

**Section 3-02**  
**Cross Sectional Elements**

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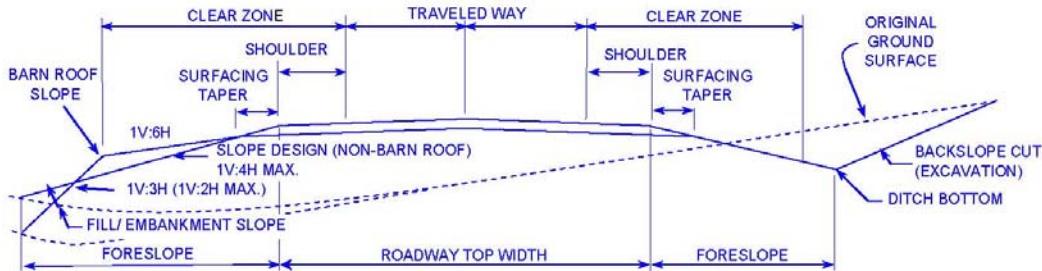
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## INTRODUCTION

**General:** Use the following criteria for the design of roadway cross-sectional elements. Exhibit 1 shows the cross-sectional elements of a typical roadway section.



**EXHIBIT 1**  
CROSS-SECTIONAL ELEMENTS

## CROSS-SECTIONAL ELEMENTS

**Traveled Way:** The portion of the roadway for the movement of vehicles, exclusive of shoulders.

**Shoulder:** The top surface of roadway beyond the traveled way that provides for emergency parking and as part of the recovery area for errant vehicles. See section on LANE AND SHOULDER WIDTH.

**Surfacing Taper:** The area where the thickness of the surfacing materials (including pavement and base) transitions from full depth to zero. Surfacing taper slopes are relative to the pavement slope and are included as part of the foreslope. See section on SURFACING TAPER.

**Grading Slope:** Designation of fill (embankment) and cut (excavation) slopes are relative to the vertical and horizontal and should be delineated as: 1V:4H, etc.

**Foreslope:** An embankment slope or the portion of a cut section sloping down and away from the roadway toward the ditch bottom or toe of slope. The foreslope in a fill section begins at the top outside edge of the surfaced shoulder and includes the combination of surfacing tapers and earthwork fill slope (barn roof or non-barn slope) to the existing terrain. The foreslope in a cut section also begins at the top outside edge of the surfaced shoulder and includes the combination of surfacing tapers and earthwork cut slope to the ditch bottom.

**Backslope (Cut Slope):** The portion of a cut (backslope) extending from the ditch bottom outward and upward until it catches the existing terrain.

**Embankment Slope (Fill Slope):** The fill slope beyond the surfacing taper that extends from the roadway earth grade outward and down until it catches the existing terrain.

**Clear Zone:** The area free of hazardous objects and slopes on each side of the traveled way for each direction of travel. It is intended to improve the chances of a safe recovery for errant vehicles.

**Barn Roof Slope:** A 1V:6H fixed slope within the clear zone that is followed by variable steeper slopes to existing terrain.

### **EMBANKMENT SLOPES**

**Recoverable Slope:** A slope on which a vehicle can either stop or safely return to the roadway. Recoverable slopes are 1V:4H or flatter and can be included as part of the specified clear zone width.

**Non-Recoverable Slope:** A slope that a vehicle can traverse, but it is generally too steep to allow the vehicle to stop or return to the roadway. Traversable non-recoverable slopes are between 1V:4H and 1V:3H.

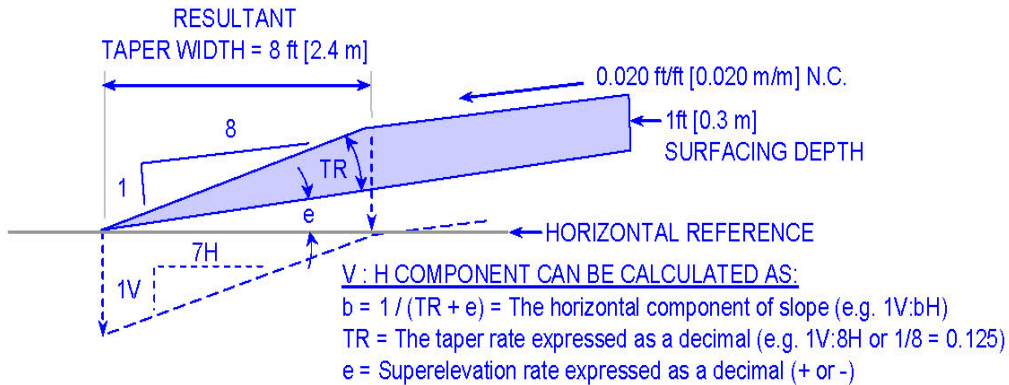
**Critical Slope:** A slope that is considered severe enough to possibly cause a vehicle to overturn. It is steeper than 1V:3H.

