Federal Lands Highways

DESIGN PROCEDURES GUIDE

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U.S. Department of Transportation
Federal Highway Administration

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LIST OF EXHIBITS

CHAPTER 1

GENERAL

The *Design Procedures Guide* provides basic guidance, recommended procedures, and instructions for developing and documenting the highway design. This includes fundamental steps for developing the geometric design and preparation of plans, specifications and estimates (PS&E), as well as related information to support the highway construction and subsequent maintenance and operation. These procedures are intended to complement the FLH Project Development and Design Manual (PDDM), and are applicable to new highway construction and reconstruction, as well as Resurfacing, Restoration and Rehabilitation (RRR) improvements. Information on how to perform basic design procedures and fundamental steps for performing the design work are typically included in this document instead of the PDDM. Refer to PDDM Chapter 9 for highway design policies, standard practices, and criteria. Additional information for performing basic design procedures, and fundamental steps for the workflow may also be provided by references to other documents.

Refer to [EFLHD – CFLHD – WFLHD] Division supplements for more information regarding division specific guidance and design procedures.

1.1 ROLE OF THE DESIGNER

Refer to the PDDM and the following chapter specific information:

- Chapter 1 – **Introduction**. .
- Chapter 2 – **Planning and Programming**.
- Chapter 3 – **Environmental Stewardship.**
- Chapter 4 – **Conceptual Studies and Preliminary Design**.
- Chapter 5 – **Survey and Mapping**.
- Chapter 6 – **Geotechnical.** Refer to the Geotechnical Technical Guidance Manual.
- Chapter 7 – **Hydrology/Hydraulics.** The FLH designer is typically responsible for developing the design for smaller culverts 1.2 m [48 inches] diameter and less
- Chapter 8 – **Safety and Traffic Operations**.
- Chapter 10 – **Structural Design**.
- Chapter 11 – **Pavements**.
- Chapter 12 – **Right-of-Way and Utilities.**
- Chapter 13 – **Design Follow-up.**

1.2 DESIGN REQUIREMENTS AND STANDARDS

Refer to the PDDM.

1.3 EXCEPTIONS TO DESIGN STANDARDS

Refer to the PDDM.

1.3.1 Need for Design Exception

Refer to the PDDM.

1.3.2 Design Exception Consequences and Risk Assessment

Refer to the PDDM.

1.3.3 Mitigating Design Exceptions

Refer to the PDDM. .

1.3.4 Documenting Design Exceptions

Refer to the PDDM.

1.3.5 Monitoring Design Exceptions

Refer to the PDDM.

1.4 DESIGN PHILOSOPHY AND CONTEXT SENSITIVE SOLUTIONS

Refer to the PDDM.

CHAPTER 2

GUIDANCE AND REFERENCES

The publications listed in this section provided fundamental source information used in the development of this chapter. While this list is not all-inclusive, the publications listed will provide the designer with additional information to supplement this *Guide*.

2.1 STANDARDS OF PRACTICE

Refer to the PDDM.

2.2 GUIDANCE

Refer to the PDDM.

2.3 INTERNAL FLH GUIDANCE

Refer to the PDDM.

CHAPTER 3

GEOMETRIC DESIGN

Refer to the PDDM.

3.1 GEOMETRIC DESIGN CONTROLS

See Chapter 4 for scoping procedures, gathering background data, and developing the preliminary design and mitigation measures, before beginning detailed design activities..

Geometric design defines the physical dimensions for the shape of a highway (e.g., alignment, cross section, sight distance, grades, slopes, roadside elements, intersections, related features). The geometric design focuses on design criteria, which are a set of dimensions and guidelines based on operational experience, driver expectation and research. Each element of the geometric design contributes an important quality to the performance of the facility. The importance of each element is related to the function, use, context and the environment in which the facility operates.

Driver behavior and vehicle operation are optimal when the context and facility are consistent with driver expectations. Although no design can account for all driver errors and actions, geometric features in the highway environment significantly affect driver behavior and vehicle operations. The application of design criteria should provide consistency in the quality, appearance and operational performance of the roadway. Consistency is important since roadways are managed by different agencies and individuals, and are operated by many diverse users, yet often serve similar functions.

3.2 AESTHETIC CONSIDERATIONS

Refer to the PDDM.

The aesthetic attributes of the highway are fundamental to any geometric design. Visual and artistic considerations contribute to the aesthetics from and of the roadway. Curvilinear alignment fits the road to the terrain and provides a pleasing visual experience for the user.

3.3 HORIZONTAL AND VERTICAL ALIGNMENT RELATIONSHIPS

Refer to the PDDM.

3.4 COMBINATIONS OF DESIGN ELEMENTS AND FEATURES

Refer to the PDDM.

3.4.1 Human Factors and Driver Performance

Refer to the PDDM.

Driver error can occur for many reasons:

- The abilities and limitations of individual drivers,
- Deficiencies in the highway design and operational features, and
- Combinations of design and operational features leading to overload of the driving task.

Drivers must gather and process visual information and often must perform multiple tasks within very short time frames, and their need for adequate information must be met via the roadway design, environment and traffic control devices that provide the necessary information at the right time. The goal of considering human factors in the highway design is to minimize confusing or unexpected situations that could lead to driver error.

Positive guidance is a procedure for identifying information needs and providing suitable, expected information when needed, where required and in the form best suited for its intended purpose. The highway design should reinforce the information needs and expectancies of the driver, reinforce the desired behaviors and avoid misleading signals or clues.

3.4.2 Design Consistency

Refer to the PDDM.

Driver’s experiences with the highway, roadside and operational features along the road are the factors that establish their expectations and influence their behavior. Drivers tend to react in a consistent manner to familiar situations; conversely, if drivers experience new situations or situations they are not expecting, their reactions are often delayed and can be detrimental.

3.4.3 Combinations of Design Elements with Intersections and Bridges

Refer to the PDDM.

3.4.4 Additive Design Risk Assessment

Refer to the PDDM.

3.5 HORIZONTAL ALIGNMENT

Refer to the PDDM.

3.5.1 Horizontal Curves

Refer to the PDDM.

The theoretical model on which AASHTO design guidelines are based is described in the *Green Book* in Chapter 3 §Horizontal Alignment ~Theoretical Considerations. The design features of the horizontal curve consisting of its radius and superelevation are based on the selected design speed and a side friction factor. The horizontal curve design model is intended to facilitate driver control and avoid loss of control due to skidding, which occurs if the side friction demand exceeds the pavement friction available. In applying the curve model, the AASHTO guidelines are based on more conservative assumptions of side friction demand that provide a level of comfort to drivers as well as safe operation.

3.5.1.1 Speed

Refer to the PDDM.

The geometric design of the road affects operating speeds, as it defines the driving task. Narrow lanes and sharp curves make the driving task more demanding and tend to constrain operating speed. Drivers develop expectations about the intended, and comfortable, speeds based on their experiences of various geometric design elements. Operating speeds may be very different from the design speed when the geometric design characteristics and the design speed are at variance. In some situations, sight distance needs for design may be more appropriately determined based on operating speed, if higher than the design speed. Design elements that influence operating speed include:

- Alignment (horizontal and vertical)
- Lane and shoulder width,
- Proximity of roadside features, and
- Road surfacing and friction.

Speed is primarily related to radius of curvature. Operating speed on curves can be predicted based on radius, curve deflection angle and curve length. A fundamental relationship in the AASHTO horizontal curve criteria is that the design radius of a curve is an exponential function of the velocity, such that the design radius increases by the square of the velocity, and not proportionally to the velocity (i.e., if the velocity doubles, the design radius of the curve increases by approximately four times). Once the curve radius exceeds 800 m [2,600 ft], curves have similar speeds to tangents.

Operating speeds on tangents are more difficult to predict and are related to an array of roadway and roadside characteristics (e.g., tangent length, radii and deflections of curves before and after the tangent section, cross-section, grade, general terrain, sight distance). The posted speed limit is a stronger factor in predicting operating speed on urban highway tangents than it is on rural highway tangents.

Lane width influences operating speed because it influences the difficulty of the driving task, and proximity to obstacles or potential conflicts. Narrower lanes require more frequent, smaller steering corrections (i.e., more driver effort). Slowing down reduces the effort required. Reducing the lane width from 3.6 m to 3.3 m [12 ft to 11 ft] is associated with a speed reduction of approximately 3 km/h [2 mph] on high design standard two-lane rural highways.

The proximity of obstacles or potential conflicts close to the edge of the travel lane (e.g., pedestrians, bicyclists, parked vehicles, foliage) can result in a reduction in operating speed. Drivers interpret the proximity of objects in peripheral vision to sense their speed.

Roadway surface condition affects operating speed somewhat. However, unless the roadway surface is very rough or slick, simple re-surfacing typically generates little or no increase in operating speed.

3.5.1.2 Side Friction Factor

Refer to the PDDM.

The effect of the side friction factor, *f*, is similar to the effect of superelevation, *e*, in the AASHTO curve criteria. The minimum curve radius for a given design speed and superelevation is based on established values for side friction factor, which varies with the design speed.

Although loss of control to skidding is a primary concern, the friction factor used in the AASHTO horizontal curve criteria is instead based on providing a level of comfort to drivers, which also assures vehicle control. The controlling values for *f* are based on research of driver behavior during cornering.

The design values for *f* provide a substantial margin of safety on most dry pavement conditions, which is necessary given the additional demands for lane changing, evasive maneuvers, braking, wet or slippery conditions and tire condition. Also, the design values provide a margin of safety for trucks and other vehicles with higher centers of gravity that tend to simply overturn rather than skid under certain combinations of curvature and speed.

3.5.1.3 Superelevation

Refer to the PDDM.

FLH standard practice is to use AASHTO Method 5 for determination of design superelevation rates for the various curve radii of a horizontal alignment. This method distributes values of *e* and *f* progressively from tangent to the minimum design radius. The method assumes an average running speed that is less than the design speed, which is used to adjust the distribution of *e* and *f* relative to the inverse of the curve radii.

3.5.1.4 Curve Radius

Refer to the PDDM.

The minimum curve radius is determined by the AASHTO curve model, in which the minimum curve radius is a function of the design speed, the side friction factor, and the maximum superelevation rate.

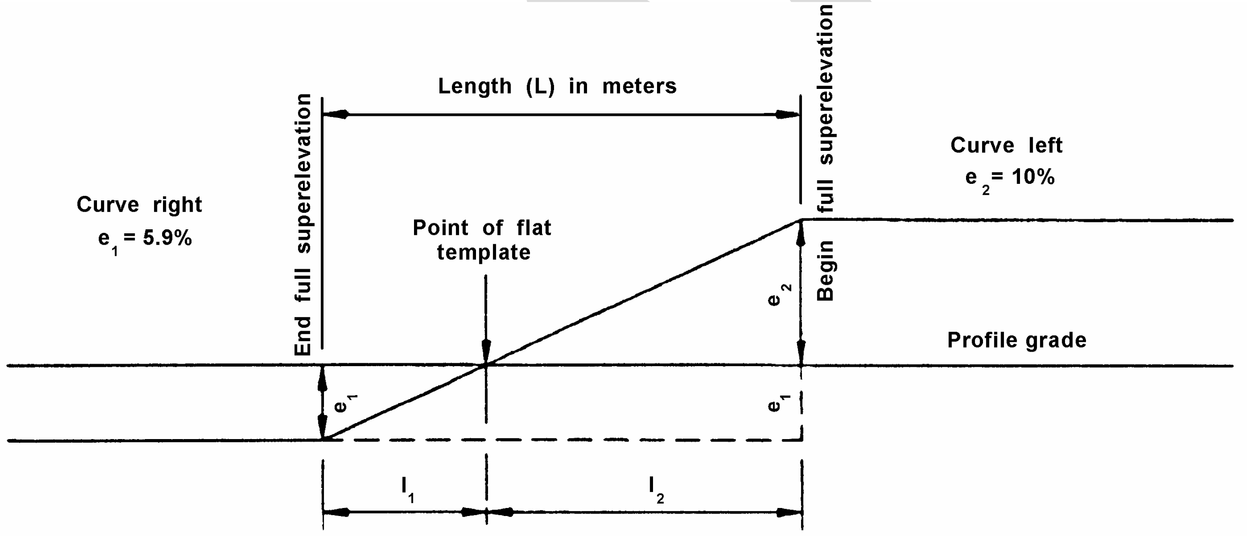
3.5.1.5 Reversals in Alignment

Refer to the PDDM.

Drivers normally expect the direction of alignment deflections of successive curves to be reversal.

Refer to Exhibit 3.5-A for a method to calculate the flat template section in a reverse curve superelevation transition.

Exhibit 3.5-A DETERMINING FLAT SECTIONS BETWEEN REVERSING CURVES WITH SHORT TANGENTS



Note:

Ratio $\frac{l_1}{L} = \frac{e_1}{e_1+e_2}$ or $\frac{l_2}{L} = \frac{e_2}{e_1+e_2}$

Therefore $l_1 = \frac{(e_1)(L)}{(e_1+e_2)}$ or $l_2 = \frac{(e_2)(L)}{(e_1+e_2)}$

3.5.1.6 Broken Back Curves

Refer to the PDDM.

3.5.1.7 Compound Curves

Refer to the PDDM.

3.5.1.8 Small Deflection Angles

Refer to the PDDM.

3.5.1.9 Curvature on Through-Fills

Refer to the PDDM.

3.5.2 Horizontal Curve and Superelevation Transitions

Refer to the PDDM.

The following terms describe template conditions and parameters applicable to superelevation transitions:

- Plane section – the cross slope is the same across the entire roadway
- Crown section – the cross slope on each side of the roadway centerline, or between travel lanes in the same direction, is different
- Normal Crown section (NCR) – the cross slope on each side of the roadway centerline, or between travel lanes in the same direction, is at the minimum specified, downward away from the center (typically, 2.0 percent downward toward the left and right)
- Full Super (FS) – the cross slope is at the full superelevation rate prescribed for the particular curve (based on its radius, the design speed, and the maximum superelevation rate)
- Full Super Station (FSS) – the location where the full superelevation rate for a curve is attained, and the superelevation transition for the back tangent ends (or vice versa, where the full superelevation rate ends and the superelevation transition for the ahead tangent begins)
- Minimum Super – the template is in a plane section at the minimum specified cross slope, typically 2.0 percent (right or left). This is also referred to as Reverse Crown
- Minimum Super Station – the location where the superelevation has transitioned to the minimum super rate, typically 2.0 percent, and the template is a plane section

- End super transition – the location of the superelevation transition ending for the back curve, either at normal crown (superelevation runoff and tangent runout), or at the zero percent position (plane section) for reverse curves

- Begin super transition – the location where the superelevation transition begins, either at normal crown (begin tangent runout) or at the zero percent position for reverse curves

- Superelevation runoff – the length needed to accomplish a change in outside-lane cross slope from zero (flat) to full superelevation, or vice versa.

- Tangent runout – the length needed to accomplish a transition from normal crown to where the outside lane is at zero cross slope (flat), or vice versa.

- Relative gradient – the difference in the longitudinal gradients of the axis of rotation (typically the centerline edge of the travel lane) and the outside edge of the travel lane, for the superelevation runoff. The relative gradient equals the full superelevation rate (e) multiplied by the travel way width (L) divided by the superelevation runoff length (L_r)

- Super transition length – For transition between normal crown and full super, the superelevation transition length includes both the superelevation runoff length and the tangent runout. For connected transitions between reverse curves, the transition length consists of the runoff length necessary to attain the full superelevation rate from zero cross slope

- Super transition rate – the rate of change in the cross slope in relation to distance, corresponding to the superelevation runoff length divided by the superelevation rate (e), expressed as meters [ft] per each 1.0 percent change in the cross slope

- Zero percent position – the location at which the roadway is in a plane section with zero cross slope in superelevation transitions between reverse curves

- Critical transition conflict – for reverse curves, the case where the length of a normal crown section is less than a specified minimum critical threshold value (and more than a supercritical value), which results in adjustments to the back and ahead super transitions to provide a longer normal crown length that meets the specified minimum value

- Supercritical transition conflict – for reverse curves, the case where the length of a normal crown section is less than a specified minimum supercritical threshold value, which results in both super transitions and the short normal crown section being nullified; and both super transitions are merged and adjusted to provide a transition maintaining plane sections with an intervening zero percent position

3.5.2.1 Attainment of Superelevation on Tangent and Curve

Refer to the PDDM.

Tangent sections of roadways are normal crown, and curved sections are superelevated. Transitions provide a gradual change between curved sections or between a curved section and normal crown. Superelevation runoff is the length of roadway needed to transition from full superelevation on a curve to a section on the adjoining tangent where the outside lane is flat. Tangent runout is the length of tangent necessary to transition from the above flat section to normal crown.

3.5.2.2 Reverse Curve Transitions

Reverse curve transitions may be categorized as one of three treatments:

1. Short intervening tangent with connected superelevation runoffs
2. Intermediate intervening tangent with a minimum super rate (reverse crown) section
3. Long intervening tangent with a normal crown section

For reverse with short to intermediate length tangents. Conflicts occur when reverse curves have designed superelevation transitions that overlap or are in close proximity, such that the normal crown section is less than the desired minimum length

If the intervening tangent is short, such that the designed length of normal crown section is far less than the minimum, then the situation may be described as a supercritical conflict condition. A supercritical transition conflict is the condition where the length of a normal crown section is less than a specified minimum supercritical threshold value, in which case both super transitions and the short normal crown section are redesigned; and the two superelevation runoff lengths are connected (merged) and adjusted to provide a continuous transition maintaining plane sections with an intervening zero percent position (above treatment 1). The supercritical threshold value is typically set within a range equivalent to one or two typical cross section intervals, or 20 to 40 m [50 to 100 ft]. FLH standard practice is to set the supercritical threshold at 30 m [75 ft], and combine (merge) the two transitions if normal crown length is less. Such transitions should use the same uniform relative gradient for each transition, with the zero percent positioning determined either by the original designed (unadjusted) full super (FS) stations, or by the ratio of the superelevation rates (*e*) of each curve. FLH standard practice is to hold the original designed (unadjusted) FS stations in this case, and verify that the resultant relative gradient is within the maximum and minimum values. Otherwise, the location of the superelevation transition with respect to the end of curve (PT and PC) may be adjusted by designating the relative gradient or by designating the zero percent position. If the FS stations are not held, the location of the zero percent positioning may be designated either at the midpoint of the intervening tangent, or located along the tangent at a distance ratio based on either the superelevation rate (*e*) or the radius of the curves. In this case, FLH standard practice is to locate the zero percent position at a distance ratio based on the superelevation rate (*e*) of each curve. The relative gradient that is used may be based on the overall distance between the original designed FS stations, or the average of the two original designed relative gradients, or the original designed relative gradient of either curve transition. FLH standard practice in this case is to use the average of the two original designed relative gradients, and verify that it is within the maximum and minimum values. Regardless of these options, **Error! Reference source not found.** shows an example for locating the flat spot and distributing the superelevation runoff between reversing curves with short tangent lengths, for the situation described above as treatment 1.

If the intervening tangent is an intermediate length such that the designed length of normal crown section is slightly less than the minimum specified, then the situation may be described as a critical conflict condition. A critical transition conflict is the condition where the length of a normal crown section is less than a specified minimum critical threshold value (and more than the supercritical value), in which case the back and ahead super transitions are redesigned and adjusted, using the original relative gradients, to provide a longer normal crown section length that meets the minimum critical value. The minimum critical threshold value is normally set within a range equivalent to two or three typical cross section intervals, or 40 to 60 m [100 to 150 ft]. FLH standard practice is to set the critical minimum normal crown length threshold value equal to 40 m [100 ft]. If the supercritical and critical values are the same, the transition conflict is resolved by redesigning the transition as described above for treatment 1. Otherwise, to resolve the critical conflict situation either the necessary length of normal crown section should be provided as described above for treatment 3, or an intervening section of minimum super rate (reverse crown) should be provided as described for treatment 2.

