEO 2 V 40
Like their strong-post counter parts, weak post barriers have been shown to perform well for a range on vehicle impacts from small cars	✓✓ Crash test involving small car on G-2 weak-post barrier (FHWA should have footage in files from NCHRP 289 or other test). IMPACT CONDITIONS
NARRATIVE	**VIDEO 2 V 41**
up to full size passenger cars	✓✓ Crash test involving full-size car on G-2 W-beam. (Obtain from FHWA files.)
NARRATIVE	**VIDEO 2 V 42**

Like strong-post W-beams, recent tests indicate weak-post W-beam barriers may not be able to contain and redirect full-size pickup trucks or larger vehicles for severe impact conditions representing test Level 3 in NCHRP Report 350.	✓✓ Full size pickup truck crash test on G-2 W-beam guardrail resulting in penetration. (From recent FHWA crash tests.)
NARRATIVE	**VIDEO 2** **V 43**
Because they use lighter weight posts and no blockouts, these weak-post barriers are lower in cost than strong-post W-beam barriers. Typical cost of weak-post W-beam guardrail is about $25 per meter installed by contractors, less than 2/3 the cost of strong-post W-beam.	@ X-section drawing of G-2 W-beam guardrail, both steel post and wood post versions. $25/M
NARRATIVE	**VIDEO 2** **V 44**
The comparable median barrier version costs about $33.50 per meter, also well below the cost of the comparable strong- post W-beam.	@ X-section drawing of MB-2 W-beam median barrier - steel post only. $33.50/M

NARRATIVE	VIDEO 2 V 45
As would be expected, the weaker posts mean these barriers experience greater deflections -- as much as 2.4 meters for high speed passenger car impacts, more than 2 1/2 times the standard strong post deflection. However, using closer post spacings can reduce the standard deflection to only about 1.5 meters. These larger deflections mean fixed objects must be kept further from the edge of the shoulder.	*@ One or more views of W-beam G-2 barrier protecting fixed objects on the roadside. One view should show standard spacing, one view showing reduced post spacing. (from New York)

NARRATIVE	VIDEO 2 V 46
Weak post W-beam barriers are also more susceptible to accident damage -- even after moderate impacts, posts are knocked down and separated from the rail. Such damage must be repaired quickly to restore the structural integrity of the system.	*@ Moderate impact damage on G-2 W-beam with 2 or 3 post knocked down, minor sag in rail. (from New York)

NARRATIVE	VIDEO 2 V 47
More severe hits by passenger cars result in the barrier being essentially unserviceable until repairs are made.	*@ Serious damage to G-2 W-beam -- several post down, rail sagging to ground level. (from New York)

NARRATIVE	VIDEO 2 V 48
In spite of its larger deflections and greater susceptibility to impact damage, the lower cost and simplicity of weak post W-beam makes it an attractive alternative for moderate volume highways. If severe impacts by large vehicles are unlikely, and maintenance forces can provide timely repairs to the infrequent impacts likely on such roads, it can enhance roadside safety where the higher cost of strong-post W-beam is prohibitive.	* Overall view of G-2 weak post W-beam on moderate volume rural 2-lane roadway with moderate passenger car traffic. ([from New York)

NARRATIVE	VIDEO 2 V 49
Ever-increasing traffic volumes, including more larger vehicles such as school buses and trucks, sometimes indicates the need for barriers with greater capacity than is provided by W-beam barriers.	✓ Close-up views of newspaper headlines and photos involving bus and truck crashes. [FHWA thrie beam video]

NARRATIVE	VIDEO 2 V 50
A need for higher performance guardrails that would safely redirect both typical passenger cars as well as trucks and buses was the motivation behind the development of thrie-beam guardrails.	✓ View of thrie-beam guardrail on both sides of the road with truck passing by. [FHWA thrie beam video]

NARRATIVE	VIDEO 2 V 51
Thrie-beam is similar to W-beam, but there are several differences.	✓ Cross-section of thrie-beam rail. [FHWA thrie beam video]
NARRATIVE	**VIDEO 2 V 52**
A W-beam has 2 corrugations, the thrie-beam has 3. W-beam is 312 mm deep, but thrie-beam is 506 mm deep because of the extra corrugation.	✓ Introduce cross-section of W-beam rail to the right of thrie-beam. [FHWA thrie beam video] THRIE-BEAM W-BEAM
NARRATIVE	**VIDEO 2 V 53**

The standard thrie-beam barrier, called the G-9 in the AASHTO Roadside Design Guide, was developed to improve the performance of the strong post W-beam guardrail. The top of the thrie-beam is 810 mm above ground, compared to 685 mm for W-beam.	✓ Cross-section views of thrie-beam and W-beam side-by-side. Shadow the depth of the thrie-beam across the W-beam. [FHWA thrie beam video]
NARRATIVE	**VIDEO 2** **V 54**
The greater height of the thrie-beam was expected to make this system more effective than the W-beam in collisions with larger vehicles.	✓ G-9 barrier in place with section of rail removed, showing cross section of actual barrier with rail, blockout, post. [FHWA thrie beam video]
NARRATIVE	**VIDEO 2** **V 55**
As would be expected, this barrier performs well in passenger car impacts, as seen in this test. It is also expected that it will safely contain and redirect severe impacts by pickup trucks.	✓ Large car crash test on G-9 thrie-beam guardrail. [FHWA thrie beam video] 4500 LBS - 60 MPH - 25°
NARRATIVE	**VIDEO 2** **V 56**

Unfortunately, the G-9 guardrail performed little better than the strong-post W-beam guardrail in this school bus collision. The bus still rolled over.	✓ School bus test on G-9 thrie-beam barrier - rollover. [FHWA thrie beam video] 20,000 LBS - 60 MPH - 15°
NARRATIVE	**VIDEO 2** **V 57**
The modified thrie-beam was developed specifically to provide better performance in large vehicle impacts, while also performing well for passenger vehicles.	✓ Start with X-section drawing of modified thrie-beam guardrail. [FHWA thrie beam video]
NARRATIVE	**VIDEO 2** **V 58**
The primary difference between the modified and the standard thrie-beam is the shape of the blockout. The purpose of guardrail blockouts is to keep the vehicle wheels from contacting the guardrail posts.	Introduce X-section drawing of G-9 thrie- beam on right. Arrow identifies modified blockout. MODIFIED STANDARD

NARRATIVE	VIDEO 2 V 59
The modified thrie-beam blockout is much deeper than the typical blockout and it has a unique notch at the bottom.	✓ Close-up view of modified thrie-beam guardrail - focus in on notch. [FHWA thrie beam video]
NARRATIVE	**VIDEO 2 V 60**
During an impact, the notch closes up causing the thrie-beam to remain nearly vertical as the post rotates in the soil.	✓ Backside view during crash test on Modified thrie-beam - highlight notch in close-up view. [FHWA thrie beam video]
NARRATIVE	**VIDEO 2 V 61**

NARRATIVE	VIDEO 2
The modified thrie-beam performs well in large and small car tests and	✓ Backside view of modified thrie-beam crash test. [FHWA thrie beam video] 1800 LBS - 60 MPH - 15°

NARRATIVE	VIDEO 2 V 62
provides drastically improved performance with larger vehicles like this school bus,	✓ Backside view of school bus crash test on modified thrie-beam. [FHWA thrie beam video] 20,000 LBS - 55 MPH - 15°

NARRATIVE	VIDEO 2 V 63
As well as this 32,000 pound coach bus. Even after this severe test, this bus	✓ Backside view of coach bus test on modified thrie-beam. [FHWA thrie beam video] 32,000 LBS - 60 MPH - 15°

NARRATIVE	VIDEO 2 V 64
was still operable.	✓ Coach bus driving away after test. [FHWA thrie beam video]

NARRATIVE	VIDEO 2 V 65
While these tests show that the modified thrie-beam can contain and redirect a much wider range of vehicles than either the standard thrie-beam or W-beam guardrail systems,	✓ Overhead view, 3 crash tests on modified thrie-beam side-by-side. [FHWA thrie beam video]

NARRATIVE	VIDEO 2 V 66
improved performance alone is not adequate justification for spending more money on roadside hardware. Highway agencies typically have more needs than resources, and the added cost of a high performance barriers must often be balanced against reduced maintenance costs.	✓ Backside view of modified thrie-beam barrier in mountain setting. [FHWA thrie beam video]

NARRATIVE	VIDEO 2 V 67
In several demonstration projects, the cost of the modified thrie-beam averaged about $112 per meter, only slightly higher than the $108 per meter average cost of the standard thrie-beam.	✓ Another view of modified thrie-beam barrier with coach bus passing by. [FHWA thrie beam video]

NARRATIVE	VIDEO 2 V 68
For locations where there's a good chance of frequent collisions involving large vehicles, the reduction in maintenance costs may more than offset the higher initial cost, which is more than 2 times that of standard strong-post W-beam barrier.	✓ Modified thrie-beam with tractor-trailer passing by. [FHWA thrie beam video]

NARRATIVE	VIDEO 2 V 69
In this crash test, a bus collision severely damaged 156 ft. of W-beam barrier, which would cost about $1900 to rebuild.	✓ Severely damaged G-4 guardrail after crash test. [FHWA thrie beam video]

NARRATIVE	VIDEO 2 V 70
However, a similar impact on modified thrie-beam damaged only 50 ft. of guardrail, and cost less than $1200 to repair, a savings of more than $700 compared to W-beam.	✓ Crash test damage to modified thrie-beam guardrail. [FHWA thrie beam video]

NARRATIVE	VIDEO 2 V 71
Many of the posts were not seriously damaged, and could probably be reused, resulting in even greater savings.	✓ Close-up of post displaced in crash test of modified thrie-beam. [FHWA thrie beam video]

NARRATIVE	VIDEO 2 V 72
The modified thrie-beam guardrail can also tolerate most nuisance hits without any adverse effects on the system's performance	✓ Close-up view of very minor accident damage to rail of modified thrie-beam. [FHWA thrie beam video]

NARRATIVE	VIDEO 2 V 73
Even severe hits involving small cars result in minor damage to the blockout tabs and displacement of the posts -- these repairs can be made by maintenance crews at very low cost.	✓ Close-up view of bent block-tab of modified thrie-beam guardrail after small car crash test. [FHWA thrie beam video]

NARRATIVE	VIDEO 2 V 74
Use of safe, crash-tested terminals with these barriers is essential to anchor the rail elements so they can resist midstream impacts, and to protect occupants of vehicles that impact near the end of a barrier.	* Select a good view of a W-beam barrier with a terminal -- (avoid BCT).

NARRATIVE	VIDEO 2 V 75
Use of untested designs, or improper installation of approved designs, can lead to catastrophic results, such as rollover or spearing of the vehicle.	✓ Accident photo - beam penetration in front of car. [FHWA thrie beam video]

NARRATIVE	VIDEO 2 V 76
A wide range of terminals are available for W-beam and thrie-beam barriers. For weak-post W-beam, and in some cases for strong-posts as well, a simple, low cost turn-down anchors the rail and eliminates the risk of spearing. However,	*@ Weak-post G-2 W-beam guardrail with turned down terminal flared outside the clearzone.

NARRATIVE	VIDEO 2 V 77
high speed impacts, especially involving small cars, may result in violent rollovers. If turned-down terminals are used, they must be flared away from the roadside and terminated beyond the clearzone to reduce this risk.	✓✓ Crash test on turned-down terminal resulting in rollover.

NARRATIVE	VIDEO 2 V 78
A variety of terminals are available for strong-post W-beam. Terminating the rail at a concrete barrier buried in the backslope is both inexpensive and effective.	*@ Footage of strong-post W-beam terminal in backslope.

NARRATIVE	VIDEO 2 V 79
Other non-propriety terminals such as this modified eccentric loader terminal -- MELT--	*@ Footage of MELT on strong-post W-beam.

NARRATIVE	VIDEO 2 V 80
and a variety of proprietary terminals are available to address a wide range of roadside situations.	*@ Select any of the proprietary terminals on strong-post - W-beam -- CAT may be good choice.

NARRATIVE	VIDEO 2 V 81
However, the Breakaway Cable Terminal -- BCT--, which was a common W-beam terminal for years, should no longer be installed because it does not perform well for crashes involving small cars.	✓✓ Small car crash test on BCT resulting in spearing.

NARRATIVE	VIDEO 2 V 82
Most of the W-beam terminals can also be used effectively with thrie-beam by first transitioning to W-beam. Some terminals such as this SENTRE can be attached directly to the thrie-beam.	✓ View of SENTRE terminal on thrie-beam. [FHWA thrie beam video]
NARRATIVE	**VIDEO 2 V 83**
Another important feature of these barriers is the ease in transitioning between systems and to other roadside features. Transitions may be needed when it is necessary to reduce barrier deflection, such as this transition from weak to strong post W-beam. Decreasing post spacings on the weak-post system gradually increases barrier stiffness so the vehicle does not pocket or snag on the first strong post.	* Overall view of transition from weak to strong-post W-beam sharing reduced post spacings. (New York footage)
NARRATIVE	**VIDEO 2 V 84**

A simple transition beam element provides a simple, effective transition from W-beam to thrie-beam.	✓ Side view of W-beam to thrie-beam transition - focus in on transition. [FHWA thrie beam video]
NARRATIVE	**VIDEO 2** **V 85**
Transitions to rigid objects such as bridge rail or a rigid concrete barrier are more complex because the stiffness of the guardrail must be gradually increased to match the rigid barrier. In addition, the geometry of the rail must prevent the vehicle from snagging on the end of the bridge. Because of their wide traffic faces and their ability to control vehicle deflections, W-beam and thrie-beam rails form the basis of most such transitions now in common use.	* Overall view of one or two scenes showing transition from W-beam guardrail to bridge rail. Focus in on reduced post spacing and traffic face to show snag protection.
NARRATIVE	**VIDEO 2** **V 86**
The design and construction of terminals and transitions is a complex subject that is covered at more length in over videos developed for this course.	* View of a W-beam to concrete safety shape barrier transition on similar transition.

NARRATIVE	VIDEO 2 V 87
W-beam and thrie-beam barriers are versatile systems that can be used for a wide range of highway situations	* Roadside W-beam guardrail with terminal, car passing by.

NARRATIVE	VIDEO 2 V 88
ranging from low volume rural highways, where the low cost of weak-post W-beam barriers offers cost-effective roadside protection,	* Rural 2-lane highway with weak-post W-beam barrier -- choose modern highway, good standards, moderate traffic. (New York)

NARRATIVE	VIDEO 2 V 89
to higher volume expressways, where the added strength and reduced maintenance requirements of strong-post W-beam make it an ideal choice.	* Strong-post W-beam barrier on 4-lane expressway, substantial car traffic passing by.

NARRATIVE	VIDEO 2 V 90
For roadways carrying high volumes of buses and large trucks, the higher performance of modified thrie-beam barrier, coupled with its ability to withstand impacts with little or no repair, may make the added investment for this barrier worth while.	* Modified thrie-beam barrier with coach buses or large trucks passing by.

NARRATIVE	VIDEO 2 V 91
Coupled with simple transitions and a wide choice of effective terminals, these barriers can provide a high level of roadside safety for most highway situations.	* Closing view of modified thrie-beam barrier with traffic. CREDITS

VIDEO STORYBOARD - 3
(Modules G and H)
CABLE BARRIER SYSTEMS
AND
AESTHETIC & LOWER SERVICE LEVEL BARRIER SYSTEMS

Left column is narration - right column is video scene.
Captions for video footage are in caps and are boxed.

Material in parentheses ( ) is comment or explanation.
Material in brackets [ ] identifies existing video footage.
✓ - indicated footage to be obtained from existing presentation quality video.
✓✓ - indicated footage to be obtained from existing crash test videos.
* - indicates new footage to be obtained.
@ - indicates possible use of existing photographs.

NARRATIVE	VIDEO 3 V 1

	* View of highway with cable guardrail - select a scenic view with steel or wood posts. CABLE GUARDRAILS LOW SERVICE LEVEL GUARDRAILS AESTHETIC BARRIERS (Add any necessary opening credits, etc., during this scene)
NARRATIVE	**VIDEO 3** **V 2**
Modern highways are build with a consideration for the safety of vehicles that leave the pavement. Design principles call for a clear recovery zone alongside the pavement to allow errant vehicles to come to a safe stop or regain control and return to the pavement.	* Modern freeway showing wide median and clear zone with moderate traffic - shot from an overpass.
NARRATIVE	**VIDEO 3** **V 3**

Fixed objects should be redesigned	* Breakaway or slip-base support - shot so traffic shows in background.
NARRATIVE	**VIDEO 3** **V 4**
or removed from the clear zone	* Sign support located on back slope.
NARRATIVE	**VIDEO 3** **V 5**
When this cannot be done, traffic barriers may be used to shield hazards from impact.	* Traffic barrier shielding roadside hazard.

NARRATIVE	VIDEO 3 V 6
Numerous types of traffic barriers are available which are suitable for a wide range of highway facilities ranging from modern freeways carrying high volume of large trucks	** High-volume freeway with heavy trucks - show concrete median barrier or heavy post median barrier against moving traffic backdrop.

NARRATIVE	VIDEO 3 V 7
to lower volume rural highways	* Hi-standard rural 2-lane with heavy post W-beam.

NARRATIVE	VIDEO 3 V 8
to scenic park highways.	* Cable guardrail in scenic setting.

NARRATIVE	VIDEO 3 V 9
This video examines cable guardrails which are suitable for a wide range of highway conditions,	*@ Cable guardrail - closeup - still

NARRATIVE	VIDEO 3 V 10
low service level guardrails	* Close-up still of a 2-cable guardrail.

NARRATIVE	VIDEO 3 V 11
and aesthetic barriers.	* Close-up still of steel-backed timber guardrail.

NARRATIVE	VIDEO 3 V 12
Cable guardrails are one of the oldest types of traffic barrier in use today.	✓ G-1 cable - view from back side. [FHWA Cable Guardrail video.]
NARRATIVE	**VIDEO 3 V 13**
Some of the first guardrail used in the U.S. used cables mounted on wood posts.	✓ 3 - cable on wood post. [FHWA Cable Guardrail video.]
NARRATIVE	**VIDEO 3 V 14**

Wood posts began to be replaced by concrete	✓ Wood post - 3 cable - closeup. [FHWA Cable Guardrail video.]
NARRATIVE	**VIDEO 3** **V 15**
and cold rolled steel sections. These in turn	✓ View of G-1 with post. [FHWA Cable Guardrail video.]
NARRATIVE	**VIDEO 3** **V 16**
were replaced by hot-rolled steel I-sections.	✓ View of G-1 with post. [FHWA Cable Guardrail video.]
NARRATIVE	**VIDEO 3** **V 17**

Recent research has improved the performance and reduced the costs of cable guardrail. There are a variety of reasons for using Cable Guardrail rather than other guardrail systems.	✓ View of turned down cable guardrail anchor scanning in to run of G-1 cable. [FHWA Cable Guardrail video.]
NARRATIVE	**VIDEO 3** **V 18**
They are easy to install and cost about 1/3 as much as strong post w-beam guardrail.	✓ Worker driving steel post on G-1 cable guardrail. [FHWA Cable Guardrail video.]
NARRATIVE	**VIDEO 3** **V 19**
The large deflection characteristics of cable guardrail can be advantageous where there is adequate space behind the guardrail. Large deflections cause the impact to be softer, and therefore less harmful to occupants.	✓✓ Crash test #46 on cable guardrail.

NARRATIVE	VIDEO 3 V 20
Cable systems can be more aesthetically pleasing than w-beam or thrie-beam	✓ View of Mt. Rushmore with W-beam obstructing. [FHWA Aesthetic and Cable Guardrail video.]
NARRATIVE	**VIDEO 3 V 21**
since they do not obstruct the view.	✓ Cable guardrail with river behind. [FHWA Aesthetic and Cable Guardrail video.]
NARRATIVE	**VIDEO 3 V 22**

The slender cross section is also an advantage in snowy regions of the country. W-beam guardrail can act like snowfences, causing a large pile of snow and ice to accumulate along the barrier.	✓ View of W-beam guardrail with snow pile in front. [FHWA Aesthetic and Cable Guardrail video.]
NARRATIVE	**VIDEO 3** **V 23**
Cable systems offer very little resistance so most windblown and plowed snow will pass through the barrier without accumulating.	✓ View of G-1 cable with lake behind. [FHWA Aesthetic and Cable Guardrail video.]
NARRATIVE	**VIDEO 3** **V 24**

Low installation and maintenance costs reduced impact severity open profile and resistance to snow drifting	*@ Cable guardrail view with captions appearing sequentially. • Low Cost • Reduced Severity • Aesthetics • Snow Drift Resistant
NARRATIVE	**VIDEO 3** **V 25**
are characteristics that can make cable guardrail an attractive alternative in many situations.	Hold scene of video G24.
NARRATIVE	**VIDEO 3** **V 26**
Although there are a variety of cable guardrail systems in use today,	✓ Old strong post cable guardrail. [FHWA Cable Guardrail video.]

NARRATIVE	VIDEO 3 V 27
they all share a number of similar characteristics.	✓ G-1 cable guardrail. [FHWA Cable Guardrail video.]

NARRATIVE	VIDEO 3 V 28
The AASHTO Roadside Design Guide designates the most common cable system as the G1 guardrail.	✓ G-1 cable on corten posts [FHWA Cable Guardrail video.]

NARRATIVE	VIDEO 3 V 29

It was developed by the New York State Department of Transportation in the 1960s.	✓✓ Crash test of cable guardrail.
NARRATIVE	**VIDEO 3** **V 30**
When correctly used in appropriate sites the G-1 guardrail has proven to be a very forgiving barrier system	✓ View of crash test site after the test showing car and barrier. [FHWA Cable Guardrail video.]
NARRATIVE	**VIDEO 3** **V 31**
The G-1 consists of 3 cables	✓ View of G-1 zooming to close-up of cables. [FHWA Cable Guardrail video.]

NARRATIVE	VIDEO 3 V 32
J-bolts for attaching the cables to (pause)	✓ Close-up of J-bolts. [FHWA Cable Guardrail video.]