### **LANE AND SHOULDER WIDTH**

The roadway width, number of lanes, and shoulder width are determined in accordance with AASHTO standards on the basis of the highway's functional classification, design speed, traffic volumes, level of service desired, and make-up of the traffic. Typically a 12 ft [3.6 m] lane width is used.

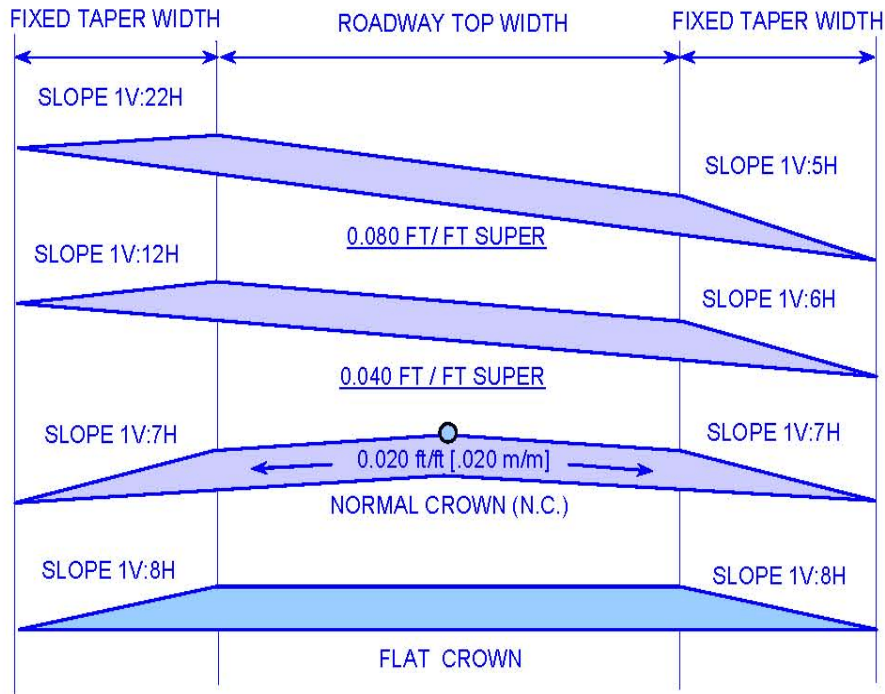
### **SURFACING TAPERS**

**General:** The surfacing taper extends from the outside edge of the full depth surfaced shoulder and extends out and away from the roadway until the entire depth of surfacing materials have been transitioned to zero depth, which is typically the hinge point for the earthgrade template. The distance is fixed to the earthgrade template hinge points so that the surfacing tapers are set at a fixed distance from the shoulder and are free to rotate with the earthgrade template when rotated into and out of normal crown and superelevation. The width of the surfacing taper is calculated based on an assumption of a defined slope for the taper applied on a flat template (no crown) and multiplied by the depth of surfacing materials. Previous design policies applied only one slope to the surfacing taper, typically a 1:8. Exhibits 2 and 3 shows the effective slopes for a 1:8 taper as the template is rotated into normal crown and superelevation.