If a merged superelevation transition described above as treatment 1 is created for an intermediate or long tangent, then the resultant transition may reduce the relative gradient (lengthen the superelevation runoff) and increase the proportion and amount of superelevation applied on the tangent. A relative gradient that is too low for the design speed (superelevation runoff length too long) may create driver discomfort, and excessive superelevation on the tangent may result in vehicle lateral shifts and more difficult steering.

For intermediate tangent lengths between reversing curves, when the designed tangent length is insufficient to develop a normal crown section of at least 30 m [100 ft], yet is too long to transition comfortably between the curves with the desired relative gradient and/or ratio of superelevation runoff on the curve, a section of minimum super rate (reverse crown) may be provided within the transition, described above as treatment 2. This treatment provides plane sections throughout the transition from full super rate on one curve to the minimum super rate (reverse crown) section along a portion of the tangent, with a uniform transition from the reverse crown section passing through zero percent (flat) to full super on the second curve. The transition from full super to minimum super (reverse crown) passing through zero percent may be associated with either curve depending on other geometric or pavement drainage considerations. For this transition treatment, provide a minimum length of reverse crown section of at least 20 m [50 ft], or 1 second of travel time at the design speed whichever is greater. Design the resultant superelevation transitions to provide the same relative gradient for each curve transition, within the maximum relative gradient recommended in the *Green Book*, Exhibit 3-30, with approximately one-third of the theoretical superelevation runoff for each transition located on the curve and two-thirds on the tangent. An example of this superelevation transition treatment is shown in **Error! Reference source not found.**.

3.5.2.3 Compound Curve Transitions

Refer to the PDDM.

3.5.2.4 Broken Back Curve Transitions

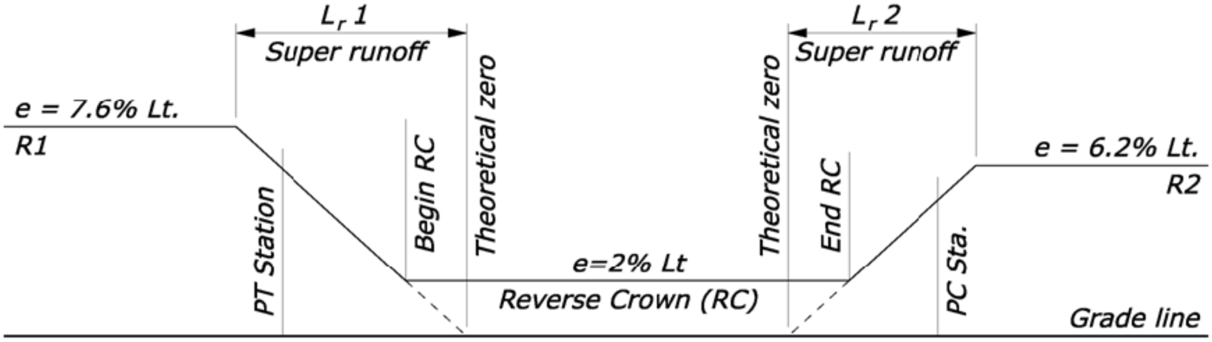
Refer to the PDDM.

Excessive superelevation on the tangent may result in vehicle lateral shifts and more difficult steering.

3.5.2.5 Short Curve Transitions

Refer to the PDDM.

Exhibit 3.5-B SUPERELEVATION TRANSITION ON SHORT TANGENTS



Example with V = 80 km/h [50 MPH]:

Location	Metric	US Custom.	Metric	US Customary
R1 L_r1	300 m 55 m	1000 ft 185 ft	Calculation of Begin RC Station	
e=7.6% Lt	16+291	534+47	.020/.076(55)=**14.474 m** 16+346 - 14.474 m = **16+331.526**	.020/.076(185)=**48.68’** 534+32 - 48.68’ = **535+83.32**
PT	16+302	534+84		
Begin RC	See Calculation →			
End L_r1	16+346	536+32		
R2 L_r2	450 m 45 m	1500 ft 150 ft	Calculation of End RC Station	
Begin L_r2	16+394	537+84	.020/.062(45)=**14.516 m** 16+394 + 14.516 m = **16+408.516**	.020/.062(150)=**48.39’** 537+84 + 48.39’ = **538+32.39**
End RC	See Calculation →			
PC	16+430	539+04		
E=6.2% Lt	16+439	539+34		

3.5.2.6 Vehicle Tracking

Refer to the PDDM.

The introduction of a horizontal curve creates lateral acceleration on vehicles entering, during, and exiting the curve. The driver’s steered path is greatly influenced by the transitions of the roadway cross slope and the alignment geometry. If the driver’s steered path is inconsistent with the alignment geometry a lateral drift results with the vehicle not tracking in the center of the travel lane. Research shows that the actual vehicle path does not follow a true circle, and that drivers ‘overshoot’ the curve (track a path sharper than radius). The overshoot behavior is independent of speed, and the tracked path is a spiral. When lane widths are narrower than 3.6 m [12 ft], the transition design becomes much more critical. The curve transitions should not be designed to be either sudden (less than 2 seconds), or of extended duration (over 4 seconds), as each case creates difficulty for the driver’s control of the vehicle path tracking within the travel lane.

3.5.2.7 Spiral Transitions

Refer to the PDDM.

A spiral transition curve provides a gradual change in radius from infinity on the tangent to that of the circular curve so centrifugal force and side friction also develop gradually. The radius at any point on the spiral varies inversely with the distance measured along the spiral. In the case of a spiral transition connecting two circular curves having different radii, also referred as a partial spiral, there is an initial radius rather than an infinite value. Longer transition lengths can improve the aesthetic quality of the alignment, however excessive spiral transition lengths (over 4 seconds driving duration) become less comfortable to drive. Spirals improve the appearance of a highway, more closely approximate the vehicle path to reduce the lateral drift of vehicles entering and exiting curves, and provide a suitable location for transitioning of superelevation runoff and traveled way widening at the ends of curves.

3.5.2.8 Location of Profile Grade and Superelevation Pivot Point

Refer to the PDDM.

3.5.2.9 Combination of Superelevation Transition and Grades

Refer to the PDDM.

3.5.3 Risk Assessment and Mitigation

Refer to the PDDM.

3.6 VERTICAL ALIGNMENT

Refer to the PDDM. .

Vertical alignment consists of a series of gradients connected by vertical curves. The terms vertical alignment, profile grade and grade line are interchangeable.

3.6.1 Vertical Curves

Refer to the PDDM.

Vertical curves provide a gradual change between tangent grades. (See Exhibit 3-69, “Types of Vertical Curves” in the *Green Book*.) The symmetrical parabolic curve with an equivalent vertical axis centered on the vertical point of intersection (VPI) is primarily used in roadway profile design. For certain situations, critical clearance or other controls may require the use of asymmetrical parabolic vertical curves.

The minimum lengths of vertical curves used in design are determined by Equation 9.3(2):

$$L = AK \qquad \text{Equation 9.3(2)}$$

Where:

L = Minimum length of vertical curves in m (ft). (Round up to even tens, fifties or hundreds)

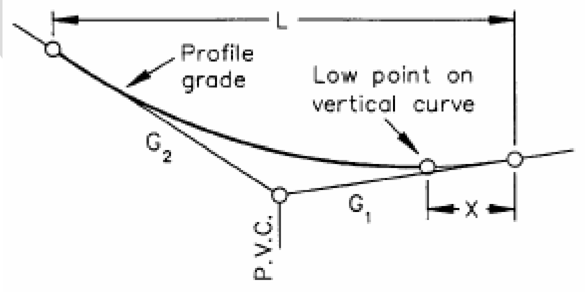
A = Algebraic difference in grade (percent).

K = Rate of change of grade (a constant value for a particular design speed and type of sight distance).

Exhibit 3.6-A provides a method of determining the low point on a vertical curve when the grades are unequal. This will identify locations for the installation of pipe culverts, catch basins or other such drainage facilities.

Exhibit 3.6-B shows a way to eliminate a series of broken-back vertical curves.

Exhibit 3.6-A DETERMINING LOW POINTS ON VERTICAL CURVES WITH UNEQUAL GRADES



Where:

G_2 = Steeper grade (%)
G_1 = Flatter grade (%)

L = Length of vertical curve (m [ft])

$$X = \frac{G_1(L)}{G_2+G_1}$$ **Distance in (m[ft]) from end of vertical curve of flatter grade to low on vertical curve.**

Example:

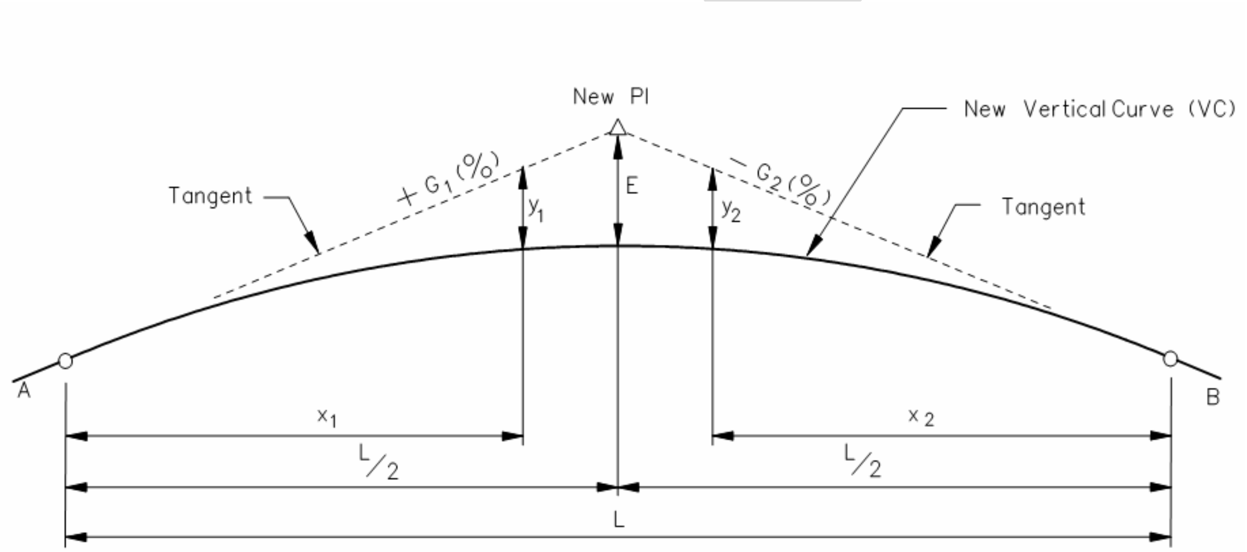
Let G_2 = 4% and G_1 = 2%

L = 300 m (1,000 ft)

therefore $X = \frac{(+2)\,(300)}{4+2} = \frac{600}{6} = 100$ m (Metric)

therefore $X = \frac{(+2)\,(1{,}000)}{4+2} = \frac{2{,}000}{6} = 333$ ft (US Customary)

Exhibit 3.6-B ELIMINATING BROKEN-BACK VERTICAL CURVES



VC = vertical curve

To determine the station and elevation of a new PI by extending existing grades to intersection:

1. Select a random even station for point A and determine the elevation for it from the old grade PI. Elevation of Point B = Elevation of Point A.

2. Determine the station of Point B from the old grade PI.

3. Distance L equals difference in stations between A and B in meters (feet):

   G_1 = Ascending grade (%)
   G_2 = Descending grade (%)

   $$x = \frac{G_2 L}{G_1+G_2}$$

$y = L - x$

$$\text{Elevation of new PI} = \text{Elevation point A} + \frac{G_1X}{100}$$

$$= \text{Elevation point B} + \frac{G_2Y}{100}$$

Note: For small changes in grade (A) or for small values of (K), the computed lengths of vertical curves may be very short. When practical, it is desirable to design vertical curves of 150 m (500 ft) or more in length, in order to create a pleasing appearance.

3.6.2 Maximum Grade

Refer to the PDDM.

See Example 9.3(1).

Example 9.3(1)

Conditions:

Rural Area
Highway Functional Classification is Rural Collector
60 km/h (40 mph) Design Speed
Rolling Terrain

According to the *Green Book* (Exhibit 6-4, "Maximum Grades for Rural Collectors"), the maximum grade for this example is 8 percent.

3.6.3 Minimum Grade

Refer to the PDDM.

3.6.4 Critical Lengths of Grade

Refer to the PDDM.

3.6.5 Intersection Considerations

Refer to the PDDM.

3.6.6 Hidden Dips

Refer to the PDDM.

3.6.7 Switchbacks

Refer to the PDDM.

3.6.8 Drainage Considerations

Refer to the PDDM.

3.6.9 Vertical Clearance

Refer to the PDDM.

3.6.10 Risk Assessment and Mitigation

Refer to the PDDM.

3.7 SIGHT DISTANCE

Refer to the PDDM.

3.7.1 Determination of Sight Distance Requirements

Refer to the PDDM.

Sight distance requirements are based on a mechanistic model of driver behavior and capabilities that represent the needs of most drivers. There are several primary components that together determine the sight distance that the driver requires to safely execute a maneuver, which should be considered in design.

Sight distances directly relate to the design speed of the road. Vehicle speed translates time requirements into distance needs. The operating speed determines the distance traversed during the PRT and MT. Depending on the sight distance situation being considered, the relevant speed may be that of the driver's own vehicle (as in stopping sight distance) or the speed of the approaching vehicle (as in stop-controlled intersection sight distance) or both (as in passing sight distance). In addition to providing the multiplier that converts PRT and MT to distances, speed can also affect distance requirements in several other ways. Maneuvers (e.g., braking) require greater distances at higher speeds. Under some conditions, speed can directly influence PRT by altering how and where drivers allocate their attention. Speed can influence the options the driver has and the difficulty and urgency of the decision.

3.7.1.1 Perception-Reaction Time

Refer to the PDDM.

Before performing a maneuver, the driver must recognize there is a need for some action and decide what that action should be. This mental activity – detection, perception and cognition – precedes a deliberate vehicle control action and takes some amount of time. Perception-reaction time (PRT) is typically defined as the period from the time the object or condition requiring a response becomes visible in the driver's field of view to the moment of initiation of the vehicle maneuver (e.g., first contact with the brake pedal). Although a particular PRT value (e.g., 2.5 seconds) is used in deriving sight distance requirements for a given design situation, this "reaction time" value should not be assumed as a fixed human attribute.

Refer to the *Manual on Uniform Traffic Control Devices* 2003, Section 2C.05, Placement of Warning Signs which describes a PRT model known as the PIEV (Perception-Identification-Emotion-Volition) model. The *MUTCD* Tables 2C-4 (metric) and 2C-5 (US Customary) show advance warning sign placement as a function of speed based on PIEV time requirements.

Various design recommendations to support older drivers include consideration of older driver perception-reaction time and sight distance needs

3.7.1.2 Maneuver Time

Refer to the PDDM.

Maneuver time (MT) is the interval from the initiation of the vehicle control response (i.e., end of the PRT) to the completion of the driving maneuvers (e.g., braking, turning, passing). The amount of distance needed for the safe and comfortable completion of the maneuver is dependent upon MT but also to other maneuver requirements. Maneuver distance (e.g., braking distance) is directly related to the physics of the situation (e.g., tire-pavement friction, grade), including vehicle performance capabilities. Maneuver time is also related to individual driver characteristics. For responding to an unexpected need to stop, the *Green Book* assumes a braking maneuver with a deceleration of 3.4 m/s^2 [11.2 ft/s^2]

3.7.2 Stopping Sight Distance

Refer to the PDDM.

The SSD is measured from the eye height of a passenger car driver, 1.08 m [3.5 ft] above the center of the inside lane, to an object 0.6 m [2.0 ft] high on the center of the inside lane on the roadway ahead.

The *Green Book*, Chapter 2 discusses driver reaction time and related issues in driver performance. The *Green Book* value for perception-reaction time (PRT) is 2.5 seconds. Under unfavorable conditions, PRTs can be 5 seconds or more, such as the following:

- Hazard camouflaged by background and initially off line-of-sight,
- Nighttime,
- Hazard unreflectorized and not self-illuminated,
- Hazard self-illuminated or retro-reflectorized but lighting configuration is unfamiliar to the driver,
- Low-beam headlights with or without streetlighting,
- Hazard off line-of-sight, and
- Glare from oncoming vehicles headlights or commercial lighting.

PRT does not start until drivers can see and, to some degree, recognize the hazard. The distance at which drivers can see an unilluminated, unreflectorized hazard depends on their headlights, their sensitivity to contrast and on their expectation of seeing the hazard. At speeds of 60 km/h [40 mph] and greater, using low beam headlights, most drivers will be too close to an unexpected, unreflectorized hazard at the point they can detect it in time to stop. A very low contrast hazard may not even be detected in time to start braking; therefore, objects blocking the road path (e.g., traffic islands) must be reflectorized. PRT may also be longer at locations of high driver workload (e.g., turns, multiple signs to be read).

3.7.3 Decision Sight Distance

Refer to the PDDM.

Decision sight distance is the sight distance that should allow drivers to detect an unexpected or difficult-to-perceive information source or condition, recognize the condition or its potential threat, select an appropriate speed and path, and initiate and complete the maneuver safely and efficiently.

The *Green Book* defines five maneuver types:

1. **Avoidance Maneuver A**. Stop on rural road where t = 3.0 seconds.
2. **Avoidance Maneuver B**. Stop on urban road where t = 9.1 seconds.
3. **Avoidance Maneuver C**. Speed/path/direction change on rural road where t varies between 10.2 and 11.2 seconds.
4. **Avoidance Maneuver D**. Speed/path/direction change on suburban road where t varies between 12.1 and 12.9 seconds.

5. **Avoidance Maneuver E**. Speed/path/direction change on urban road where t varies between 14.0 and 14.5 seconds.

The t values are pre-maneuver PRT values (i.e., pre-braking in the case of maneuvers A and B) and pre-lane changing in the case of maneuvers C, D and E. More PRT is allotted on urban roads than on rural roads. Urban roads generally involve higher traffic levels and greater visual complexity of the driving environment.

Avoidance maneuvers A and B involve the driver recognizing the roadway or traffic situation, identifying alternative maneuvers and comfortably braking to a stop. Avoidance maneuvers C, D and E involve the driver recognizing the roadway or traffic situation, identifying alternative maneuvers and making a lane change. Lane changes are assumed to require 3.5 to 4.5 seconds with decreasing time required at increasing speeds.

In computing and measuring DSD, 1.08 m [3.5 ft] eye-height and 0.6 m [2.0 ft] object height are assumed as for SSD.

For determining DSD, PRT includes time to detect the roadway change, recognize the need to make a decision, make the decision and initiate the response. The response may include searching for a gap in traffic in order to make a lane change and/or speed reduction for turns. Where lane changes are required, PRT includes time for drivers to search for a gap in traffic. Depending on the site, there are a number of potential cues that a decision point is ahead: signs, markings, traffic patterns, parked vehicles, etc., and site geometry (e.g., lane split).

Situational variables that may affect PRT are:

- High driver workload due to concurrent tasks (e.g., traffic merging, presence of guide, warning or regulatory signs unrelated to the lane drop);
- Dense traffic;
- Truck traffic that intermittently blocks the view;
- Off roadway clutter that can distract drivers; and
- Poor weather that increases driver workload and makes cues (especially markings) less conspicuous.

3.7.4 Passing Sight Distance

Refer to the PDDM.