NARRATIVE	VIDEO 3 V 33
the S 3 x 5.7 steel posts,	✓ G-1 - close-up of post. [FHWA Cable Guardrail video.]

NARRATIVE	VIDEO 3 V 34

a concrete anchor and hardware for attaching the cables to the anchor block.	✓ Turndown anchor, scanning back to G-1 guardrail. [FHWA Cable Guardrail video.]
NARRATIVE	**VIDEO 3** **V 35**
In recent years, several variations of the basic G-1 guardrail have been developed that reduce the cost and enhance the performance of cable guardrail.	✓ G-1 guardrail with corten posts [FHWA Cable Guardrail video.]
NARRATIVE	**VIDEO 3** **V 36**
The state of South Dakota has developed a cable guardrail that is similar to the G-1 system except that a smaller, less expensive post is used. The flanged	✓ View of South Dakota cable system back side view. [FHWA Cable Guardrail video.]
NARRATIVE	**VIDEO 3** **V 37**

channel post used in the South Dakota system weights only 4 pounds per foot, 40% lighter than the standard S 3 x 5.7 post.	View of South Dakota cable - post close-up (zoom back and introduce view of S 3 x 5.7 post on right). FLANGED CHANNEL POST S 3 X 5.7 POST
NARRATIVE	**VIDEO 3** **V 38**
A flanged channel post and soil plate made of rerolled rail steel would cost about 1/2 as much as the standard G-1 post and soil plate. The South Dakota cable system cost about $1 per linear foot less than the G-1 guardrail.	✓ Hold side-by-side views of South Dakota & G-1 . [FHWA Cable Guardrail video.]
NARRATIVE	**VIDEO 3** **V 39**
In this test of the South Dakota system, the cables wrap around the front corner of the small car when it hits the barrier. The cables slip off the posts ahead of the collision and the posts either snap off or bend over as they're struck by the car. The cables redirect the car parallel to the barrier. It comes to a controlled stop after braking.	✓✓ Crash test of South Dakota guardrail with small car. [FHWA Cable Guardrail video.] (add captions) 2000 - 60 MPH - 20°

NARRATIVE	VIDEO 3 V 40
In another test, this large car travels about 12 feet past the barrier line before being redirected parallel to the guardrail. The performance of this system is similar to the G-1 cable guardrail system.	✓✓ Crash test of South Dakota with large car. [FHWA Cable Guardrail video.] (add caption) 4600 - 60 MPH - 25°

NARRATIVE	VIDEO 3 V 41
The location of the guardrail on slopes is an important design consideration.	✓ Still shot (large car and cable guardrail on slope). [FHWA Cable Guardrail video.]

NARRATIVE	VIDEO 3 V 42

If the guardrail is located on the slope but too close to the edge of the pavement, the cables may contact the vehicle below the front bumper, allowing the car to ride over the cables and penetrate the barrier.	✓✓ Crash test of cable guardrail on slope - large car. [FHWA Cable Guardrail video.] (add caption) 4615 - 60 MPH - 25°
NARRATIVE	**VIDEO 3** **V 43**
If the guardrail is placed at least 18 feet away from the pavement, the vehicle has more time to stabilize before it strikes the cable.	✓ Still shot (large car at cable guardrail on slope). [FHWA Cable Guardrail video.]
NARRATIVE	**VIDEO 3** **V 44**

In this test, the vehicle's suspension had returned to its normal position when the car struck the cables.	✓✓ Crash test on slope. (add caption) 4615 - 60 MPH - 25°
NARRATIVE	**VIDEO 3** **V 45**
The cables wrapped around the car just above the front bumper, allowing the guardrail to redirect the vehicle.	✓✓ Close-up view of same crash test.
NARRATIVE	**VIDEO 3** **V 46**
Steel is not the only material that can be used for posts. Cable guardrails with wood posts have been used by some states for decades.	* View of 3 cable guardrail on wood posts.

NARRATIVE	VIDEO 3 V 47
Recent tests evaluated a modification of the Minnesota state standard design that used 5 1/2 inch diameter post with a 1 1/2 inch hole drilled through it 5 1/2 inches below the ground.	✓ Isometric drawing of Minnesota cable guardrail zoom in on hole. [FHWA Cable Guardrail video.]
NARRATIVE	**VIDEO 3 V 48**
This hole helps to weaken the post in the longitudinal direction, ensuring that it breaks away when hit head on.	✓ Close-up - Minnesota cable guardrail post and cables. [FHWA Cable Guardrail video.]
NARRATIVE	**VIDEO 3 V 49**

The post spacing used in 12 feet - 6 inches rather than the 16 feet that is typical for the G-1 system.	✓ Wider view of Minnesota cable guardrail. [FHWA Cable Guardrail video.]
NARRATIVE	**VIDEO 3** **V 50**
This small car was successfully redirected without exceeding the allowable occupant response values.	✓✓ Crash test - small car. (add caption) 2000 LBS - 60 MPH - 25°
NARRATIVE	**VIDEO 3** **V 51**
This system was also strong enough to contain and redirect this large passenger sedan. The maximum barrier deflections were comparable to the G-1 system in these 2 tests.	✓✓ Crash test - large car. (add caption) 4600 LBS - 60 MPH - 25°

NARRATIVE	VIDEO 3 V 52
As with all types of longitudinal barriers, designing effective end-treatments for cable barriers has been a difficult problem.	✓ Minnesota cable guardrail terminal. [FHWA Cable Guardrail video.]
NARRATIVE	**VIDEO 3 V 53**
Vehicles tend to stay in contact with cable guardrails longer than other barrier systems. This is generally desirable, but as posts are weakened to soften the impact, the cable anchor takes more and more of the impact load. If the anchor is too strong, it may not break away if a vehicle strikes it. When an impact occurs near the end of the guardrail, the vehicle can wedge under the sloping anchor cables, causing the vehicle to roll over.	✓✓ Small car crash test - end on view or [FHWA Cable Guardrail video]. (add caption) 1800 LBS - 60 MPH - 20°
NARRATIVE	**VIDEO 3 V 54**

When this same problem was recognized for both the standard G1 design and the flanged channel post design, the state of New York set out to develop an alternative anchor.	✓✓Small car crash test (end on view with rollover). (add caption) 1800 LBS - 60 MPH - 15°
NARRATIVE	**VIDEO 3** **V 55**
The result is a modified terminal consisting of a concrete anchor, and attachment bracket, and a slip-base post. The cables pull free from the slots in the bracket during an impact.	* Close-up view (New York cable anchor).
NARRATIVE	**VIDEO 3** **V 56**
The whole anchorage assembly is flared back from the roadway to reduce the chance of an direct collision.	* Overall view - New York Cable Anchor.

NARRATIVE	VIDEO 3 V 57
In this test series, a small car ran over the anchorage in both directions without being tripped.	✓ Crash test-anchor-departure. [FHWA Cable Guardrail video.] (add caption) 1800 LBS - 60 MPH - 15°
NARRATIVE	**VIDEO 3 V 58**
The performance of the improved anchor was much better than the original design.	✓ Crash test-anchor-approach. [FHWA Cable Guardrail video.] (add caption) 1800 LBS - 60 MPH - 15°
NARRATIVE	**VIDEO 3 V 59**

The improved terminal was also strong enough to provide adequate anchor strength in this large car test. Although these collisions are still severe, this anchor design appears to be the only cable terminal that does not cause small cars to rollover when the impact occurs near the end of the guardrail.	✓ Crash test - large car-middle of G-1 cable. [FHWA Cable Guardrail video.] (add caption) 4850 LBS - 57 MPH - 25°
NARRATIVE	**VIDEO 3** **V 60**
When used at appropriate sites, cable guardrails have significant advantages over other types of guardrails. Low cost, easy maintenance and installation procedures, resistance to snow drifting and aesthetic appeal make cable guardrail an attractive	✓ View of 3-cable guardrail. (Note - This narrative and video is moved from its location in the present video to improve the flow of the story.) [FHWA Cable Guardrail video.]
NARRATIVE	**VIDEO 3** **V 61**

option for many transportation agencies.	Continue above footage.
NARRATIVE	**VIDEO 3** V 62
While cable systems are often used on major highways, their reduced cost makes them especially appropriate for low volume, low speed rural roadways. However, even the inexpensive G-1 guardrail shown here may not be cost-effective on some low-volume rural roadways.	* G-1 - corten posts - on rural roadway.
NARRATIVE	**VIDEO 3** V 63
Several new less costly guardrails were developed in a recent HCHRP project for application on roadways that might not warrant more expensive systems. These new barriers were tested using different speeds, angles, and vehicles than the optional lower service level test recommended in NCHRP Report 230. (This narrative is modified from original text to include all low-service level barriers)	✓ Close-up of G-1 cables and post. [FHWA Cable Guardrail video.]

NARRATIVE	VIDEO 3 V 64
These systems used either 2 cables with the higher cable mounted 27 inches above the ground, or standard w-beams as the rail elements. (Narrative modified.)	✓ 2 cable guardrail on wood post. [FHWA Cable Guardrail video.]
NARRATIVE	**VIDEO 3 V 65**
Three different types of posts were used in the crash tests - the S 3 x 5.7 post, the flanged channel post, and the round wood post.	✓ Stills (side-by-side of 3 cable system showing 3 post types). [FHWA Cable Guardrail video.] S 3 x 5.7 FLANGED CHANNEL 5 1/2" WOOD
NARRATIVE	**VIDEO 3 V 66**

NARRATIVE	VIDEO 3
All 3 cable systems performed satisfactorily, deflecting between 6 and 8 feet behind the barrier line.	✓✓ Crash test zooming to still shot with caption. S 3 x 5.7
NARRATIVE	**VIDEO 3** **V 67**
The flanged channel post tended to fracture easily and some were thrown back into the roadway. The cable in the flanged channel post system rode over the top of the vehicle, so its performance was considered acceptable though not desirable.	✓ Crash test zooming to still shot. [FHWA Cable Guardrail video.] Side-by-side still shots with captions S 3 x 5.7 FLANGED CHANNEL
NARRATIVE	**VIDEO 3** **V 68**
Information on these low-service level barriers and warrants for their use were developed in NCHRP Project 22-5A, covering both the cable and w-beam systems.	✓✓ Crash test - 2 cable wood post - zoom to 3 side-by-side stills with captions. S 3 x 5.7 FLANGED CHANNEL 5 1/2" WOOD

NARRATIVE	VIDEO 3 V 69
These systems should provide a cost-effective guardrail on lower-service level highways that would not otherwise be protected.	✓ Low service level highway - river in background. [FHWA Aesthetic Barrier video.]
NARRATIVE	**VIDEO 3 V 70**
	✓ Another view of low-service level highway. [FHWA Aesthetic Barrier video.]
NARRATIVE	**VIDEO 3 V 71**

Roadways in national and state parks, national forests, and historic communities serve an important function because they make the scenic beauty of these places accessible to all people.	✓ Scenic view of G-1 cable on corten posts - river or mountain background. [FHWA Aesthetic Barrier video.]
NARRATIVE	**VIDEO 3** **V 72**
It's easy to forget that automobile accidents can happen as easily inside the park boundaries as outside. Safety should be as important on a scenic roadway as it is on any other transportation facility.	✓ Scenic roadway with rail fence. [FHWA Aesthetic Barrier video.]
NARRATIVE	**VIDEO 3** **V 73**

Of course, not all roads requiring aesthetically pleasing roadside hardware	✓ 2 lane road - no guardrail. [FHWA Aesthetic Barrier video.]
NARRATIVE	**VIDEO 3** **V 74**
are rustic pathways through the wilderness.	✓ 2 lane road with timber guardrail. [FHWA Aesthetic Barrier video.]
NARRATIVE	**VIDEO 3** **V 75**
Some roadways are interstate parkways that provide transportation access to facilities as well as the beauty of the surroundings. Roadside safety hardware on these roads must balance the need for protecting motorists with consideration for the scenic beauty of the surrounding area.	✓ Parkway with stone bridge overpasses. [FHWA Aesthetic Barrier video.]

NARRATIVE	VIDEO 3 V 76
Some roadways that must coordinate aesthetic beauty with their transportation function are located in congested urban	✓ George Washington parkway with heavy traffic. [FHWA Aesthetic Barrier video.]

NARRATIVE	VIDEO 3 V 77
areas like this parkway near Washington, D. C.	✓ Close-up of heavy traffic. [FHWA Aesthetic Barrier video.]

NARRATIVE	VIDEO 3 V 78

Among standard barrier systems, cable guardrails may be an excellent choice for such areas, because their open profile does not interfere with the scenic beauty of the roadside.	* G-1 cable on corten posts with scenic background.
NARRATIVE	**VIDEO 3** **V 79**
The visual appeal of the standard cable systems can be enhanced in such settings through the use of weathering steel or wood posts.	* 3 cable - wood post guardrail - try to select a scene with some visual appeal.
NARRATIVE	**VIDEO 3** **V 80**

Recently, three new roadside barriers were developed that combine safety with aesthetics. These safety appurtenances can be used on roadways where preserving the scenic beauty or historical character of an area is important. (Text modified to eliminate Br. Rails)	✓ Focus in on stills of 3 guardrail hold 3 guardrail stills (do <u>not</u> use Br. Rails. Go to diagonal arrangement of 3 guardrail stills.) [FHWA Aesthetic Barrier video.]
NARRATIVE	**VIDEO 3** **V 81**
One of the earliest attempts to build guardrails that blend into the surroundings, was the timber guardrail. typically, these rails were too low and fractured too easily to be effective roadside appurtenances.	✓ Old timber guardrail. [FHWA Aesthetic Barrier video.]
NARRATIVE	**VIDEO 3** **V 82**

Because timber does not have good strength properties in an impact, the vehicles often penetrated the unreinforced timber guardrail.	✓ Crash test - old timber guardrail. [FHWA Aesthetic Barrier video.] (caption) 4600 LBS - 60 MPH - 20°
NARRATIVE	**VIDEO 3** **V 83**
A strip of steel plate was added behind the rail to reinforce the wooden beam and provide continuity from rail to rail.	✓ Close-up - back side of rail and post. [FHWA Aesthetic Barrier video.]
NARRATIVE	**VIDEO 3** **V 84**
This modification, along with raising the height of the wood rail to 25 1/4 inches, make the	✓ Backside view of steel-backed timber guardrail. [FHWA Aesthetic Barrier video.]

NARRATIVE	VIDEO 3 V 85
steel backed timber guardrail a more effective safety treatment.	✓ Crash test . [FHWA Aesthetic Barrier video.] (caption) 4600 LBS - 60 MPH - 20°
NARRATIVE	**VIDEO 3 V 86**
Walls made of native stone have also been used for many years as guardrails along scenic roadways.	✓ Old stone wall along roadside. [FHWA Aesthetic Barrier video.]
NARRATIVE	**VIDEO 3 V 87**

Like unreinforced timer, typical stone masonry walls do not have good strength characteristics in impacts. To improve the performance of this type of system, a precast or cast-in-place concrete cove can be used to provide the strength necessary in an impact. The concrete cove is covered with natural stone masonry.	✓ Stone Masonry Guardwall. [FHWA Aesthetic Barrier video.]
NARRATIVE	**VIDEO 3** **V 88**
This system is strong enough to contain and redirect a large passenger car even if the impact is quite severe. The rough surface of the stone digs into the sheet metal of the car causing the car to slow down rapidly.	✓ Crash test - large car on Stone Masonry Guardwall. [FHWA Aesthetic Barrier video.] (add caption) 4600 LBS - 60 MPH - 20°
NARRATIVE	**VIDEO 3** **V 89**
Although this guardwall looks like natural stone,	✓ Precast simulated stone guardwall. [FHWA Aesthetic Barrier video.]

NARRATIVE	VIDEO 3 V 90
it is actually made of concrete ship lapped units.	✓ End view of precast simulated stone guardwall. [FHWA Aesthetic Barrier video.]
NARRATIVE	**VIDEO 3 V 91**
The precast panels are interlocked and can be rotated to accommodate horizontal curvature.	✓ Front view - precast simulated stone guardwall. [FHWA Aesthetic Barrier video.] (add highlight to one section)
NARRATIVE	**VIDEO 3 V 92**

This design was strong enough to contain and redirect this 4600 pound passenger car.	✓ Crash test -precast simulated stone guardwall. [FHWA Aesthetic Barrier video.] (add caption) 4600 LBS - 60 MPH - 20°
NARRATIVE	**VIDEO 3** **V 93**
These new guardrails combine safety and visual appeal, but they do so at a price. All of these systems are expensive because they use special techniques to enhance the aesthetics of normally utilitarian traffic barriers. The steel backed timber guardrail is the least expensive system costing more than twice as much as a typical strong post guardrail.	✓ Steel backed timber guardrail. [FHWA Aesthetic Barrier video.]
NARRATIVE	**VIDEO 3** **V 94**
The precast and masonry stone guardwalls cost 6 to 12 times more than a typical strong post guardrail.	✓ Stone masonry guardwall with deer in foreground. [FHWA Aesthetic Barrier video.]

NARRATIVE	VIDEO 3 V 95
Where costs are a major consideration, use of cable guardrails on wood or weathering steel posts may be an acceptable compromise--these barriers generally cost less than typical strong post guardrail, even when more visually attractive posts are used.	✓ Cable guardrail - wood or corten steel posts. [FHWA Aesthetic Barrier video.]
NARRATIVE	**VIDEO 3 V 96**
Safety and aesthetics need not be conflicting goals on scenic roads and highways. These guardrails can be used on park roads and scenic parkways as well as on roadways in communities where more typical roadside barriers would compromise the historical or aesthetic character of the surroundings.	✓ Sunset view with guardrail. [FHWA Aesthetic Barrier video.]
NARRATIVE	**VIDEO 3 V 97**

NARRATIVE	VIDEO 3 V 98
Ensuring that scenic areas remain aesthetically pleasing is of course very important. Providing safe roads for those who enjoy the view can be a compatible priority.	✓ Continue sunset view of guardrail.

Add credits, etc.

VIDEO STORYBOARD - 4
(Modules I, J, M and N)
COMMERCIALLY AVAILABLE TERMINALS, COMMERCIALLY AVAILABLE BARRIER SYSTEMS, CRASH CUSHIONS: CONNECTICUT SYSTEMS AND SAND BARRIERS AND COMMERCIAL CRASH CUSHIONS

Left column is narration, - right column describes video scene.
Captions for video footage are in caps and are boxed.

Material in parenthesis ( ) is comment or explanation.
Material in brackets [ ] identifies existing video footage.
✓ - indicates footage to be obtained from existing presentation quality video.
✓✓ - additional footage to be obtained from existing videos.
* - indicates footage to be obtained.
@ - indicates possible use of existing photographs.

NARRATIVE - COMMERCIALLY AVAILABLE TERMINALS	VIDEO 4 V 1
Longitudinal barriers have the benefit of redirecting vehicles away from potential hazards. An untreated end of a roadside barrier is particularly hazardous since the barrier rail can spear the impacting vehicle and penetrate the passenger compartment.	✓ @ Picture(s) and video of rail penetrating the vehicle. COMMERCIALLY AVAILABLE TERMINALS (Include all opening credits, etc.)
NARRATIVE	VIDEO 4 V 2

Commercially available terminals include ADIEM II, BRAKEMASTER, CAT, ET-2000, GREAT, SENTRE, Slotted Rail Guardrail Terminal, and TREND.	(@) Each system will be shown.
NARRATIVE	**VIDEO 4** **V 3**
The Advanced Dynamic Impact Extension Module II or ADIEM II is manufactured by SYRO, Inc., a subsidiary of Trinity Industries, Inc. The ADIEM II is a energy absorbing end treatment for temporary and permanent locations.	(✓✓) or (✓) Show videos of crash testing. ADVANCED DYNAMIC IMPACT EXTENSION MODULE II OR ADIEM II
NARRATIVE	**VIDEO 4** **V 4**
Ten light weight modules are placed on a sloping anchored concrete base. The modules crush under the force of an impacting vehicle, bringing the vehicle to a controlled stop. The sloped base provides a track for the module placement and enables the system to sustain side hits.	✓ Video of the system as a terminal.
NARRATIVE	**VIDEO 4** **V 5**

The BRAKEMASTER is manufactured by Energy Absorption Systems, Inc. The system consists of a framework of W-beam steel guardrail panels and a special braking mechanism which brings an impacting vehicle to a safe and complete stop.	(✓✓) or (✓) Show video of crash testing. BRAKEMASTER
NARRATIVE	**VIDEO 4** **V 6**
	✓ Short video showing the BRAKEMASTER.
NARRATIVE	**VIDEO 4** **V 7**
The Crash-Cushion/Attenuating Terminal or CAT is manufactured by SYRO, Inc., a subsidiary of Trinity Industries, Inc. The CAT is a bi-directional or uni-directional energy absorbing end treatment..	(✓✓) or (✓) Crash testing video. CRASH-CUSHION/ ATTENUATING TERMINAL OR CAT

NARRATIVE	VIDEO 4 V 8
	✓ Short video showing the CAT as Terminal.

NARRATIVE	VIDEO 4 V 9
The ET-2000 Guardrail Extruder Terminal is manufactured by SYRO, Inc., a subsidiary of Trinity Industries, Inc. ET-2000 is a energy absorbing end treatment that dissipates the energy by the flattening of the guardrail as it feeds through the extruder.	(✓✓) or (✓) Show crash test video. ET - 2000

NARRATIVE	VIDEO 4 V 10
	✓ Short video showing the ET-2000

NARRATIVE	VIDEO 4 V 11
The G-R-E-A-T is manufactured by Energy Absorption Systems, Inc. The G-R-E-A-T consists of crushable HEX-Foam II cartridges surrounded by a framework of triple corrugated steel guardrail.	(✓✓) or (✓) Footage of crash testing. G-R-E-A-T
NARRATIVE	**VIDEO 4 V 12**
	✓ Short Video showing the G-R-E-A-T as a terminal.
NARRATIVE	**VIDEO 4 V 13**

The SENTRE is manufactured by Energy Absorption Systems, Inc. The SENTRE is made up of fender panels, support posts with slipbases, and sand-filled contours that help dissipate the impact energy and a redirecting cable which guides the impacting vehicle away from the end of the barrier.	(✓✓) or (✓) Video of crash testing. SENTRE
NARRATIVE	**VIDEO 4 V 14**
	(✓) Short video showin the SENTRE or @.
NARRATIVE	**VIDEO 4 V 15**
The Slotted Rail Terminal or SRT is manufactured by SYRO, Inc., a subsidiary of Trinity Industries, Inc. The SRT is a cable-anchored system similar to the BCT. Longitudinal slots have been introduced to reduce the dynamic buckling during impact.	✓✓ Crash test video. SLOTTED RAIL TERMINAL OR SRT

NARRATIVE	VIDEO 4 V 16
	✓ OR @ Footage showing the SRT.