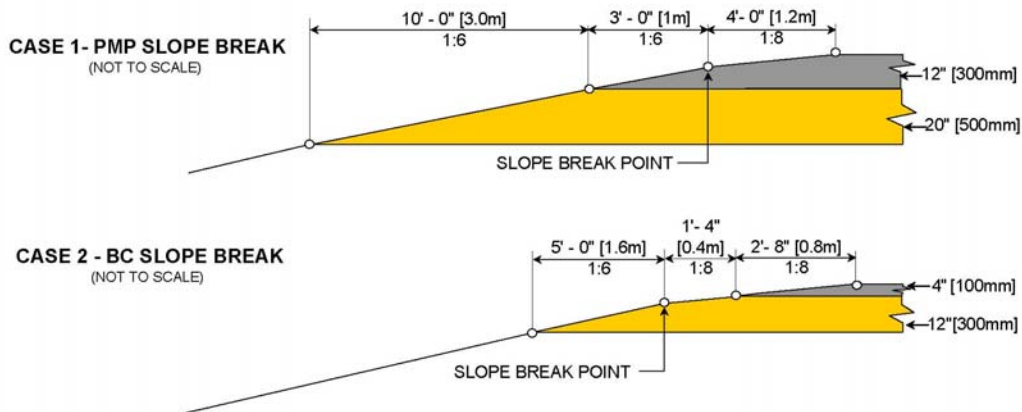
TAPER WIDTH = SURFACING DEPTH X 1:8 TAPER SLOPE = 1ft [0.3 m] X 8 = 8 ft [2.4 m].  
TAPER WIDTHS ARE FIXED AND DO NOT CHANGE WITH SUPERELEVATION ROTATION.  
TAPER SLOPES ARE RELATIVE TO THE PAVEMENT TOP AND ROTATE WITH SUPERELEVATION.

**EXHIBIT 2**  
 EXAMPLE OF TAPER SLOPE AND WIDTH



**EXHIBIT 3**  
 EFFECT OF SUPERELEVATION ON TAPER SLOPE

**Multiple Surfacing Tapers:** Design policies may require a two slope component to the surfacing taper. The first slope is typically fixed at 4 ft [1.2 m] and is assumed to be a 1:8. The final width of the next component of the surfacing taper is calculated based on transitioning out the remaining depth of surfacing materials on a 1:6. For plant mix pavements, this gets even more complicated since the zero depth edge of the plant mix pavement may fall either in the first or second surfacing taper depending on depth. This phenomenon is demonstrated in Exhibit 4.



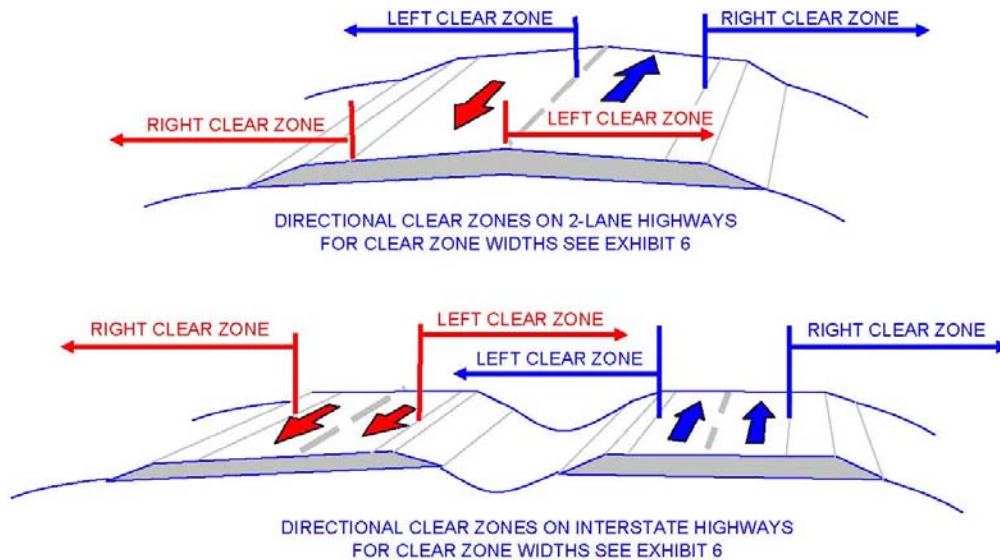
**EXHIBIT 4**  
TWO-COMPONENT PAVEMENT TAPER

Note that surfacing taper slopes are designated as 1:8 or 1:6 (not 1V:8H or 1V:6H) because they are relative slopes that rotate with the crown or superelevation. Slope designated as 1V:8H or 1V:6H, such as embankment slopes, are true to the vertical and horizontal axis and do not rotate.

Also note that most guardrail installations require flatter slopes than typical surfacing taper slopes leading into the face of the guardrail, so acceptable slope modifications are necessary.

### CLEAR ZONE DESIGN CRITERIA

**General:** Clear zones should be free of fixed object hazards and have 1V:4H or flatter slopes to reduce the likelihood of a rollover and allow a vehicle to come to a controlled stop. Objects that are located within the clear zone should be crashworthy to minimize the chance of serious injury or death. The clear zone is the specified width as measured from the traveled way and includes the shoulder and surfacing taper. The clear zone also applies to the left edge of the traveled way for a given direction of travel. See Exhibit 5.