The available PSD has considerable influence on the average speed of traffic, particularly when a road is operating near capacity. Road users benefit considerably when operating at or near design speeds with minimal traffic interference, and the designer should consider these beneficial effects when setting horizontal and vertical alignments. Lack of sufficient PSD opportunities affects traffic operations and may elevate the level of safety risks that are taken by drivers when passing. Where both the volume of traffic and percentage of trucks or other slow-moving vehicles are high, the lack of PSD can constrain capacity and traffic operations.

The *Green Book* model for PSD is based on data for single passenger vehicles passing single passenger vehicles. It is further based on the assumption that once drivers begin to pass, they have no opportunity to abort the pass. The *MUTCD* guidelines for markings, on the other hand, assume that drivers can abort the pass, and the assumed required passing sight distance is much shorter (e.g., *Green Book*, Exhibit 3-6, indicates that when the speed of the passing vehicle is 40 km/h [25 mph] that the total passing sight distance is 160 m [525 ft], compared to the *MUTCD* which indicates 140 m [460 ft]). The discrepancy is much higher at higher speeds; e.g. when the speed of the passing vehicle is 120 km/h [75 mph], the total passing sight distance calculated is 915 m [3000 ft] as compared to the *MUTCD* minimum of 395 m [1295 ft].

Geometric design for PSD includes four components to be evaluated (refer to the *Green Book*, Exhibit 3-4):

1. **d_1**. d_1 is traversed during PRT and during the interval when the driver brings the vehicle from the trailing speed to the point of encroachment of the passing lane.
2. **d_2**. d_2 is traversed while the passing vehicle occupies the passing lane.
3. **d_3**. d_3 is the distance between the passing vehicle at the end of its maneuver and the opposing vehicle.
4. **d_4**. d_4 is traversed by the opposing vehicle for two-thirds of the time the passing vehicle occupies the passing lane (i.e., 2/3 of d_2).

Consider that PSD will be longer for the following conditions:

- Passenger vehicle passing multiple vehicles,
- Passenger vehicle passing truck,
- Truck passing other vehicle, and
- Passing occurring on an upgrade.

3.7.5 Intersection Sight Distance

Refer to the PDDM.

The *Green Book* criteria assume a 7.5-second time gap for left-turning and 6.5 seconds for right-turning drivers turning in front of passenger cars. However, when drivers accept gaps less than 10 seconds, the major road vehicle typically slows to accommodate the entering vehicle.

Two types of clear sight triangles are used at each intersection: approach sight triangles and departure sight triangles. Approach sight triangles are applicable for when the minor road driver is in motion, while departure sight triangles apply when the minor road vehicle is accelerating from a stop position.

The object height is considered to be equivalent to the driver's eye height of 1.08 m [3.5 ft] above the surface of the intersecting road.

There is an assumption of some cooperative behavior from the conflicting (major road) traffic. The values for sight distance provide time for the minor road vehicle to accelerate from a stop and complete a left-turn without unduly interfering with major-road traffic operations.

At intersections with more complex geometry (e.g., offset or curve), a 1 to 2 seconds additional gap may be needed for passenger car drivers. Single unit trucks may require on additional 2.6 seconds and double unit trucks may require 4.0-second gaps for left turns than passenger car drivers.

Passenger car critical gaps for right turns are approximately 1.7 seconds shorter than for left-turns. On a multilane situation, a 0.7 second adjustment per additional lane in the critical gap size should be made for right turns, 0.4 seconds for left-turns and 0.5 seconds for crossing maneuvers. For intersections on a grade, critical gaps are longer by 0.1 second per percent grade for right turns, and 0.2 seconds per percent grade for left turns or crossing maneuvers. Accepted gaps for older drivers average about 1 second longer than those for younger drivers. The accepted gap may also be lengthened by high driver workload (e.g., multiple lanes to cross and therefore more than one oncoming vehicle to consider, several signs to be read, entrances and exits in area of influence of the intersection).

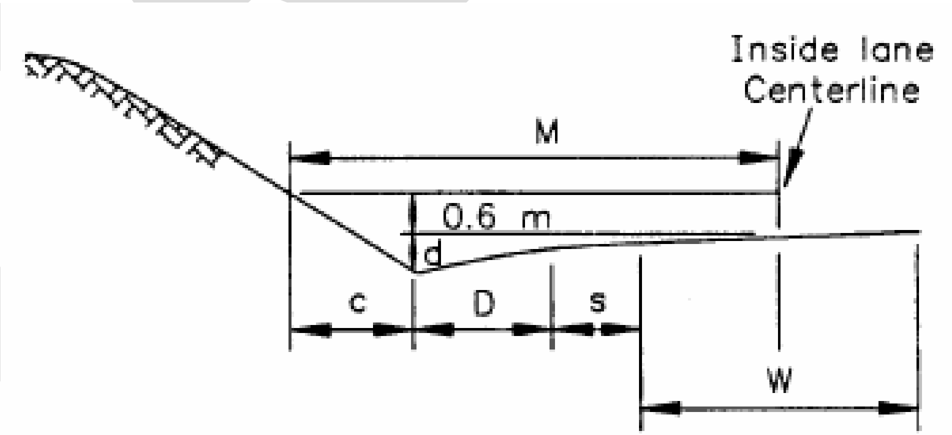
ISD criteria are based on time gaps and include assumptions about speed adjustments made by the major-road driver. Additional distance may be required in situations where the approaching driver may not slow sufficiently if the conflict recognition is delayed.

3.7.6 Limiting Conditions and Restrictions

Refer to the PDDM.

See Exhibit 3.7-A for an example of a sight line offset (M) on a cut slope.

Exhibit 3.7-A LATERAL CLEARANCE FOR STOPPING SIGHT DISTANCE



Offset (M) = c + D + s + 0.5W

Where:

c = the drop (d) from the center of the inside lane to the bottom of the ditch plus 0.6 m (2.0 ft) multiplied by the cut slope ratio.

D = the total ditch width from bottom of ditch to edge of shoulder.

s = the shoulder width

W = width of the inside lane

Note: When vegetation is expected to grow on the cut slope, the drop (d) should be reduced by the estimated depth of the vegetation. On crest vertical curves, (d) should be reduced appropriately. On sag vertical curves, (d) should be increased.

When vegetation is not controlled on the cut slope, reduce c to zero.

3.7.7 Risk Assessment and Mitigation

Refer to the PDDM.

3.7.8 Sight Distance References

Refer to the PDDM.

3.8 GEOMETRIC CROSS SECTION

Refer to the PDDM.

3.8.1 Traveled Way (Lane) Width

Refer to the PDDM.

3.8.2 Shoulder Width

Refer to the PDDM.

3.8.3 Horizontal Clearance to Structures

Refer to the PDDM.

3.8.4 Pavements and Design Considerations

Refer to the PDDM.

3.8.4.1 Cross Slope

Refer to the PDDM.

3.8.4.2 Pavement Structure

Refer to the PDDM.

A typical pavement structure design has a 20- to 25-year service life. The pavement design is based on soil samples and the predicted volume and type of traffic using the highway during the design life. The pavement structure thickness also varies with climatic conditions and the type and strength of subgrade material used (usually in the top 300 mm to 600 mm [1 ft to 2 ft] of subgrade). Generally, free-draining, high-strength granular materials require less thickness than low-strength materials containing primarily clay or silt.

3.8.5 Risk Assessment and Mitigation

Refer to the PDDM.

3.9 ROADWAY WIDENING

Refer to the PDDM.

For simple curves, applying the total traveled way widening on the inside of the curve more closely approximates the vehicle path through the curve and avoids a bulge in the outside edge of pavement at the tangent to curve transitions.

3.9.1 Traveled Way Widening on Curves

Refer to the PDDM.

3.9.2 Auxiliary Lanes

Refer to the PDDM.

Auxiliary lanes are portions of the roadway that adjoin the through lanes and provide for parking, speed change, turning, weaving, truck climbing, passing or other purposes supplementary to through-traffic movement. They might be a part of the traveled way, such as lanes for passing, truck climbing, and weaving. They also maintain lane balance and accommodate entering and exiting traffic. Lanes for turning, storage for turning, and acceleration/deceleration are not part of the traveled way, but require a shoulder. Facilities for parking lanes, bike lanes, bus pullouts, etc., may replace the shoulder.

3.9.3 Parking Lanes

Refer to the PDDM.

3.9.4 Speed Change Lanes

Refer to the PDDM.

3.9.5 Turning Lanes

Refer to the PDDM.

3.9.6 Weaving Sections

Refer to the PDDM.

3.9.7 Climbing Lanes

Refer to the PDDM.

3.9.8 Passing Zones and Lanes

Refer to the PDDM.

The IHSDM Traffic Analysis Module uses the TWOPAS traffic simulation module to estimate traffic quality of service measures for an existing or proposed design under current or projected future traffic flows. The traffic analysis module facilitates use of TWOPAS using the roadway geometry data stored by IHSDM. TWOPAS is the traffic simulation model used to develop the two-lane highway chapter of the Transportation Research Board's (TRB) *Highway Capacity Manual*. TWOPAS produces measures including average speed and percentage of time spent following other vehicles. TWOPAS has the capability to simulate any combination of grades, curves, sight restrictions, no passing zones and passing and climbing lanes. The traffic analysis module is particularly useful during project scoping and preliminary engineering for evaluating the operational performance of alternatives to two-lane cross sections, including passing lanes, climbing lanes and short four-lane sections.

3.9.9 Slow Moving Vehicle Turnouts

Refer to the PDDM.

3.9.10 Parking Pullouts

Refer to the PDDM.

3.9.11 Shoulder Widening for Barriers

Refer to the PDDM.

3.10 MEDIANS

Refer to the PDDM.

A median is an important consideration in the design of multilane highways. Medians may also be used on two-lane roadways; however additional traveled way and shoulder width is usually required for emergency vehicle access, construction and temporary traffic control, and for maintenance and snow removal activities. The median is the portion of a highway separating opposing directions of the traveled way. The median width is the dimension between the edges of the traveled way including the shoulders (paved or unpaved), slopes, ditches, barriers and other features. Medians may be depressed, raised or flush with the traveled way surface. Raised medians are normally associated with design speeds of 70 km/h [45 mph] or less.

3.10.1 Benefits and Disadvantages of Medians

Refer to the PDDM.

3.10.2 Urban Medians

Refer to the PDDM.

A two-way continuous left-turn lane (TWLTL) is a paved, flush median that allows left-turning movements in either direction.

3.10.3 Rural Medians

Refer to the PDDM.

3.10.4 Variable Medians and Independent Alignments

Refer to the PDDM.

3.11 CURBS

Refer to the PDDM.

Curbs are raised delineation barriers within or along the edge of the roadway. The type and location of curbs affects driver behavior and the safety and utility of a highway. Aside from their positive aspects in performing certain functions, curbs can be obstructions and can adversely affect operations and safety. Typically, curbs do not have any significant re-directional capabilities, and can be a detriment to errant vehicles.

3.11.1 Vertical Curbs

Refer to the PDDM.

Vertical curbs are defined as those having a vertical or nearly vertical traffic face. These are intended to discourage motorists from deliberately leaving the roadway. Vertical curb may deter some vehicles from intentionally entering the area behind the curb, but will generally not prevent an errant vehicle from mounting the curb. Vertical curbs located near the edge of the travel lane have an effect on lateral position of vehicles, causing them to shy away from the curb, which reduces the effective lane or shoulder width.

3.11.2 Sloping Curbs

Refer to the PDDM.

3.11.3 Curb Offsets

Refer to the PDDM.

3.11.4 Accessibility Issues with Curbing

Refer to the PDDM.

3.12 ROADSIDE DESIGN CONSIDERATIONS

Refer to the PDDM.

3.13 FORESLOPES

Refer to the PDDM.

Foreslopes ensure the stability of the roadway and provide an opportunity for recovery of an errant vehicle.

3.13.1 Recoverable Foreslopes

Refer to the PDDM.

3.14 DESIGN OF INTERSECTIONS

Refer to the PDDM.

At-grade intersections are a critical part of highway design. The efficiency of a road network depends on the effectiveness of the intersections. The number of possible conflicts and crashes at intersections is very high compared to normal roadway operations. Proper design practice will minimize the safety risk of these areas of high crash potential.

Traffic control facilitates traffic movement and decreases the potential for conflict, but limits the capacity of intersecting roadways and affects the delay to users

3.14.1 Intersection Characteristics

Refer to the PDDM.

3.14.2 Intersection Types

Refer to the PDDM.

3.14.3 Intersection Design Vehicle

Refer to the PDDM.

Design vehicles have selected dimensions and operating characteristics. Each represents a class of vehicles that establish design controls for specific conditions. The design vehicle affects the horizontal and vertical alignments, lane widths, turning radii, intersection sight distance, storage length requirements and acceleration and deceleration lengths of auxiliary lanes.

3.14.4 Intersection Alignment

Refer to the PDDM.

3.14.4.1 Horizontal Alignment and Skew

Refer to the PDDM.

Skew angles create problems with visibility, pedestrian safety, and vehicle turns. Skew angles also adversely affect sight distance and design of vehicle swept paths, increase the open pavement areas within the intersection, and increase the area of conflicting movements. Operationally, the skews increase crossing times for vehicles and pedestrians, and can adversely affect the intersection capacity.

3.14.4.2 Lane Shifts

Refer to the PDDM.

The driver may not have a clear view of the receiving lanes through an intersection due to other vehicles. If a shift occurs in the intersection where there are no pavement markings, the vehicles following the platoon through may have their vision blocked by larger leading vehicles. If the front vehicle shifts through the intersection, the following vehicles may assume that the lead driver is drifting or changing lanes, and therefore do not follow. This combination of sight restriction and erratic vehicle operation could lead a following vehicle out of the travel lane.

3.14.4.3 Vertical Alignment

Refer to the PDDM.

3.14.4.4 Intersection Lane Widths

Refer to the PDDM.

3.14.5 Sight Distance at Intersections

Refer to the PDDM.

3.14.6 Left-Turn Lanes

Refer to the PDDM.

Left-turn lanes are an important element of the intersection as they allow speed changes and turning maneuvers to occur outside of the normal flow of highway traffic. This reduces the incidence of rear-end collisions and helps to maintain through traffic flow on the highway. Design of left-turn lanes includes the taper, deceleration and storage.

A left-turn lane is an auxiliary lane on the left side of a one-directional pavement for use as speed change and storage of left-turning vehicles. Left-turn movements result in more critical traffic conflicts than do right-turn movements. Left-turn movements encounter delays while waiting for gaps in opposing traffic, in addition to conflict with other vehicles at the intersection or access point. Vehicles stopped in the through lane while waiting to make left-turn present multiple safety hazards, causing other vehicles to rapidly stop or use the shoulder or other lanes to avoid them. Left-turn vehicles stopped in a through lane can drastically reduce the safety and service conditions of the highway by increasing the possibility of rear-end collisions and impeding through traffic flow.

Left-turn lanes are an economical way to reduce delays and crashes at intersections.

3.14.7 Right-turn Lanes

Refer to the PDDM.

Right turn lanes reduce the incidence of rear-end collisions and help to maintain through traffic flow on the highway.

Where adequate right-of-way exists, providing right-turn lanes is usually cost-effective and can provide increased safety and operational efficiency.

The design of the corner radius affects how drivers traverse the turn, including speed and merging path.

3.14.8 Bypass Lanes

Refer to the PDDM.

3.14.9 Channelization

Refer to the PDDM.

3.14.10 Islands

Refer to the PDDM.

3.14.11 Pedestrian and Bicycle Considerations at Intersections

Refer to the PDDM.

3.14.12 Signalization

- Refer to the PDDM.

3.15 RAILROAD-HIGHWAY GRADE CROSSINGS

Refer to the PDDM.

3.15.1 Survey and Mapping

Refer to the PDDM.

3.15.2 Highway Design

Refer to the PDDM.

3.15.3 Traffic Control and Protection

Refer to the PDDM.

3.16 PEDESTRIAN CONSIDERATIONS AND FACILITIES

Refer to the PDDM.

3.16.1 Sidewalks

Refer to the PDDM.

3.16.2 Walking and Hiking Trails

Refer to the PDDM.

3.16.3 Accommodation of the Disabled

Refer to the PDDM.

The following accessibility requirements apply to the design of parking areas and loading zones:

- Parking spaces for disabled persons and accessible passenger loading zones must be the spaces or zones located closest to the nearest accessible entrance on an accessible route.

- Parking spaces for disabled persons must be at least 2440 mm [84 in] wide for passenger cars and 3350 mm [132 in] wide for van accessible spaces, and shall have an adjacent access aisle at least 1525 mm [60 in] wide. One in every eight accessible spaces, but not less than one, must be designated "van accessible." Van parking spaces are permitted to be 2440 mm [96 in] wide minimum where the adjacent access aisle is 2440 mm [96 in] wide minimum. Two accessible parking spaces may share a common access aisle. Parking access aisles must adjoin an accessible route to the facility and must comply with width and slope requirements for accessible routes.

- Access aisles must extend the full length of the parking spaces they serve.

- Access aisles must be marked to discourage parking in them.

- Accessible routes must connect parking spaces to accessible entrances. In parking facilities where the accessible route must cross vehicular traffic lanes, marked crossings enhance pedestrian safety, particularly for people using wheelchairs and other mobility aids. Where possible, it is preferable that the accessible route not pass behind parked vehicles.

- Accessible routes must have a minimum clear width of 915 mm [36 in] and no running slope greater than five percent.

- Parking spaces and access aisles must be level, with surface slopes not exceeding 2 percent in all directions.

- The surface of all accessible routes must be stable, firm, and slip resistant.

- Changes in the level of accessibility lanes up to 6 mm [¼ in] may be vertical and do not require edge treatment.

- Changes in level between 6 mm and 12 mm [¼ in and x ½ in] shall be beveled with a slope no greater than 1V:2H. Changes in level greater than 12 mm [½ in] require a bevel at the slope of 1V:12H.

- Parking spaces must be reserved for the disabled by a sign showing the symbol of accessibility. The signs must be visible, even when a vehicle is parked in the space. The sign should be post mounted and be located at the front center of the parking space. The sign should be on the near side of any adjacent sidewalk. Each parking stall shall have a sign.

3.17 BICYCLE CONSIDERATIONS AND FACILITIES

Refer to the PDDM.

3.18 TRANSIT CONSIDERATIONS AND FACILITIES

Refer to the PDDM.

3.19 PARKING LOT LAYOUT CONSIDERATIONS

Refer to the PDDM.

CHAPTER 4

RESURFACING, RESTORATION AND REHABILITATION (RRR) DESIGN

Refer to the PDDM.

4.1 APPLICATION OF DESIGN STANDARDS

Refer to the PDDM.

4.2 IMPROVEMENT OF SAFETY PERFORMANCE

Refer to the PDDM.

4.3 EVALUATION OF EXISTING GEOMETRIC DESIGN

Refer to the PDDM.

Horizontal and vertical curvature and stopping sight distance directly relate to the speed of vehicles. As a consequence, deviations from the standards applicable to the current design speed of vehicles may cause safety problems.

4.4 IMPROVEMENT OF ROADSIDE CONDITIONS

Refer to the PDDM.

Safety items reduce the severity of run-off-the-road crashes. These items include traffic barriers (including bridge rails), barrier and bridge rail transitions, flattening slopes to eliminate the need for barriers, crash cushions, breakaway or yielding sign supports and breakaway luminaire supports.

The project engineer can contact the jurisdictional agency traffic engineer to arrange for a curve speed determination.

4.5 IMPROVEMENT OF TRAFFIC OPERATIONS

Refer to the PDDM.

4.6 EVALUATION OF PAVEMENT AND DRAINAGE STRUCTURES

Refer to the PDDM.

4.7 MITIGATION OF SUBSTANDARD DESIGN FEATURES

Refer to the PDDM.