NARRATIVE	VIDEO 4 V 17
The TREND is manufactured by Energy Absorption Systems, Inc. The system is similar to the SENTRE, but it has a build in transition for a connection directly to a rigid object.	(✓✓) or (✓) Crash test video. TREND

NARRATIVE	VIDEO 4 V 18

	✓ Show footage of TREND.
NARRATIVE - COMMERCIALLY AVAILABLE BARRIER SYSTEMS	**VIDEO 4** **V 19**
The majority of the barrier systems used today can be classified as non-proprietary. There are also several proprietary patented systems. The general application of these systems are as temporary or work zone applications.	* Views of different types of barriers. COMMERCIALLY AVAILABLE BARRIER SYSTEMS
NARRATIVE	**VIDEO 4** **V 20**
Commercially available barrier systems include the Barrier Gate, Quickchange Movable Barrier, J-J Hooks Portable Concrete Barrier, Triton Barrier, and Guardian Safety Barrier System.	(@) or (✓) Show each of the systems.

NARRATIVE	VIDEO 4 V 21
The Barrier Gate is manufactured by Energy Absorption Systems, Inc. It opens to provide a 7.9 m or 12.2 m wide opening controlled access through a barrier. It has been crash tested as a test level 3 devise.	(✓✓) or (✓) Show videos of crash testing. BARRIER GATE
NARRATIVE	**VIDEO 4 V 22**
The gate assemblies lock together with a pin and hook type connection. The movement of the gate assemblies is directed by tracks anchored to a concrete foundation. The system can be operated either electrically or manually.	(✓) or (*) or (@) Shown from existing promotional video.
NARRATIVE	**VIDEO 4 V 23**

The Quickchange Moveable Barrier is manufactured by Barrier Systems, Inc. The design of the concrete barrier allows it to be used as a temporary or permanent barrier that can be quickly moved by a transfer barrier in a lane change operation.	(✓✓) or (✓) Show the crash test of the system. QUICKCHANGE MOVEABLE BARRIER
NARRATIVE	**VIDEO 4** **V 24**
The vertical faces of the barrier segments are tapered back to allow for rotation between the segments. The hinge assembles are attached to continuous steel through-rods that are embedded into the concrete segments to assure a strong, positive connecting between segments. The transfer vehicle can move the barrier laterally from 1.25 m to 5.5 m at a speed of 8 km/h.	✓ Show footage of the system in operation.
NARRATIVE	**VIDEO 4** **V 25**
The J-J Hooks Portable Concrete Barrier is manufactured by Easi-Set Industries.	(✓✓) or (✓) Video of crash testing of the system. J-J HOOKS PORTABLE CONCRETE BARRIER

NARRATIVE	VIDEO 4 V 26
Both ends are symmetrical and identical with integral steel connections which are continuous through the barrier. The J-J Hooks connections eliminate concerns associated with systems that require separate elements to connect adjacent precast units.	✓ Show the system in operation.
NARRATIVE	**VIDEO 4 V 27**
The Triton Barrier System is manufactured by Energy Absorption Systems, Inc. The barrier has been crash tested under the test level 2 criteria.	(✓✓) or (✓) Show the crash testing of the system. TRITON BARRIER SYSTEM
NARRATIVE	**VIDEO 4 V 28**
Each section is constructed of a polyethylene plastic shell designed to accept water as a ballast. A steel cable along the top of the section resists the tensile forces generated during impacts. The Triton Barrier acts as its own end terminal when the front section is left empty of water.	✓ Show video of the system in operation.

NARRATIVE	VIDEO 4 V 29
The Guardian Safety Barrier System is manufactured by Safety Barrier System. With the addition of the 350 HIGHWAY KIT, the system was crash tested in accordance with the NCHRP 350 Test Level 2 requirements. The GUARDIAN will need to be shielded with a conventional work zone crash cushion or flared an appropriate distance from the approaching traffic.	(✓✓) or (✓) Show video of crash testing. GUARDIAN SAFETY BARRIER SYSTEM
NARRATIVE	**VIDEO 4 V 30**
The Guardian Safety Barrier is constructed of a polyethylene plastic designed to accept water ballast. The function of the 350 HIGHWAY KIT is to provide reinforcement to the outer surface of the barrier during impact and to tie the barriers together and distribute the load over several barriers.	✓ Video showing the system in operation.
NARRATIVE - CRASH CUSHIONS: CONNECTICUT SYSTEMS AND SAND BARRIERS	**VIDEO 4 V 31**

Crash Cushions are designed to dissipate the kinetic energy of an impacting vehicle. Some crash cushions, when impacted on their sides, will capture the errant vehicle while others will redirect it. When a crash cushion is designed to dissipate the energy through the deformation of the system, the systems are called compression crash cushions. When the energy is dissipated by the movement of material such as sand within the system, the systems are called inertial crash cushions. The use of compression crash cushions will require some form of a back up wall. The inertial crash cushions do not require a backup wall.	(*) or (✓) Views of the Connecticut System and Sand Barrels. CRASH CUSHIONS: CONNECTICUT SYSTEM AND SAND BARRELS
NARRATIVE	**VIDEO 4** **V 32**
The Connecticut Systems are classified as compression crash cushions. The three types of Connecticut Systems are: - The Connecticut Impact Attenuation System (CIAS) - The Generalized Connecticut Impact Attenuation System (GCIAS) - The Narrow Connecticut Impact Attenuation System (NCIAS) - The Sand Barrel Systems are classified as inertial crash cushions. The Sand Barrel Systems available are: - Energite III - Fitch Sand Barrel	(@) Picture or video showing each system.
NARRATIVE	**VIDEO 4** **V 33**

The Connecticut Impact Attenuation System (CIAS) is manufactured by Roadway Safety Service, Inc.	(✓✓) or (✓) Crash test video. THE CONNECTICUT IMPACT ATTENUATION SYSTEM (CIAS)
NARRATIVE	**VIDEO 4** **V 34**
The system is composed of 14 steel cylinders. It has a maximum width of 3.7 m and 7.3 m long. The cylinders are bolted together, placed on a concrete pad, and has an appropriate backup wall.	(✓) Video showing the system.
NARRATIVE	**VIDEO 4** **V 35**
The Generalized Connecticut Impact Attenuation System performs the same as the CIAS. In this system the barrel configuration will be different for each location, depending on the length and width available. The manufacture should be contacted for system configuration.	(@) or (✓) Showing the system. THE GENERALIZED CONNECTICUT IMPACT ATTENUATION SYSTEM (GCIAS)
NARRATIVE	**VIDEO 4** **V 36**

The Narrow Connecticut Impact Attenuation System will operate the same as the CIAS and GCIAS. The only difference between this system and the CIAS and GCIAS is that it is a single roll of steel cylinders, thus its name, Narrow Connecticut Impact Attenuation System.	(@) or (✓) Video showing the system. NARROW CONNECTICUT IMPACT ATTENUATION SYSTEM (NCIAS)
NARRATIVE	**VIDEO 4** **V 37**
Sand Filled Plastic Barrels Systems are arrays of plastic barrels filled with varying amounts of sand. These systems don't have any redirectional capabilities. It is important that the sand employed in this type of crash cushion be clean and relative free of moisture.	(✓✓) Video showing crash testing. SAND FILLED PLASTIC BARREL SYSTEMS • ENERGITE ™ III • FITCH SAND BARREL SYSTEMS
NARRATIVE	**VIDEO 4** **V 38**
The Energite III is manufactured by Energy Absorption Systems, Inc. It consists of an array of sand filled plastic barrels with several different cones to create barrels with varying weights of sand. The manufacture should be contracted for the appropriate array for a specific design speed.	(@) or (✓) Video showing the system. ENERGITE ™ III
NARRATIVE	**VIDEO 4** **V 39**

The Fitch Sand Barrel Systems is manufactured by Roadway Safety Service, Inc. The Fitch system consist of two identical cylinder halves and four sliding zip strip connectors to make the barrels. Sand support structures can be placed in the barrels to create varying weights of sand. The manufacture should be contacted for the appropriate array for a specific design speed.	(@) or (✓) Video showing the system. FITCH SAND BARREL SYSTEMS
NARRATIVE - COMMERCIAL CRASH CUSHIONS	**VIDEO 4 V 40**
Besides the Connecticut Systems, the following are Commercial Compression Crash Cushions: - ADVANCED DYNAMIC IMPACT EXTENSION MODULE II (ADIEM II) - C-A-T SYSTEM - G-R-E-A-T SYSTEM - G-R-E-A-T CZ SYSTEM - HI-DRO CELL CLUSTER - HI-DRO SANDWICH SYSTEM - HEX-FOAM SANDWICH SYSTEM - LMA LOW MAINTENANCE ATTENUATOR - ALPHA 1000 TMA - HEX-FOAM TMA - TRUCK MOUNTED CRASH CUSHION (TMCC)	(✓) or (@) Video showing each of the systems. COMMERCIAL COMPRESSION CRASH CUSHIONS
NARRATIVE	**VIDEO 4 V 41**

The Advanced Dynamic Impact Extension Module II or ADIEM II is manufactured by SYRO, Inc., a subsidiary of Trinity Industries, Inc. The ADIEM II is a energy-absorbing crash cushion for temporary and permanent locations	(✓✓) or (✓) Show videos of crash testing. ADVANCED DYNAMIC IMPACT EXTENSION MODULE II OR ADIEM II
NARRATIVE	**VIDEO 4** **V 42**
	✓ Video of the system as a crash cushion.
NARRATIVE	**VIDEO 4** **V 43**
The Crash-Cushion/Attenuating Terminal or CAT is manufactured by SYRO, Inc., a subsidiary of Trinity Industries. The CAT is a bi-directional or uni-directional energy absorbing crash cushion.	(✓✓) or (✓) Crash testing video. CRASH-CUSHION/ ATTENUATING TERMINAL OR CAT
NARRATIVE	**VIDEO 4** **V 44**

	✓ Short video showing the CAT as crash cushion.
NARRATIVE	**VIDEO 4** **V 45**
The G-R-E-A-T is manufactured by Energy Absorption System, Inc. The G-R-E-A-T consists of crushable HEX-Foam II cartridge surrounded by a framework of triple corrugated steel guardrail.	(✓✓) or (✓) Footage of crash testing. G-R-E-A-T
NARRATIVE	**VIDEO 4** **V 46**
	✓ Short video showing the G-R-E-A-T as a crash cushion.

NARRATIVE	VIDEO 4 V 47
The G-R-E-A-T CZ System is manufactured by Energy Absorption Systems, Inc. The system is similar to the G-R-E-A-T System but is designed for temporary placement in construction zones.	(✓✓) or (✓) Video showing the crash testing of the system. G-R-E-A-T CZ SYSTEM

NARRATIVE	VIDEO 4 V 48
This system does differ from the G-R-E-A-T in that it doesn't require a backup wall. The backup wall is built into the system. The G-R-E-A-T CZ can be installed on a concrete pad, concrete surface, or a minimum of 80 mm thick asphaltic surface.	✓ Video showing the system installed. or @ Pictures showing the system installed.

NARRATIVE	VIDEO 4 V 49
The HI-DRO Cell Cluster System is manufactured by Energy Absorption Systems, Inc. The system is designed for areas where space is limited and traffic speed do not exceed 72 km/hr. During an impact, the cells compress and the enclosed water is forced out through the orifices in the insert. The orifices regulate the rate of water expulsion, causing pressure to build within each cell. This establishes a resistance which absorbs and dissipates the impact energy, bringing the vehicle to a controlled, safe stop.	(✓✓) or (✓) Crash test of the system. HI-DRO CELL CLUSTER SYSTEM

NARRATIVE	VIDEO 4 V 50
The water filled polyvinyl tubes are bolted together in a cluster and wrapped with a flexible "safety belt". A backup wall and concrete pad is required for its installation. The manufacturer should be contacted for the cluster design for a specific site.	✓ Video showing installation.
NARRATIVE	VIDEO 4 V 51
The HEX-FOAM Sandwich System is manufactured by Energy Absorption Systems, Inc. The system consists of a series of crashable HEX-FOAM cartridges placed between light weight tubular steel diaphragms and surrounded by telescoping fender panels. When hit head-on, the cartridges are crushed, stopping the vehicle gently. Hit at an angel, the vehicle is redirected.	(✓✓) or (✓) Showing the crash testing of the system. HEX-FOAM SANDWICH SYSTEM
NARRATIVE	VIDEO 4 V 52

The HEX-FOAM Sandwich System is available in standard widths from 914 mm to 2388 mm. The installation of the system requires a footing and a backup wall.	(✓) or (@) Video showing the system.
NARRATIVE	**VIDEO 4** **V 53**
The LMA (Low Maintenance Attenuator) System is manufactured by Energy Absorption Systems, Inc. The system has low maintenance costs due to its reusable components and its ability to be placed back into service quickly and easily.	(✓✓) or (✓) Video of crash testing. LMA SYSTEM (LOW MAINTENANCE ATTENUATOR)
NARRATIVE	**VIDEO 4** **V 54**
The system consists of specially formulated elastomeric cylinder surrounded by a framework of triple corrugated steel diaphragms and guardrails. When impacted head-on, the elastometric cylinders compress, absorbing energy of the impact. The system requires a concrete footing and a backup wall.	(✓) or (@) Video showing the system.
NARRATIVE	**VIDEO 4** **V 55**

The ALPHA 1000 TMA is manufactured by Energy Absorption Systems, Inc. The basic components of the system is an unique configuration of aluminum cells. With its columnar design the crushable aluminum cartridge takes the brunt of the impact and uniformly dissipates the impact energy. The system mounted to a truck provides protection for maintenance crews, highway construction workers, and errant motorists.	(✓✓) or (✓) Video showing crash testing and system in operation. ALPHA 1000 TMA
NARRATIVE	**VIDEO 4** **V 56**
The HEX-FOAM TMA is manufactured by Energy Absorption Systems, Inc. The system is made up of a matrix of hexagonal shaped honeycomb cells filled with polyurethane. When impacted, the walls of one honeycomb layer shear into the walls of the adjoining layer as well as into the foam. This unit also mounts to a truck and provides portable protection for maintenance crews, highway construction workers, and errant motorist.	(✓✓) or (✓) Crash testing of the system and the system in operation. HEX-FOAM TMA
NARRATIVE	**VIDEO 4** **V 57**

The Dragnet Vehicle Arresting Barrier is manufactured by Roadway Safety Service, Inc. The system uses a chain link fence or fibre arresting net to span the roadway, a cable to hook the fence to, canisters of steel alloy type, and a series of pins in the canisters which acts as a shock absorber. The manufacturer should be contacted for the design details for a specific application.

(✓✓) or (✓) Video showing crash testing and system installed.

THE DRAGNET VEHICLE ARRESTING BARRIER

VIDEO STORYBOARD - 5
(Modules K and L)
BRIDGE RAILS

Left column is narration, - right column describes video scene.
Captions for video footage are in caps and are boxed.

Material in parenthesis ( ) is comment or explanation.
Material in brackets [ ] identifies existing video footage.
✓ - indicates footage to be obtained from existing presentation quality video.
✓✓ - additional footage to be obtained from existing videos.
* - indicates footage to be obtained.
@ - indicates possible use of existing photographs.

NARRATIVE - BRIDGE RAILS	VIDEO 5 V 1
A bridge railing is a longitudinal structure installed to prevent an errant vehicle from running off the edge of a bridge or culvert. Summary accident statistics indicate that there were 480 fatalities and approximately 6,000 injuries resulting from an estimated 16,000 accidents with bridges during 1992. The results of a study published in 1983 stated, that based on length above, bridges were approximately six times more hazardous than the average highway section.	BRIDGE RAILS (Opening credits with bridge in background.)
NARRATIVE	**VIDEO 5 V 2**
As with longitudinal barriers, bridge railings are designed to protect occupants of impacting vehicles and of other vehicles near the collision. While the intended function is the same there are vast differences between longitudinal barriers and bridge rails that need to be addressed in bridge rail design.	* View of stretch of guardrail with bridge rail upstream.

NARRATIVE	VIDEO 5 V 3
Bridge rails are usually designed to have virtually no deflection upon impact. They are normally constructed of a metal and concrete post and railing system, a concrete safety shape or a combination of metal and concrete.	* Movement between views or a collage of different rail types.

NARRATIVE	VIDEO 5 V 4
The concern for deflection is because bridge railings have no room for vehicle encroachment beyond the bridge edge. Vehicle occupants, and often persons and property on roadways and areas underneath the bridge, achieve greater safety by remaining on the bridge.	* View along outer edge of bridge showing traffic, sheer dropoff or houses beneath bridge.

NARRATIVE	VIDEO 5 V 5
Most bridge rails are an integral part of the bridge structure. They are physically connected to the bridge deck and, in many cases, the lower portion of the railing is part of the bridge structure concrete casting.	@ Close up view of old concrete railing base.

NARRATIVE	VIDEO 5 V 6
The dead weight of the barrier system is often a concern for bridge railings. Older structures are frequently posted with load limits that can be sensitive to the additional weight of the barrier itself.	@ Old bridge.

NARRATIVE	VIDEO 5 V 7
Since bridges span obstacles to movement, they often have provisions for pedestrians, in addition to vehicular traffic. When a bridge serves pedestrians and/or cyclists, then a barrier to shield them from vehicular traffic may be required. The result is a traffic barrier between vehicular traffic and pedestrian/ bicycle traffic and a pedestrian or bicycle barrier placed near the edge of the bridge.	@ Old bridge with sidewalks but no barrier separation.

NARRATIVE	VIDEO 5 V 8
The available clearance from the edge of the traveled way often places a restriction on the types of bridge railing that can be installed.	@ Old narrow bridge.

NARRATIVE	VIDEO 5 V 9
The ends of the bridge are rigid objects that must be treated to prevent vehicle impacts.	@ Bridge with untreated ends.
NARRATIVE	**VIDEO 5 V 10**
The "Guide Specifications for Bridge Railings," published in 1989 by AASHTO, introduced the concept of multiple performance levels and the requirement that future bridge railing designs be crash tested to confirm that they meet the requirements of a specified performance level. The multiple performance level concept allows for the selection of a bridge railing based on site-specific conditions.	* View of someone holding 1989 AASHTO guide.
NARRATIVE	**VIDEO 5 V 11**
Although penetration of any railing by a vehicle is potentially hazardous to its occupants, there are bridge locations where vehicle penetration could be particularly hazardous to others as well. The multiple performance level approach considers design speed, average daily traffic (ADT), traffic mix, roadway design characteristics and the presence of vulnerable elements beneath the bridge.	* View of heavy mixed traffic and high performance bridge rail.

NARRATIVE	VIDEO 5 V 12
This approach provides the opportunity to install low-cost bridge railings on low-speed, low volume roadways such as this performance level 1 (PL1) railing. PL1 is the lowest level bridge rail designed to contain and redirect passenger cars, light trucks and vans.	* Good installation of low cost bridge rail on low volume road.

NARRATIVE	VIDEO 5 V 13
The ability to contain and redirect larger vehicles, as required for PL2 and PL3, is dependent upon the railings strength, effective height and shape of the railing face. The required strength may be as high as 1.4 million kPa for a 36,200 kg tractor-trailer striking the railing at 80 km/h at an angle of 15 degrees.	* Good installation of high performance bridge rail.

NARRATIVE	VIDEO 5 V 14
Height is a prime concern in designing a bridge railing. A railing may have sufficient strength to prevent penetration, but if an adequate effective height is not available an impacting vehicle or its cargo may roll over the railing.	✓ Crash test of truck on bridge railing.

NARRATIVE	VIDEO 5 V 15
The height is measured from the top of the roadway surface to the top of the rail. It varies from 685 mm for a performance level 1 railing	* View of performance level 1 railing.

NARRATIVE	VIDEO 5 V 16
to 1980 mm for a performance level, PL-4T, is for a virtually unbreakable railing. It provides the height required for the containment and stable redirection of tank trucks. The optional PL4 levels are for locations where truck volumes and highway alignment combine to produce site conditions that justify a performance level greater than PL3.	* View of performance level 4 railing.

NARRATIVE	VIDEO 5 V 17
The shape of the railing face is the last major item which affects bridge railing performance. For example, safety shape concrete railings can cause large vehicles to roll up to 24 degrees before it contacts the upper edge of the railing. Due to this a vertical face railing, may be more appropriate when heavy vehicle rollover is a concern. The traffic face of all railings should be smooth and continuous to reduce snagging. If the traffic railing separates vehicular, and pedestrian or bicycle traffic, then both sides of the traffic barrier should be smooth and continuous.	* View along the face of a vertical railing.

NARRATIVE	VIDEO 5 V 18
There are a number of factors that should be considered in determining which railing is the most appropriate. Considerations such as cost and aesthetics should be considered, but these considerations must never compromise the ability of the railing to contain and redirect the design vehicle.	SELECTION GUIDELINES (Superimposed over a collage.)

NARRATIVE	VIDEO 5 V 19
Bridge rails must have adequate strength to prevent penetration and also to provide smooth redirection when impacted by the design vehicle. Traffic and site characteristics, as well as accident history, should be used to select the appropriate performance level of the railing by use of the 1989 AASHTO bridge guide.	PERFORMANCE REQUIREMENTS (Superimposed on view of bridge with heavy traffic.)