**EXHIBIT 5**  
DIRECTIONAL CLEAR ZONES


**Hazards Within Clear Zone:** Clear zones are to be free of fixed object hazards and critical slopes. To mitigate or shield hazards within the clear zone, consider the following options, which are listed in **order of priority**:

1. Remove or make safely traversable
2. Relocate object
3. Make breakaway
4. Shield with an approved longitudinal roadside barrier

A roadside barrier is a hazard in itself and should be used only as a last alternative. Before installing a roadside barrier, make sure the hazard cannot be mitigated by one of the higher priority options.

**Clear Zone Distance:** Clear zone distances shown in Exhibit 6 below represent the minimum values for the conditions stated in the table. The use of midrange or higher values as shown in the Roadside Design Guide is desirable where it can be shown that using those values will not add significant cost, where appreciable safety enhancements can be achieved or where it is desirable to be consistent with adjacent

roadway sections. See the AASHTO Roadside Design Guide for a more in-depth discussion of clear zones and WYDOT's 4R,3R,2R,1R Guides for application of clear zones.

CLEAR ZONE REQUIREMENTS - RURAL ROADWAYS a)			
ROADWAY DESIGN SPEED mph [km/h]	PROJECTED DESIGN ADT VEHICLES/DAY	MINIMUM CLEAR DISTANCE - ft. [m]	
		1V:6H FIXED SLOPE TO CLEAR ZONE b)	1V:4H SLOPE TO CLEAR ZONE
		2 LANE OR MULTI-LANE ROADWAYS NHS-ARTERIALS (NON- INTERSTATE) NON-NHS ARTERIALS NON-NHS COLLECTORS	NON-NHS LOCAL ROADS AND STREETS
40 [60] OR LESS	UNDER 750	8 [2.5]	10 [3] FOR ALL DESIGN SPEEDS AND VOLUMES  
	750 - 1500	10 [3]	
	1500 - 6000	12 [3.5]	
	OVER 6000	14 [4.5]	
45-50 [70-80]	UNDER 750	10 [3]	
	750 - 1500	14 [4.5]	
	1500 - 6000	16 [5]	
	OVER 6000	20 [6]	
55 [90]	UNDER 750	12 [3.5]	
	750 - 1500	16 [5]	
	1500 - 6000	20 [6]	
	OVER 6000	22 [6.5]	
60 [100]	UNDER 750	16 [5]	
	750 - 1500	20 [6]	
	1500 - 6000	26 [8]	
	OVER 6000	30 [9]	
65 [105] OR GREATER	UNDER 750	18 [5.5]	
	750 - 1500	24 [7.5]	
	1500 - 6000	28 [8.5]	
	OVER 6000	30 [9]	
CLEAR ZONE REQUIREMENTS - INTERSTATE HIGHWAYS AND RAMPS a)			
PROJECTED DESIGN ADT (VEHICLES/DAY)	CLEAR DISTANCE - ft. [m]		
	1V:6H FIXED SLOPE TO CLEAR ZONE b)		
VOLUME ADT <6000	30 [9]		
VOLUME ADT >6000	35 [11]		

**EXHIBIT 6**  
MINIMUM CLEAR ZONE DISTANCE

- a) The clear zone distance may be increased on curves or tangents where the crash history indicates a need or a specific site investigation shows a definitive crash potential that could be significantly lessened by increasing the clear zone width and such increases are cost effective. The designer should also consider other options that might better reduce or eliminate crash potential. The use of curve correction factors as outlined in the *AASHTO Roadside Design Guide* is not required but can be used in certain circumstances.

Projects that have been previously safety graded to provide a clear zone distance of 30 ft [9 m] or greater do not have to be upgraded, providing there is no crash history to warrant an increase in the clear zone distance.

- b) The barn roof design with a 1V:6H fixed slope to the clear zone width is required for all 4R and 3R rural construction projects, with the exception of “Local Roads and Streets” where a 1V:4H fixed slope is required.

**FACTORS THAT AFFECT CLEAR ZONE DISTANCE**

**Design Speed:** As vehicles travel at higher speeds, their lateral encroachment distance increases.

**Embankment Slope:** On steep slopes, errant vehicles travel farther and therefore require larger distances to recover safely.