CHAPTER 5

OTHER HIGHWAY DESIGN ELEMENTS

5.1 EARTHWORK DESIGN

Refer to the PDDM.

Roadway excavation is not classified for measurement or payment purposes, but may be categorized for computation of earthwork design and mass purposes as the following types:

1. **Common Material**. Common material is largely earth or earth with detached boulders less than 0.5 m^3 [0.5 cuyd].
2. **Rippable Rock**. Rippable rock refers to material ready for excavating after being loosened by a ripper.
3. **Solid Rock**. Solid rock includes hard rock in place, ledge rock and boulders requiring drilling and blasting equipment for removal. Any blasting work will be performed according to the rock blasting section specifications.

5.1.1 Clearing and Grubbing

Refer to the PDDM.

5.1.2 Removal of Structures and Obstructions

Refer to the PDDM.

5.1.3 Design of Excavation and Embankment

Refer to the PDDM.

5.1.4 Determination of Excavation and Embankment Volumes

Refer to the PDDM.

5.1.4.1 General

Use the average end-area method of determining volumes. The total volume of earthwork is the sum of the volumes of the prismoids formed by adjacent cross sections.

When using the average end-area method, the prismoid is treated as a prism whose cross section is the mean of the two end areas of the prismoid. Equation 5.1(1) presents the formula for use in the average end-area method.

$$V = L\left(\frac{A_1 + A_2}{2}\right) \qquad \text{Equation 5.1(1)}$$

Where:

V = Volume (m^3 [cubic yard])
A1 and A2 = Cross sectional end areas (m^2 [square feet]).
L = Distance between the cross sections (m [ft]).

This formula is approximately correct. Due to its simplicity and substantial accuracy in the majority of cases, it has become the formula in common use. It gives results, in general, larger than the true volume.

When the earthwork center of mass (centroid of the area of cut or fill) is not centered about the roadway, and the alignment is in curvature, the actual volume calculated is not correct since the true distance between the end area centroids will differ from the distance along the centerline. In this case it may be necessary to adjust excavation volumes for curvature in order to properly account for earthwork. In many cases this is not necessary since the eccentricities about centerline of the earthwork mass tend to equalize themselves over the route.

5.1.4.2 Shrink and Swell Factors

Using data furnished by the Geotechnical Unit, the designer must check the characteristics of the material to be excavated or placed in embankments. The excavation used for embankments will range from rock to earth and have shrink/swell factors assigned for design purposes.

The values shown in Exhibit 5.1-A may be used for estimating purposes prior to obtaining the project specific information from the Geotechnical Unit.

Exhibit 5.1-A SHRINK/SWELL FACTORS FOR COMMON MATERIALS*

Material	Measured							
	In-Situ		Loose			Embankment		
	Mass Density[1]		Mass Density[2]		% Swell[3]	Mass Density[2]		% Swell/-Shrink[3]
	kg/m^3	lb/ft^3	kg/m^3	lb/ft^3		kg/m^3	lb/ft^3	
Andesite	2930	4950	1760	2970	67	2050	3460	43
Basalt	2935	4950	1790	3020	64	2160	3640	36
Bentonite	1600	2700	1185	2000	35	–	–	–
Breccia	2400	4050	1800	3040	33	1890	3190	27

Material	Measured							
	In-Situ		Loose			Embankment		
	Mass Density[1]		Mass Density[2]		% Swell[3]	Mass Density[2]		% Swell/-Shrink[3]
	kg/m^3	lb/ft^3	kg/m^3	lb/ft^3		kg/m^3	lb/ft^3	
Calcite-Calcium	2670	4500	1600	2700	67	–	–	–
Caliche	1440	2430	1245	2100	16	1900	3200	-25
Chalk	2410	4060	1285	2170	50	1810	3050	33
Charcoal	–	–	610	1030	–	–	–	–
Cinders	760	1280	570	960	33	840	1420	-10
Clay								
- Dry	1910	3220	1275	2150	50	2120	3570	-10
- Damp	1985	3350	1180	2010	67	2205	3720	-10
Conglomerate	2205	3720	1660	2800	33	–	–	–
Decomposed rock								
- 75%R. 25%E.	2445	4120	1865	3140	31	2185	3680	12
- 50%R. 50%E.	2225	3750	1610	2710	38	2375	4000	-6
- 25%R. 75%E.	2005	3380	1405	2370	43	2205	3720	-9
Diorite	3095	5220	1855	3130	67	2165	3650	43
Diotomaceous earth	870	1470	540	910	62	–	–	–
Dolomite	2890	4870	1725	2910	67	2015	3400	43
Earth, loam								
- Dry	1795	3030	1230	2070	50	2090	3520	-12
- Damp	2000	3370	1400	2360	43	2090	3520	-4
- Wet, mud	1745	2940	1745	2940	0	2090	3520	-20
Feldspar	2615	4410	1565	2640	67	1825	3080	43
Gabbro	3095	5220	1855	3130	67	2165	3650	43
Gneiss	2700	4550	1615	2720	67	1885	3180	43
Gravel (Dry)								
- Uniformly Graded	1770	2980	1600	2700	10	1870	3150	-5
- Avg. Gradation	1945	3280	1620	2730	20	2120	3570	-8
- Well Graded	2180	3680	1645	2770	33	2450	4130	-11
Gravel (Wet)								
- Uniformly Graded	1965	3310	1870	3150	5	1870	3150	-5
- Avg. Gradation	2160	3640	1950	3290	10	2120	3570	-2
- Well Graded	2425	4090	2090	3520	16	2450	4130	-1
Granite	2695	4540	1565	2640	72	1880	3170	43

Material	Measured							
	In-Situ		Loose			Embankment		
	Mass Density[1]		Mass Density[2]		% Swell[3]	Mass Density[2]		% Swell/-Shrink[3]
	kg/m^3	lb/ft^3	kg/m^3	lb/ft^3		kg/m^3	lb/ft^3	
Gumbo								
- Dry	1915	3230	1275	2150	50	2120	3570	-10
- Wet	1985	3350	1200	2020	67	2205	3720	-10
Gypsum	2420	4080	1410	2380	72	–	–	–
Igneous rocks	2795	4710	1675	2820	67	1960	3300	43
Kaolinite								
- Dry	1915	3230	1275	2150	50	–	–	–
- Wet	1985	3350	1190	2010	67	–	–	–
Limestone	2600	4380	1595	2690	63	1910	3220	36
Loess								
- Dry	1910	3220	1275	2150	50	2120	3570	-10
- Wet	1985	3350	1190	2010	67	2205	3720	-10
Marble	2680	4520	1600	2700	67	1875	3160	43
Marl	2220	3740	1330	2240	67	1555	2620	43
Masonry, rubble	2325	3920	1395	2350	67	1630	2750	43
Mica	2885	4860	1725	2910	67	–	–	–
Pavement								
- Asphalt	1920	3240	1150	1940	50	1920	3240	0
- Brick	2400	4050	1440	2430	67	1685	2840	43
- Concrete	2350	3960	1405	2370	67	1645	2770	43
- Macadam	1685	2840	1010	1700	67	1685	2840	0
Peat	700	1180	530	890	33	–	–	–
Pumice	640	1080	385	650	67	–	–	–
Quartz	2585	4360	1550	2610	67	1780	3000	43
Quartzite	2680	4520	1610	2710	67	1875	3160	43
Rhyolite	2400	4050	1435	2420	67	1700	2870	43
Riprap rock	2670	4500	1550	2610	72	1870	3150	43
Sand								
- Dry	1710	2880	1535	2590	11	1920	3240	-11
- Wet	1915	3090	1835	3230	5	2050	3460	-11
Sandstone	2415	4070	1495	2520	61	1795	3030	34
Schist	2685	4530	1610	2710	67	1880	3170	43

Material	Measured							
	In-Situ		Loose			Embankment		
	Mass Density[1]		Mass Density[2]		% Swell[3]	Mass Density[2]		% Swell/-Shrink[3]
	kg/m^3	lb/ft^3	kg/m^3	lb/ft^3		kg/m^3	lb/ft^3	
Shale	2640	4450	1470	2480	79	1775	2990	49
Silt	1920	3240	1410	2380	36	2310	3890	-17
Siltstone	2415	4070	1495	2520	61	2705	4560	-11
Slate	2670	4500	1540	2600	77	1870	3150	43
Talc	2750	4640	1650	2780	67	1930	3250	43
Topsoil	1440	2430	960	1620	56	1945	3280	-26
Tuff	2400	4050	1600	2700	50	1810	3050	33

Notes:

1. Subject to average ±5% variation.
2. Mass densities are subject to adjustments in accordance with modified swell and shrinkage factors.
3. Based on average in-situ densities. A negative number represents a shrinkage. Factors subject to ±33% variation.

Roadway excavation is typically measured in the original, undisturbed position. The specifications must clearly state the place and method of measurement because almost all materials change volume in their movement from cut to fill.

Excavated common material will expand beyond its original volume in the transporting vehicle but will typically shrink below the excavated volume when compacted into the fill. To illustrate, 1 m^3 [1 cuyd] of earth in the cut may use 1.25 m^3 [1.25 cuyd] of space in the transporting vehicle, and finally occupy only 0.65 m^3 to 0.85 m^3 [0.65 cuyd to 0.85 cuyd] in the embankment. This, of course, depends on its original density and the compactive effort applied. This difference between the original volume in a cut and the final volume in a fill is the shrink.

Excavated solid rock placed in a fill typically occupies a larger volume. This change in volume is the swell. When the voids in the rock embankment become filled with earth or other fine material, the volume in the fill will just about equal the combined volumes in the two source locations.

For light soil excavation and for fills constructed on swampy ground subject to settlement, the shrink may range from 20 to 40 percent or even greater. For moderate soil excavation, the shrink ranges from ten to 25 percent. For heavy soil excavation with deep cuts and fills, expect a range of approximately 15 percent shrink to five percent swell. Shrink generally includes the slight waste in transporting material from cut to fill and the loss for material that escapes beyond the toe of slopes. Embankments that are slightly overbuilt also contribute to an apparent shrink.

The underlying soil below embankments may also settle and compact, or be displaced, due to placement and compaction of the embankment, contributing to an apparent shrink. Settlement results in apparent shrinkage, but one is not directly proportional to the other. Do not confuse shrink with subsidence. Subsidence is settlement of the entire embankment due to weak foundation conditions (e.g., placing heavy fill on swampy soil).

A swell of 5 to 25 percent is often anticipated in rock excavation depending upon the proportion of solid rock and upon the size of the rock placed in the fill. Rock blasting, especially cushion blasting, is inexact and may result in slightly over-excavated slopes, contributing to an apparent swell.

When available, the design should consider actual field shrink and swell factors for like material used on adjoining projects.

The shrink factor is determined by Equation 5.1(2):

$$\text{Shrink Factor} = \frac{1}{1+\frac{\%\ \text{shrinkage}}{100}} \qquad \text{Equation 5.1(2)}$$

Thus, if the percent of shrink is 25 percent, the shrink factor would be:

$$\frac{1}{1+\frac{25}{100}} = \frac{1}{1.25} = 0.8$$

The swell factor for rock excavation is determined by Equation 5.1(3):

$$\text{Swell Factor} = 1+\frac{\%\ \text{swell}}{100} \qquad \text{Equation 5.1(3)}$$

Thus, if the percent of swell is 25 percent, the swell factor would be the following:

$$1+\frac{25}{100} = 1.25$$

The shrink/swell factors are typically applied to the excavation quantities to arrive at the adjusted quantities.

5.1.5 Balancing Earthwork

Refer to the PDDM.

It frequently happens that the material from the adjacent cuts is not sufficient to make the intervening fill. In this case, material is borrowed from outside the construction limits.

When there is an excess of excavated material, it may be necessary to dispose of the material. Instead of long hauls, it may be more economical to dispose of the material by widening shoulders or placing the material in disposal areas than to pay hauling costs.

If the earthwork is not in balance, the designer should try to adjust grade line or centerline so it is in balance. When a balanced project is not practical or desirable, the designer either disposes of excess material or borrows material to obtain a balance. Designated disposal or borrow areas require clearance for proper ownership, rights-of-use, environmental concerns and applicable permits.

Waste areas for the disposal of excess material and/or borrow areas should be shown on the plans.

5.1.6 Haul

Refer to the PDDM.

Haul consists of transporting material from its original position to its final location. The cost to haul material is required to estimate the unit price of various items of work.

Haul costs are based on hauling one cubic meter [cubic yard] of material a distance of 1 km [1 mi] or 1 metric ton [1 ton] of material a distance of 1 km [1 mi] using the shortest practical route. Haul costs are generally based on a rate per unit of time for the hauling equipment multiplied by the actual time needed to move the material. This is quite simple when calculating costs to haul from crusher sites to the middle of a project. It is more complicated to estimate the costs to haul material between balance points on a grading project. The use of a mass diagram as described below will provide the quantity of haul within balance points as well as other helpful information. The haul cost will be much greater for haul in the uphill direction than in the downhill direction.

5.1.7 Mass Diagram

Refer to the PDDM.

A mass diagram is a continuous curve showing the accumulated algebraic sum of the excavation (cuts (+)) and embankment (fills (–)) from some initial station to any succeeding station. The points of the mass curve are plotted to a horizontal scale of distances (same as profile) and a vertical scale of cubic meters [cubic yards] (e.g., 1 mm = 50 m^3 [1 in = 1000 cuyd]).

The characteristic properties of a mass diagram (or curve) are as follows:

- The ordinate at any point on the mass curve represents the cumulative cubic meter (cubic feet) to that point on the profile.
- Within the limits of a single cut, the curve rises from left to right. Within the limits of a single fill, it falls from left to right.
- Sections where the cumulative cubic meter (cubic feet) changes from cut to fill correspond to a maximum. Sections where the cumulative cubic meter (cubic feet) changes from fill to cut correspond to a minimum.

- Any horizontal line cutting off a loop of the mass curve intersects the curve at two points. Within this area the cut is equal to the fill (if adjusted for shrinkage). This line is called a balance line.
- The loops that convex above a balance line show that the haul from cut to fill is in the forward direction. Loops that concave below a balance line indicate a reverse direction of haul.
- The total area of the loop above (or below) the balance line represents the quantity of haul for an earthwork balance between the two balance points.

A mass diagram can assist in balancing cuts and fills and showing the best distribution of materials. The mass diagram shows the most economical procedure for the disposing of excavated material. It also shows which part to move forward or backward, and whether borrowing and wasting are advisable. It presents a graphic picture of the distribution of materials and the haul involved in the placement.

5.1.8 Borrow and Offsite Borrow Areas

Refer to the PDDM.

Borrow excavation consists of material used for embankment construction that is obtained from outside the roadway prism. Borrow excavation includes unclassified borrow, select borrow, and select topping. In addition to meeting the embankment needs to balance earthwork volumes, borrow may be used to improve the quality of the subgrade in both cuts and fills and to reduce the pavement structural section.

5.1.9 Waste and Offsite Waste Areas

Refer to the PDDM. for the roadway is applicable to offsite waste areas.

Waste consists of excess and unsuitable roadway excavation and subexcavation that cannot be used onsite.

5.1.10 Rock Blasting

Refer to the PDDM.

Rock blasting consists of fracturing rock and constructing stable final rock cut faces using controlled basting and production blasting techniques. Controlled blasting uses explosives to form a shear plane in the rock along the designed backslope, and includes either presplitting or cushion blasting techniques. Production blasting uses explosives to fracture rock within the volume for excavation, as applicable to expedite the earthwork handling and production.

Rock blasting includes the requirement for the contractor to develop and provide blasting plans and to use special blasting construction expertise and procedures.

5.1.11 Watering and Water Sources

Refer to the PDDM.

5.1.12 Structural Excavation and Backfill

Refer to the PDDM.

Calculate the average end area and compute the excavation quantity.

For determining an estimated quantity, round the structure excavation for each pipe to the nearest cubic meter [cubic yard] and show this quantity on the Drainage Summary Sheet of the plans.

Structure excavation for foundation trenches for riprap, walls, footings, etc., should be calculated by average end area methods for the various locations and shown on the plans.

5.1.13 Conservation of Materials

Refer to the PDDM.

5.1.14 Roadway Obliteration

Refer to the PDDM.

Material from the old roadway used in the new roadway, and material from the new roadway used in obliteration of the old roadway, is paid for under Section 204 or other Sections of the *Standard Specifications*. The designer may obtain topsoil or other recyclable materials in this manner.

5.1.15 Linear Grading

Refer to the PDDM.

Linear grading consists of the design and construction of the roadway template with allowance during the construction for shifts and variations in the roadway horizontal alignment and profile grade, within specified grading tolerances. The horizontal tolerances are typically a maximum of 3 m [10 ft] left or right of the designed centerline, and modification of the designed radii of up to 50 percent. The vertical tolerances are typically a maximum of 1.5 m [5 ft] up or down from the design profile grade elevation, provided the new grade tangent does not vary more than 2 percent from the design grade. Lesser tolerances may be specified, as appropriate.

5.1.16 Subgrade Treatments and Stabilization

Refer to the PDDM.

5.1.16.1 Subexcavation

Refer to the PDDM.

5.1.16.2 Subgrade Stabilization

Refer to the PDDM.

5.1.16.3 Topping

Refer to the PDDM.

5.1.16.4 Earthwork Geotextile Stabilization

Refer to the PDDM.

In brief, geotextiles are a broad type of geosynthetic material consisting of synthetic fibers rather than natural fibers such as cotton, wool or silk, such that they may be stronger and resist biodegradation. The synthetic fibers are made into a flexible, generally porous fabric by standard weaving machinery or are matted together in a random, or nonwoven, manner, or they may be knit. The geotextiles are pervious to water flow but to a widely varying degree. The numerous roadway design applications fall into the following major functions:

1. **Dissimilar materials**. Separate dissimilar materials:
    - between subgrade and base,
    - between foundation and structural embankments,
    - between pervious and impervious subgrade materials, and
    - between soils and rock riprap.
2. **Weak Soils**. Reinforce weak soils or other materials:
    - over soft soils for placement of embankments,
    - over soft soils for placement of subbase or base,
    - to reinforce the strength of subbase or base layers,
    - to reinforce structural embankments, and
    - to contain rock buttresses or filter mattresses.
3. **Filtration** (across the geotextile). Use the following for filtration:
    - As a silt fence,
    - around granular backfill for underdrains, and

- around pervious subgrade drainage layers.

4. **Drainage Blanket or Interceptor** (within the geotextile). Use a drainage blanket or interceptor in the following cases:

    - drainage blanket under subbase or base layers,
    - drainage interceptor for edge drains or underdrain systems,
    - drainage interceptor for structural embankments or retained backfill, and
    - dissipate drainage from within embankments.

5. **Moisture Barrier**. When impregnated with rubber or plastic as a geomembrane, use a moisture barrier:

    - between subgrade layers to retain or block moisture transfer in expansive soils,
    - between edge drains to direct drainage flow,
    - between soil and structural materials to block drainage infiltration, and
    - liners for containment of solutions or polluted drainage.

Other types of geosynthetic stabilization include geogrids, geonets, geomembranes, geosynthetic clay liners and combinations of geocomposite materials which have roadway design applications. Refer to PDDM Chapter 6 for information on roadway applications for these type materials.

5.1.16.5 Subgrade Drainage and Underdrains

Refer to the PDDM.