NARRATIVE	VIDEO 5 V 20
The FHWA list of approved railings, by performance levels, can then be used to select the railing type.	* Movement between different types of approved bridge rails.

NARRATIVE	VIDEO 5 V 21
Bridge railings must be considered within the system of longitudinal barriers. When the approach roadside barrier differs in strength, height and deflection characteristics from the bridge railing then a crashworthy transition section is required.	PROPER TRANSITION (Superimposed over view of transition.)
NARRATIVE	**VIDEO 5 V 22**
The initial construction, long term maintenance, and motorists costs resulting from impacts with the railing system are all costs that require consideration. As a general rule the initial cost of a system increases as the performance level increases. The increased rigidity and strength of a high performance system requires railing to bridge deck anchorage requirements that can significantly increase installation costs. In addition, high performance railings can add considerable dead load to the bridge, especially on long spans.	COSTS (Construction of high performance level railing.)
NARRATIVE	**VIDEO 5 V 23**
Conversely, long term maintenance costs decrease as the performance level increases. Some high performance railings are essentially maintenance free unless impacted by a heavy vehicle. Lower performance level railings should be standardized within each roadway agency. This reduces the amount of replacement parts that need to be stocked for maintenance repairs.	* View of damaged lower performance level railing

NARRATIVE	VIDEO 5 V 24
Another maintenance concern is the probability of damage to the bridge deck upon impact. Railings that eliminate or minimize bridge deck damage reduce maintenance costs.	* View of damaged bridge deck.

NARRATIVE	VIDEO 5 V 25
Accident costs include costs associated with occupant injury and vehicle damage. Generally, the higher the performance level, the greater the damage to impacting vehicles. The rigidity and associated deformation characteristics of a railing has a significant affect on its overall performance. A railing that allows deflection absorbs some of the impact energy, results in a smoother redirection, and imparts a smaller roll angle than a rigid railing.	* High performance level railing with chip or scrape marks.

NARRATIVE	VIDEO 5 V 26
Environmental performance is a necessary concern in some areas. Solid rail designs, such as concrete safety shapes or parapet walls, can result in the accumulation of sand and snow. The solid rails prevent the sand and snow from blowing off the bridge deck as it would through a support post railing system. The solid rails can also result in snow plowing problems.	ENVIRONMENTAL PERFORMANCE (View of snow or debris accumulation along solid bridge rail.)

NARRATIVE	VIDEO 5 V 27
Along scenic routes and park roadways the appearance of bridge railings is often considered as important. The importance of aesthetics, however, should never be greater than functional performance.	AESTHETICS * View of aesthetic barrier.
NARRATIVE	**VIDEO 5 V 28**
The most common types of bridge rails are reinforced concrete walls or metal rails on concrete parapets. If improperly treated the exposed ends of these railings can pose a rigid fixed object to errant vehicles.	TRANSITIONS (Superimposed on blunt bridge end.)
NARRATIVE	**VIDEO 5 V 29**

In most instances an approach guardrail is used to shield the exposed end of the bridge rail and to prevent errant vehicles from getting behind the railing.	* View of stretch of guardrail going into bridge.
NARRATIVE	**VIDEO 5** **V 30**
These approved guardrails are typically much more flexible than the bridge rails to which they are attached. This flexibility provides the potential for deflecting sufficiently to allow a vehicle to impact the end of the bridge railing. This possibility results in the need for a transition section wherever there is a change in the deflection characteristics between the approach guardrail and bridge rail.	* View of Impacted guardrail at bridge alignment.
NARRATIVE	**VIDEO 5** **V 31**
The transition section smoothly increases the stiffness of the approach guardrail from the more flexible to the less flexible system. The resultant decrease in lateral deflection can be achieved by varying one or more key design parameters. These include increasing the guardrail beam strength, reducing post spacing and increasing post size and embedment depth. An effective transition is one that limits deflection and minimizes vehicle pocketing or snagging on the end of the bridge rail.	* Close-up view of transition section.
NARRATIVE	**VIDEO 5** **V 32**

The purpose of the transition is to gradually stiffen the flexible approach barrier to prevent an impacting vehicle from laterally deflecting the barrier and impacting or snagging the rigid bridge structure. Transitions may not be necessary when flexible bridge railings are used. Important design details for the transition section include the following.	TRANSITION DESIGN CONSIDERATIONS (Superimposed on transition section.)
NARRATIVE	**VIDEO 5** **V 33**
• The approach barrier splice to the bridge rail must be as strong as the approach barrier itself to prevent pulling loose during impact. The use of a cast in place concrete anchor,	@ * Close-up of concrete anchor
NARRATIVE	**VIDEO 5** **V 34**
or bolting completely through the concrete wall is recommended.	@ * Close-up of side shot showing bolting through wall.

NARRATIVE	VIDEO 5 V 35
If an end shoe is used with a W-beam approach rail then four through bolts are recommended.	* Close-up of 4 bolts through shoe.

NARRATIVE	VIDEO 5 V 36
When the W-beam is connected directly to the bridge rail then eight through bolts should be placed in the valley of the W-beam.	* Direct W-beam tie in.

NARRATIVE	VIDEO 5 V 37
Strong post systems or a combination of weak post and strong beam systems are normally used on transitions to rigid bridge railings. The rails are usually blocked out to reduce the possibility of wheel snagging.	* Close-up of back of transition showing block outs.

NARRATIVE	VIDEO 5 V 38
Frequently blocking out is not sufficient to prevent wheel snagging and an additional rail is added beneath the barrier rail. The additional rail, called a rubrail is frequently used with W-beam or box beam transition members.	* Closeup of rubrail.
NARRATIVE	**VIDEO 5 V 39**
The transition section should be sufficiently long to prevent significant changes in deflection within a short distance. As a rule of thumb, the transition length should be 10 to 12 times the difference in lateral deflection between the bridge rail and approach barrier.	* View of transition with graphic "10 to 12 times deflection difference."
NARRATIVE	**VIDEO 5 V 40**

The stiffness of the approach section should increase smoothly to the bridge rail. This can be accomplished by decreasing the post spacing, increasing the post size or by strengthening the rail.	* View of transition with graphic "decrease post spacing", "increase post size."
NARRATIVE	**VIDEO 5** **V 41**
Curbs, raised drainage inlets or other features that can cause vehicle instability should not be placed in front of the barrier or transition section. The grading between the edge of the travelled lane and the barrier should be no steeper than 1:10.	* View of improper curb and damage.
NARRATIVE	**VIDEO 5** **V 42**
In some cases the presence of driveways and cross roads reduces the available area in front of a bridge, thereby, preventing the design of a proper transition section. The preferred alternative in such a case is to move the driveway or cross street away from the bridge.	* View of bridge by driveways or road.
NARRATIVE	**VIDEO 5** **V 43**

If this is not possible then the use of crash cushions or the installation of W-beam as shown here should be considered.	* View of wraparound W-beam installation.
NARRATIVE	**VIDEO 5** **V 44**
Existing bridge railings, especially those constructed prior to 1964, may not meet current performance levels. The rail provides the vehicle restraining capability and must be structurally adequate to prevent a vehicle from tearing through the railing and going off the bridge deck. Properly designed railings, when tested, will contain and redirect a 2450 kg passenger car impacting at 70 km/h and 20 degrees to qualify as a performance level 1 railing. In addition, bridge railings must be capable of redirecting an impacting vehicle without snagging.	DEFICIENT BRIDGE RAILING SYSTEMS (Superimposed on different bridge railing.)
NARRATIVE	**VIDEO 5** **V 45**
The capacity of the railing and support posts must be structurally adequate to withstand the impact loads. This is an example of an inadequate bridge railing design. In this design neither the railing or support posts are adequate to withstand an impact and prevent a vehicle from penetrating the system. Not only is the railing system inadequate but the angle shape which comprises the inadequate rail can penetrate the passenger compartment of an impacting vehicle.	@ Different views of inadequate tress bridge.

NARRATIVE	VIDEO 5 V 46
The rail to post and post to deck attachments must be in accordance with approved design. The post to deck attachment details of this design will not provide the required strength to prevent penetration during impact.	@ View of improper deck attachment.
NARRATIVE	**VIDEO 5 V 47**
Tests and accident experience has shown that an errant vehicles can impact a curb and vault over or penetrate through a bridge rail. This bridge rail design can cause vehicles impacting the curb to rise and impact the bridge rail at a height higher than the design height. The roadway agency recognized the hazard of curb and placed a hazard marker in the vicinity of the curb but in front of guardrail. This creates an additional fixed object and compounds the problem.	@ View of curb which has been impacted.
NARRATIVE	**VIDEO 5 V 48**

The face of the bridge rail should be placed out as far as the curb if the curb can be removed. If sidewalks are present then a traffic barrier should be between traffic and pedestrian areas and a pedestrian/bicycle railing placed at the bridge edge.	* View of guardrail at proper distance.
NARRATIVE	**VIDEO 5** **V 49**
If guardrail is used as the bridge rail it must be installed in accord with approved design specifications. This W-beam installation has inadequate flare and is mounted too high.	* @ View of inadequate guardrail bridge rail.
NARRATIVE	**VIDEO 5** **V 50**
The bridge rail must have continuity to prevent vehicle snagging. Splices in metal bridge rail should be as strong as the rail itself. Lapped splices should be placed so that the outer rail overlaps in the downstream direction to reduce snagging. Splices in concrete bridge rail should be smooth. This bridge rail presents the failure that can occur with lack of continuity in concrete bridge rail.	* View of bridge rail with wrong lap or splices.
NARRATIVE	**VIDEO 5** **V 51**

Almost all existing W-beam guardrail systems that connect directly to a bridge rail without adequate blockouts or a subrail near the bridge connection should be considered unsatisfactory. These systems can result in vehicle snagging and catastrophic accidents. Retrofits must be designed with adequate blockouts, subrails or other features to prevent snagging.	* View of improper bridge connection.
NARRATIVE	**VIDEO 5** **V 52**
Standard drawings and plan sheets should be reviewed, and upgraded or replaced, as necessary to prevent future construction of known transition deficiencies.	* View of men reviewing drawings.
NARRATIVE	**VIDEO 5** **V 53**
Retrofit designs are intended to increase the strength of the railing, provide longitudinal continuity to the system, eliminate the snagging potential or to reduce the undesirable effects of curbs or narrow walkways. A proper retrofit design should also provide an acceptable transition from the approach rail to the bridge rail itself.	RETROFIT DESIGN CONCERNS (Superimposed over a good retrofit design.)
NARRATIVE	**VIDEO 5** **V 54**

Some retrofit designs may not bring a substandard bridge railing up to full AASHTO standards but can result in significant improvements. In selecting a retrofit design, a proper perspective must be maintained on the priorities of any traffic barrier; first to safety performance, second to economics, and third to aesthetics.	SAFETY COST AESTHETICS (Superimposed over retrofit bridge rail.)
NARRATIVE	VIDEO 5 V 55
The safety concern requires that the system be capable of restraining and redirecting a vehicle that is representative of a large majority of the traffic mix. This implies that when a vehicle of specified weight, dimension, velocity and approach angle impacts a bridge rail that it will not climb over, break through or wedge under the installation. When possible, therefore, Retrofits should be designed for the appropriate performance level of the location. The cost consideration requires the retrofit to be economical in construction, installation and maintenance. Accident costs should also be considered including not only the high speed high angle impacts but the more frequent minor "brush" accidents, as well. Concerns of maintenance costs include how quickly it can be repaired when impacted, effects of exposure to moisture, snow and ice, salt, sunlight and temperature variation.	* View of traffic on 2 lane road going over bridge.
NARRATIVE	VIDEO 5 V 56

Although pavements and shoulders have been widened through reconstruction efforts the majority of bridges are narrow due to the expense and difficulty required for their modification. Accident frequency at bridge ends can be attributed to both the minimum width aspect and the funnel effect of transitioning from a wide roadway to a narrow bridge. As a result a large number of bridges that may be candidates for retrofit bridge railings cannot tolerate reduction of bridge deck width. Bridge deck retrofit designs should maintain the existing bridge deck widths.	*View of narrow bridge.
NARRATIVE	**VIDEO 5 V 57**
In the majority of cases curbs are an integral part of the bridge structure and cannot be removed unless major redesign of the bridge is performed. This necessitates accommodating the curb conditions in the retrofit design.	* View of old bridge with curbs.
NARRATIVE	**VIDEO 5 V 58**
The complete bridge railing system should be considered when designing a bridge railing retrofit. This includes, the approach guardrail and terminal,	* View of inadequate approach guardrail.
NARRATIVE	**VIDEO 5 V 59**

2) the bridge railing,	* View of inadequate railing.
NARRATIVE	**VIDEO 5** **V 60**
and 3), transition from approach guardrail to bridge railing. Consideration must be given to both ends of the bridge railing where two-way traffic conditions provide the possibility of impacts from both directions.	* View of inadequate transition.
NARRATIVE	**VIDEO 5** **V 61**
Some specific retrofit concepts that can be adapted to numerous types of deficient designs are: · Concrete safety or vertical wall shapes · W-beam/thrie beam retrofits · Metal post and beam retrofits · Tubular thrie beam retrofits	CONCRETE SHAPES W & THRIE BEAM POST & BEAM TUBULAR BEAM (Superimposed over deficient bridge.)

NARRATIVE	VIDEO 5 V 62
The concrete safety or vertical wall shapes that are commonly used for new construction can be added to an existing substandard bridge as an effective retrofit. For this retrofit design to be economical and feasible there must be; 1) the ability of the structure to carry the additional dead load, 2) sufficient deck space to install the barrier without reducing the width of the travelled way, and 3) the existing curb or railing configuration can meet the anchorage and impact forces needed for the retrofit barrier.	* Panning view of concrete safety shape installation.
NARRATIVE	**VIDEO 5 V 63**
Protruding curbs must be avoided to prevent wheel and suspension damage and to reduce the potential for vehicle vaulting in shallow angle impacts.	* Close-up of curb with concrete safety shape.
NARRATIVE	**VIDEO 5 V 64**

Continuing an approach guardrail through the structure, is an economical method of upgrading substandard bridge rails. While this treatment may not bring an existing bridge railing into full compliance with AASHTO design criteria, it can significantly improve its impact performance. This treatment can be particularly effective on low volume roadways or where the structure strength and/or width will not allow the installation of a concrete retrofit.	* View of W or thrie beam retrofit.
NARRATIVE	**VIDEO 5** **V 65**
Tests have demonstrated that a bridge railing can be effective even if it deflects several feet upon impact. A double layer of W-beam or thrie beam, with offset joints, can reduce the deflection upon impact. Continuing the approach rail across the bridge has the added advantage of eliminating the need of providing adequate anchorage to prevent the approach rail from pulling out upon impact. The transition design elements that remain a concern are providing the gradual stiffening and the elimination of snagging potential.	* View of back of retrofit at transition point.
NARRATIVE	**VIDEO 5** **V 66**
Curb mounted retrofits, work well when there is a wide walkway between a curb and the bridge rail. It has the advantages of moving the rail face to the curb line to reduce vaulting and separating pedestrians from vehicular traffic. Systems which are appropriate for curb mounted retrofits are 2-tube curb mounted bridge railing, tru-beam bridge railing, the W and tube-beam bridge railing, and the tubular W-beam bridge railing.	* View of curb mounted retrofit.
NARRATIVE	**VIDEO 5** **V 67**

W-beam and thrie-beams can be made into tubular sections that can significantly strengthen the existing railing.	* View of tubular thrie-beam installation.
NARRATIVE	**VIDEO 5** **V 68**
The tubular section is produced by welding similar shapes back-to-back continuously along the top and bottom seams.	* View of the welded thrie-beam.
NARRATIVE	**VIDEO 5** **V 69**
The tubular beams are then blocked out from the existing railing by a rigid structural member and a 152 mm diameter, 3.2 mm thick tube section. The tube section is intended to collapse upon impact providing 150 mm of deflection which reduces both the deceleration forces on the impacting vehicle and the potential for damage to the substandard bridge rail.	* Close-up view of tube section.
NARRATIVE	**VIDEO 5** **V 70**

The railing is set in line with the face of the curb. Using a larger tube to provide a greater deflection distance would further reduce the deceleration forces but would result in vehicle interaction with the exposed curb.	* View showing alignment with curb.
NARRATIVE	VIDEO 5 V 71
A major advantage to this retrofit system is its adaptability. Changing the size of the structural members and tubing enables its installation on different railings and bridge deck designs.	* View showing total system.
NARRATIVE	VIDEO 5 V 72
The transition from the approach guardrail to the bridge railing must be sufficiently rigid to prevent impact with the bridge structure. Appropriate transition designs are presented in module K. Design elements to look for on the inspection of existing structures include:	IDENTIFYING SUBSTANDARD TRANSITIONS (Superimposed on view of improper transition.)
NARRATIVE	VIDEO 5 V 73

The approach rail must be connected to the bridge rail. The failure to connect as shown here can result in snagging or impact with the bridge wall.	* View of unattached transition.
	VIDEO 5 V 74
The approach guardrail to bridge rail connection must be as strong as the approach rail itself to prevent separation upon impact. Less than 4 bolts as shown here can result in separation upon impact.	* View of improper number of bolts.
NARRATIVE	VIDEO 5 V 75
The stiffness of the approach rail should be gradually increased to the more rigid bridge rail. This is usually accomplished by using a strong post system and decreasing the post spacing or increasing the post size and by strengthening the rail element. Improper post spacing and size as shown here can result in enough deflection for impact on the bridge end.	* View of improper transition.
NARRATIVE	VIDEO 5 V 76

Strong post systems should be blocked out and rubrails used to reduce the possibility of snagging. This installation can result in vehicle snagging.	* View of improper block out.
NARRATIVE	**VIDEO 5** **V 77**
Deficient transitions should be corrected by applying the proper designs or retrofitting the transition. Often a proper connection to the bridge rail requires the addition of a separate end block to accommodate the tensile load or to block the approach rail to the curb face.	CRASHWORTHY TRANSITION DESIGNS
NARRATIVE	**VIDEO 5** **V 78**
In this retrofit alternative the first three posts adjacent to the concrete parapet are replaced with 2440 mm long, 200 x 31.2 post. The longer posts are embedded to a depth of 1730 mm as presented in figure L12. The use of the 200 x 31.2 posts and increased embedment depth results in a greater stiffness. This increased stiffness requires an increase in the barrier stiffness to reduce the rail deflection and wheel snagging on the end of the parapet to acceptable levels. This increased stiffness is recommended to be achieved by nesting 12 gauge W-beam rails. If a steel spacer tube can be used, it is only attached to the guardrail.	* View of an installation or diagram of larger post size.

NARRATIVE	VIDEO 5 V 79
This retrofit transition design uses W 150 x 22.3 structural steel posts with two sets of reduced post spacings. Adjacent to the concrete parapet the post spacing is 475 mm which is followed by a post spacing of 955 mm. In a retrofit situation this will often involve placing additional posts between the existing posts. The post spacing increases the system stiffness and nested 12-gage W-beam is recommended to reduce vehicle snagging. The spacer pipe is only connected to the guardrail when used.	* View of an installation or diagram of reduced post spacing pan to tub spacer.
NARRATIVE	**VIDEO 5 V 80**
This system can be used as a transition between any strong post W-beam system and a curved back concrete bridge parapet. This transition features a W-beam rubrail to reduce wheel snagging on the end of the bridge rail. The transition is appropriate for connection to a vertical curved back concrete wall and should not be connected directly to a concrete safety shape or vertical concrete wall. The rubrail is not connected to the vertical curved back concrete wall. The rubrail and the first top rail require special punching of holes for bolting to posts. The rubrail may be shop bent in the last 915 mm to ease installation.	* W-beam to curved back wall transition view or diagram pan to first top rail then to rubrail.
NARRATIVE	**VIDEO 5 V 81**

This system can be used as a transition between any strong post W-beam system and a vertical concrete bridge Parapet. This design features a rubrail and nested W-beam approach rail. This transition is appropriate for connection to a vertical concrete shape and should not be connected directly to a concrete safety shape. Concrete safety shapes should be transitioned to a vertical shape at the guardrail connection. Bridge rail ends and bridge parapets must be of adequate strength to accept full performance level loading. The rubrail may be shop bent in the late 915 mm to ease installation.	* Nested W-beam to vertical wall transition view or diagram pan to rubrail.
NARRATIVE	**VIDEO 5** **V 82**
This system can be used as a transition between any strong post W-beam or thrie beam system and a vertical concrete bridge parapet. The design, features a nested thrie-beam approach rail. Bridge rail ends and bridge parapets must be of adequate strength to accept the desired performance level impact loading.	* Nested thrie beam to vertical wall transition view or diagram.
NARRATIVE	**VIDEO 5** **V 83**
This system can be used as a transition between any strong post thrie-beam system and a vertical flared back concrete shape. The design features a nested thrie-beam. The steel spacer tube is connected only to the guardrail beam and is designed to collapse upon impact. Use of wood or steel blockouts instead of the collapsible steel spacer tube is not recommended as the resultant system proved too rigid in crashtest.	* Nested thrie beam to flared wall transition view or diagram pan to spacer tube.
NARRATIVE	**VIDEO 5** **V 84**

This transition can be used to change the face of safety shaped bridge railings to a vertical wall. The result is a transition surface for attaching the flexible approach barrier to the rigid bridge rail. This design reduces the potential for vehicle snagging on the lower portion of the concrete safety shape that is used as the bridge rail.	* Safety shape to vertical wall transition view or diagram.
NARRATIVE	**VIDEO 5** **V 85**
This system can be used as a transition between any strong post W-beam system and a flared back concrete bridge parapet. The system features a nested W-beam rail used to gradually increase the stiffness as the bridge railing is approached. The transition is appropriate for connection to a vertical flared back concrete shape and should not be connected directly to a concrete safety shape. Concrete safety shapes should be transitioned to a vertical shape at the guardrail connection. The steel spacer tube is connected only to the guardrail beam and is designed to collapse upon impact. Use of wood or steel blockouts instead of the collapsible steel spacer tube is not recommended as the resultant system proved too rigid in crash test.	* W-beam to flared wall transition view or diagram panning to change from concrete flare shape to vertical shape and then spacer tube.
NARRATIVE	**VIDEO 5** **V 86**
Bridges are an integral part of our roadway system that are expensive to build and maintain. Both the accident and maintenance cost can be reduced by the selection of the proper performance level bridge railing for new bridge construction. Similarly the safety level of existing bridges can be increased by the inspection of and retrofiting of existing bridges which are deficient in their railings, transitions and approaches.	[Closing credits.]