**Traffic Volume:** On roadways with low traffic volumes, fewer vehicles leave the traveled way, thus justifying the use of a narrower clear zone.

**EMBANKMENT SLOPE DESIGN CRITERIA**

**Barn Roof Design:** Consists of a fixed 1V:6H slope extending from the outside edge of the surfacing taper to the outside edge of the clear zone followed by a variable embankment (fill) slope selected from the table shown in Exhibit 7. The barn roof design is the preferred method of for all 4R and 3R rural construction projects.

<b>BARN ROOF DESIGN</b>	
1V: 6H SLOPE TO CLEAR ZONE a), b)	
FILL HEIGHT FROM HINGE POINT ft [m]	FILL SLOPE 1V : ?H
0 - 8 [0 - 3]	1 : 5
8 - 12 [3 - 4]	1 : 4
>12 [4]	1 : 3 c)

**EXHIBIT 7**  
BARN ROOF SLOPE CRITERIA

- a) The barn roof slope design is required for 4R and 3R rural reconstruction projects. However, for widening and overlay projects, the non-barn roof slope design may be used at the designer’s discretion in special cases on

slope widening projects with shallow fills.

- b) Special slope design modifications are required for median slopes and guardrail installations. See **INTERSTATE MEDIAN DESIGN CRITERIA** and **SLOPE DESIGN FOR GUARDRAIL INSTALLATIONS** sections.
- c) In areas where 1V:3H fill slopes cannot be incorporated because of justifiable constraints or economic reasons, slopes may be steepened to 1V:2H with consideration being given to placing guardrail near the outside edge of the barn roof section. If slopes steeper than 1V:3H are used, consider placing guardrail where there are long high fill sections, on the outside of curves, on steep down grades, etc. At the designer's discretion in special cases on short tangent sections of roadway with flat grades, a 1V:2H barn roof embankment slope may be used without guardrail. For example, a 200 ft± [60 m±] tangent section of roadway with flat grades may not require guardrail if there are no other extreme hazards at the bottom of the slope. If longer sections of 1V:2H slopes are used or there are severe hazards at the bottom of the slope, consider widening the barn roof or placing guardrail. An evaluation is necessary on an individual project basis including factors such as costs, traffic volumes, grades, prevalent snow conditions, etc., to determine if guardrail is justified. Vehicle trajectory on slopes should be considered when determining the location for the guardrail.

**Non-Barn Roof Slope Design:** Consists of a variable embankment (fill) slope selected from the table in Exhibit 8 below. Slopes extend from the outside edge of the surfacing taper down to natural (existing) terrain. This option is used at the designer's discretion on non-NHS collectors with < 750 ADT, non-NHS local roads, widening projects, and projects with shallow fills.

<b>NON-BARN ROOF SLOPE DESIGN</b>	
1V: 4H OR FLATTER SLOPE WITHIN THE CLEAR ZONE a)	
FILL HEIGHT FROM HINGE POINT ft [m]	FILL SLOPE 1V : ?H
0 - 4 [1]	1 : 6
4 - 8 [1 - 3]	1 : 5
8 - 12 [3 - 4]	1 : 4
>12 [4]	USE BARN ROOF DESIGN

**EXHIBIT 8**

NON-BARN ROOF SLOPE DESIGN CRITERIA

- a) With this slope option, use the clear zone distances given in the *AASHTO Roadside Design Guide* for the 1V:5H to 1V:4H foreslopes.

**EXCAVATION SLOPE DESIGN CRITERIA**

**Ditch Section:** Appropriate combinations of a ditch shape, foreslope, and backslope that are traversable and can be located within the clear zone are given in the *AASHTO Roadside Design Guide*. Example: For a V-ditch section within the clear zone (foreslope/backslope combination) where the foreslope is 1V:6H, the backslope should be no steeper than a 1V:4H. See the *AASHTO Roadside Design Guide* for further information concerning preferred ditch cross sections.

**Interstate:** Ditches should have a 1V:6H foreslope, with the ditch bottom preferably located at or beyond the clear zone limit. The use of trapezoidal, flat bottom, or rounded ditch sections is preferred.

**Rural Two Lane:** The foreslope should be no steeper than 1V:6H. Ditch sections normally range in depths from 1 ft [0.3m] to 3 ft [1m] with deeper ditches usually being used on roadways with higher functional classifications and traffic volumes or in heavy snow areas. If the ditch section is located within the clear zone, the foreslope/backslope combination should meet the requirements given in the *AASHTO Roadside Design Guide*. In choosing the type and depth of ditch section for use on a project, consider factors such as safety, good drainage, the required amount of excavation, right-of-way availability, snow depths, and other factors, as applicable.