Subgrade drainage consists of drainage blankets, underdrains, sheet drains and pavement edge drains. Subgrade drainage systems facilitate the interception and removal of water from the subgrade to improve the strength and bearing capacity, and to improve long-term performance of the base and pavement. Drainage systems may be either vertical or horizontal layers of free-draining granular material separated by geotextile, and may include drainage pipe, or may consist of prefabricated geocomposite systems. As applicable, design subgrade drainage and underdrains where subsurface water is apparent and abundant. Separate the subgrade drainage system from collecting surface drainage (e.g., from the roadway ditch), using semi-permeable or impermeable materials. In addition to subgrade drainage systems, consider widening and deepening shallow ditches in cut areas. Also consider longitudinal subgrade drainage systems in cut areas where side slope stability is a concern. Coordinate closely with the Geotechnical Unit in the location, depth, materials and other aspects of the subgrade drainage design, as described in PDDM Chapter 6.

For additional information on subdrainage design refer to:

- FHWA-RD-30, *Guidelines for the Design of Subdrainage Drainage Systems for Highway Structural Sections*, FHWA, 1972.

- FHWA-TS-80-224, *Highway Subdrainage Design*, FHWA, 1980

- MS-15, *Drainage of Asphalt Pavement Structures*, The Asphalt Institute, 1981.

5.2 SLOPE TREATMENTS

Refer to the PDDM.

5.2.1 Safety Considerations

Refer to the PDDM.

5.2.2 Geotechnical Considerations

Refer to the PDDM.

5.2.3 Grading Techniques

Refer to the PDDM.

5.2.3.1 Slopes of Cuts and Fills

Refer to the PDDM.

5.2.3.2 Transitioning Cut and Fill Slopes

Refer to the PDDM.

5.2.3.3 Slope Rounding

Refer to the PDDM.

Rounding at the top of cut slopes is especially important to reduce erosion and ensure long-term stability and revegetation of cut slopes. It also adds to the aesthetics of the finished project by blending the slope into the natural terrain.

5.2.3.4 Slope Roughening and Terracing

Refer to the PDDM.

The practice is appropriate for all slopes, although different methods are used depending on the steepness of the slope, the type of slope (cut or fill), soil and rock characteristics, future mowing and maintenance requirements and type of equipment available.

Minor slope roughening can be achieved by irregular loosening of the slopes with tracked excavation equipment; however, this technique has limited effectiveness except as a basic, slope finishing technique. More intensive roughening requires deliberate placement, manipulation and control of the materials on the slope.

Slope roughening generates local areas of steeper terrain on the slope in balance with the flatter areas that are desired. Use slightly flatter slopes overall, to enable access by tracked equipment and to avoid localized instabilities in the slope, than would otherwise be proposed for design of more traditional, non-roughened slopes.

In some soils the gradient terraces may cause sloughing if excessive water infiltrates the soil. Serrated slopes and benching are different techniques than slope roughening, and are applicable to specific design situations described in other Sections. After the designed gradient terraces are constructed they should be designated or specified to be slightly roughened overall, immediately prior to the topsoil placement, seeding and plant establishment.

5.2.3.5 Embankment Slope Benching

Refer to the PDDM.

The interface of the new embankment with the existing ground may form a weakened shear plane for settlement or slippage of differing materials, which may be alleviated with embankment slope benching.

The volume of additional material that is excavated for benching is typically not included in the roadway excavation payment quantity, but the material may be subject to compaction and shrinkage during construction.

5.2.3.6 Slope Daylighting

Refer to the PDDM.

5.2.4 Slope Waterways and Catchment Basins

Refer to the PDDM.

Incorporate slope design modifications into the development of cross sections and earthwork computations, and construction staking reports, as applicable.

5.2.5 Rock Cut Slopes

5.2.5.1 General

Refer to the PDDM.

Generally, rock slopes vary from near vertical to 1V:1H, depending on the type and quality of rock, joint patterns, fractures, cross bedding, etc. Rock slopes dipping toward the roadway may require flatter slopes.

In some locations there may be an overriding goal to create a more natural appearing rock face that will be compatible with the natural existing rock faces in the area. In some locations the appearance of drill hole traces may be undesired to remain after rock blasting, and will need to be removed or the blasting designed to eliminate or minimize them after excavation. These types of provisions are generally covered in the contract requirements rather than in the roadway design.

5.2.5.2 Rockfall Considerations

Refer to the PDDM.

High cuts, particularly in weathered or weak rock, may require fallout ditches for stability and safety. A fallout ditch at the bottom of high rock cuts keeps falling rock from encroaching on the highway. A geotechnical investigation will determine the need for fallout ditches, their width and necessary configuration.

From a safety viewpoint, rock cuts should be vertical or nearly vertical if the rock will stand on these slopes. Under these conditions, falling rocks seldom roll once they hit the ditch. Rock cuts on the inside of curves designed on 5V:1H or flatter slopes prevent the appearance of an overhang to drivers.

5.2.6 Slides and Slope Stabilization

Refer to the PDDM.

5.2.7 Slope Protection

Refer to the PDDM.

5.3 EARTH RETAINING STRUCTURES

Refer to the PDDM.

5.3.1 Determination of Need

Refer to the PDDM.

5.3.2 Alternative Wall Systems

Refer to the PDDM.

Options that may be considered for design development are to prepare:

- Multiple designs for all feasible and acceptable alternatives;
- Several designs including the most feasible one to three acceptable alternatives;
- A specific design for the most feasible alternative, and designate additional acceptable alternatives that could be bid and designed by the contractor for approval; and
- A generic design applicable for all acceptable alternatives, and designate the acceptable alternatives that may be bid and designed by the contractor for approval.

Any of these approaches may be appropriate depending on project conditions and constraints. On large projects, the fourth option should generally be provided. On smaller projects, the third option may be the most efficient. In any case,

5.3.3 Selection of a Retaining Wall System

Refer to the PDDM.

Retaining structures resist applied loads by a variety of methods including structure mass, structural stiffness and load transfer, and internal and external restraining elements.

The wall system must be capable of supporting the temporary loads anticipated or which may occur during the retaining structure construction. The design surcharge loadings for walls must be shown on the retaining wall details. The temporary excavation for construction of walls and foundations should be evaluated regarding the anticipated slope of the excavation, in terms of its constructability, effect on maintenance of traffic and adjacent property and the potential need for design and construction of temporary shoring or bracing.

The design of a retaining structure includes an analysis of loads that will act on the structure and the development of a retaining structure to safely withstand these loads. In addition, the retaining structure and adjacent surrounding soil mass must be internally and globally stable as a system, and the predicted vertical and horizontal deformations must be within acceptable limits.

A primary cause of retaining wall failure is the additional load imposed by hydrostatic pressure due to saturated soils behind the wall. The overall wall design must provide adequate drainage facilities for the site to prevent entrapment of water.

Provide the highway facility owner, the land-owning agency, cooperators and resource agencies an opportunity to provide input and recommendations for wall selections.

When the design includes proprietary wall systems, contact the company representatives during the design stage to obtain general information on timeframes, detailing, oversight responsibility and other factors necessary to complete the design and construct the wall. The wall companies will require specific site information (e.g., typical cross sections, plan and profiles, soils and foundation criteria, special design parameters).

Structural or geotechnical engineers with expertise in the proposed retaining wall system must design, review and approve the retaining walls. Geotechnical engineers must prepare the external stability analyses and prepare or review all special foundation designs. Hydraulic engineers must review any wall designs located in a floodplain or potentially affected by flooding.

5.3.4 Retaining Wall Systems

Refer to the PDDM.

5.3.4.1 Design Considerations

Refer to the PDDM.

A retaining wall is a structure built to provide lateral support for a mass of earth or material and to support a variety of dead and live load surcharges.

5.3.4.2 Types of Retaining Wall Systems

Refer to the PDDM.

There are a wide variety of retaining wall types available for design consideration. Each type has its limitations and usefulness. Consider the advantages and limitations of each system in relation to the site conditions and constraints. Families of retaining wall systems have similar characteristics, advantages and disadvantages; yet, each wall product within the family generally has some unique design and construction features. The following walls are commonly used in highway construction situations:

1. **Gravity Walls**. Gravity walls consist of mortared rock or other material that forms a solid mass to support an embankment or excavation. Gravity walls are usually cost-effective in cut or fill situations for smaller wall areas and lower heights.

2. **Mass Concrete Walls**. Mass concrete walls are gravity walls made of solid concrete. The economic overall height of mass concrete walls is about 1.2 m [4 ft]. Short sections with heights up to 2 m [6.5 ft] may be cost-effective in cut or fill situations. Mass concrete gravity walls can be used in conjunction with cantilever walls for higher applications.

3. **Reinforced Concrete Cantilever and Counterfort Walls**. Reinforced concrete and counterfort walls consist of reinforced concrete in the shape of an inverted “T” or “L” shape Reinforced concrete cantilever walls have application for cut or fill situations at heights up to 10 m [33 ft] but are most economical below 6 m [20 ft]. They lend themselves readily to a variety of aesthetic facial treatments.

4. **Buttressed Walls**. Buttressed walls may be relatively expensive, but may be constructed where right-of-way is unavailable for other wall types. These walls have been used in the 9 m to 15 m [30 ft to 50 ft] height range.

5. **Gabion Walls**. Gabion walls consist of compartmented metallic mesh containers filled with 100 mm to 150 mm [4 in to 6 in] rock backfill. They have been successfully constructed to heights of 12 m [40 ft] with adequate foundation support. The walls are somewhat flexible and tolerate some settlement. Gabion walls may be relatively inexpensive if a source of rock is readily available.

6. **Crib Walls**. Crib walls have a limited flexibility and will tolerate some differential settlement along the base. Crib walls may be difficult to construct in curved alignment, as this usually requires special detailing, particularly when the wall face is battered. Open crib wall faces that can be climbed are not recommended for urban sites or locations readily accessible to the public.

   Concrete crib may be closed face and applicable where impinging drainage is a problem. Concrete crib walls may be precast modules of various sizes and shapes. Some crib walls have planters incorporated in their faces to grow shrubs and vines to partially conceal the walls.

   Metal crib wall elements are relatively light in weight, easily transported and installed.

   Timber or log crib wall material has a relatively rustic appearance. The wall elements may be more easily cut to fit combinations of curved alignment and battered face. The service life of pressure preservative treated timber wall is comparable to that of concrete or metal crib walls.

7. **Slurry Walls**. Slurry walls have been used when soil retention is needed while the surrounding soil is excavated, or where ground water is a problem. A trench is excavated in stages and immediately backfilled with a bentonite or other type of slurry. The slurry restricts the ground water flow and supports the trench sides in place. Reinforcing steel is then placed in the slurry-filled trench followed by placement of concrete by tremie or a concrete pump. After the concrete has cured, the excavation can proceed.

   When a slurry wall is exposed to view, some form of facing (i.e., precast, cast-in-place, shotcrete) may provide a more pleasing appearance. Typically, slurry walls are designed as cantilever walls without footings. Tiebacks are compatible with this type of wall. Slurry walls are seldom used in highway applications, other than large urban projects, due to their unique features and relatively high cost. Slurry walls may be applicable for certain cut situations.

8. **Rock Walls**. Rock walls consist of stacked large rock or masonry, either mortared or un-mortared. Rock walls are used primarily in cut sections where very capable soil exists. Rock walls may provide erosion protection and limited earth support. They are generally 5 m [16 ft] or less in height for cut sections and less than 3 m [10 ft] in fills.

9. **Modular Precast Concrete Walls**. This wall system consists of precast, interlocking and reinforced concrete elements of varying size depending upon the application. Most of these wall systems are proprietary and are typically available and cost competitive on a regional basis. As the units are placed and locked together, they are backfilled with granular material.

   Modular precast concrete walls are relatively straightforward to install and the modular precast materials may be placed relatively quickly. Exposed aggregate finishes or other surface textures may enhance the wall face aesthetic appearance.

10. **Cantilever Pile Walls**. These walls include cantilever, sheet, anchored or soldier pile walls. The walls consist of sheet or soldier piles made from concrete, steel or timber; either driven or placed in drilled holes and backfilled. The soldier pile walls commonly have either concrete facing or timber lagging.

    These walls are suitable where horizontal deformation is not anticipated. The wall cost is relatively expensive and may be significantly higher where the embedded portion of the wall requires significant rock excavation. A cantilever pile wall may be applicable for roadway widening in cut or fill situations where design heights are generally less than 6 m [20 ft].

11. **Anchored Walls**. These walls are also referred to as tieback walls. These walls are often used up to heights of 15 m [50 ft]. The walls are practical in cut sections where a wall is needed before the soil is excavated and are applicable where cantilever walls are not cost effective. Anchored walls require a specialty contractor and are not suitable in certain soil types. These walls generally require some type of facial treatment for aesthetic purposes. These walls are commonly used in conjunction with temporary excavation support based on the need for deformation control and economics.

    One advantage of a tieback wall is that it causes minimal disturbance to the soil behind the wall and to any structures resting on this soil. At wall heights of about 5 m [16 ft] or more, the walls may become economical compared with cantilever construction. The number of tieback rows, spacing and loading is project specific. Tiebacks offer the advantage of construction confidence, since each tieback is normally tested to a specified loading for acceptance. Specialized geotechnical and structural expertise is necessary for wall designs of this type. Tieback walls can be built in a fill side situation. However, difficulties with construction of the fill over the ties and control of the face deflections must be considered in the design for using this wall type in fill side situations.

12. **Mechanically Stabilized Earth (MSE) Walls**. MSE walls consist of facing elements, metallic or polymeric reinforcing elements, and a constructed-in-place or precast facing. Many of the available systems are proprietary. MSE walls offer cost-effective alternatives for fill-type retaining structures in the height range of 5 m to 15 m [16 ft to 50 ft]. MSE earth retaining systems are most applicable for embankment situations and will structurally tolerate considerable horizontal and vertical deformations.

    The walls can be designed for moderately poor foundation soils and are flexible enough to accommodate some settlement. Transitions in the foundation material along the base of the wall require special attention. An aggregate base or lean concrete footing is optional and may expedite the initial construction to meet the foundation grades. These walls have considerable economic advantage for temporary applications and detours.

The proprietary wall company should furnish the wall materials or have oversight of their production, and be available to provide periodic technical assistance to the wall installation contractor at the project site.

Several types of MSE walls use a welded wire mesh, a polymer mesh or fabric. Some examples of these types of MSE walls follow:

a. *Welded Wire Walls*. Welded wire walls are proprietary systems, and typically use metallic welded wire mat units as the soil reinforcement and/or facing elements.

b. *Geotextile and Geogrid Walls*. Geotextile wall systems use geotextile fabric for the soil reinforcement and can use a variety of facing elements depending on project requirements. Most designs and materials are proprietary. The face may remain exposed if the geotextile is adequately treated to prevent decay from ultra-violet rays. Concrete panels, masonry, rock or shotcrete coatings may also be used as facing materials. This type of wall also has application for temporary fill wall installations.

   Geogrid walls use a high tensile strength plastic grid as the soil reinforcing element of the wall. Geogrid walls are proprietary wall systems. The geogrid can be precast into concrete facing panels, can be used with precast segmental block facing elements as the wall is constructed or attached to precast face panels after wall construction. Some wall facing details are designed as battered walls or enable the development of vegetation. Details should include typical base width (typically 0.7 of the wall height) for MSE walls to indicate much room is required.

c. *MSE Slopes*. The MSE Slopes use geogrid or geotextile for soil reinforcement. They may be used as alternatives for retaining walls in some situations. The MSE Slope is constructed similar to MSE Walls, except the slope does not have a structural facing and is designed using slope stability methods (typically 45 degrees or less). MSE structures with slopes between 70 degrees and 90 degrees are classified as retaining walls and are designed using retaining wall design procedures. When applicable, MSE slopes may be more cost-effective than MSE walls.

13. **Soil Nailed Walls**. This type of wall uses grouted metal bars as soil reinforcement. Soil nailing is a cost-effective wall system suitable for use either as temporary shoring or for new wall construction in cut applications, grade separation, widening and rehabilitation of existing retaining walls. The fundamental concept of soil nailing is to reinforce and strengthen the existing ground by installing closely spaced grouted steel bars called “nails” into a slope or excavation as construction proceeds from the “top down.” Similar to tieback walls, this top down construction technique offers the significant advantages of continuous support of the excavation (and adjacent structures if there are any), cost savings through elimination of the need for structural excavation and imported wall backfill (as for conventional gravity cut walls) and reduced environmental impact. Soil

nail walls are not applicable for some ground conditions. The ground should be capable to stand unsupported on a vertical or steeply sloped cut of 1 m to 2 m [3.3 ft to 6.5 ft], for at least one to two days. Soil nail walls are not suitable in loose cohesionless soils (e.g., caving sands) below the water table. Facing options may include sculpted or hand-carved and stained shotcrete, rock or masonry façade, etc.

5.3.5 Geometric Information for Design of Retaining Wall Systems

Refer to the PDDM.

The retaining wall design may consist of a range of level of detail and data provided for the PS&E, including end result specifications, basic line diagrams, general wall design criteria, and an estimate of wall area or other pay item units. The design may include details for all acceptable alternative retaining wall systems, or it may include one or more complete designs and permit alternative contractor furnished designs. The Project Manager will usually make this determination with input from the interdisciplinary team, considering the project size and the number of retaining walls involved, and other factors.

5.4 LANDSCAPING AND RESTORATION OF VEGETATION

Refer to the PDDM.

Landscaping can be used to affect driver behavior by creating the perception that the roadway is narrower than it actually is, which may result in reduced vehicle speeds. This is of particular interest in desired low speed environments. However, the growth of vegetation can create sight distance conflicts affecting the visibility and thus the safety of highway users, and can grow large enough to become a roadside hazard. It is therefore beneficial to develop a landscaping and vegetation plan to site-specifically remove, retain, or to select and locate appropriate species of plant materials. The landscaping plan requires consideration of not only the safety of all facility users, but also the maintenance necessary to appropriately sustain the vegetation and protect public safety as well as the investment, and to manage risks over the life of the facility.

5.4.1 Enhanced Clearing Techniques

Refer to the PDDM.

5.4.2 Enhanced Grading Techniques

Refer to the PDDM.

5.4.2.1 Cut Slope End Treatment

Refer to the PDDM.

5.4.2.2 Serrated Slopes

Refer to the PDDM.

The steps allow weathering and decomposing rock to accumulate for stability and to provide a growing medium for plants. The flat steps also retain moisture for use by the growing plants. When using serrated slopes, consider local environmental conditions, soil and plant growth potential.

5.4.3 Enhanced Rock Work

Refer to the PDDM.

5.4.4 Topsoil Placement

Refer to the PDDM.

5.4.5 Restoration of Vegetation

Refer to the PDDM.

Vegetated slopes are not only pleasing to view but have greater stability and require less maintenance. Re-established vegetation is also important as cover and food for wildlife. Vegetated slopes that are restored to 70 percent of natural conditions are typically a requirement of NPDES permits for termination of the permit.

Hydrophilic shrubs (e.g., willow, birch) grouped in areas of excess soil moisture will aid in stabilizing the overly wet areas of new slopes.

5.4.6 Landscape Planting

Refer to the PDDM.

5.4.7 Slope Enhancements

Refer to the PDDM.

5.4.8 Ornamental Landscapes

Refer to the PDDM.

5.5 DRAINAGE DESIGN

Refer to the PDDM.

Drainage facilities convey both surface runoff and subsurface water, including an expected recurrence risk of flood and storm waters, across, along or away from the highway. Consider the most cost-efficient and practical manner to accomplish this with compatibility to the highway, the drainage facility or adjacent stream channels and property. Various types of drainage methods may accomplish the objectives, including the use of open channels, riprap and channel lining, bridges, culverts, storm drains, underdrains and related appurtenances. Some installations may require provisions for fish or wildlife passage.

Include consideration for all of the drainage facilities in the development of the roadway and roadside design, and in the contract plans, and ensure that the *Specifications* and cost estimate contain provisions for these facilities.

Bridge hydraulic-related design (e.g., layout, minimum opening under bridge, pier placement) should be a joint responsibility of the bridge unit and the hydraulics engineer such that expertise of both disciplines is brought together to optimize the bridge design.