VIDEO STORYBOARD - 6
(Modules O and BB)
TREATMENT OF WIDE MEDIANS, BARRIER ENVELOPES, CURVED BARRIER SECTIONS, AND OTHER METHODS FOR PROTECTING LARGE AREAS
AND
SAFETY CONSIDERATIONS OF LANDSCAPING AND VEGETATION CONTROL

Left column is narration, - right column describes video scene.
Captions for video footage are in caps and are boxed.

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NARRATIVE - TREATMENT OF BARRIERS AND METHODS FOR PROTECTING LARGE AREAS	VIDEO 6 V 1

An important safety feature of modern highways is wide, traversable medians which provide protection against crossover accidents, while providing the opportunity for errant vehicles to regain control. When a potential hazard cannot be removed or redesigned, it may be necessary to provide protection by means of a barrier.	* Video showing a clear median, median with barrier systems in them. TREATMENT OF WIDE MEDIANS, BARRIER ENVELOPES, CURVED BARRIER SECTIONS, AND OTHER METHODS FOR PROTECTING LARGE AREAS (Include all opening credits, etc.)
NARRATIVE	**VIDEO 6** **V 2**
Earth berms provides a good treatment for bridge piers or sign structures located near the center of the median. It is important that the earth berm be installed in accordance with the States standard. An improperly constructed berm could result in the vehicle impacting the hazard that the berm is trying to shield. A major advantage to the earth berm is its cost and very little or no maintenance required.	(*) or (@) Showing earth berms. EARTH BERM
NARRATIVE	**VIDEO 6** **V 3**

When a wide median has a barrier down the middle and a hazard is encounter, a method to shield the hazard is to split the barrier. This allows the barrier to be placed closer to the pavement and to reduce the potential for a high impact angle hit. Care should be taken that the flare rate not be exceed while moving the barrier close to the pavement.	@ Could use Figure 09 as well as some pictures as examples. SPLIT BARRIER OR BARRIER ENVELOP
NARRATIVE	**VIDEO 6** V 4
In some cases with a wide median, a barrier may not be required, but a hazard is encountered. In this case, the barrier can be placed close to the hazard and on each side. Each end of the barrier would then have to be protected with an appropriate end treatment. The reason for placing the barrier close to the hazard is to provide the errant vehicle room to recover. W-beam or concrete barrier can be used as the barrier system.	(@) and (*) Show Figure 0-10 and examples.
NARRATIVE	**VIDEO 6** V 5
There are several types of barrier treatments for twin bridges. The type of treatment depends on the median width. In some cases, a standard run of guardrail could be used. The back side of the rail needs to be checked to see that it isn't a hazard for the opposite direction traffic.	(@) and (*) Show Figure 013 and pictures of such installations. TWIN BRIDGES

NARRATIVE	VIDEO 6 V 6
In cases where the median is narrow to where the backside of the guardrail becomes a hazard, a bullnose attenuator system should be used. There are currently three types of this system available: - Minnesota bullnose - Colorado 3F, and - the Thrie-beam bullnose	@ Show video of each of the bullnose attenuator system. BULLNOSE ATTENUATORS
NARRATIVE	**VIDEO 6 V 7**
The Minnesota Bullnose Attenuator can be used to shield the end of twin structures as well as the opening between the structure. When struck on the end, the rail wraps around the vehicle as it penetrates, and the vehicle is gradually decelerated as posts on each side of the envelope are broken off by the impact. For side impacts, the bullnose redirects the vehicle in the same manner as a conventional barrier. It is important that the area in front of the system be flat so that the vehicle will not dip under the rail during impact.	@ Video using photographs. MINNESOTA BULLNOSE ATTENUATOR
NARRATIVE	**VIDEO 6 V 8**

The Colorado 3F is different from the Minnesota Bullnose in that it is narrower and depends on the flattening of the rail elements to reduce its bending resistance. The system also requires several footings to assure that the posts break off at the ground line during impact.	@ Video showing the different features of the system. COLORADO 3F
NARRATIVE	**VIDEO 6** **V 9**
The Thrie-beam bullnose system uses a combination of thrie-beam and a flat plate nose section. The flat plate has a horizontal slot to help the system capture the vehicle. The primary advantage of this system is that it provides excellent protection against penetration, and an extensive series of full-scale crash tests conducted during its development indicates that it performs better than many other median barrier bullnose treatments currently in use.	✓ ✓ Video showing the crash test of the system. THRIE-BEAM BULLNOSE SYSTEM
NARRATIVE	**VIDEO 6** **V 10**
At intersecting roadways, two curved W-beam barrier systems have been developed to shield the roadside hazards falling with the guadrant formed by the intersecting roadways. Both systems are a weak post system to reduce the severity of the impact, and require a special end anchor. One system is designed with a maximum radius of 2590 mm and the other with a maximum radius of 10 670 mm.	(✓✓), (✓) and (@) Crash testing CURVED W-BEAM BARRIER AT INTERSECTIONS

NARRATIVE	VIDEO 6 V 11
The Dragnet Vehicle Arresting Barrier is manufactured by Roadway Safety Service, Inc. The system uses a chain link fence or fibre arresting net to prevent vehicles from entering closed areas or roadways or encountering hazards such as the opening between twin bridges. It may also be suitable for use opposite the approach road at a "T" intersection to decelerate vehicles crossing the intersection. The system can also be used at R/R crossings to prevent vehicles from entering onto the train tracks. A cable is used to hook the fence to steel alloy tape which is encased in a canister. A series of pins in the canisters act as a shock absorber. The manufacturer should be contacted for the design details for a specific applications.	(✓✓) and (✓) DRAGNET VEHICLE ARRESTING BARRIER
NARRATIVE - SAFETY CONSIDERATIONS OF LANDSCAPING AND VEGETATION CONTROL	**VIDEO 6 V 12**

Carefully planned landscaping and vegetation design can help to provide a safe, stable and visually pleasing highway facility. Benefits that can be derived are soil stability, visually pleasing facility, alleviate driver fatigue, screen headlight glare, and serve as natural crash cushions.	(*) and (@) Video showing different safety benefits. SAFETY CONSIDERATIONS OF LANDSCAPING AND VEGETATION CONTROL
NARRATIVE	**VIDEO 6** **V 13**
While there are benefits, there can be disbenefits such as overhanging trees, bushes, etc. that obscure traffic signs. Encroaching vegetation can cause reduced lane width and vertical clearance as well as causing sight restrictions at intersections, railroad grade crossings, and horizontal curve. Naturally occurring trees that are not cut as saplings can grow sufficiently large to eventually propose a safety hazard. Subsequent efforts to remove the trees can be met with resistance by environmental activist groups.	(@) and (*) Video showing the different cases.
NARRATIVE	**VIDEO 6** **V 14**

The primary goal of vegetation control is to increase traffic safety. A major safety problem occurs when vegetation blocks regulatory or warning signs. Since traffic control devices are installed for a purpose, the signs need to be visible to the motorists.	(*) and (@) Pictures showing vegetation infringing on the sight or view of regulatory or warning signs. REGULATORY OR WARNING SIGNS
NARRATIVE	VIDEO 6 V 15

Intersections must have sufficient sight distance available to permit safe intersection operation with the type of traffic control devices present. Sight distance requirements at stop sign controlled intersection requires sufficient sight distance to allow the minor roadway vehicle to perform a maneuver across or onto the major roadway. This sight distance must be such that a safe maneuver can be made even if the approaching vehicle comes into view just as the stopped vehicle initiates its departure maneuver. Intersections with no control or yield signs must have sufficient sight distance to ensure that a safe approach speed exists. The drivers of vehicles approaching intersections that do not assign directional priority should have an unobstructed view of the entire intersection and sufficient lengths of the opposing roadway to avoid an accident. Urban intersections formed by residential streets frequently have private property which comes up to the street corner. Intersection sight obstruction will frequently be the result of vegetation growing on private property.	(*) and (@) Video for each of the intersection conditions. INTERSECTIONS
NARRATIVE	**VIDEO 6** **V 16**
Ordinances need to be established that sets the intersection sight distances and allow the maintenance crews to remove such vegetation if it becomes a hazard. Rural intersections usually operate at a higher speed than urban intersections, and sometimes consist of gravel surfaces. These intersections are subject to variable sight distances due to the different use of the surrounding property. It is important to know how the property is used so the intersection will be evaluated during the time the least restricted sight distance will occur. Based on the evaluation, the appropriate traffic control device should be installed.	

NARRATIVE	VIDEO 6 V 17
Adequate stopping sight distance must be maintained along the inside of horizontal curves. Trees and vegetation growing on the inside of horizontal curves reduces the motorists ability to see ahead around the curve. It is important that maintenance crews have a program to regularly remove the obstructing vegetation.	(*) and (@) Showing vegetation on curves, vegetation removed, and maintenance crews removing vegetation. HORIZONTAL CURVES

NARRATIVE	VIDEO 6 V 18
Median crossovers on divided highways are just a special roadway intersection. The sight distance for these crossovers is the same as for any highway intersection. Because the medians are on the highway right-of-way, it should be easier for the maintenance crews to maintain the sight distance.	(*) and (@) Video showing median crossovers. MEDIAN CROSSOVERS

NARRATIVE	VIDEO 6 V 19
Railroad grade crossings are a special case of a highway-highway intersection. It is a special case in that the train is unable to stop and has the right of way, thus the motorist is responsible to stop for the train. It is the responsibility of the roadway agency to ensure that the motorist is aware of the grade crossing, and adequate sight district is provided. If sight obstructions cannot be removed to provide the sight distance, then train activated warning devices should be installed at the crossing.	(*) and (@) Video showing R/R Crossings, with and without activated devices. RAILROAD GRADE CROSSINGS

NARRATIVE	VIDEO 6 V 20
Trees greater than 100 mm in diameter located in the clear zone need to be evaluated to determine if there is a need to remove all of them, or to what extend they should be removed. It may be practical to remove a few trees to gain a consistent clear zone that would be appropriate for that section of highway. Each State should establish a procedure to address trees so they are evaluated consistently. Stumps protruding more than 100 mm above the ground should be cut off flush to the ground line. Failure to address the stumps will leave hazards that will either cause the vehicle to snag or rollover.	(*) and (@) Video of trees that need to be removed, trees removed, and stumps left. TREES IN THE CLEAR ZONE

VIDEO STORYBOARD - 7
(Modules P, Q and R)
BREAKAWAY SYSTEMS

Left column is narration, - right column describes video scene.
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NARRATIVE	VIDEO 7 V 1
	BREAKAWAY SUPPORT SYSTEMS (Opening Credits)
NARRATIVE	**VIDEO 7 V 2**
The need for traffic signs, roadway illumination, utility service and postal delivery results in roadside features frequently placed within the roadway right-of-way. The presence and location of these obstacles varies by roadway type and location. Rural freeways, for example, can be designed where traffic signs are the only obstacles that are added to the roadside. Signs, light pole standards, utility poles and mail boxes are all frequently encountered on rural collections. These obstacles, when present, perform a necessary function, but are also potential fixed objects for an errant vehicle. To reduce accident severity it is important that signs, roadway illumination supports, utility poles and mailboxes be properly designed, located and placed when necessary within the right-of-way. As a general rule, there are a	* View of busy roadway with signs, utility poles, luminaries on roadside.

NARRATIVE	VIDEO 7 V 3
number of options that can be used by design engineers to provide a safe design. In order of preference these options are	

NARRATIVE	VIDEO 7 V 4
• Do not install the obstacle.	* View of clear roadside with heavy traffic.

NARRATIVE	VIDEO 7 V 5
• Install it on existing overhead structures, where it does not become an additional fixed object hazard.	* View of sign installed overhead on a bridge.

NARRATIVE	VIDEO 7 V 6
• Locate the feature away from the traveled way or behind existing barriers where it will be less likely to be struck.	* View of sign installed far from road on upslope.
NARRATIVE	**VIDEO 7 V 7**
• Reduce impact severity by using appropriate breakaway or yielding design.	* View of roadway lighting pole with frangible couplings.
NARRATIVE	**VIDEO 7 V 8**
• Shield the feature with a properly designed longitudinal barrier or crash cushion if it cannot be eliminated, relocated or redesigned.	✓ View of cantilever sign or light pole behind guardrail.

NARRATIVE	VIDEO 7 V 9
• Delineate an existing feature if other measures are not practical. Putting up hazard markers is a cost effective method for alerting motorists to an existing hazard. Obviously, delineators will not make any difference if a driver hits the object but they might help a driver avoid running off the road at that spot.	*@ View of proper installation with hazard markers also installed.
NARRATIVE	**VIDEO 7 V 10**
Yielding or breakaway supports are recommended on all types of sign, luminaries, traffic signal and mailbox supports that are located within the desirable clear zone. The clear zone is the total roadside area, starting at the edge of the traveled way, that is available for safe use by a vehicle. The desirable width of the clear zone is depended upon traffic volume, speed and the roadside geometry.	* View of traffic and clear zone. CLEAR ZONE
NARRATIVE	**VIDEO 7 V 11**

The transversable area is the roadside border area that permits a motorist to maintain vehicle control including being able to slow and stop safely. The transversable area can exceed the desirable clear zone called for in the <u>Roadway Design Guide</u> <u>[P1]</u>. Only yielding or breakaway supports should be permitted in the transversable roadside, even if it is located beyond the clear zone.	* View of wide flat clear roadside with breakaway sign far from roadway edge. TRANSVERSABLE
NARRATIVE	VIDEO 7 V 12
In those instances where yielding or breakaway supports are not possible, such as large cantilever sign installations, shielding with crash cushions or guardrail should be used.	* Sign shielded by barrier.
NARRATIVE	VIDEO 7 V 13
Yielding supports refer to those supports that are designed to remain in one piece and bend at the base upon vehicle impact. The anchor portion remains in the ground and the upper assembly passes under the vehicle.	*@ Close-up view of U-channel at ground level.
NARRATIVE	VIDEO 7 V 14

The term "breakaway support" refers to support systems that are designed to break into two parts upon vehicle impact. The release mechanism for a breakaway support can be a slip plane, plastic hinges, fracture elements or a combination of these.	*@ Split screen with views of slip bases, frangible couplings.
NARRATIVE	**VIDEO 7** **V 15**
It is important to use only those support assemblies that have been tested, using the standard specifications, and subsequently approved for use by the FHWA. This is true for city and county jurisdictions where roadway speeds are generally less than what can be expected on State and rural roadways.	* View of traffic with sign support in background. FOR EXISTING CONDITIONS
NARRATIVE	**VIDEO 7** **V 16**
NCHRP Report 350 establishes current testing guidelines for vehicular tests to evaluate the impact performance of permanent and temporary highway features. These guidelines include a range of test vehicles, impact speeds, impact angle, point of impact on the vehicle and surrounding terrain features for use in evaluating impact performance. Acceptance test of yielding and breakaway supports require evaluation in terms of	* View of NCHRP 305.

NARRATIVE	VIDEO 7 V 17
the structural adequacy of the device to determine if detached elements, fragments or other debris from the assembly penetrate, or show potential for penetrating, the passenger compartment or present undue hazard to other traffic.	✓✓ Crash of sign panel entering passenger compartment. STRUCTURAL ADEQUACY
NARRATIVE	**VIDEO 7 V 18**
A range of preferable and maximum vehicle changes in velocity resulting from impact with the support system. The preferable change in vehicle velocity is 3.0 m/s or less. The maximum acceptable change in vehicle velocity is 5.0 m/s.	✓✓ Crash test demonstrating acceptable velocity change. VELOCITY CHANGE $\leq$ 3M/S DESIRABLE $\leq$ 5 M/S ACCEPTABLE
NARRATIVE	**VIDEO 7 V 19**

The impacting vehicle remain upright during and after the collision with the vehicle trajectory and final stopping position after impact should intrude a minimum distance, if at all, into adjacent or opposing lanes.	✓✓ Crash test of vehicle overturning. REMAIN UPRIGHT WITH ACCEPTABLE TRAJECTORY
NARRATIVE	**VIDEO 7 V 20**
The acceptance testing guidelines are intended to enhance experimental precision while maintaining cost within acceptable bounds. The wide range of vehicle speeds, impact angle, vehicle types, vehicle condition and dynamic behavior which vehicles can impact the support can not be economically replicated in a limited number of standardized tests. The use of an approved device does not, therefore, guarantee that it will function as planned under all impact conditions.	* Views of heavy traffic in urban area and high speed rural traffic.
NARRATIVE	**VIDEO 7 V 21**
Impacts with supports can be hazardous even at lower speeds, especially for occupants of a small vehicle. It should be noted that many supports can be more hazardous at low speeds (25 to 40 km/h) than at high speeds (90 to 100 km/h. For example, sign supports that fracture or breakaway can be more hazardous at low speeds where the energy imparted to the support is not sufficiently large to make the device swing up and over the vehicle. The result can be intrusion of the lower portion of the support into the passenger compartment.	✓✓ Crash scene of low speed impact with large slip base.
NARRATIVE	**VIDEO 7 V 22**

Similarly, devices designed to yield are generally more hazardous at high speed, due to the reduced time available for deformation and subsequent passage beneath the vehicle.	✓✓ Crash scene of high speed impact with U-channel.
NARRATIVE	**VIDEO 7 V 23**
However, the failure or adverse performance of a highway safety feature can often be attribute to improper design or construction details. The incorrect orientation of a unidirectional breakaway support, or something as simple as a substandard washer, or anchor pieces extending more than 100 mm from the ground are major contributors to improper function. It is important for proper device function that the safety feature has been properly selected, assembled and erected and that the critical materials have the specified design properties.	*@ Views of improper installation.
NARRATIVE	**VIDEO 7 V 24**
There are a variety of systems used to support ground mounted traffic signs. These systems were often categorized by whether they intended to support small or large signs. An alternative method of categorizing sign types is by designating them as single or multiple mounts systems.	* View of traffic with sign supports in the background. SIGN SUPPORTS - SINGLE - MULTIPLE WITH ACCEPTABLE TRAJECTORY

NARRATIVE	VIDEO 7 V 25
Sign panels supported by a single support or by multiple supports less than 2100 mm apart are considered as single mounts. The 2100 mm separation criteria allows for the possibility that a vehicle, leaving the roadway at an angle, can impact more than one support.	*@ View of single sign support.
NARRATIVE	VIDEO 7 V 26
Multiple mounts include two or more supports that are separated by 2100 mm or more.	*@ View of multiple mount sign.
NARRATIVE	VIDEO 7 V 27

Signs supported by more than one support, in addition to being separated by more than 2100 mm, must also be designed for each support to independently release from the sign panel. Multiple support systems, therefore, must have sign panels with sufficient torsional strength to ensure proper release from the impacted support while remaining upright on the support(s) which were not impacted. This also requires that the remaining supports(s) have sufficient strength properties to prevent the sign panel from breaking loose and entering the passenger compartment or becoming a projectile.	✓✓ Crash test demonstrating sign panel holding impacted support.
NARRATIVE	VIDEO 7 V 28
Metal supports which yield upon impact have been used for many years to provide effective economical supports for traffic signs. The U-channel post design is the most widely used support for both single and multiple support designs. Yielding supports are designed to bend at the base and have no built-in breakaway or weakened design. Systems in this category include the full length steel U-channel, aluminum shapes, aluminum X-posts and standard steel pipes. For successful impact performance the support must bend and lay down or fracture without causing a change in vehicle velocity of more than 5 m/s. Tests have shown that supports which fracture offer much less impact resistance, especially at high speed impacts, than yielding supports of equal size.	*@ View of U-channel, other shapes. BASE BENDING
NARRATIVE	VIDEO 7 V 29

The impact performance of base bending supports depends upon the interaction between the structure and the soil in which it is embedded. Soil conditions vary drastically with location, even within small geographic locations. Due to this variability NCHRP 350 has established standard soil conditions previously referred to as "strong soil") and weak soil for testing. Weak soil consists of relatively fine aggregates which provide less resistance to lateral movement than that provided by a standard soil. The proper performance of some base bending supports require that they do not pull out of the soil upon low speed. Placing these base bending device in weak soil, when it has only been approved for use in standard soil, or at an improper embedment depth, will not provide acceptable low speed performance.	* View of work crew at sandy soil site. (May be of running sand through fingers.)
NARRATIVE	VIDEO 7 V 30
When weak soil conditions are encountered soil plates, anchor system or other alternatives should be investigated rather than the use of a system approved for standard soil only.	* View of work crew installing sign or of other type of support system.
NARRATIVE	VIDEO 7 V 31

Breakaway supports are designed to separate from the anchor base upon impact. Breakaway designs include supports with frangible couplings, supports with weakened sections, bolted sections and slip base designs.	*@ View of square tube, slip base, weakened wood frangible couplings. BREAKAWAY SUPPORTS
NARRATIVE	**VIDEO 7** **V 32**
Breakaway supports are classified by their ability to properly separate from the base upon impact from one direction (unidirectional)	@ Inclined slip base with arrow.
NARRATIVE	**VIDEO 7** **V 33**
from two directions (bidirectional)	@ Horizontal slip base with 2 arrows.

NARRATIVE	VIDEO 7 V 34
or from all directions (multidirectional)	@ Multidirectional slip base with 4 arrows.

NARRATIVE	VIDEO 7 V 35
for example, weakened wood sections can be bidirectional	@ Weakened wood sign support.

NARRATIVE	VIDEO 7 V 36
and frangible couplings are multidirectional.	@ Frangible coupling sign support.

NARRATIVE	VIDEO 7 V 37
The primary purpose of roadway illumination is to increase safety by enhancing night time visibility. The net safety benefit from increased visibility is influenced by the hazard posed by the roadway lighting or luminarie support acting as a fixed object. If roadway illumination is not warranted, or if it is installed wrong, there is a strong possibility that traffic hazards will be increased rather than reduced by providing illumination.	* View of night traffic with roadway illumination.