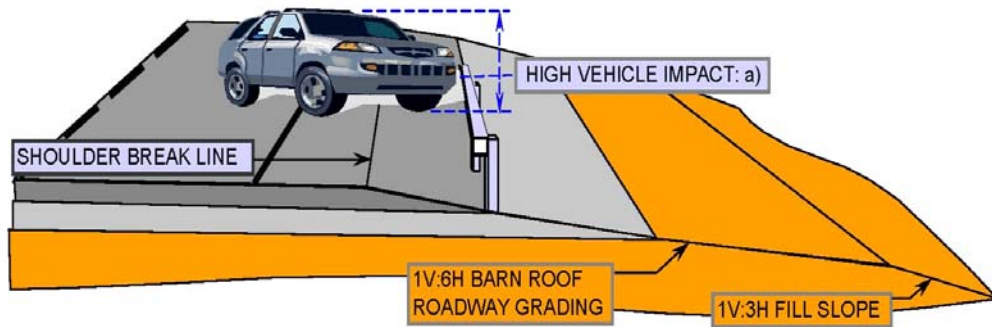
**Backslope:** For purpose of revegetation, the use of a 1V:3H or flatter backslope is desirable. Steeper slopes may be used when justified for design reasons. However, steeper slopes may be difficult to revegetate, are subject to excessive erosion, or may become unstable. A fixed catch distance from the ditch bottom, with variable backslopes, is typically used for cut sections.

**SLOPE DESIGN FOR GUARDRAIL INSTALLATIONS**

**General:** The performance of guardrail on slopes steeper than 1V:10H or where the slope breakover angle is abrupt can be unpredictable and should be avoided. Guardrail design requires the proper slope grading from the shoulder break line of the roadway to beyond the back of the guardrail posts.

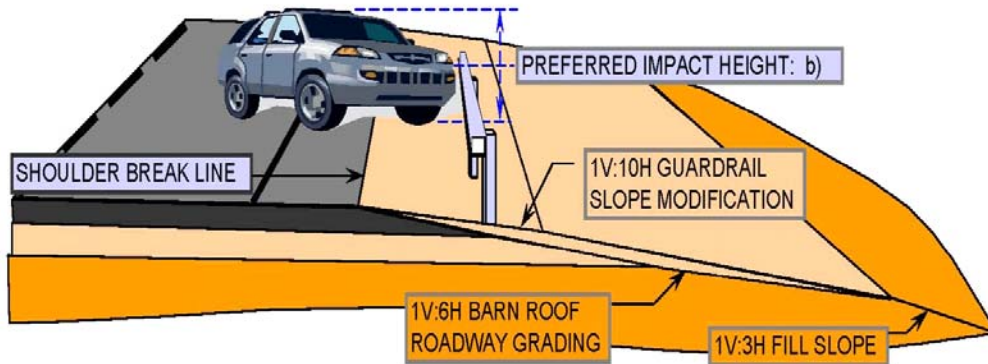
Vehicles depart the roadway at various angles. Depending on the encroachment angle, a vehicle crossing a slope break line (for example, change in slope) may become airborne or have its suspension compressed. To ensure that errant vehicles contact guardrail installations at the correct height, it is important to provide flat slopes and small breakover angles at slope break points. At locations where guardrail is to be installed, the standard roadway slope design should be modified to provide a 1V:10H or flatter slope extending from the shoulder break line to a minimum of 2 ft [0.6m] behind the guardrail posts. See Exhibits 9 and 10. The slope modification should begin a sufficient distance in advance of the guardrail and extend out far enough to provide a 1V:10H slope platform for errant vehicles approaching the

guardrail terminal end.



**EXHIBIT 9**  
GUARDRAIL WITHOUT SLOPE MODIFICATION

- a) Exhibit 9 illustrates how a vehicle crossing a steep breakover angle is likely to contact the guardrail too high, potentially causing it to vault over the guardrail.