Large culverts and channels are normally sized by the hydraulic engineer or may be sized by the designer using methodology and oversight provided by the hydraulic engineer. For large culverts and channels, the hydraulic engineer may develop a conceptual or preliminary design with the final design and detailing performed by the roadway designer.

Bridge hydraulic-related design (e.g., layout, minimum opening under bridge, pier placement) should be a joint responsibility of the bridge unit and the hydraulics engineer such that expertise of both disciplines is brought together to optimize the bridge design.

The geotechnical discipline provides expertise for the specialized design of underdrains, horizontal drains, drainage blankets and subdrainage systems using geotextile fabrics. They also provide expertise for determining pH values of soils and waters for consideration in the selection or specification of drainage materials. Coordinate with the geotechnical discipline to ensure that soils are tested and evaluated as input to determine acceptable culvert materials. The geotechnical discipline also provides expertise for determining the subsurface conditions at foundations and the parameters for design of bridge foundations and large culvert foundations.

As applicable, furnish lines, grades, cross sections, detail maps and vicinity maps of the roadway design to the hydraulic, bridge and geotechnical disciplines for design of large or complex drainage facilities.

Indicate the quantity of flow or discharge as designated by the letter “Q” in hydraulic formulas and charts. The discharge is the number of cubic meters per second [cubic feet per second] of water flowing into or out of a drainage facility or a segment of the facility. For all drainage structures 1.2 m [4 ft] in diameter or larger, show the drainage area (A), design discharge (Q) and design headwater (HW) on the profile portion of the highway plans.

5.5.1 Safety Considerations

Refer to the PDDM.

5.5.2 Roadway Ditches and Channels

5.5.2.1 Shape and Depth

Refer to the PDDM.

Drainage channels may require a design by the hydraulic engineer when the accumulated discharge is greater than the capacity of the normal roadway ditch. When applicable, furnish the alignment, grades, cross sections and pertinent information about the existing site conditions to hydraulic discipline for the channel design. Include provisions for fish habitat and aesthetics in the design. Fish habitat includes pools, riffles, boulders, logs and gravels in the streambed and brush and shade on the stream banks. For design of channel changes, obtain guidance and direction regarding specific habitat features to include. Include the design of drainage channels and channel changes in the roadway design, and provide typical sections and detailed drawings in the design plans.

Roadway ditches should have a smooth and rounded cross section for safety (see the AASHTO *Roadside Design Guide*) and ease of maintenance. Wide ditch bottoms are used in rock fallout areas as well as in projects designed with side borrow.

Roadway ditches commonly have a “V” shape formed by the foreslope from the subgrade shoulder and cut slope. Flat bottom ditches typically perform better than “V” ditches from a hydraulic and safety standpoint, but are less simple to construct.

5.5.2.2 Lining Materials

Refer to the PDDM.

5.5.2.3 Ditch Grades and Transitions

Refer to the PDDM.

The amount of water that the ditch can carry and the depth of flow vary with the grade of the ditch line. On very flat grades, the water may not drain fast enough to prevent saturation of the subgrade. Saturated subgrade situations may cause pavement failures. Drainage problems may be alleviated by designing deeper, or flat bottom, ditches, steepening the ditch grade, decreasing the distance between ditch relief drains, paving the ditch or adding culverts. Give the highest consideration to the ditch grade.

5.5.3 Culverts

Refer to the PDDM.

The sizing of the culverts 1.2 m (48 in) or smaller is normally done by the designer using established methods (refer to PDDM Chapter 7). Larger culverts are normally sized or checked by the hydraulic engineer.

They require hydrology design procedures to determine size. The sizing of the culverts 1.2 m [48 in] or smaller is normally done by the designer using established methods (refer to PDDM Section 7.2). Larger culverts are normally sized or checked by the hydraulic engineer.

5.5.3.1 Locations

Refer to the PDDM.

After sizing the culverts, determine the maximum height of cover of fill over the culverts and calculate the structural excavation and other items of work associated with the culvert.

5.5.3.2 Cover and Roadway Grade

Refer to the PDDM.

The maximum cover of each culvert determines the culvert wall thickness for alternative metal culvert pipe materials and corrugations or the reinforcement class for conference alternatives. Select the wall thickness and reinforcement classes from the *Standard Drawings*. Any required or optional special coatings on metal pipe must be shown in the contract.

5.5.3.3 Inlet Considerations

Refer to the PDDM.

5.5.3.4 Outlet Considerations

Refer to the PDDM.

5.5.4 Pavement Drainage

Refer to the PDDM.

5.5.5 Downdrains and Pipe Anchors

Refer to the PDDM.

At locations of minimal erosion, the designer should consider placing graded gravel or a rock at the outfall to control scour. Areas where significant scour is anticipated will require a special design with specific details included in the contract.

For tongue and groove concrete pipe, use concrete anchor blocks on grades steeper than 10 percent. For bell and spigot concrete pipe and metal pipe culverts on grades steeper than 25 percent, use pipe anchors as detailed on the approved *Standard Drawing*.

When specifying pipe anchors for a project, list them on the drainage summary.

5.5.6 Storm Drains

Refer to the PDDM. .

5.5.7 Underdrains and Horizontal Drains

Refer to the PDDM.

5.5.8 Riprap Slope Protection

Refer to the PDDM.

5.5.9 Energy Dissipators and Outlet Detention Basins

Refer to the PDDM.

5.6 SOIL EROSION AND SEDIMENT CONTROL

Refer to the PDDM.

5.6.1 Developing Erosion and Sediment Control Plans

Refer to the PDDM.

The purpose of an erosion control plan is to provide the best available guidance in preventing erosion and controlling sediment during construction. As applicable, develop such plans as part of the roadway design for the project. Many of the controls identified in the plan may be designed from engineering computations that may already be performed for the design of various drainage structures.

In developing the erosion control plans, several overall principles are observed. By designing a plan to include these principles through each stage of construction, the appropriate controls can be selected and erosion will be minimized. These principles are discussed below:

1. **Stabilization**. The key to successful erosion and sediment control is the prevention of erosion. In highway construction, this is best achieved through effective stabilization of the slopes and waterways. By preventing erosion from occurring in the first place, the overall net loss of sediment from the site is minimized. Stabilization is achieved with temporary and permanent turf establishment, mulching, erosion control mats and blankets. It is much more effective to prevent erosion from occurring than to try to filter or trap sediment with other measures. Controls based on the principles of filtering and trapping have limited efficiencies and are used as backup measures.

2. **Limit Exposure**. Another related principle to minimize erosion is to limit the time and area of exposure. The potential for erosion is greatly reduced if less area is disturbed or if the area is disturbed for a shorter duration. In many instances, stabilization can take place as the construction progresses instead of waiting until the final grade is established. Stabilization is ultimately required for all disturbed areas, so timely stabilization is also cost-effective. Although minimizing the area disturbed may be difficult, it should be considered in determining the construction limits. These limits should be clearly shown on the plans.

3. **Retain Sediment On-Site**. A third principle in controlling erosion and sedimentation is to retain the sediment on the site. This is achieved by using devices that filter sediment from runoff or detain runoff so that soil particles will settle out. By using controls (e.g., silt fence, straw bales, brush barriers), sediment can be filtered from runoff before it leaves the site. These devices should be used only for sheet flow or low concentrations of flow. Where flow occurs in greater quantities, runoff can be detained in a settling structure until the particles settle out. These temporary devices are called sediment traps or, for larger areas, sediment basins. Settling structures are appropriate where disturbed areas of sufficient size drain to one location. The size of the structures is based on the contributing drainage area. Since these structures can become quite large, sufficient area must be available to construct the facility on the site. These larger devices have limited application to highway construction due to limited right-of-way.

4. **Management of Runoff**. An additional principle that should be followed is to manage only the sediment and runoff from the site. This becomes more challenging in highway construction where off-site drainage intercepts roadways or where roads cross streams. When possible, runoff from undisturbed areas should be diverted around disturbed areas by constructing diversion berms and channels. Also, streams and swales should remain uncontrolled, allowing clean water to pass through the site. It is inefficient to combine sediment laden runoff with clean runoff before passing through filter barriers or settling structures. With settling structures, the storage volume becomes very large if drainage from undisturbed areas is allowed to flow to the structure.

5.6.2 Erosion and Sediment Control Phases

Refer to the PDDM.

Erosion control plans should be developed with the above principles in mind. In addition, the plans must address the different stages of construction. By dividing the construction into three separate phases, the selection of the erosion controls is easier, especially on larger, more complicated projects.

5.6.2.1 Phase I — Perimeter Erosion and Sediment Controls

Refer to the PDDM.

1. **Filter Barriers**. Filter barriers (e.g., silt fence, straw bales, sediment control logs, brush barriers) are placed around the perimeter of the site to filter out sediment from sheet flow. They are the primary control used in this phase.
2. **Diversion Structures**. Where large amounts of sheet flow from undisturbed areas intercept the construction limits, it may be effective to divert this runoff around the site, thereby minimizing the erosion and the amount of runoff to be controlled. This is done by constructing diversion berms and channels around the site.
3. **Settling Structures**. When sufficiently large disturbed areas drain to an appropriate location, settling structures may be used to detain the runoff and settle out sediment. These devices are called sediment traps and sediment basins. Diversions may be used to channel sediment laden runoff to these structures. Provide for design and contract requirements and mechanisms enabling these structures to be cleaned out periodically.

5.6.2.2 Phase II — Intermediate Erosion and Sediment Controls

Refer to the PDDM.

5.6.2.3 Phase III — Final Erosion and Sediment Controls

Some controls may actually serve in more than one phase. For instance, filter barriers and settling structures may control sediment from the initial phase through the final slope stabilization. Also, in some reconstruction projects, the only erosion control phases may be the initial and final controls. The most important factor is to ensure that each appropriate phase is considered when selecting controls and developing erosion control plans.

Refer to the PDDM.

5.7 PARKING AND REST AREAS

Refer to the PDDM.

5.8 ROADWAY APPURTENANCES

5.8.1 Highway Lighting Systems

Refer to the PDDM.

5.8.2 Fencing

Refer to the PDDM.

This means some right-of-way corners or monuments will remain outside the fence line. Fencing on a continuous alignment has a cleaner appearance and is more economical to construct. In rural areas, the designer should contact the property owners to determine locations for the fence line. In many instances, the landowner will request a fence outside the right-of-way line for ease of maintenance.

Some projects require log rail, buck rail, worm rail and other types of wood fences on projects for aesthetic reasons and the degree and type of fencing depends on the requirements of each site.

Fence measurement is taken along the slope of the fence. The design quantities should reflect this measurement.

5.8.3 Cattle Guards

Refer to the PDDM.

5.9 RIGHT-OF-WAY AND UTILITY CONSIDERATIONS

Refer to the PDDM.

5.10 ENVIRONMENTAL PROTECTION AND ENHANCEMENTS

Refer to the PDDM.

5.11 CONSTRUCTION CONSIDERATIONS

Refer to the PDDM.

CHAPTER 6

PLANS SPECIFICATIONS AND ESTIMATE (PS&E) DEVELOPMENT

Refer to the PDDM.

6.1 PS&E PACKAGE

Refer to the PDDM.

The following items represent the minimum requirements necessary to complete a basic PS&E assembly:

- Plans are graphic representations (e.g., typical cross sections, drawings, details) of the proposed work. The completed plans are the contract drawings.
- Specifications is a general term applied to all directions, provisions and requirements concerning the quality and performance of the work for a project. Specifications include the Standard Specifications (FP-XX) and the Special Contract Requirements (SCRs).
- A cost estimate consists of the engineer's estimate and cost analysis to perform the work. It serves as the basis of the probable construction amount to evaluate bidders' proposals and for programming funds for construction, related engineering, utility work, etc.
- An estimated construction schedule and contract time is necessary for preparation of a construction contract.
- During solicitation various physical data is made available to the bidders (e.g., CADD output reports, hydraulic analysis, geotechnical data, cross sections).
- Supporting information includes all information that documents the development of the geometric design and preparation of the PS&E to support construction stakeout and control and for construction management.

6.2 ALTERNATIVE PS&E DEVELOPMENT AND CONTRACTING OPTIONS

Refer to the PDDM.

6.3 PS&E DEVELOPMENT AT VARIOUS STAGES OF DESIGN

Refer to the PDDM.

6.3.1 Conceptual Studies and Preliminary Design

Refer to PDDM Chapter 4 for the design development activities at the conceptual and preliminary design phase. The plans and cost estimate are typically developed to the 30 percent level for preliminary design.

6.3.2 Intermediate Design

Refer to the PDDM.

6.3.3 Intermediate Design Revisions

Refer to the PDDM.

6.3.4 Plan-in-Hand (PIH) PS&E

Refer to the PDDM.

6.3.5 Final Design

Refer to the PDDM.

6.4 REVIEWS

Refer to the PDDM.

PS&E development involves various stages of review. The objective of a field review/plan-in-hand inspection is to ensure to the maximum extent practical that the location and design reflect and are consistent with Federal, State and local goals, objectives and standards.

All cooperating agencies and appropriate Federal Lands Highway Division staff should be invited to each field review. These reviews give the designer the opportunity to present the proposed design to the cooperating agencies and to solicit comments to ensure that the design is being developed in compliance with the intended scope and social and environmental commitments.

Field reviews provide the designer the opportunity to verify data and check the design as developed in the office against field conditions to minimize construction concerns.

Field reviews provide the project team and cooperating agencies a medium for free and open discussion that encourages early and amicable resolution of controversial issues that may arise during the development of the PS&E package.

The reviews may range from multi-disciplinary and multi-agency inspections to specialized on-the-ground meetings with a single discipline to resolve a specific problem. In all cases, the conclusions reached at the field reviews require documentation and distribution to the interested parties.

Prior to conducting field reviews, it is important to provide the reviewers with the appropriate information (e.g., plans, specifications, cost estimate, exhibits, visualizations) sufficiently in advance for them to schedule their time to perform a comprehensive review of the information and to formulate their input or questions, prior to the onsite meeting. To expedite the field review, arrange in advance to provide an appropriate level of stakeout (e.g., marking or flagging the centerline, proposed slope stakes, structural foundations), as applicable.

6.4.1 Preliminary Design (15 or 30 Percent) Review

The Preliminary Design review is normally held during the preliminary design phase and is described in PDDM Section 4.9.1.

6.4.2 Intermediate Design (50 Percent) Review

Refer to the PDDM.

6.4.3 Plan-In-Hand Design (70 Percent) Review

Refer to the PDDM.

6.4.4 Final PS&E (95 Percent) Review

Refer to the PDDM.

6.4.5 PS&E Approval and Authorization (100 Percent)

Refer to the PDDM.

6.4.6 Value Engineering

Refer to the PDDM.

6.5 PLANS

Refer to the PDDM.

Plans are, in effect, instructions using drawings containing engineering data or details pertaining to roadway geometry, drainage, structures, soils and pavements and other appurtenances.

6.5.1 Format

Refer to the PDDM.

6.5.2 Drafting Standards

Refer to the PDDM.

Such highlighting may unintentionally diminish the importance of other contract requirements.

There are situations where the size and weights need to be adjusted to emphasize or clarify specific information on a plan sheet. For example, centerline stationing along the plan alignment may require a heavier weight for clarity where culture or other background data tends to clutter up a drawing

6.5.3 Required Elements of Plans

Refer to the PDDM.

6.5.3.1 Title Sheet

Refer to the PDDM.

6.5.3.2 Typical Sections

Refer to the PDDM.

6.5.3.3 Summary of Quantities

Refer to the PDDM.

6.5.3.4 Tabulation of Quantities

Refer to the PDDM.

6.5.3.5 Plan and Profile

Refer to the PDDM.

6.5.3.6 Bridge Plans

Refer to the PDDM.

6.5.3.7 Cross Section Plans

Refer to the PDDM.

6.5.3.8 Temporary Traffic Control Plans

Refer to the PDDM.

6.5.3.9 Permanent Signing and Marking Plans

Refer to the PDDM.

6.5.3.10 Erosion and Sediment Control Plans

Refer to the PDDM.

6.5.3.11 Landscaping and Revegetation Plans

Refer to the PDDM.

6.5.3.12 Environmental Mitigation

Refer to the PDDM.

6.5.3.13 Major Drainage Facilities Plans

Refer to the PDDM.

6.5.3.14 Material Source Reclamation Plans

Refer to the PDDM.

6.5.3.15 Right-of-Way and Utility Plans

Refer to the PDDM.

Refer to PDDM Chapter 12 for guidance on preparation of right-of-way plans.

6.5.3.16 Contiguous Projects

Refer to the PDDM.

6.5.4 FLH Standard Drawings, Division Standard Details and Special Details

Refer to the PDDM.

6.5.4.1 FLH Standard Drawings

Refer to the PDDM.

Standard drawings are designed for repetitive use and to provide uniformity of design and construction where the construction details are the same from project-to-project. Use standard drawings for culverts, minor drainage structures, guardrail and other items as appropriate. Local or State or highway agency Standard Drawings may be used where Divisions deem their use is more appropriate.

FLH Standard Drawings are usually incorporated into the contract plan assembly and not issued as a separate booklet.

6.5.4.2 Management of FLH Standard Drawings

Refer to the PDDM.

6.5.4.3 Division Standard Details

Refer to the PDDM.

6.5.4.4 Special Details

Refer to the PDDM.

6.6 SUPPORTING INFORMATION

Refer to the PDDM.

6.6.1 Computation of Quantities

Refer to the PDDM.

Guidance is also provided on items where it is difficult to separate quantity and payment. In addition, miscellaneous information is included to assist the designer in selection of items and how to place the items on the plans.

6.6.1.1 Division 100 General Requirements

This part of the FP-XX contains general contract requirements applicable to all projects. No direct payment is made under Division 100. Within this Division, Section 109, "Measurement and Payment," covers most of the details the designer should become familiar with to compute quantities.

6.6.1.2 Division 150 Project Requirements

This part of the FP-XX contains project requirements applicable to all projects. Work under Division 150 will be paid for directly when there is a pay item in the bid schedule for it. When there is no work item, no direct payment will be made.

1. **Section 151 — Mobilization**. On large projects, use six to eight percent of the construction estimate rounded to the nearest $5,000 or $10,000. On small projects, use nine to ten percent of the construction estimate rounded to the nearest $1,000 or $5,000. Do not completely rely on the Engineer's Estimate system to calculate the mobilization amount. Adjust the amount by rounding off so it is a reasonable dollar value of the contract.

2. **Section 152 — Construction Survey and Staking**. Determine the bid price of this work on the basis of crew size, survey requirements and equipment to estimate hours and cost. A general rule of thumb is one minute per survey terrain shot. When using average bid prices from previous contracts, ensure the survey requirements are essentially the same or the comparison will be flawed. The basis of payment under this section is lump sum, per km [mile], each, hour or other appropriate units.

3. **Section 153 — Contractor Quality Control**. This work is not measured for payment. Even though there is no payment for this work, it does cost contractors money. It is assumed that the contractor's bid price for work under the applicable sections of the FP-XX includes the costs of the work under this section.

4. **Section 154 — Contractor Sampling and Testing**. The cost of the work under this section is usually based on average bid prices. Although there is considerable variance in average bid prices, an amount equal to 2 to 2½ percent of the construction estimate

will usually cover the work involved. Determine if the project requires a minimal amount or an extraordinary amount of testing in relation to the construction estimate before applying the 2 to 2½ percent rule. The basis of payment is lump sum although other units could be used in unique and unusual circumstances.

5. **Section 155 — Schedules for Construction Contracts**. Base the cost of the work under this section on average bid prices and any special contract requirements.