NARRATIVE	VIDEO 7 V 38
Luminaries are usually supported by utility poles, high mast structures (for area lighting) and by special luminaire supports. The presence of any of these support structures within he clear zone should be either of breakaway design or properly shielded. Breakaway luminaire supports due to their relatively large mass are under separate testing and acceptance criteria per NCHRP Report 350. The upper acceptable limit of allowable speed change is 9.1 m/s. Since acceptable performance is already high care must be exercised to prevent even minor deviations from what has been tested as acceptable.	* Views of different types of lighting supports.

NARRATIVE	VIDEO 7 V 39
Luminaire supports are usually made of timber, steel, aluminum, fiberglass, or concrete. The mass of luminaire structures requires careful consideration to placement concerns. The presence of curbs, fill slopes or other features which result in impacts above the design impact point will result in unsatisfactory luminaire performance upon impact.	*@ Examples of bad light pole placement.

NARRATIVE	VIDEO 7 V 40
Roadway lighting supports are available in slip base designs	* View of slip base lighting design.

NARRATIVE	VIDEO 7 V 41
and in frangible coupling designs.	* View of frangible coupling design.

NARRATIVE	VIDEO 7 V 42
Lighting supports that are on high speed facilities should be of either breakaway design or shielded by a longitudinal barrier or crash cushions.	* View of lighting support behind guardrail.

NARRATIVE	VIDEO 7 V 43
Traffic signal supports should not be of a breakaway design. The potential hazard of the fallng signal heads and the accident potential of the traffic signal being out of operation is consdered as a greater total hazard than that experienced by the impacing vehicle.	* View of traffice signal supports.

NARRATIVE	VIDEO 7 V 44
Similarily the use of breakaway design is not used when light supports are placed on top of concrete median safety shapes.	* View of light support on top of concrete median safety shape

NARRATIVE	VIDEO 7 V 45
Support poles of breakaway design should use wiring devices that provide a positive electrical disconnect that does not leave exposed and energized conductors.	@ View of exposed wires after an impact (with a red X through view).

VIDEO STORYBOARD - 8
(Modules S and T)
SIGN SUPPORTS

Left column is narration, - right column describes video scene.
Captions for video footage are in caps and are boxed.

Material in parenthesis ( ) is comment or explanation.
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✓ - indicates footage to be obtained from existing presentation quality video.
✓✓ - additional footage to be obtained from existing videos.
* - indicates footage to be obtained.
@ - indicates possible use of existing photographs.

NARRATIVE	VIDEO 8 V 1
An important element to a safe highway environment is the proper construction and maintenance of traffic signs. Good designs and the best of materials will not be effective in reducing accident potential or severity if the traffic signs are improperly placed or installed. This requires that field crews be knowledgeable of proper installation techniques and to report and correct any possible problems instead of merely placing the signs at the roadside.	MAINTENANCE AND CONSTRUCTION OF SIGN SUPPORTS (Opening credits)
NARRATIVE	VIDEO 8 V 2

There are two primary classifications of sign supports that will be discussed. The type of construction and required maintenance will depend upon whether it is a single mount or multiple mount construction.	SINGLE MOUNT AND MULTIPLE MOUNT (Superimposed over a view of roadway traffic.
NARRATIVE	**VIDEO 8 V 3**
Signs are classified as single mounts if there is only one support or if the supports are separated by more than 2100 mm. The idea behind the word "single" is that an errant vehicle will only be able to impact a one post.	* View of split screen with single support and supports further than 2100 mm apart.
NARRATIVE	**VIDEO 8 V 4**
Multiple mount systems have two or more supports within 2100 mm of each other. Tests have indicated that spacing this close can result in an errant vehicle striking every post that is within the 2100 mm distance.	* Views of multiple support systems.
NARRATIVE	**VIDEO 8 V 5**

All sign support systems must have been tested and approved for use by the Federal Highway Administration (FHWA). The testing and approval includes a note on whether the system is approved for one, two or three post installations. This designation refers to the number of posts within the 2100 mm span.	✓ Crash test of sign supports.
NARRATIVE	**VIDEO 8** **V 6**
Posts and assemblies approved for use as single systems should not have more than one post installed within the 2100 mm pail.	* View of single post installation.
NARRATIVE	**VIDEO 8** **V 7**
In addition to the correct sign support type and its method of installation there are general placement guidelines that increase the sign's effectiveness, safety operation and maintenance.	* View of roadway with signs.
NARRATIVE	**VIDEO 8** **V 8**

Warning signs should be placed sufficiently in advance so that the driver has adequate time to perceive, identify, decide and perform any necessary maneuver.	* View of warning sign.
NARRATIVE	**VIDEO 8** **V 9**
A guide for the placement distance of warning signs is contained in the Manual of Uniform Traffic Control Devices (MUTCD).	* View of someone holding the MUTCD.
NARRATIVE	**VIDEO 8** **V 10**
This manual also guidelines on the distance signs should be set back from the traveled way for urban and rural roadways for expressways and freeways. Signs placed too close to the roadway increase the probability of vehicle impacts and damage by turning trucks.	* View of sign damaged by turning truck.
NARRATIVE	**VIDEO 8** **V 11**

All sign assembles located within the transversable area must be capable of giving safely away upon impact. This requires that it results in a maximum vehicle deceleration of 5 m/s and that the sign assembly does not protrude into the passenger compartment. The proper installation of only FHWA approved devices will satisfy this requirement.	✓ Crash test of sign support.
NARRATIVE	**VIDEO 8** **V 12**
The height from the ground to the top of the sign should be 2750 mm. In the majority of cases following the minimum of 2100 mm requirement of the MUTCD to the bottom of the sign will achieve the 2750 mm top of the sign requirement. The 2750 mm requirement should, however, be the governing criteria since tests have demonstrated that signs mounted with their tops at this height will hit the roof rather than the windshield upon impact.	* View of sign with graphic measurement distance.
NARRATIVE	**VIDEO 8** **V 13**
Sign supports installed with anchor systems must have a maximum height of 100 mm from the ground level to the top most part of the anchor. Anchor pieces extending higher than 100 mm from the ground can snag the undercarriage of impacting vehicles.	* View of horizontal slip base and included slip base with graphic measurement distances.
NARRATIVE	**VIDEO 8** **V 14**

Most sign support assemblies are designed to function properly when impacted at bumper height, typically about 500 mm above the ground. If impacted at a higher point the assembly may bind at the planned shear point resulting in non-activation of the breakaway mechanism. For this reason it is critical that breakaway sign assembles not be located near ditches or on steep slopes or other locations where the vehicle can become partially airborne at the time of impact.	✓ Crash test of a support at higher than design point.
NARRATIVE	**VIDEO 8** **V 15**
Sign supports should not be placed in ditches. The water in the ditch can erode the soil around the base of the support, cause premature deterioration of the post and freeze resulting in unpredictable performance during impact. The ditch can also act as a guide way that directs errant vehicles into the sign assembly.	* View of sign placed in ditch with RED X through it.
NARRATIVE	**VIDEO 8** **V 16**
Sign support assemblies are tested in both strong and weak soils. Supports which are designed to yield, or fracture, upon impact generally perform better in strong soil. Strong soil holds the buried portion in position providing sufficient resistance for the sign support to break near ground level.	* ✓ U-Channel sign post after impact in strong soil.
NARRATIVE	**VIDEO 8** **V 17**

Weak soils do not provide this resistance resulting in movement within the ground and unpredictable results.	* ✓ View of U-Channel sign impacted with weak soil.
NARRATIVE	VIDEO 8 V 18
Yielding or fracturing supports that are embedded less than 1000 mm, in weak soil will often pull out of the soil. While this may provide acceptable impact performance the force of the wind and ice loads may cause the sign assembly to rotate or fall down.	* ✓ View of U-Channel post pulled out of ground.
NARRATIVE	VIDEO 8 V 19
The actual soil type that is present may not be known until the start of installation. Weak soils are those that offer relatively little resistance to driving the sign post. If weak soils are encountered, there are measures that can be taken to maintain sign orientation, due to environmental loads, and still result in proper operation during impact. These include embedding the sign post to 1000 mm, the use of anchor plates, concrete footings and commercially available anchor systems.	* View of sign crew with running sand through hand.
NARRATIVE	VIDEO 8 V 20

Single sign support systems are designed to operate safely when only one support is struck upon impact. Tests have shown that an errant vehicle, leaving the roadway at an angle, can impact more than one support if they are not separated by more than 2100 mm. This separation applies to other fixed objects as well as sign posts. For example, a 75 mm diameter tree is sufficiently small to provide acceptable impact performance. Installing a sign support 2000 mm from this tree, however, can result in an errant vehicle impacting both the tree and the sign post. The combined effect of the tree and sign can provide unacceptable impact performance.	* Sign support installed too close to small tree.
NARRATIVE	**VIDEO 8** **V 21**
Study the traffic patterns and surrounding geometries prior to installing any sign. If the sign assembly can be expected to be struck from more than one direction then the sign support should be expected to properly operate when impacted from more than one direction. Two lane, rural roadways should use roadside supports that function safely when impacted from two directions.	@ * Views of square tube, u-channel, multi-directional and horizontal slip bases, and frangible couplings.
NARRATIVE	**VIDEO 8** **V 22**
Installations on freeways, with wide medians or positive median barriers, can be expected to be impacted from only one direction.	@ View of inclined slip base.
NARRATIVE	**VIDEO 8** **V 23**

In summary be aware of what is required for sign installations to function properly for both the environmental loads and vehicle impact. Do not install a device simply because it has been specified on the sign order. The actual site conditions may have been unknown, or different from what was expected by the designer who specified the type of sign assembly. If problems are identified, contact a supervisor to determine if changes should be made.	@ View of sign truck with different sign posts and men standing in back of it.
NARRATIVE	**VIDEO 8** **V 24**
The correct installation of sign support assemblies is dependent upon the type of support post, the type of soil present and the impact performance design of the sign assembly. Installation instructions are contained in your State's standard drawings and; for proprietary devices, from sign post manufacturers. Appendix Q contains a list of acceptable single sign supports and, in many instances, information on proper installation procedures. Proper installation practices for the most common types of single support assemblies are presented below.	INSTALLATION OF SINGLE MOUNT SIGN SUPPORTS (Superimposed on work crew placing sign support.)
NARRATIVE	**VIDEO 8** **V 25**
There are many types of approved supports for single mount sign assemblies. These include u-channel, square steel tube, wood posts, engineered wood posts, steel pipe posts, aluminum shapes fiberglass, and slip base designs.	* Collage of various support types.
NARRATIVE	**VIDEO 8** **V 26**

U-Channel posts can be installed by direct burial or as a two piece anchor base assembly.	U-CHANNEL - Direct Burial - Anchor Base (Superimposed on a new u-channel installation.)
NARRATIVE	VIDEO 8 V 27
The most common method of installing u-channel posts is by direct burial. The burial can be achieved by mechanical post drivers,	* View of u-channel being installed by mechanical post driver.
NARRATIVE	VIDEO 8 V 28
by sledge hammer	* View of sledge hammer.
NARRATIVE	VIDEO 8 V 29

or by drilling a hole and back filling.	* View of auger installation.
NARRATIVE	**VIDEO 8** V 30
If the post is to be placed by driving into the ground then a driving cap should be used to prevent damage to the end of the u-channel.	* View of man placing driving cap on u-channel.
NARRATIVE	**VIDEO 8** V 31
Drive or place the posts at least 900 mm, but no more than 1100 mm into the ground to make it easier to pull out damaged posts.	* Graphic of post showing depth.

NARRATIVE	VIDEO 8 V 32
U-channel posts can be installed as two piece assemblies consisting of an anchor base and the post support. The advantages of the two piece assembly is that the post will break off from the anchor piece upon impact. This often improves safety upon impact, makes repairs easier and makes it possible to salvage portions of a damaged u-channel post.	* View of splice assembly.
NARRATIVE	**VIDEO 8 V 33**
An anchor base assembly is especially advantageous when the post is placed in a paved area, such as a concrete median.	* View of splice in concrete area.
NARRATIVE	**VIDEO 8 V 34**
The anchor piece can be directly driven, buried 900 mm in the ground	* View of anchor piece only.
NARRATIVE	**VIDEO 8 V 35**

or embedded 610 mm in a concrete foundation that is 200 mm in diameter and 760 mm deep.	* View of anchor piece in concrete foundation.
NARRATIVE	**VIDEO 8** **V 36**
The anchor piece should not extend more than 100 mm above the ground to prevent snagging the vehicle undercarriage.	* View of anchor piece with graphic 100 mm.
NARRATIVE	**VIDEO 8** **V 37**
The sign post can be attached to the anchor piece by an Arizona splice or the use of commercially available devices.	* View of Arizona, Eze Exect, Minute Man, frangible couplings
NARRATIVE	**VIDEO 8** **V 38**

NARRATIVE	VIDEO 8 V 39
The Arizona splice requires the sign post to overlap the anchor piece by 150 mm to provide stability against the environmental loads. Since the anchor piece cannot extend more than 100 mm above the ground, this means that the sign post is at least 50 mm below ground level.	* View of installation with post below ground.

NARRATIVE	VIDEO 8 V 40
The post is placed behind the anchor stub and the posts are attached together with two 8 mm bolts spaced 100 mm apart. Extra 8 mm nuts are used as spacers between the two post pieces to prevent binding during impact.	* View of installing bolts of assembly emphasizing spacers.

NARRATIVE	VIDEO 8 V 41
A number of commercially available splicing devices are approved for use with u-channel posts. The manufacturer's directions must be followed for proper assemble.	* View of Eze-Erect, Minute-Man and frangible couplings.

No matter the type of splice used the top of the anchor piece must not extend more than 100 mm from the ground.	* View of lower portion of frangible coupling block.
NARRATIVE	**VIDEO 8** **V 42**
Square steel tube is available from a number of manufacturers in perforated, and punched but not perforated, styles. Square tube sign supports can be installed as one piece direct burial and with anchor piece assemblies. The anchor piece assemblies have the advantages of more predictable performance upon impact, a larger range of permissible sizes and reduced maintenance required for repair after impact.	SQUARE STEEL TUBE (Superimposed an square tube installation.)
NARRATIVE	**VIDEO 8** **V 43**
Square steel tube sign supports up to 57 mm x 57 mm in size, can be installed by direct burial. Sizes larger than 57 x 57 mm require an anchor base assembly to provide acceptable impact performance characteristics. The most common method of direct burial is by driving directly into the ground, using a driving cap to protect the end, by mechanical drivers or a sledge hammer.	* View of placing drive cap on tube.
NARRATIVE	**VIDEO 8** **V 44**

Drive or place the square tube at least 900 mm deep but no more than 1100 mm into the ground to make it easier to pull out damaged posts.	* Graphic of depth measurements.
NARRATIVE	VIDEO 8 V 45
Repair of damaged square tube is easier to perform when an anchor base assembly is used. The anchor base assembly for square tube usually consists of a 760 mm long anchor piece, one size larger than the sign post, and an 450 mm long stiffening sleeve, one size larger than the anchor piece. The sleeve provides a double walled anchor base that helps prevent damage to the anchor assembly and makes the breakaway characteristics of the sign post more predictable.	* View of man holding anchor piece then sliding stiffener piece over it.
NARRATIVE	VIDEO 8 V 46
Acceptable impact performance can also be obtained by the use of only the anchor piece but damage to the anchor piece and increased maintenance is more likely to occur than when using a stiffening sleeve.	* View of man extending only anchor piece.
NARRATIVE	VIDEO 8 V 47

The square tube anchor assembly is installed by driving the anchor post 150 - 200 mm into the ground then removing the post and knocking out the soil from the post end.	*Installation of final few mm, removal and knocking out of soil.
NARRATIVE	**VIDEO 8** **V 48**
After removal of the soil the post is reinserted into the soil and driven with the stiffener sleeve to 25 to 50 mm above ground level	* Placement of stiffener sleeve and reinsertion into hole.
NARRATIVE	**VIDEO 8** **V 49**
The sign post is then inserted 150 to 200 mm into the base and fastened with bolt.	* Placement of sign post into anchor assembly.

NARRATIVE	VIDEO 8 V 50
In addition to the telescoping anchor bases, made from larger sizes of square tubing, there are heavy duty anchor bases commercially available. These bases can be used in hard or rocky soil conditions that can present problems for driving the regular sized tubing as anchor pieces.	* View of heavy duty anchor bases.
NARRATIVE	VIDEO 8 V 51
Do not over tighten the bolts which fasten the sign post to the anchor assembly. Tightening the bolt too much will distort the tubing and hinder the removal or insertion of the sign post into the anchor assembly. Corner bolts can be used which reduce the possibility of distortion from overtightening.	* View of corner bolt and it being installed.
NARRATIVE	VIDEO 8 V 52
Sections of square steel tube can be spliced together to allow the reuse of damaged posts. The splice is made by using a 300 mm long section of tubing one size smaller than the tubing to be repaired. The 300 mm section is inserted halfway into one of the tubes and secured with two drive rivets or one bolt. The second tube is then slipped over the free end of the 300 mm section and fastened in place.	* View of splicing pieces together.
NARRATIVE	VIDEO 8 V 53

Wooden posts are available in shaped, round and engineered types. Shaped wooden posts are the most common types in most areas and come in various sizes. The smallest size typically used is 90 mm x 90 mm. Round wood posts, also called timber posts are also used in many areas and the smallest diameter typically used is 100 mm. Engineered wood posts refer to hollow box shapes available from manufacturers.	WOODEN POSTS (Superimposed on collage of wooden post type.)
NARRATIVE	**VIDEO 8** **V 54**
The most common wooden supports for single sign installation are the 90 mm x 90 mm shaped and the 100 mm diameter round posts. These posts should be directly buried to a depth of at least 920 mm. Deeper burial is often performed to reduce vandalism.	* View of 90 mm x 90 mm wood post.
NARRATIVE	**VIDEO 8** **V 55**
Posts larger than the 90 mm x 90 mm and the 100 mm diameter posts require drilled holes to reduce the cross section and embedment in concrete so as to safely break away during impact. The size of the holes depends upon the size of the post.	* View of large wooden post with holes.
NARRATIVE	**VIDEO 8** **V 56**

The bottom hole should never be centered more than 100 mm above the ground so that the stub piece remains at 100 mm or less after impact. Rectangular shaped posts are placed with the long post dimension parallel to the direction of travel. The holes of the propel size for the post are drilled perpendicular to the expected direction of impact.	* Close up view of holes on rectangular wooden post.
NARRATIVE	**VIDEO 8** **V 57**
Steel pipe (schedule 40) posts have the advantage of being readily available from local hardware and plumbing supply businesses. Sizes smaller than 51 mm internal diameter (ID) can be directly buried and still provide acceptable impact performance. In addition to standard steel pipe there are round steel tube sign supports available.	STEEL PIPE POSTS (Superimposed over new steel pipe installation.)
NARRATIVE	**VIDEO 8** **V 58**
Due to their round shape, however, direct burial pipe has the tendency to rotate under prolonged wind loads. A steel earth plate measuring 102 mm x 305 mm x 6 mm, or two sign clamps, should be bolted or welded to the pipe, beneath ground level, to prevent rotation. Schedule 40 steel pipe supports should be direct buried, with the attached earth plate, to a depth of at 1070 mm to provide acceptable performance upon impact.	* View of earth plate and of 2 clamps on round post.
NARRATIVE	**VIDEO 8** **V 59**

A breakaway collar assembly is required for schedule 40 standard pipe that is equal to or greater than 51 mm ID. The breakaway collar can be made by the use of a regular pipe coupling or reducing coupling. The reducing coupling is recommended since it reduces the probability of damage to the anchor piece, thereby, easing repair. The anchor piece is usually one size larger than the sign post. The anchor assembly consists of a 610 mm long anchor piece placed in a concrete footing that is 760 mm deep and 300 mm in diameter.	* View of round post with reducing collar.
NARRATIVE	**VIDEO 8** **V 60**
Commercial anchor systems, such as the Poz-Loc™, can be used for the round steel tubes and for the standard pipe which is 51 mm or less in size. The use of commercial anchor systems requires closely following the manufacturer's instructions for proper performance.	* View of Poz-Loc™ system.
NARRATIVE	**VIDEO 8** **V 61**
Aluminum, fiberglass and engineered wood shapes are also available for use as sign supports. The manufacturer's installation instructions should be followed for proper installation.	* View of alumimum, fiberglass, and engineered wood shapes.
NARRATIVE	**VIDEO 8** **V 62**

Narrative	Video
Slip base designs for single sign supports provide the opportunities to use stronger sign supports than would be possible without the slip base design. The purpose of the slip base is to provide a separation plane between the sign support and the anchor system. The two pieces are fastened together with bolts that must be properly tightened, or torqued.	SLIP BASE DESIGNS (Superimposed over view of slip base.)
NARRATIVE	**VIDEO 8** **V 63**
If the bolts are not torqued enough the bolts will become loose due to vibration from environmental loads, causing the sign assembly to separate. If the bolts are torqued too much the friction between the base of the sign post and the anchor piece will be too large to permit proper separation upon impact.	@ View of loose slip base.
NARRATIVE	**VIDEO 8** **V 64**
Experience with slip base designs have shown, that even with proper bolt torque, the vibration, due to environmental loads, can cause the bolts to "walk" out of the slip base. A "keeper plate" consisting of thin sheet metal is inserted between the faces of the top and bottom slip bases to prevent the bolts from migrating out of the assembly. This keeper plate must be sufficiently thin to allow the bolts to tear through the plate upon impact. Keeper plates thicker than 20 to 28 gauge must not be used for proper operation.	@ Close up view of disassembled slip base with someone holding keeper plate.
NARRATIVE	**VIDEO 8** **V 65**