**EXHIBIT 10**  
GUARDRAIL WITH 1V:10H SLOPE MODIFICATION

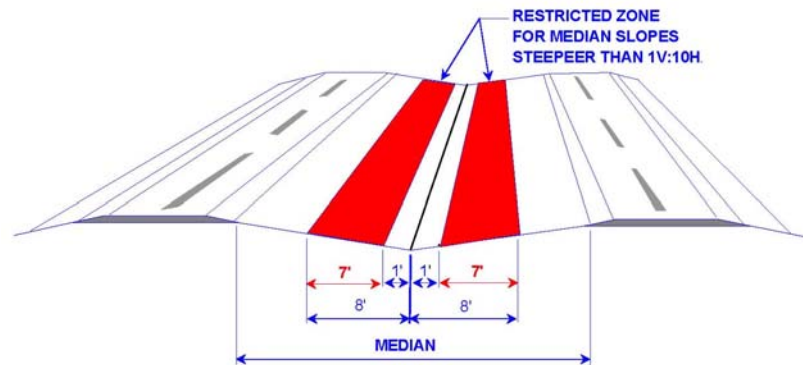
- b) Exhibit 10 illustrates how 1V:10H guardrail slope modification reduces the break over angle to keep the vehicle and guardrail height compatible, therefore providing a safe redirection of the vehicle.

Median ditches tend to have high breakover angles, even with fairly flat embankment slopes. Do not install guardrail across median ditches unless the ditch section is made very flat. Slopes as flat as 1V:20H are recommended on each side of the ditch in areas where the guardrail must cross the median or where a guardrail terminal is located at or near the ditch line. The high side of superelevated sections also have high breakover slope angles that merit special consideration. Locate guardrail (when needed) close to the roadway on these sections.

Slope criteria for cable guardrail is more flexible than for other barrier systems. The cable barrier system has been shown to perform adequately on slopes as steep as 1V:6H; however, it will deflect more than other systems and proper placement in narrow medians is critical to ensure proper performance. The typical cable barrier system used in Wyoming has a lateral deflection distance up to about 9 ft [2.7 m] when impacted.

The optimum placement of cable median barrier is 8ft [2.4 m] or more from the median ditch to prevent vehicles from deflecting into or through the ditch bottom, causing the vehicle to submerge, under-ride, and penetrate the bottom cable, thus allowing penetration of the barrier. Because cable barriers deflect much more than conventional barriers, it is desirable to keep vehicles from deflecting into the median ditch. This is particularly true when the median slopes are steeper than 1V:8H.

In narrow medians (35 ft [11 m] wide or less) where it may not be feasible to flatten the existing slopes or to place the barrier at 8 ft [2.4 m] or more from the ditch bottom, the cable median barrier has also been shown to perform adequately when placed at 1 ft [0.3 m] or less from the median ditch bottom. Where the median slopes are steeper than 1V:10H, avoid placing cable median barrier in the restricted zone between 1 ft [0.3 m] to 8 ft [2.4 m] from the ditch bottom. See Exhibit 11.



**EXHIBIT 11**  
CABLE MEDIAN BARRIER RESTRICTED ZONE

Where the median slopes are steeper than 1V:10H, it is acceptable to place the cable median barrier at up to 1 ft [0.3 m] or at 8 ft [2.4 m] or farther from the median ditch bottom, but avoid placing cable median barrier in between 1 ft [0.3 m] and 8 ft [2.4 m] from the median ditch bottom.

It is also important to place the cable barrier so that it will not deflect into oncoming traffic, and, if possible, it is desirable to provide additional lateral distance to reduce the likelihood of dangerous avoidance maneuvers by oncoming traffic. Where cable median barrier must cross the median, the slopes should be 1V:10H or flatter whenever possible.