6. **Section 156 — Public Traffic**. The work described in this section is measured for payment under other sections of work with one exception. If a detour is constructed and maintained under a lump-sum item, include the work under this section. If there are extraordinary complications with public traffic, adjust the prices in the appropriate section to cover the work or add additional items of work in the sections.

7. **Section 157 — Soil Erosion Control**. Work under this section covers the erosion control plan for the project. It also provides items of work necessary for the Storm Water Pollution Prevention Plan, which is included in most construction contracts.

   Most projects will have several items in the bid schedule to cover this work. A very simple project where the erosion control features can be completely detailed on the plans and described in the Special Contract Requirements may be a lump-sum item. The use of an item for soil erosion control, using a contingent sum pay unit is not permitted. In addition to lump sum, per meter [foot], each, per square meter [square yard], hectare [acre], kilogram [pound], hour and other related units are acceptable.

   The past practice for developing erosion control is no longer adequate for today's requirements. The current emphasis is to retain all sediments within the construction limits and stabilize them in place.

   Evaluate every cut slope, embankment, stream crossing or other disturbance, and determine what effort and devices are required to stop sediment from escaping beyond the construction limits. Transcribe this evaluation to the erosion control plan. If a stage construction concept is being considered, evaluate each stage of the work to arrive at an adequate erosion control plan.

   Consider the items in the FP-XX as a good beginning for erosion control devices. Do not hesitate to propose additional methods of controlling erosion and sedimentation. Not all temporary and permanent erosion control features need to be addressed under Section 157. They can be incorporated into other sections of work if it is more appropriate.

6.6.1.3 Division 200 Earthwork

1. **Section 201 — Clearing and Grubbing**. The design program computes quantities for clearing and grubbing and provides subtotals as desired by sheet total or 350-m [1500-ft] intervals or as user defined. These subtotals are placed on the profile part of the plans or on a separate tabulation of quantities to the nearest 0.01 hectares [0.01 acres]. It may be necessary to round the subtotals so the total shown on the plans

equals the design program output. Compute the acreage of any isolated areas and road approaches of significant size or measure the areas by planimeter or CADD. Show this quantity on the plans with the mainline roadway quantities using an appropriate note.

On the supporting data sheet, show the design program total plus any manually computed hectares. The total of these hectares [acres] is the plan quantity shown on the Summary of Quantities sheet of the plans. Add an allowance so the bid schedule quantity reflects the next tenth of a hectare [acre]. If there is a large number of hectares [acres], rounding up more than a tenth of a hectare [acre] as appropriate. If lump sum is used as a payment, show the number of hectares [acres] used for the lump sum calculations on the Summary of Quantities sheet or other plan sheet.

2. **Section 202 — Additional Clearing and Grubbing**. Although the design program can be used to compute hectares [acres] under this section, it is seldom worth the effort. Manual computations are usually faster and easier. Follow the rounding guidance under Section 201 for hectare [acre] pay units.

   Plan and bid schedule quantities are usually the same. Quantities for removal of individual trees and individual stumps are usually estimated during one of the field reviews.

3. **Section 203 — Removal of Structures and Obstructions**. Computations of quantities under this section are typically obtained from the survey notes or from measurements taken at the field reviews. If average bid price data is not available for the work proposed, use equipment rental rates, labor rates and overhead and profit margins for the estimate. There is a tendency to underestimate the time to remove structures and obstructions, therefore, be somewhat liberal in estimating the number of hours to perform work.

   Use this section where the work consists of salvaging, removing and/or disposing. If the work consists of removing and reincorporating or resetting an item on the project, put the work under the applicable section (e.g., removing and resetting guardrail) is provided for under Section 617 of the FP-XX.

   Provide sufficient information about removal items that they can be properly bid and administered during construction.

4. **Section 204 — Excavation and Embankment**. The design programs provide a listing of the mainline quantities for a project. Manually compute or estimate additional quantities outside the normal roadway prism. Insert these quantities into the design program as an “added quantity” so they can be included in the mass figures. Show excavation quantities on the plans and show the totals on the Summary of Quantities Sheet.

   Show the design program total on the supporting data sheet total plus any added quantities. This total is the plan quantity shown on the Summary of Quantities Sheet. Add about ten percent to obtain the bid schedule quantity. The allowance used should round the bid schedule amount to an even 1000 m^3 [1000 cuyd].

When computing quantities for borrow, topping or embankment, use an appropriate shrink or swell factor to arrive at the quantity required making the computed volume in the roadway. For borrow and topping, add about a five percent allowance to obtain an even 500 m^3 [500 cuyd] bid schedule quantity. The plan quantity and bid schedule quantity for embankment construction, furrow ditches and rounding cutslopes does not usually require an allowance.

5. **Section 205 — Rock Blasting Drill Hole**. Although few projects have a pay item for this work, it is still necessary to estimate the amount of controlled blast drill hole required to arrive at the correct unit price analysis for roadway excavation. Only a few projects are applicable for estimating direct or indirect costs for drill holes, when there is a special need. Use the average height of the rock face times the length, and 1 or 1.5 m [3 or 5-ft] spacings to arrive at the estimated meters [feet] of the drill hole. Round the figure to the nearest 50, 100 or 500 m [50, 100 or 500 ft] depending on the quantity. Rounding within the original computations so the plan and bid schedule quantity is the same.

6. **Section 206 — Watering for Dust Control**. Estimate the number of expected days requiring dust control and multiply by an appropriate number of cubic meters [cubic yards] units per day. Climate, traffic volumes and soil conditions have major effects on this item. Construction records from previous projects in the area are very helpful in estimating quantities. The plan quantity and bid schedule quantity should be the same. Round within the original computations.

   Water for compaction of embankments is not included in water for dust control. However, the same source of water and equipment may be used for both. Evaluate the amount and availability of water for compaction at the same time that water for dust control is being estimated so that the interaction of both activities is considered.

7. **Section 207 — Earthwork Geotextiles**. Compute the square meters [square yards] of coverage required. For small quantities of less than 3000 m^2 [3,000 sqyd], add about ten percent to round to the nearest 100 m^2 [100 sqyd]. On quantities over 3,000 m^2 [3,000 sqyd], add five percent and round to nearest 500 m^2 [500 sqyd].

8. **Section 208 — Structure Excavation and Backfill for Selected Major Structures**. Compute the quantities of structure excavation, foundation fill, structural backfill and structural backfill for walls as detailed in the FP-XX. Add a small allowance to obtain an even 10, 50, or 100 m^3 [10, 50 or 100 cuyd] for the bid schedule quantities.

   In many instances, it is the Structures Section's responsibility to compute these quantities. The quantities are usually shown as contract quantities. The Structures Section will provide quantities needed for shoring and bracing and cofferdams.

9. **Section 209 — Structure Excavation and Backfill**. Although there is no pay item for work under this section, it is necessary to compute the quantities for bidders to use in estimating costs. This is particularly true with culverts where the estimated excavation is shown on the Drainage Summary Sheet.

10. **Section 211 — Roadway Obliteration**. Compute areas by any acceptable method including planimeter. Add about 10 percent and round to 100, 500 or 1000 m^2 [100, 500

or 1000 sqyd] depending on quantities. When using a lump-sum pay unit, show the approximate square meters [square yards] of obliteration on the plans.

11. **Section 212 — Linear Grading**. The measurement unit for this work is by station. However, show the design earthwork quantity in cubic meters [cubic yards] on the plans for the bidders information. Without a good history of average bid prices, use the cubic meter [cubic yard] quantity to determine the unit price, which is then converted to stations. Round this item to the nearest 0.001 station. It is almost always a contract quantity.

12. **Section 213 — Subgrade Stabilization**. Compute quantities by the square meter [square yard] or metric ton [ton] as appropriate. Round square meter [square yard] computations to 100 or 5,000 m^2 [sqyd]. Round metric tons [ton] to 10 metric tons [tons].

6.6.1.4 Division 250 Structural Embankments

1. **Section 251 — Riprap**. Measurement of riprap is cubic meter [cubic yard] or metric ton [ton]. Add at least 10 percent allowance to obtain an even 50, 100 or 500 m^3 [cuyd] or metric tons [tons] is the bid schedule. Show the class of riprap on the plans by one or all of the following methods:

   a. By tables;
   b. On special typical sections for riprap; and
   c. On the Drainage Summary, if riprap is associated with culvert work.

   Excavation for toe trenches is seldom paid for directly; however, show quantities on the plans for informational purposes. Where toe trenches are excavated under an existing structure or adjacent to piers, etc., that involves structural excavation under Section 208, it may be appropriate to include toe trench excavation for payment under Section 208.

   The supporting data sheet should have a list or table of riprap showing locations, elevations of top of riprap, class, quantity of riprap and quantity of the trench excavation.

2. **Section 252 — Special Rock Embankment and Rock Buttress**. The measurement of rock embankment is cubic meter [cubic yard] or metric ton [ton]. Add at least 10 percent allowance to obtain an even 10, 50 or 100 m^3 [cuyd] or metric tons [tons] in the bid schedule. Show the rock embankment on the plans by one or all of the following methods:

   a. Tables;
   b. Special typical sections for rock embankment; and
   c. Drainage Summary, if rock embankment is associated with culvert work.

   Excavation for toe trenches or embedment is not paid for directly; however, account for quantities in the earthwork design and show quantities on the plans for informational purposes.

3. **Section 253 — Gabions**. Measurement of gabions is square meter [square feet] of face elevation or cubic meter [cubic yards] in place. Only minor rounding of about 10 m^2 [100 square ft] or 10 m^3 [10 cuyd] is required.

   Show gabion elevation and cross section views on the plans. Plan views are helpful where there are variations in the face of wall distance to a reference line. Tables on the plans showing station-to-station, wall quantities and excavation are appropriate.

4. **Section 254 — Crib Walls**. Follow the guidance for gabions.

5. **Section 255 — Mechanically Stabilized Earth (MSE) Walls.** Follow the guidance for gabions.

6. **Section 257 — Alternate Retaining Walls**. Although the measurement for this work is lump sum, provide the estimated square meters [square feet] for informational purposes.

6.6.1.5 Division 300 Aggregate Courses

1. **Section 301 — Untreated Aggregate Courses**. The method of measurement under this section is cubic meter [cubic yard], metric ton [ton] or square meter [square yard].

   Compute the compacted volume of the material to be placed on the roadbed by using the dimensions shown on the Typical Section Sheet. In addition, compute the compacted volumes for widened areas, approach roads, parking area and tapers for channelized intersections.

   To determine the hauling vehicle volume, multiply the compacted volume by 1.33. To determine metric tons [tons]:

   a. Multiply the compacted volume by 1.33, then

   b. Convert to metric tons (t) [tons] by multiplying by 1.66 t/m^3 [1.4 tons/cuyd]. (If the material is pugmill mixed, compensate for the mixing water by multiplying by 1.06].

   The 1.66 t/m^3 [1.4 tons/cuyd] factor applies to aggregate with a specific gravity of around 2.70. For sources with significantly different specific gravity, it is appropriate to multiply the 1.66 [1.4] factor by the known specific gravity divided by 2.70.

   The quantities for crushed aggregate base are usually shown on a Tabulation of Quantities Sheet in the plans. Show the rate of application in metric tons [tons] or cubic meters per kilometer [cubic yards per mile] or per square meter [square yard] for the bidder's information. Also, specify if the quantities include the six percent water additive.

   Aggregate by the cubic meter [cubic feet] = (Average W)(D)(L)(1.33)

   Aggregate by the metric ton = (Average W)(D)(L)(1.33)(1.66*)(1.06**) (Metric)

Aggregate by the ton = (Average W)(D)(L)(1.33)(0.052*)(1.06**) (US Customary)

Where:

W = Width in m [ft]
D = Depth in m [ft]
L = Length in m [ft]

* t/m^3 [tons/cubic feet]
** Six percent allowance for mixing water where a pugmill is required.

When the maximum dry density is available from the lab reports, multiply the compacted volume by the dry density and convert to metric tons [tons].

Multiply the aggregate by the area, m^2 [square ft] = (W)(L)

If square meter [square yard] measurement is used, show the exact limits used to arrive at the quantities on the Typical Section. Where measurement is by the square meter [square yard], compute the cubic meters [cubic yards] or metric tons [tons] to provide bidders with an application rate.

Add a 5 to 10 percent allowance to quantities measured by the metric ton [ton] or cubic meter [cubic yard] so the bid schedule quantity is an even 500 m^2 or 1000 m^2 [500 sqyd or 1000 square yd] or metric tons [ton]. Square meter [square yard] measurements require very little allowance as the limits are pretty well predetermined on the Typical Sections. Round up to an even 1000 m^2 [1000 sqyd] for the bid schedule.

2. **Section 302 — Treated Aggregate Courses**. Compute quantities for this section similar to Section 301 for metric tons [tons] or square meters [square yard].

3. **Section 303 — Road Reconditioning**. Measurement under this section is kilometers [miles] or square meters [square yard]. Use kilometers [miles] for mainline work and side roads where widths are relatively constant. Use square meters [square yard] for parking areas and other oddly shaped areas or for very small quantities of work. Round kilometers [miles] to the nearest 0.01 km [0.01 mi] for the bid schedule. Add 5 to 10 percent to the square meter [square yard] to obtain an even 100 m^2 or 500 m^2 [100 sqyd or 500 sqyd] in the bid schedule.

4. **Section 304 — Aggregate Stabilization**. Measurement for aggregate stabilization is kilometers [miles] or square meters [square yard]. Follow the guidance under Section 303 to compute quantities.

   Provide an allowance for chemical additives so the bid schedule quantity comes out to an even 10, 50 or 100 metric ton [ton] quantity.

5. **Section 305 — Aggregate/Topsoil Course**. Measurements under this section include metric ton [ton], square meter [square yard], cubic meter [cubic yard] or meter [feet]. Provide an allowance to round the bid schedule amount to an even 10, 100 or 500 units as appropriate.

6. **Section 306 — Dust Palliative**. Measurement for the dust palliative application is the kilometer [mile] or square meter [square yard]. Very little allowance is needed. The dust palliative material is measured by the metric ton [ton]. Add a 5 to 10 percent allowance to get an even 10, 50 or 100 metric ton [ton] bid schedule quantity.

7. **Section 307 — Stockpiled Aggregates**. Measurement for stockpiled aggregate is the metric ton [ton] or cubic meter [cubic yard]. Usually the amount has been predetermined and no allowance is necessary.

   The preparation of stockpile sites is measured by the hectare [acre]. Provide an allowance so the bid quantity shows a whole hectare [acre].

8. **Section 308 — Minor Crushed Aggregate**. Measurement is based on cubic meter [cubic yard] or metric ton [ton]. Be liberal in estimating quantities so that only minimal, if any, rounding is required for the bid schedule quantity.

9. **Section 309 — Emulsified Asphalt Treated Base Course**. The measurement for this section is metric ton [ton] or square meter [square yard]. Compute metric tons [ton] accordingly to the guidance under Section 301. For square meters [square yard], use length times width. Show the exact limits used in the computations on the Typical Section. Only a minor allowance should be used with square meters [square yard]. Round up to an even 1000 m^2 [1000 sqyd] for the bid schedule.

6.6.1.6 Division 400 Asphalt Pavements and Surface Treatments

1. **Section 401 — Hot Asphalt Concrete Pavement through Section 407 — Open-Graded Emulsified Asphalt Pavement**. Measurement under these sections is the metric ton [ton]. Compute the compacted cubic meter [cubic foot] volume of the material to be placed on the roadway using the dimensions shown on the Typical Section Sheet. In addition, compute the volumes for widened areas, approach roads, parking areas and tapers for channelized intersections.

   For dense graded mixes, multiply the volumes by 2.30 metric tons/m^3 [0.072 tons/cubic cubic feet] to obtain tonnage. This factor assumes a plant mix mass unit weight of 2300 kg/m^3 [145 lb/cubic feet].

   Asphalt Pavement for metric tons [tons] = (Average W)(D)(L)(2.30*) (Metric)
   Asphalt Pavement for tons = (Average W)(D)(L)(0.072*) (US Customary)

   Where:

   W = Width in m [ft]
   D = Depth in m [ft]
   L = Length in m [ft]

   * The maximum density obtained from the lab reports should be substituted for this factor in the equation.

For open-graded mixes, multiply the volume by the metric ton per cubic meter [ton per cubic foot] factor obtained from the Materials Section. The unit mass density of a cubic meter [cubic foot] of open-graded mix is considerably less than dense graded-mix.

To the total of the above quantities, add an allowance of three to five percent to obtain an even 500 or 1,000 metric tons [tons] in the bid schedule quantity.

When the asphalt is a separate pay item, use six percent of the metric tons [tons] of asphalt base or pavement mix for dense-graded mixes. Check with the Materials Section for any significant differences on a particular project. For open-graded mixes, the Materials Section will provide recommendations on percentages. If asphalt quantities are based on rounded quantities of base or pavement quantities, very little additional rounding is necessary. Rounding to an even 5 or 10 metric tons [tons] is usually sufficient.

2. **Section 408 — Cold Recycled Asphalt Base Course**. The measurement for this section is metric ton [ton] or square meter [square yard]. Compute metric tons [tons] according to the guidance under Sections 401 through 407. For square meters [square yard], use length times width, and show the exact limits used in the computations on the Typical Sections. Only a minor allowance should be used with square meters [square yard]. Round up to an even 1,000 m^2 [1,000 sqyd] for the bid schedule quantity.

3. **Section 409 — Asphalt Surface Treatment**. Measurement is by the metric ton [ton] or cubic meter [cubic yard] under this section. Compute metric tons [tons] according to the guidance under Sections 401 through 407. For square meters [square yard], use length times width and show the exact limits used in the computations on the Typical Sections. Only a minor allowance should be used with square meters [square feet]. Round up to an even 1000 m^2 [1000 sqyd] for the bid schedule.

4. **Section 410 — Slurry Seal**. Measurement is by the square meter [square yard]. Round quantities according to Section 408 above. The quantities of aggregate and asphalt should be calculated for the unit price analysis unless there is a good bid history of average bid prices.

5. **Section 411 — Asphalt Prime Coat**. Measurement under this section is metric ton [ton] or liter [gallon]. Compute the quantity of asphalt using an application rate of 1.5 L/m^2 [0.038 gal/square feet] for cut-back asphalt and 1.1 L/m^2 [0.027 gal/square feet] for emulsified asphalt. To convert liters [gallons] to metric tons [tons], use 1,040 L/t [303 gal/ton] for cut-backs and 1,000 L/t [291 gal/ton] for emulsion. Round to an even 10 metric tons [10 tons] or 5,000 L [5,000 gal] for the bid schedule.

   For blotter material, use 10 kg/m^2 to 14 kg/m^2 [2 lb/square feet to 3 lb/square feet]. If an inverted prime is desired, use 19 kg/m^2 [4 lb/square feet]. Round to an even 10 metric tons or 100 metric tons [10 tons or 100 tons] for the bid schedule.

6. **Section 412 — Asphalt Tack Coat**. Measurement is based on metric ton [ton] or liter [gallon]. Use an application rate of 0.35 L/m^2 [0.008 gal/square feet] for plan quantities. Round to an even 5 metric tons or 10 metric tons [5 tons or 10 tons] or 5,000 liters [5,000 gallons] for the bid schedule.

7. **Section 413 — Asphalt Pavement Milling**. Measurement is based on square meter [square yard] or kilometer [mile]. Round square meters [square yard] up to an even 1,000 in the bid schedule. Round length to 0.01 km [0.01 mi].

8. **Section 414 — Asphalt Pavement Crack and Joint Sealing**. Measurement is based on liter [gallon], kilogram [pound] and meter [foot]. It is difficult to estimate the exact amount of work that will be required in the field under this section. Be liberal in estimating the estimate of work so that only minimal, if any, rounding is required for the bid schedule quantity.