There are three basic types of slip base designs for single sign supports. The inclined slip base is the recommended type of slip base for single sign supports when impact can be expected from only one direction. Its performance upon impact is designed to cause the upper sign support and sign panel to raise up allowing the vehicle to pass completely under the support assembly. The anchor piece of the inclined slip base must be installed so that approaching vehicles encounter the lower edge before the high edge.	@ * View of inclined slip base.
NARRATIVE	**VIDEO 8** **V 66**
The horizontal slip base is a design that will operate properly when impacted from either the front or the back. Horizontal slip base designs do not provide the lift capability available from inclined or multidirectional designs. Horizontal slip bases, when used as single sign supports do not, therefore, function as well upon impact as the other slip base designs.	@ * View of horizontal slip base.
NARRATIVE	**VIDEO 8** **V 67**
The third basic design is the multi-directional slip base,	@ View of multi-directional slip base.
NARRATIVE	**VIDEO 8** **V 68**

This design is fastened together with 3 bolts and has a lift cone fastened to the bottom plate. The sign support is tubular with a maximum size of 127 mm diameter.	* View of disassembled multi-directional slip base.
NARRATIVE	VIDEO 8 V 69
All of the slip base designs require a firm foundation for proper operation. Concrete foundations should be used for all slip bases since direct burial may result in base movement and improper release of the slip base. No part of the anchor piece and its attached slip base must extend more than 100 mm above ground level to prevent snagging of the vehicle undercarriage.	* View of slip base anchor in concrete with 100 mm graphic.
NARRATIVE	VIDEO 8 V 70
Use proper size bolts for the slip base fastening. Bolts which are too small may not be able to be sufficiently tightened and may fail under environment loads. Bolts which are too large may become stuck in the release slots upon impact and prevent proper separation.	* View of bolt being inserted into slip base.
NARRATIVE	VIDEO 8 V 71

Three washers should be used on each bolt one each beneath the nut and bolt head and one between the upper and lower faces of the slip base. The purpose of the washer between the two slip faces is to prevent binding upon impact. All galvanizing runs or beads should be removed from both the upper and lower faces in the washer areas.	* View of assembly with emphasis on 3 washers.
NARRATIVE	**VIDEO 8** **V 72**
Use proper size and strength washers. The washers beneath the nut and head surfaces should be sufficiently strong to withstand the torque requirements without deforming into the release slots of the base.	* View of workman torquering bolts.
NARRATIVE	**VIDEO 8** **V 73**
Multiple mount sign supports are required to support sign panels that are too large to withstand wind and ice loads with the use of only one support. Multiple mount sign supports are designed to provide acceptable performance upon impact when the supports are placed 2100 mm, or closer, to each other. This close spacing results in the possibility of a vehicle, leaving the roadway at an angle, impacting more than one support simultaneously.	MULTI-MOUNT SIGN SUPPORTS (Superimposed over multimount sign supports.)
NARRATIVE	**VIDEO 8** **V 74**

Multiple sign supports are designed to operate correctly when either one or all of the supports within a 2100 mm radius are impacted. When only one support is impacted the remaining sign post should support the sign and prevent it from penetrating the windshield. The majority of support types approved for use within 2100 m or less of each other require the use of anchor pieces or frangible couplings. The base releases upon impact and the impacted support rotates up allowing the vehicle to pass underneath the sign. This requires that the post be cut, at least 2100 mm above the ground, to provide a hinge for rotation.	✓✓ Crash test of multiple mount showing support swinging up and over vehicle.
NARRATIVE	**VIDEO 8** **V 75**
Direct burial assemblies that are approved for use include dual 4.5 kg/m u-channel and dual 90 mm x 90 mm wooden posts that have been modified with two 38 mm holes placed at 100 mm and 460 mm above the ground line. Other than the above exceptions multiple mount sign supports require the use of anchor pieces, sleeves, slip bases or frangible couplings for acceptable impact performance.	* View of dual 90 mm x 90 mm wooden post installation.
NARRATIVE	**VIDEO 8** **V 76**

Frangible coupling designs are bolting assemblies designed to break, or fail, during an impact.	FRANGIBLE COUPLER DESIGNS (View of frangible coupler installation.)
NARRATIVE	**VIDEO 8** **V 77**
Frangible couplers are available, in both concrete footing and direct burial designs, for relatively small supports such as u-channel 76 mm to 114 mm round pipe, 76 mm to 127 mm square tube	@ View of u-channel frangible coupler system.
NARRATIVE	**VIDEO 8** **V 78**

and for wide flange and standard shapes.	* View of large frangible coupling system.
NARRATIVE	**VIDEO 8** **V 79**
Frangible couplings have a number of advantages to slip base designs. One advantage is that the critical torque requirements of the slip base bolts are eliminated by the use of frangible couplings. There are retrofit kits available, such as this from Transpo Industries, for wide flange and standard beam supports, that use the existing slip base anchor to convert to a frangible coupler design.	* View of retrofit kit being installed.
NARRATIVE	**VIDEO 8** **V 80**
Another advantage of the break-safe™ system is that the concrete base installations do not require a protruding stub. This decreases the probability of snagging the undercarriage of an impacting vehicle, and damage to the anchor system itself. The protruding stub is eliminated by bolting the frangible coupling into anchors placed in the concrete footing.	* View of flush base without assembly complete.
NARRATIVE	**VIDEO 8** **V 81**

Proper assembly requires that the anchors be accurately placed for each type of support system. Accurate anchor placement requires the use of an installation jig.	* View of crew using installation jig.
NARRATIVE	VIDEO 8 V 82
Another advantage of frangible and load concentration couplers is that they usually perform satisfactorily when struck from any directions.	* View of close up frangible coupler installation.
NARRATIVE	VIDEO 8 V 83
The concept behind multi-mount slip base designs and single slip bases is the same with two major exceptions.	MULTI-MOUNT SLIP BASES (Superimposed on a multi-mount slip base design.)
NARRATIVE	VIDEO 8 V 84

One exception is that the sign panel itself becomes a structural member supporting the upper part of the impacted post.	* View of impacted sign with panel holding ruined support.
NARRATIVE	VIDEO 8 V 85
The other exception is that large posts must be weakened or hinged about 2100 mm above the ground to permit swinging up and away from the impacting vehicle.	* View of hinge mechanism.
NARRATIVE	VIDEO 8 V 86
Manufacturers are developing devices that enable the use of heavier single support shapes while providing acceptable impact performance. Such as this slip base assembly for square tube supports, manufactured by Unistrut Corporation. This base is acceptable for three 64 mm x 64 mm supports within a 2100 mm path. The bottom subassembly is inserted into a 760 mm long anchor piece and placed in a 200 mm diameter, 760 mm deep concrete foundation, figure T8b.	* View of multiple support with square tube slip base.
NARRATIVE	VIDEO 8 V 87

Slip base designs for multiple sign supports are usually of horizontal design. Horizontal slip bases, when used in multiple sign support systems, only operate satisfactorily when impacted from one direction. Horizontal slip bases should not, therefore, be used for multiple sign support where there is a high probability of impacts from more than one direction.	* View of large horizontal slip base.
NARRATIVE	VIDEO 8 V 88
Hinges for large sign supports consist of three basic designs; 1) partially cut post with front friction plate, 2) completely cut post with front friction and rear hinge plate, and 3) completely cut post with weakened front plate and rear hinge plate.	@ * Isometric views of the three types.
NARRATIVE	VIDEO 8 V 89
The friction and rear hinge plates differ in thickness and hole design. The friction plate contains slotted holes. When the post is struck, the friction plate separates from the lower post through the slotted bolt holes as the rear flange or hinge plate bends.	@ View of friction and hinge plates with subtitles.
NARRATIVE	VIDEO 8 V 90

The partial cut design creates a maintenance problem since the post is destroyed and must be replaced after each impact. It is also more difficult to predict performance with the partial cut since the resistance of the hinge is dependent upon the post size and depth of cut.	@ * Side view of partial cut (preferably impacted).
NARRATIVE	VIDEO 8 V 91
Completely cutting through the post, and using a rear hinge plate, provides more predictable performance than the partially cut post design.	@ * Side view of total cut (preferably impacted).
NARRATIVE	VIDEO 8 V 92
Weakened front plate designs include shop fabricated and commercially available front plates. Weakened plate designs require that the post be completely cut and a hinge plate used. The shop fabricated plate requires drilling holes, centered on the cut line of the post, so that only 33% of the horizontal plate material remains.	@ * Isometric view of fabricated front plate.
NARRATIVE	VIDEO 8 V 93

Commercial front and hinge plates are also available such as these from Transpo Industries.	@ * Isometric view of commercial front plate.
NARRATIVE	**VIDEO 8** **V 94**
Proper performance of the hinge requires the correct selection of plate size, bolt size and torque. If the plate or bolt size are too small, or if insufficient torque is used, the hinge can separate due to environmental loads resulting in the upper portion of the supports and the sign falling down. If the plate or bolt sizes are too large, or too much torque is applied, the assembly can cause too much resistance upon impact.	@ * View of sign with upper portion blown over.
NARRATIVE	**VIDEO 8** **V 95**
The proper performance of traffic signs depends upon proper installation and maintenance. There is no more important component to increasing traffic safety than the work and efforts of the field crews. They must know the requirements for proper placement and operation of each sign installed.	* View of roadway with signs (closing music).

VIDEO STORYBOARD - 9
(Modules U, V, W and X)
CRASH TESTED LIGHT SUPPORTS, BREAKAWAY UTILITY POLES, CRASHWORTHY MAILBOX SUPPORTS, AND SAFETY CONSIDERATIONS WHEN DESIGNING AND LOCATING TRAFFIC SIGNAL SUPPORTS AND CONTROLLER BOXES

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✓ - indicates footage to be obtained from existing presentation quality video.
✓✓ - additional footage to be obtained from existing videos.
* - indicates footage to be obtained.
@ - indicates possible use of existing photographs.

NARRATIVE - CRASH TESTED LIGHT SUPPORTS	VIDEO 9 V 1

Narrative	Video
Roadway illumination is installed for a number of reasons, including enhancing roaduser safety, deterring crime, enhancing business activity and to establish a community image. Roadway illumination is usually provided by locating luminaires along the side of the road, in the median area, or offset from the roadway outside the clear zone. Breakaway devices should be used on all poles for which one is available, except for those installed on median barriers. Poles, which are not outside the clear zone but for which no breakaway device is available, must be shielded with appropriate barriers or crash cushions.	@ Video showing different types of illumination situations. CRASH TESTED LIGHT SUPPORTS
NARRATIVE	VIDEO 9 V 2
The luminaire support includes all structural hardware required to hold the support in place. This generally includes the following parts: - Pole - Mast arm - Foundation - Base - Towering device	@ Showing video of each part as they are mentioned. LUMINAIRE SUPPORT
NARRATIVE	VIDEO 9 V 3

Poles are available in a number of materials: - Steel - Aluminum - Stainless Steel - Fiberglass - Wood - Concrete	@ Show video of each type as they are identified. POLES
NARRATIVE	**VIDEO 9 V 4**
The purpose of the mast arm is to extend the luminaire over the edge of the roadway while permitting the pole to be placed at a distance from the roadway edge. Mast arms can be as short as 1 meter and as long as 9 meters. They can be installed with one arm per pole for roadside installations, or with two masts for median installations.	@ Showing both single and double mast arms. MAST ARM
NARRATIVE	**VIDEO 9 V 5**
There are numerous types of bases current in service. Some of these are designed for breakaway operation and others are not designed to yield. The most common base types are: - Direct Burial Base - Flange Base - Cast Aluminum Transformer-Base (T-base) - Flangible Couplings - Slip Base - Shear Base	@ Video of each type of base mentioned. BASES
NARRATIVE	**VIDEO 9 V 6**

NARRATIVE	VIDEO 9 V 7
The foundation for a luminaire pole must provide sufficient resistance to overturning moments caused by the static load of the mast arm plus a wind and/or an ice load. It must be capable of maintaining the correct alignment of the luminaire and able to withstand the impact should the pole be struck. For breakaway poles the foundation must be rigid enough to allow the breakaway device to operate while not becoming a hazard itself.	FOUNDATIONS
Historically, pole foundations have been poured-in-place concrete with steel reinforcing rods and anchor bolts.	Show Figure U5
Another type of foundation used by the States instead of concrete is the galvanized steel augerbase foundation. The augerbase foundation is an effective method of reducing the diameter of the foundation.	Show Figure U6

In addition to the pole itself having breakaway ability, it is recognized that the underground wiring system also be capable of properly separating. There are a number of reasons for requiring proper separation of the wiring system. One of these reasons is that the size, and associated tensile strength, of the wire cable is sufficient to significantly increase the deceleration rate of impacting vehicles and to also change the trajectory of the falling pole. Another reason is that improper separation of the electrical cable can result in bare conductors that are still energized, these posing an electrical and possible fire hazard at the accident scene.	@ Show video of wiring. BREAKAWAY WIRING SYSTEMS @ Show video of burned car.
NARRATIVE	**VIDEO 9** **V 8**
The FHWA Office of Engineering has issued acceptance letters to manufacturers of luminaire support systems which have been determined as acceptable in accord with the 1985 AASHTO specifications on sign and luminaire supports.	FHWA APPROVAL

NARRATIVE - BREAKAWAY UTILITY POLES	VIDEO 9 V 9
Fixed object collisions account for approximately 23 percent of all passenger vehicle accidents and one-third of all passenger car occupant fatalities. Utility poles are the second most frequently struck fixed object resulting in approximately 1500 to 2000 fatalities per year. In addition to fatalities it is estimated that 65,000 to 110,000 individuals are injured each year from utility pole collisions. Utility poles are massive fixed objects that are frequently placed relatively close to the traveled way. Over 50 percent of all injury, single vehicle and run-off-road accident, involve a utility pole.	(✓) and (@) and (*) Show pole locations that look dangerous. BREAKAWAY UTILITY POLES

NARRATIVE	VIDEO 9 V 10
Corrective action to reduce both the frequency and severity of utility pole accidents include: - Increasing the lateral separation between poles and traffic flows. - Placing the utilities underground. - Using crash attenuators or longitudinal barriers to shield the pole. - Improve roadway alignment, surface resistance, delineation, or improve pole location.	

NARRATIVE	VIDEO 9 V 11
Constraints associated with these countermeasures resulted in efforts to develop a forgiving utility pole, or one that will become breakaway when struck. The first system successfully crash tested was the HAWKINS BREAKAWAY System (HBS). The HBS consisted of a lower shear connection and a upper hinge connection. Two cables were connected to the adjacent poles to prevent the pole from dropping to the ground after impact.	✓✓ Show crash testing of the system. (*) or (@) Show HBS installed. HAWKINS BREAKAWAY SYSTEM (HBS)

NARRATIVE	VIDEO 9 V 12
This system was later modified and is marketed as the AD-IV. The goal of the AD-IV was to reduce cost and improve performance. Three areas of concern were investigated. They were: 1. The circular slip base design; 2. The steel straps in the upper connection, and 3. The high repeated wind loads.	1. SLIP BASE DESIGN 2. STEEL STRAPS 3. WIND LOADS

NARRATIVE	VIDEO 9 V 13
To address these concerns, the following changes were made to the HBS. - The slip plates were changed from round to square and 4 bolts instead of 6 were used; - The straps were changed to reduce tolerances at installation, and - Wind bolts to provide initial bending resistance.	Show slip plates. Show straps. Show wind bolts.
NARRATIVE	VIDEO 9 V 14

Identifying specific locations where utility poles present high hazard requires an investigation of accidents, site review and input from local agency personnel. Single poles, or a number of adjacent poles, struck more than once in a five year period are candidates for breakaway installation. A combination of site characteristics have been determined to have an increased potential for utility pole accidents. Roadways with posted speeds of 50 to 65 km/h and widths of 9 to 15 meters often have a high utility pole accident frequency. But it should be noted that accident severity is greater in rural areas than in urban due to higher impact speeds. Accident severity can be decreased at high accident potential sites by the installation of breakaway poles only if suitable site characteristics exist. This includes a clear recovery area to reduce the probability of secondary collisions. Also poles which carry transformers, or attached to service lines over the roadway or which have heavy guy wires should not be replaced with a breakaway utility pole. It is the policy of the FHWA to encourage the use of breakaway utility poles only at sites which are suitable for proper performance and where pole activation will not create on increased hazard to other motorists or pedestrians.	
NARRATIVE - CRASHWORTHY MAILBOX SUPPORTS	**VIDEO 9** **V 15**

Mailboxes are fixed objects placed within the highway right-of-way that presents a unique highway safety problem. The problem is unique because the highway agency often has little or no regulatory control over the type of mailbox installed or its placement along the roadway.	(@) and (*) and (✓) Different locations of mailbox installations. CRASHWORTHY MAILBOX SUPPORTS
NARRATIVE	VIDEO 9 V 16
Mailboxes are typically installed and maintained by the property owner who often considers the mailbox as an extension of their home. The result is masonry, field plows, railroad rail and ties, filled barrels and other massive devices used as mailbox supports. These all present a sever roadside hazard.	(✓) or (*) or (@) Different types of substandard mailbox supports.
NARRATIVE	VIDEO 9 V 17
Proper placement of mailboxes requires careful consideration to the safety and convenience of the postal service, postal patrons and the general traffic stream. As a general rule it is desirable to move the boxes as far away from the roadway edge as practical and to reduce the number of mailbox locations.	(✓) or (*) or (@) Showing boxes a long ways away from the roadway edge and many boxes together.
NARRATIVE	VIDEO 9 V 18

Careful consideration must be given to the placement of mailboxes in the vicinity of intersections. Potential problems with intersection locations are related to sight restrictions and intersection operations. At intersections controlled by stop signs, vehicles which are stopped at a near side mailbox can pose sight restrictions between vehicles on the approaches.	(✓) or (*) or (@) Show mailbox locations at intersections.
NARRATIVE	**VIDEO 9** **V 19**
Mailbox heights are usually at 1065 mm to 1220 mm above the surface to permit easy access from a vehicle.	(✓) or (*) or (@) Showing a vehicle and a mailbox.
NARRATIVE	**VIDEO 9** **V 20**
On high volume, high speed roadway, a 3.1 m to 3.7 m set back to the mailbox is recommended. A paved turnout, at least 3.1 m wide, should be provided on high volume, high speed roadways, when a comparable wide paved shoulder does not exist. In all cases the roadside face of the mailbox should be set 200 mm to 300 mm outside the all weather surface of the shoulder or turnout to provide space for opening the mailbox door and for vehicle clearance. Surface of the shoulder or turnout to provide space for opening the mailbox door and for vehicle clearance.	(✓) or (*) or (@) Showing pullouts.
NARRATIVE	**VIDEO 9** **V 21**

The mailbox should be of light sheet metal or plastic construction. The use of homemade boxes or boxes of heavy construction are not approved for use since they increase the chance of protrusion into the passenger compartment upon impact. To further reduce the chance of intrusion, the post to box attachment details should be of sufficient strength to prevent the box from separating from the post.	(✓) or (*) or (@) Show different types of mailboxes approved and unapproved.
NARRATIVE	VIDEO 9 V 22
Single 90 mm x 90 mm and 115 mm diameter wooden or a metal post with a strength no greater than 50 mm standard steel pipe are acceptable for use as mailbox supports. The supports should not be embedded more than 610 mm into the ground. If an anti-trust device is used for the round steel support, it should be embedded more than 250 mm below the ground surface. When more than 1 post is installed, the minimum spacing between the centers of the support posts should be ¾ the height of the posts above the groundline.	* Video showing the different posts. SINGLE AND DOUBLE WOOD AND ROUND TUBE SUPPORTS (*) or (@) Show post spacing.
NARRATIVE	VIDEO 9 V 23
A bracket is used for both the wooden and tubular support to fasten the platform onto the post. For single box installations the mailbox is fastened directly on the platform. For double box installations, the mailboxes are mounted on a shelf, and the shelf is mounted on the platform.	* Show the component of connecting to a post.
NARRATIVE	VIDEO 9 V 24

Many multiple mailbox supports have been constructed by supporting a horizontal member, usually a timber plank, with two or more posts. When struck, these horizontal members can enter the passenger compartment and decapitate or impale motorists. Mailbox installations that uses a horizontal member should be removed and replaced with an approved multiple mailbox support.	✓ Show multiple mailboxes on a single horizontal member. @ Show approved multiple mailbox support.
NARRATIVE	**VIDEO 9** **V 25**
The Minnesota Department of Transportation has designed a swing-away mailbox that has been tested for use with a single mailbox assembly. The Minnesota mailbox support uses a cantilevered arm for attachment of the mailbox assembly. The cantilever design is used to permit snow plowing operation without damaging the mailbox support.	✓ Show the Minnesota system

NARRATIVE - SAFETY CONSIDERATIONS WHEN DESIGNING AND LOCATING TRAFFIC SIGNAL SUPPORTS AND CONTROLLER BOXES	VIDEO 9 V 26
The decision to install a traffic signal should be based on established warrants. These warrants are guantitative guidelines that help the traffic engineer determine if the benefits to be obtained by signal installation outweigh the disadvantage. The objective of the installation phase is to provide signal head visibility while not creating an undue safety hazard due to the placement of the signal poles and controllers.	(@) and (*) Show signals and controller locations. SAFETY CONSIDERATIONS WHEN DESIGNING AND LOCATING TRAFFIC SIGNAL SUPPORTS AND CONTROLLER BOXES
NARRATIVE	**VIDEO 9 V 27**
The requirements of the MUTCD place emphasis on enabling drivers to determine the right-of-way assignment. Sections 4B-12 and 4B-13 of the MUTCD provide the requirements for signal face placement. Attaining the proper signal face placement while reducing the potential for errant vehicle impacts with the signal support poles and controller cabinet requires consideration of the following factors: - Type of signal installed - Motorist Safety - Maintenance Cost - Maintenance Crew Safety - Future Upgrade Costs	(@) and (*) Show the cover of the MUTCD. Show different signal face placement.

NARRATIVE	VIDEO 9 V 28
Traffic signal supports are not designed with any breakaway features. This is because of the hazard that a fallen pole would create to the remaining intersection motorists as well as the potential hazard created by the temporary loss of full signalization at the intersection Because the signal support is not designed with a breakaway support, its location along the highway is important in addressing highway safety. On high speed facilities, traffic signals should have their supports placed as far away from the roadway as possible. In some cases when the support is in the clear zone, some type of shielding may be considered.	(@) and (*) Show different signal pole bases. Show signals on high speed facilities, Show some with barrier.