### **INTERSTATE MEDIAN DESIGN CRITERIA**

**Width 60 ft [20 m] or Less:** 1V:8H median slopes are preferred.

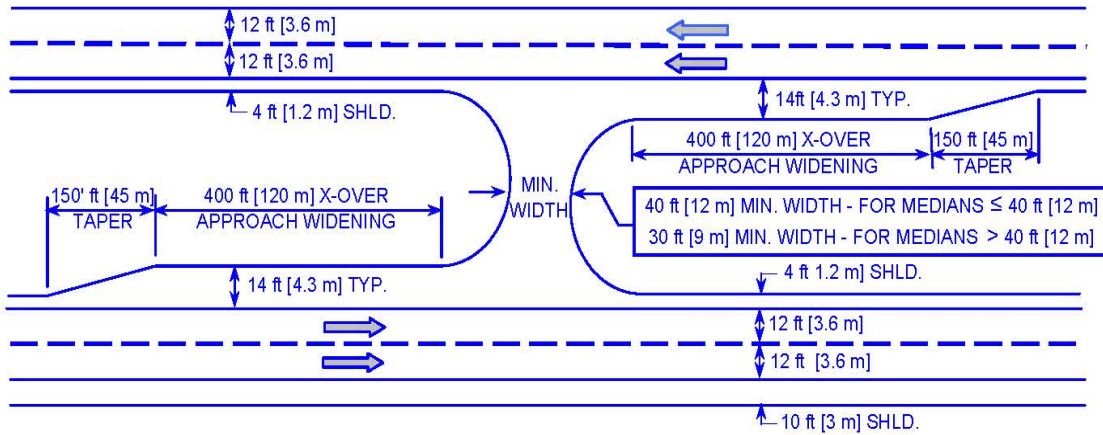
**Median Width 60 ft to 126 ft [20 m to 35 m]:** Use the applicable clear zone and fill slope criteria, preferably with no slope steeper than 1V:6H.

**Median Width 126 ft [35 m] or Greater:** Use the applicable clear zone and fill slope criteria.

**Median Barrier:** Designers should justify the need for median barrier on a project-by-project basis based on accident history and other pertinent factors.

**Median Crossover and Drainage Dike (Berms):** Crossovers and drainage dikes are hazardous features that should be used only where necessary. The embankment slopes are perpendicular to the roadway and can cause severe vaulting of errant vehicles, even with relatively flat slopes. Embankment slopes should be 1V:10H or flatter. The location of median crossovers or drainage dikes should be carefully considered. AASHTO criteria should be applied wherever possible; however, snow removal operations must be accommodated along with safe highway operations. District personnel should provide recommendations that justify and document the location of crossovers or dikes, especially in narrow medians where crossovers must be wide enough to prevent snow plows (typically 40 ft [12 m] long) from encroaching into travel lanes while waiting for opposing traffic to clear.

**Crossover Approach Widening:** Shoulder widening should be provided at median crossovers where feasible. See Exhibit 12.



**EXHIBIT 12**  
CROSSOVER APPROACH WIDENING

**Median Inlets:** On median widths of 60 ft [20m] or less, use M-1 inlets or safety grates on exposed culvert ends is recommended.

### APPROACH DESIGN CRITERIA

Approaches are to have embankment slopes of 1V:8H or flatter for that portion of the approach which is located within the clear zone.

### SHOULDER WIDTH

On rural highways, the shoulder width is measured from the edge of the traveled way to where the surfacing taper begins. On urban streets with curb and gutter, the shoulder width is measured from the edge of the traveled way to the vertical face of the curb. The minimum shoulder width from face of curb is 2 ft [0.6 m]. The gutter section is never considered part of the travel way, but it is considered part of the usable shoulder width.

### CURBS

Curbs are frequently used on low-speed roadways (design speed of 45 mph [70km/h] or less) to control drainage and to provide separation between traffic and pedestrians. The standard curb and gutter section used is a Type A Curb, which is 6 in [150 mm] high with a nearly vertical face. The use of curbs along high speed roadways (design speeds greater than 45 mph [70km/h]) is strongly discouraged due to a vehicle's propensity to lose control when impacting and traversing curbs at high speeds. Vehicles that encounter sliding, yawing, or both during slick conditions or other loss of control can also be "tripped" when impacting a curb, potentially causing a rollover. If it is determined a curb is necessary to control drainage on a high speed

roadway, the curb should be no higher than 4 in [100 mm] and have a batter of approximately 1V:2H.

The combination of curb and roadside barriers should also be avoided, particularly on high speed roadways, unless a crash tested design is used. Use care when placing curbs for low speed roadways where a roadside barrier is present. The barrier face of a metal beam guardrail should be flush with or in front of the curb face. Curbs should not be used with concrete barriers, although the barrier shape itself can be used for drainage control. Curbs can be used on high speed roadways when they are fully shielded by a roadside barrier (for example, located far enough behind the guardrail to accommodate full deflection). However, it is important that rigid pavement not be placed directly around guardrail posts; “pavement leave-outs” should be provided to allow guardrail posts to rotate normally under impact and to facilitate replacement.

#### **SNOW DRIFTING CONSIDERATIONS**

Based on input from the District Maintenance and Blowing Snow Team, analyze the cross-section design to ensure its adequacy under snow drifting situations.