NARRATIVE	VIDEO 9 V 29
Signal installations on roadways with curbs should have a minimum distance of not less than 610 mm from the face of the curb. At locations where there is no curb, the signal poles should have a minimum horizontal clearance of 3050 mm from the edge of the traffic lane or 610 mm from the edge of the shoulder, which ever is greater. The further the support poles are placed from roadway, the smaller is the probability of both impacts and damage due to large trucks sideswiping the pole while turning.	(@) and (*) Show Figure X2 Show Figure X3 Show some poles at intersections.

NARRATIVE	VIDEO 9 V 30
When pedestrians are present, the placement of the pole should not interfere with their movements. The presence of pedestrians usually precludes the shielding of the pole. If the pole is evaluated to be a hazard to the motoring public, then it should be moved outside the clear zone by using a special designed.	(@) and (*) Show pole location with a sidewalk.

NARRATIVE	VIDEO 9 V 31
The size of the controller cabinet varies depending upon the manufacturer and whether the system is pretimed or actuated. The cabinet should be located in a position which minimizes the probability of being impacted by an errant vehicle. When ground mounted, it should be at least four feet from the nearest edge of pavement of curb face. The foundation base should not be higher than 100 mm to prevent vehicle snagging.	(@) or (*) Show controller cabinet locations.
If pedestrians are present, the placement of the cabinet should not hinder their movement.	Show controller cabinet location with respect to sidewalks.
Also, the placement of the cabinet should take into account the safety of the maintenance workers, as well as giving them unrestricted view of the signal heads while working at the controller cabinet.	Show cabinet locations with maintenance workers.

NARRATIVE	VIDEO 9 V 32
Considering probable future improvements at the time of initial signalization can save construction costs. Areas undergoing rapid development from rural to urban/suburban are often equipped with traffic signals prior to the roadway geometric improvements. Placing the signal supports and controller in a location that is correct for the planned future geometrics will eliminate the need for pole relocation. In many cases this is not done and support poles are not relocated during construction. The result is a newly constructed intersection with signal support poles located closer than the minimum recommended distance.	(@) and (*) Show signals where the road has been widened. Some good locations and some bad locations.

NARRATIVE	VIDEO 9 V 33
When it comes to railroad warning devices, the highway agency has the responsibility to cooperatively work with the railroad to determine the proper location. The highway agencies responsibility should include ensuring that no sight restrictions between motorists and approaching trains exist on both the approach and at the stop bar, and that the traffic control devices are properly located. Longitudinal barriers are sometimes not used to shield active railroad warning devices because there is insufficient space for proper downstream end treatment. If the downstream end of the barrier is outside of the clear zone for the opposing traffic, then the installation of a barrier would be appropriate. If it is determined that the warning devices should be shielded, and longitudinal barriers are not practical, then crash cushions should be considered.	(@) and (*) Show video of good sight distances. Show signals with and without barriers and some with crash cushions.

VIDEO STORYBOARD - 10
(Modules Y, Z and AA)
INTRODUCTION TO TRAVERSABLE TERRAIN FEATURES,
TRAVERSABLE AND NON-TRAVERSABLE DITCHES AND BACKSLOPES
AND
TRAVERSABLE AND NONTRAVERSABLE DRAINAGE FEATURES

Left column is narration, - right column describes video scene.
Captions for video footage are in caps and are boxed.

Material in parenthesis ( ) is comment or explanation.
Material in brackets [ ] identifies existing video footage.
✓ - indicates footage to be obtained from existing presentation quality video.
✓✓ - additional footage to be obtained from existing videos.
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NARRATIVE - INTRODUCTION TO TRAVERSABLE TERRAIN FEATURES	VIDEO 10 V 1

The American Association of State Highway and Transportation Official (AASHTO) has played a notable role in the formation of highway design standards. A report of the Special AASHTO Traffic Safety Committee entitled "Highway Design and Operational Practices Related to Highway Safety," known as the "Yellow Book," was approved by the Executive Committee of AASHTO in 1966. A revised version was issued in 1974. The reports stressed identification of design and operational features which can be improved to increase safety. Emphasis was given to removing roadside hazards, providing flatter slopes, providing wider medians, breakaway supports for signs and lighting, improved guardrail and barrier designs, attenuation devices, improved signing and marking and skid resistance surfaces. The yellow book first introduced the concept of a 9 m clear zone. This distance was based on a study which indicated that a width of 9 m or more from the edge of traveled way permitted about 80 percent of vehicles leaving a roadway to recover.	INTRODUCTION TO TRAVERSABLE TERRAIN FEATURES
NARRATIVE	**VIDEO 10** V 2
The 9 m clear zone was modified by the 1977 AASHTO "Guide for Selecting, Locating and Designing Traffic Barriers." This publication introduced a variable clear zone concept based on traffic volumes, speeds, and roadside geometry.	* Show cover of 1977 Guide and the curves showing the variable clear zone curves.
NARRATIVE	**VIDEO 10** V 3

This variable clear zone concept was carried into the 1988 "Roadside Design Guide."	Show cover of the 1988 Roadside Design Guide and clear zone curve and chart.
NARRATIVE	**VIDEO 10** **V 4**
The term "clear zone" refers to the desirable unobstructed area available for the recovery of vehicles that have left the traveled way. When there are obstructions that cannot be removed, then engineering judgment must be used to determine if the obstruction should be shielded by a longitudinal barrier or a crash cushion. A barrier should only be installed, however, if it is clear that an impact resulting from a vehicle striking the barrier will be less severe than the accident resulting from striking the unshielded object. Installation of barriers and crash cushions often results in increased accident frequency.	CLEAR ZONE CONCEPT
NARRATIVE	**VIDEO 10** **V 5**

The characteristics of the roadside terrain have a direct impact on a driver's ability to maintain control of a vehicle after it leaves the roadway. Since the type and rate of slope of embankments affects vehicle control and occupant safety, an understanding of embankments is necessary to apply the clear zone concepts.	ROADSIDE TERRAIN FEATURES
NARRATIVE	**VIDEO 10** **V 6**
If the roadway was constructed by building up or filling, the resultant embankment is termed foreslope, fill slope, or negative slope. All three terms indicated that the embankment slopes away from an elevated roadway.	Show Figure Y1
NARRATIVE	**VIDEO 10** **V 7**
When the roadway was constructed by removing material or cutting, the resulting embankment is termed a backslope, cut slope or positive slope. All three terms indicate that the embankment slopes toward a depressed roadway. It should be pointed out that the clear zone starts at the edge of the traveled way.	Show Figure Y2
NARRATIVE	**VIDEO 10** **V 8**

Embankments that are parallel to the travelled way are classified as recoverable, non-recoverable, or critical.	PARALLEL SLOPE EMBANKMENTS
NARRATIVE	**VIDEO 10** **V 9**
Motorists who enter a recoverable slope, which is 1:4 or flatter, can generally stop their vehicle or slow them enough to return to the roadway.	RECOVERABLE SLOPE
NARRATIVE	**VIDEO 10** **V 10**
Motorists who enter a non-recoverable slope, which is between 1:4 and 1:3, are generally able to slow and stop safely, but unable to return to the roadway. It is expected the vehicle will reach the bottom of the slope, thus a clear runout area at the base is desirable.	NON-RECOVERABLE SLOPE
NARRATIVE	**VIDEO 10** **V 11**

Narrative	Video
Vehicles entering a critical slope, which is steeper than 1:3, could overturn. If the critical slope falls within the clear zone, barrier may be required if the slope cannot be flattened.	CRITICAL SLOPE
NARRATIVE	**VIDEO 10** **V 12**
For median crossovers, the side slopes should be 1:10. For intersecting roadways or driveways, the desirable side slope should be 1:10. In most cases this slope is not achievable due to width restrictions and maintenance problems associated with drainage pipe. The maximum slope at these locations is 1:6. A flatter slope is preferred. Intersecting slopes steeper than 1:6 may be considered for urban areas or for low speed routes.	INTERSECTING EMBANKMENTS (CROSS SLOPES)
NARRATIVE	**VIDEO 10** **V 13**
Proper application of the clear zone concept with regard to fixed objects requires consideration to the following:	APPLYING THE CLEAR ZONE CONCEPT FOR FIXED OBJECTS
NARRATIVE	**VIDEO 10** **V 14**

Values of the desirable clear zone are not intended to be absolute values. The values are based on limited test data that have been expanded to include a range of speed, volume and roadside conditions.	• **VALUES OF THE DESIRABLE CLEAR ZONE ARE NOT INTENDED TO BE ABSOLUTE VALUES.**
NARRATIVE	VIDEO V 15
Correct application of the clear zone concept often results in more than one possible solution. An economic analysis can be used to determine if a fixed object should be removed, relocated, modified, shielded or if no treatment is required.	• VALUES OF THE DESIRABLE CLEAR ZONE ARE NOT INTENDED TO BE ABSOLUTE VALUES. • **CORRECT APPLICATION OF THE CLEAR ZONE CONCEPT OFTEN RESULTS IN MORE THAN ONE POSSIBLE SOLUTION.**
NARRATIVE	VIDEO 10 V 16
When a clear zone distance is determined as required, then no solid fixed objects should be allowed to remain unshielded.	• VALUES OF THE DESIRABLE CLEAR ZONE ARE NOT INTENDED TO BE ABSOLUTE VALUES. • CORRECT APPLICATION OF THE CLEAR ZONE CONCEPT OFTEN RESULTS IN MORE THAN ONE POSSIBLE SOLUTION. • **WHEN A CLEAR ZONE DISTANCE IS DETERMINED AS REQUIRED, THEN NO SOLID FIXED OBJECTS SHOULD BE ALLOWED TO REMAIN UNSHIELDED.**

NARRATIVE	VIDEO 10 V 17
Barriers are themselves fixed objects. Barriers should be installed only if it is clear that a vehicle striking the barrier will be less severe then the accident resulting from hitting the unshielded object.	• VALUES OF THE DESIRABLE CLEAR ZONE ARE NOT INTENDED TO BE ABSOLUTE VALUES. • CORRECT APPLICATION OF THE CLEAR ZONE CONCEPT OFTEN RESULTS IN MORE THAN ONE POSSIBLE SOLUTION. • WHEN A CLEAR ZONE DISTANCE IS DETERMINED AS REQUIRED, THEN NO SOLID FIXED OBJECTS SHOULD BE ALLOWED TO REMAIN UNSHIELDED. • **BARRIERS ARE THEMSELVES FIXED OBJECTS.**

NARRATIVE	VIDEO 10 V 18
The clear zone guidelines are most applicable on new or major reconstruction projects. For resurfacing, rehabilitation, or restoration (RRR) projects, the state should use these guidelines to establish state standards.	• VALUES OF THE DESIRABLE CLEAR ZONE ARE NOT INTENDED TO BE ABSOLUTE VALUES. • CORRECT APPLICATION OF THE CLEAR ZONE CONCEPT OFTEN RESULTS IN MORE THAN ONE POSSIBLE SOLUTION. • WHEN A CLEAR ZONE DISTANCE IS DETERMINED AS REQUIRED, THEN NO SOLID FIXED OBJECTS SHOULD BE ALLOWED TO REMAIN UNSHIELDED. • BARRIERS ARE THEMSELVES FIXED OBJECTS. • **THE CLEAR ZONE GUIDELINES ARE MOST APPLICABLE ON NEW OR MAJOR RECONSTRUCTION PROJECTS.**

NARRATIVE - TRAVERSABLE AND NON-TRAVERSABLE DITCHES AND BACKSLOPES	VIDEO 10 V 19
Ditches are present on the majority of rural roadsides. Their primary function is to collect and distribute the roadway surface water away from the roadway. Ditches also need to be designed and maintained with consideration to their effect on roadside safety.	(@) and (*) Showing a variety of ditches. TRAVERSABLE AND NON-TRAVERSABLE DITCHES AND BACKSLOPES
NARRATIVE	**VIDEO 10 V 20**
Typical ditches can be classified by whether they are designed with abrupt or gradual slope changes. Abrupt slope change designs include vee ditches, rounded ditches with a bottom width less than 2400 mm and trapezoidal ditches with bottom width less than 1200 mm.	Show Figure Z1
NARRATIVE	**VIDEO 10 V 21**
Gradual slope change ditches include rounded ditches with bottom widths of 2400 mm or more and trapezoidal ditches with bottom widths equal to greater than 1200 mm.	Show Figure Z2

NARRATIVE	VIDEO 10 V 22
Vehicles leaving the roadside and encroaching on a ditch faces three hazards. The first is the foreslopes or front slope.	• **FORESLOPES OR FRONT SLOPE.**

NARRATIVE	VIDEO 10 V 23
The second is the ditch bottom.	• FORESLOPES OR FRONT SLOPE. • **DITCH BOTTOM**

NARRATIVE	VIDEO 10 V 24
The third is the backslope.	• FORESLOPES OR FRONT SLOPE. • DITCH BOTTOM • **BACKSLOPE**

NARRATIVE	VIDEO 10 V 25
Ditches can be evaluated using this figure for abrupt slope changes or	Show Figure Z3
NARRATIVE	**VIDEO 10 V 26**
this one for gradual slope changes. If the ditch section falls inside the shaded area, the ditch is considered traversable. If the ditch section falls outside the shaded area, the ditch is considered non-traversable. As a general rule, non-traversable slopes should be beyond the clear zone, reshaped, converted to a closed system with a culvert or pipe, or in some cases shielded with a traffic barrier.	Show Figure Z4
NARRATIVE	**VIDEO 10 V 27**
Ditches, both abrupt and gradual slope designs, can funnel a vehicle along the ditch bottom. This increases the probability of impact with any fixed objects present on the front slope or ditch bottom. Therefore, nonyielding fixed objects should not be located on ditch front slopes or ditch bottoms.	(@) or (*) Showing ditches with fixed objects on the front slope or ditch bottoms.

NARRATIVE - TRAVERSABLE AND NONTRAVERSABLE DRAINAGE FEATURES	VIDEO 10 V 28
Adequate drainage facilities are required to channel water away from the roadway to prevent damage to the road bed and surface ponding. In addition to hydraulic concerns, drainage features must be designed with proper consideration to their consequences on roadside safety. The drainage features that will be covered are curbs, pipes and culverts, headwalls, and drop inlets.	(@) and (*) Different drainage features. TRAVERSABLE AND NONTRAVERSABLE DRAINAGE FEATURES
NARRATIVE	**VIDEO 10 V 29**
When dealing with drainage features, the following alternatives in order of preference are applicable: - Eliminate any drainage structures that are not necessary. - Design or modify drainage features so that they minimize the hazard to an errant vehicle. - If a necessary drainage feature cannot be designed safely or relocated, then it should be shielded by a suitable traffic barrier if it presents a hazard to vehicles.	• ELIMINATE • DESIGN OR MODIFY • SHIELD
NARRATIVE	**VIDEO 10 V 30**

Curbs are often believed to have the sole purpose of separating the roadway from the roadside. Curbs are also installed to reduce maintenance operations, provide pavement edge support, and to assist in drainage control. Curbs are usually used on urban roadways. Their use on high speed and rural highways should be avoided if at all possible.	(@) or (*) Show different types of curbs. CURBS
NARRATIVE	**VIDEO 10** **V 31**
Curbs are classified as barrier or mountable. Barrier curbs are relatively high and steep faced and are intended to inhibit vehicles from leaving the roadway. They are usually 150 mm or more in height. Mountable curbs are designed so that vehicles can easily cross them, and are not higher than 150 mm. The slope of the face will dictate the height.	(@) or (*) Show barrier and mountable curbs.
NARRATIVE	**VIDEO 10** **V 32**
Neither type of curbs should be installed on roadways where the design speed exceeds 65 km/h. When impacted at high speeds, curbs do not prevent a vehicle from leaving the roadway. Curbs can cause vehicle rollover if impacted while the vehicle is spinning or slipping sideways. Due to vehicle instability when a curb is struck, curbs with a height of 100 mm or less should be used when barrier is present. The curb should be placed flush with the face of the barrier or behind it.	Showing a vehicle striking a curb.
NARRATIVE	**VIDEO 10** **V 33**

On-roadway drainage inlets are usually located near or on the curb or shoulder of the roadway. Different types of on-roadway drainage inlets include grated inlets, curb opening inlets, slotted drain inlets or a combination of these. Proper designing on-road inlets requires: - They pose no hazard to errant motorists. - Surface inlets must be capable of supporting vehicle wheel loads and present no obstacle to pedestrian and bicycle traffic. - There are trade offs involved in the loss of hydraulic efficiency versus increase in safety.	(@) or (*) Different types of inlets. ON-ROADWAY DRAINAGE INLETS
NARRATIVE	**VIDEO 10** **V 34**
Off-road drop inlets are designed to collect runoff and are often located in roadside or median ditches. Their hazard to errant motorists can be minimized by constructing them flush with the ditch bottom or slope on which they are located. When located on a slope, the slope should not be steeper than 1.6.	(@) or (*) Show off-roadway acceptable designs or installations. OFF-ROAD DROP INLETS
NARRATIVE	**VIDEO 10** **V 35**

NARRATIVE	VIDEO 10 V 36
Cross drainage structures are designed to carry water underneath and perpendicular to the roadway. These structures can pose a hazard to errant motorists due to the design of the headwall or wingwall or the drainage opening itself. The alternative that can be taken to minimize these hazards include: - Installing a transversable design. - Moving the drainage structure away from the travelled way. - Shielding the structure.	(@) and (*) Showing the different types of systems. CROSS DRAINAGE FEATURES

NARRATIVE	VIDEO 10 V 37
The inlets and outlets of cross drainage structures can generally be located on foreslopes that are 1:3 or flatter. Matching the drainage structure to the slope of the embankment is all that is required when the slope is 1:3 or flatter and the culvert has a diameter of 915 mm or less. Culverts with a diameter greater than 915 mm can be made traversable by using grates or pipes to reduce the clear opening. The pipes should be installed so as to reduce any spacing to a maximum of 760 mm. The safety pipes for cross drainage structures should run from top to bottom of the drainage structure. This will orientate the safety pipes so that an errant vehicle, travelling parallel to the roadway, will have its wheel travel from pipe to pipe and not fall between adjacent safety pipes.	(@) and (*) Showing systems with beveled culverts and culverts with bars to make them traversable.

Extending beyond the clear zone a cross drainage structure whose inlet or outlet cannot be made traversable can reduce the possibility of the pipe end being impacted. The possibility still exists that the pipe end can be impacted by an errant vehicle. Also, if any other parts of the drainage system such as a headwall still remains in the clear zone after its extension, then the extension is not feasible and should not be done. Redesigning the inlet/outlet so that it is traversable is the preferred treatment. If this cannot be done, and extending is not the solution, then the drainage feature should be shielded.	(@) and (*) Showing the system with the pipe end extended and systems where pipe end have been extended and headwalls still remain.
NARRATIVE	**VIDEO 10** **V 38**
Shielding with an appropriate traffic barrier can often be the most effective method of decreasing accident severity. If the pipe is buried deep enough, then the standard strong post guardrail can be used. In many cases, this is not possible, so a modified strong post system can be used. Two such systems have been developed to provide a clear span of 3.81 m or 5.72 m. In both of these cases, a nested W-beam is used.	(@) and (*) Show installations using the standard post systems, and wide post systems. Show Figures AA9 and AA10.
NARRATIVE	**VIDEO 10** **V 39**

Parallel drainage culverts are those which continue the flow of parallel ditches under driveways, intersecting roadways and median crossovers. Parallel drainage features present a significant safety hazard because they can be struck head on by impacting vehicles. Effective treatments for improving the safety of these drainage features, in order of preference, are: - Eliminate the structure. - Installing a traversable design. - Move the structure away from the travelled way. - Shield the structure.	(@) and (*) Video of Parallel Drainage Structures. PARALLEL DRAINAGE STRUCTURES
NARRATIVE	**VIDEO 10** **V 40**
Eliminating parallel drainage structures is the preferred choice for increasing roadside safety. This can be accomplished by converting an open ditch to a storm drain. This treatment eliminates the embankments and ditch bottom as well as the pipe inlets and outlets. When eliminating is not possible, then	(@) and (*) Show closed systems.

NARRATIVE	VIDEO 10 V 41
the structure should be made traversable. When considering a traversable design, it is important that the embankment slopes be the flattest as possible. Cross slopes of 1:6 or flatter are suggested, with 1:10 being desirable. Pipes with a diameter of 610 mm or less and the ends tapered to the cross slope are considered traversable. Pipes with a diameter greater than 610 mm can be made traversable by installing a grate or, normal to traffic, safety pipes or bars spaced 610 mm on center. Some commercial safety slope end sections are available to make the pipe end traversable.	(@) or (*) Show beveled pipes, and pipes with grates and safety bars.

NARRATIVE	VIDEO 10 V 42
Where it is possible, the parallel drainage structure should be relocated away from the main roadway and down the intersecting road or driveway. Now the drainage system can be treated as a cross drainage feature for the intersecting road and shouldn't interfere with an errant vehicle from the main roadway.	(@) and (*) Pipes moved away from the main roadway and down the intersecting road.

NARRATIVE	VIDEO 10 V 43
Shielding the obstacle with a traffic barrier may be necessary when the parallel drainage structure cannot be made traversable, cannot be relocated or eliminated, or is too large to be treated effectively.	(@) or (*) Parallel drainage structure shielded with barrier.

NARRATIVE	VIDEO 10 V 44
Many factors that adversely affect the safety and water removal performance of drainage structures can be identified during routine maintenance. Factors that should be addressed during routine maintenance are the condition of the pipe and any safety pipes. The pipe opening should be checked for debris buildup and erosion. If a barrier is used to shield the drainage structure, this should be checked or evaluated to see if the barrier is needed, or if the barrier is to standard. For these problems that can be corrected during a maintenance operation, they should be corrected. If the work is beyond what is considered normal maintenance work, the corrections should be considered in an upcoming project.	MAINTENANCE