9. **Section 415 — Paving Geotextiles**. Measurement is based on square meter [square yard] and metric ton [ton]. Be liberal in estimating the quantities of work so that only minimal, if any, rounding is required for the bid schedule quantity.

6.6.1.7 Division 500 Portland Cement Concrete Pavement

1. **Section 501 — Portland Cement Concrete Pavement**. Measurement is based on the square meter [square yard]. Compute quantities fairly accurately for this work so rounding is minimal.

2. **Section 502 — Portland Cement Concrete Pavement Restoration**. This is a catch-all section for repair of concrete pavement. There is a tendency to be conservative in estimating this type of work. Therefore, assume a generous amount of work and use only minor rounding for bid schedule quantities.

3. **Section 503 — Portland Cement Concrete Base Course**. Follow the guidance under Section 501.

6.6.1.8 Division 550 Bridge Construction

Section 551 — Driven Piles through **Section 565 — Drilled Shafts** of the FP-XX contains the bridge construction work items. The Structures Section generally determines bridge work items and their respective quantities. The Structures Section will provide the items of work, the quantity of work and the estimated cost for the work for inclusion into the contract package.

Insert the costs provided by the Structures Section into the engineer's estimate system. Allowances are not usually added to bridge items.

6.6.1.9 Division 600 Incidental Construction

1. **Section 601 — Minor Concrete Structures**. For cubic meter [cubic yard] measurement, compute the volumes either from rates on standard plans or manually compute the quantities to the nearest 0.1 m^3 [0.1 cuyd]. Add an allowance to round the bid schedule amount to an even cubic meter [cubic yard]. Round square meter [square yard] measurements to the nearest 1, 5 or 10 units.

Where concrete is not measured for payment directly, estimate the quantity and show it on the plans for the benefit of the bidders. With footings, uniform height walls, etc., showing concrete plan quantities to three decimal places will assist bidders.

2. **Section 602 — Culverts and Drains**. List all culverts on the Drainage Summary Sheet. Show the pipe sizes, lengths and sections, bevels, structure excavation, acceptable alternates, etc. Add a cross section to the plans for pipe larger than 1,200 mm [4 ft] in diameter or equivalent diameter showing inlet and outlet elevation, design Q, end treatments, flow grade line, energy dissipators, etc.

   Small culverts for approach roads and for cross-drains should have an allowance due to normal changes that occur in the field during staking and construction. The allowance depends on the type of construction, terrain and rainfall in the area. No allowance is necessary for larger culverts.

3. **Section 603 — Structural Plate Structures**. These structures have site-specific designs. The design is the responsibility of the Hydraulics Unit and their criteria should be incorporated into the plans. No allowance is necessary under this section.

4. **Section 604 — Manholes, Inlets and Catch Basins**. The location, size, type, etc., should be shown on the plans and on the Drainage Summary Sheet. These items require Special Drawings or Standard Plans. In many instances, the roadway owning agency will request that their Standards be used for consistency with their highway system. No allowance is necessary under this section.

5. **Section 605 — Underdrains, Sheet Drains and Pavement Edge Drains**. The pay item for perforated underdrain may be modified to include the geotextile and the backfill. An allowance is appropriate for underdrain.

6. **Section 617 — Guardrail**. Compute lengths of W-beam guardrail for individual locations in multiples of 3.81 m [12.5 ft]. Round the quantity to an even 5 or 10 m [25 ft]. Guardrail is generally shown in a table on a separate plan sheet but it is permissible to show it in a straight line diagram along the top of the profile section of the plan sheets.

   Prepare a table for the supporting data showing station-to-station, guardrail left or right, length in meters [feet], terminal section type, etc. Exclude the length of terminals.

7. **Section 618 — Concrete Barriers and Precast Guardwalls**. Compute cast-in-place or slip form barriers to the nearest meter [foot] and round for the bid schedule. Precast barriers should be computed in multiples of the length specified for the precast unit; normally 3 m [10 ft]. Show this work on the plans and in the supporting data as indicated under Section 617.

8. **Section 619 — Fences, Gates and Cattle Guards**. Measurement of fencing is generally by the length (m [ft]) of slope measurement. Compute the horizontal length of fencing along the proposed fence alignment and adjust this length for the average slope of the ground.

Fencing is usually shown on a tabulated format or on a separate plan sheet. The proposed fence may also be shown on the plans by a straight line at the top of the profile on the Plan and Profile Sheets, with the type and length of fence labeled.

The supporting data sheet should have a table showing fencing by station-to-station, left or right and horizontal length.

To the plan total, add an appropriate allowance to bring the bid schedule to an even 10, 50 or 100 m [50 or 100 ft].

Show proposed gates on the straight line with the fence at the top of Plan and Profile Sheet or tabulated on a separate plan sheet.

Show cattle guards on the plan with a note indicating station, type, length and the appropriate references to Standard Plans.

9. **Section 622 — Rental Equipment**. Approach the work under this section in the same manner as work under a lump-sum item. Determine what work is required under equipment rental and then determine the size and type of equipment needed to do the work. Try to specify the equipment type and size that is common to the work required for the remainder of the contract.

10. **Section 623 — General Labor**. Determine the work required under this section and estimate the number of hours that it takes to accomplish the work. The *Means Heavy Construction Cost Data Book* provides crew sizes and hours to perform several hundred different tasks. It is a good reference if there is no history for the specific work desired under this section. The Cost Data Book is on file in the Technical Services Engineer's office.

11. **Section 624 — Topsoil**. Usually the design quantity depends on the availability of topsoil on the project within cut and fill limits. This is often an insufficient quantity to topsoil the whole project, so the plans should show which slopes are to receive topsoil. The topsoil is normally placed in 75 mm to 100 mm [3 in to 4 in] loose depth on flatter slopes (flatter than 1:1.5). Specify the depth on the Typical Section Sheet or on a special landscape drawing.

    Where conserving topsoil from roadway excavation or beneath embankment areas, remember to replace the material removed and use for topsoil by roadway excavation. Make the appropriate grade or slope changes to compensate for the removed topsoil.

12. **Section 625 — Turf Establishment**. Use the Seeding Program to compute the areas of seeding. The quantities for seeding should include the rounding shown on the plans. The design programs compute quantities for areas to be seeded on the mainline. For isolated areas and areas of old roadway obliteration, manually compute the areas by multiplying average widths (m [ft]) by average lengths (m [ft]) to obtain the area (square meters [square feet]). Then convert to hectares [acres] by multiplying by .0001 [.000023]. Where using slurry units, assume 10 slurry units per hectare [per acre]. Seeding may be shown on the plans at the bottom of the profile at regular intervals, by sheet total or by tabulation on separate plan sheets. Plan quantities should be shown in

even units. Round the plan total by adding a small allowance to bring the bid schedule to an even hectare [acre]. Round slurry units to 10 units.

13. **Section 633 — Permanent Traffic Control**. Show sign location, MUTCD number, legend, size, area (m^2 [square feet]) and post size on the plans. Tables summarizing sign quantities should be shown on the plans. The supporting data sheet may refer to the tables on the plans.

    Delineators are generally shown with a straight-line diagram or a plot of the alignment on a scale that will fit on a plan sheet. Use symbols to indicate locations of posts left and right. The diagram used is acceptable as the supporting data sheet. To determine the spacing of delineators, refer to Standard Plans or to the *MUTCD* section on traffic markings. Little or no allowance is added to the plan total for delineators.

14. **Section 634 — Permanent Pavement Markings**. Show traffic markings on the plans either by line diagrams for the entire project or by tables. Specify the beginning and ending stations of no-passing stripes and the total quantities of broken and solid striping. Round plan totals by adding an allowance that is appropriate to cover connections and intersections. The supporting data sheet may refer to the plans. Striping can also be shown on plan sheets in conjunction with the signs. This helps to visualize the finished product.

15. **Section 635 — Temporary Traffic Control**. Show all 635 items on traffic control plans. Identify the locations for installing construction signs and specify the uses for the barricades, cones and warning lights shown. Quantities for traffic control devices are summarized on the traffic control plans or on separate plan sheets.

    See PDDM Chapter 8 for guidance on preparation of temporary traffic control plan details. Where extensive detours are required, show the design alignment, grade and surfacing requirements on the plans.

    After determining the contract time and number of days for major work, compute flagging hours and pilot cars hours. Supporting data sheets for other traffic control items may refer to the plans and be shown on one sheet.

6.6.2 Design Documentation

Refer to the PDDM.

6.6.2.1 Design Files

Refer to the PDDM.

6.6.2.2 Design Exhibits

Refer to the PDDM.

6.6.2.3 Visualization and 3D Modeling

Refer to the PDDM.

6.6.2.4 Traffic Management Report

Refer to the PDDM.

6.6.3 Permits

Refer to the PDDM.

6.6.4 Design Data for Construction

Refer to the PDDM.

6.6.5 Stakeout Data and Construction Controls

Refer to the PDDM.

6.6.6 Information for the Construction Project Management Engineer

Refer to the PDDM.

6.7 COMPUTATION OF CONSTRUCTION SCHEDULE AND CONTRACT TIME

Refer to the PDDM.

Under the current Standard Specifications, contract time may be based either on a calendar day or be a fixed completion date. Generally, specify contract time on a calendar-day basis.

There are four basic methods of determining construction schedule and contract time that are in general use throughout the highway industry. They are as follows:

1. **Construction Season Limits**. The contract time ends at, or shortly follows, the end of the construction season. This is a very effective approach on surfacing and paving projects, small bridges and similar types of construction. The contract time must begin early in the year to ensure materials are available and time frames are reasonable.
2. **Quantity or Production Rates**. This method determines contract time by allowing a daily production rate for each controlling item of work in the contract that significantly

affects the project time. The concept could allow time for every item of work, but this is generally not necessary as many minor items are completed concurrently with the more costly items of work. Experience and past data from completed projects helps in establishing the production rates used.

3. **Work Flow Techniques**. Determining contract time under this method involves preparation of a bar or progress chart on normal projects to developing full critical path method (CPM) analysis on large complicated projects. A CPM plan requires extensive coordination of materials, equipment, personnel and administrative support. The more complicated this technique becomes, the more dependent it is on experience, judgment and data sources.

4. **Estimated Costs**. Under this method of determining contract time, the contract costs relate to time or working days (e.g., contractor expected to earn $15,000 per working day over life of the contract). Using this method requires an accurate and current database.

Any or all of the above methods are acceptable. It is not unusual to combine a bar time chart with production rate analysis on a project. The designer should use the method or combination of methods that are most practical using the databases available.

6.8 ENGINEER’S ESTIMATE

Refer to the PDDM.

The estimate is a critical component of the PS&E since it serves as the basis for probable construction cost as well as to support decision-making, determination of project scope, management of project costs when estimates change during the project development, and as a guide to evaluate bidders’ proposals.

6.8.1 Preliminary Engineering Cost Estimate

Refer to the PDDM.

6.8.2 Construction Engineering Cost Estimate

Refer to the PDDM.

6.8.3 Right-of-way Acquisition and Utility Relocation Cost Estimate

Refer to the PDDM.

6.8.4 Construction Cost Estimates

6.8.4.1 Class C Construction Cost Estimate

Refer to the PDDM.

Refer to PDDM Section 4.8.14.3.

6.8.4.2 Class B Construction Cost Estimate

Refer to the PDDM.

Individual pay items for minor items need not be provided at the preliminary design phase. Because of the high uncertainty of the costs at the preliminary (30 percent) design phase, a 15 percent contingency should be added to the overall construction cost estimate. For intermediate (50 percent) phase of design development, provide a defined pay item and separate cost estimate for additional major work items. For intermediate design phase typically a 10 percent contingency should be added to the overall construction cost estimate.

6.8.4.3 Class A Construction Cost Estimate

Refer to the PDDM.

Each item of work listed in an estimate needs a description and a unique number. Each Federal Lands Highway Division office maintains a current listing of contract items with their respectively assigned descriptions and unique numbers. When the listed contract items are not applicable to the anticipated work, new items with descriptions and unique numbers will be established by the responsible party and furnished to the designer.

The unique numbers assigned to the items of work serve as input into the engineer's estimate program. This program uses the unique numbers as a basis for other related programs (e.g., bid schedule, tabulation of bids, average bid prices) and the construction progress estimate. Unique numbers will be established by the responsible party and furnished to the designer. A unique number, once assigned to an item, should not be changed.

Bridge items may not be applicable to more than one bridge or structure. Only those items physically incorporated into the bridge structure are considered bridge items. For coding purposes, the following are not considered bridge items:

- Detours,
- Detour structures,
- Loose riprap,
- Slope protection, and
- Removal of existing bridge structures.

The FLH Engineer's Estimate System software program is used to prepare the engineer's estimate. The designer is responsible for entering the initial pay item names, quantities and unit bid prices into the system to obtain the engineer's estimate. The engineer's estimate is the database for preparation of the bid schedule, bid tabulation, progress and final construction estimates using other features of the Engineer's Estimate System. A bid history database is maintained that includes data on historic unit bid prices. Evaluate the bid history data to help determine the estimated unit price to be bid for the item for development of prices.

6.8.5 Development of Prices

Refer to the PDDM.

1. **Bid-Based Estimating**. This method uses historical bid data as a basis for estimating current costs. Low bids received for projects (within the past two to five years) under similar conditions usually represent the contractor's cost plus a reasonable profit for those projects. The low bid is generally the best indicator of the expected actual cost for a project. The average of the low bids received on previous projects in similar locations should be the basis for current projects.

   Each engineer's estimating software in each Federal Lands Highway Division office provides a listing of unit bid prices on contract items from previous projects. Typically, the low bid on each similar project is used to develop unit prices (an average of all bids results in higher prices than the low bid). However, using an average of the bids from the lowest three bidders is recommended to ensure the low bid is reasonable. The designer should use these prices and modify them to fit the conditions on the project, and adjust for increases in the overall cost of construction over time using an inflation index. Allow for any factors that may have a direct bearing on the prices, including the following:

   - Availability of construction material;
   - Proximity of access roads;
   - Railroads; and
   - Distance from towns, traffic, time of construction, inflation, quantities, etc.

   The historical bid price approach, tempered with engineering judgment, is recommended for estimating the minor items of work on a project. For major items of work, consideration for the cost-based estimating approach, in addition to the bid-based estimating approach, is recommended.

2. **Cost-Based Estimating**. Bid-based estimating may not be the appropriate approach for some items of work, especially major items such as roadway excavation, base and plant mix material, bridge material, etc.. These items require a supporting analysis to ensure that all factors that bear on the cost of the item receive consideration. Cost based estimating uses current labor, equipment and materials costs, production rates, as well as overhead and profit to develop unit prices.

The following are important steps in developing prices for construction cost estimating:

- Determine if the proposed unit prices are realistic for the location, time of year and characteristics of the work to be performed. Support unit prices for major items of work by an analysis prepared in sufficient detail to ensure that all factors that bear on the cost of the item have been considered. Estimated unit prices are generally based on historical data (e.g., the unit prices used for previous estimates, the corresponding bid prices on previous contracts). Review these prices at regular intervals to determine if pricing changes are needed to reflect current trends.

- Consider factors that can affect the estimated cost of a project (e.g., labor rates, equipment rates, unusually large quantities, interest rates, time allowance, competition levels, material shortages). Adjust any historical prices accordingly.
- Confirm that the bid data prices to be used are current. Update, if necessary.
- Document the methods and assumptions used to establish each unit price. The bid evaluation process will rely heavily upon this documentation to determine if all factors effecting the reasonableness of the bid have been considered.

When updating historic bid prices or other cost data, use an inflation time period that begins at the year and month the historic bid or cost data originates from, and ends in the year and month of the proposed project's anticipated construction completion.

6.9 SPECIFICATIONS

Refer to the PDDM.

Specifications are the compilation of directions, provisions and requirements about the quality and performance of the work. They should describe the work with clarity and precision and have a clear logical format.

Specifications should not specify impossibilities, near impossibilities or contain unenforceable requirements. When ideal conditions cannot be obtained, specify tolerances to permit acceptable variations in the work.

The designer is responsible for the initial preparation of all Special Contract Requirements relating to an individual project.

All specifications fall into three general categories:

1. **Performance or End Result Specifications**. These specifications give the contractor the entire responsibility for supplying an item or a product for construction that meets the specification requirements. The specification generally places no restrictions on the materials used or the methods of incorporating them into the completed work. This type of specification is suitable for use when the end product is measurable, when a quick method of testing is available and when deficiencies are correctable by reprocessing or reworking.

2. **Materials and Methods Specifications**. These specifications are suitable for use when the end product characteristics are unknown or are not measurable. They also apply when no quick method of acceptance test is available, or it is impractical to remove and

replace the defective work. Use of these specifications directs the contractor to combine specified materials in definite proportions using approved equipment or to place a specified material or product in a specified way. Normally, the operations are always under government supervision and control.

3. **Restricted Performance Specifications**. These specifications are the most widely used type. They allow the contractor the fullest possible latitude in obtaining the desired end result as stated in the contract. However, they contain certain restrictions to ensure an acceptable level of quality and prevent the construction or production of a large quantity of defective work. In most cases, a restriction on a performance specification does not relieve a contractor of all responsibility. These specifications ensure a minimum acceptable quality and they also give the contracting officer some basis on which to administer the contract and accept the work.

6.9.1 Types of Specifications

Under the three general categories, there are three distinct types of specifications used by Federal Lands Highway Division offices for contracts, and each has its place in the hierarchy of contract documents.

1. **Standard Specifications**. The *Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects,* (FP-XX) approved for general application and repetitive use.

2. **Supplemental Specifications**. Additions and revisions to the Standard Specifications.

3. **Special Contract Requirements**. Additions and revisions to the Standard and Supplemental Specifications applicable to an individual project.

See the Glossary for their definitions and relationship with each other and interaction with the other parts of a contract.

The FLH Specification Coordination Group (SCG) is responsible for the maintaining and updating of the Standard Specifications (current edition of the FP-XX). OFLH may issue Supplemental Specifications, which are to be incorporated in all applicable FLH contracts until the Supplemental Specifications are included in a Standard Specifications update. The designer is responsible for the initial preparation of all Special Contract Requirements relating to conditions peculiar to an individual project. Special Contract Requirements are specifications that add to, delete, modify or revise the Standard or Supplemental Specifications. This section will describe the methods and techniques for developing and writing Special Contract Requirements.

The contract specifications will sometimes refer to a specification, standard or test method adopted by a recognized technical association. Some of the recognized associations follow:

- American Association of State Highway and Transportation Officials (AASHTO),
- American National Standards Institute (ANSI),
- Association of Official Agricultural Chemists (AOAC),
- American Road and Transportation Builders Association (ARTBA),

- American Society for Testing and Materials (ASTM),
- American Wood Preservers Association (AWPA),
- American Welding Society (AWS), and
- American Water Works Association (AWWA).

Occasionally, a contract may use State transportation agency specifications. This can range from total use of State specifications to allowing some State-specified methods or products to be acceptable alternatives to Federal requirements.

Government specifications and standards used by reference include the following:

- Federal specifications and standards approved for use by the General Services Administration.

- Voluntary products standards published by the National Institute of Standards and Technology, US Department of Commerce. Standards published before 1966 are referred to as “Commodity Standards” or “Simplified Practice Recommendations.”

- Military standards approved for use by the US Department of Defense.

When the contract lists or refers to a specification, standard or test method of an accepted association or other Government agency, the specification standard or test method cited becomes a part of the contract. Citing these documents has the same legal effect as though every word of the specification, standard or test method had been written in the contract.

Ensure the specifications incorporated into the contract by reference do not conflict with other contract documents.

6.9.2 Developing Special Contract Requirements

These requirements provide additions and revisions to the Standard or Supplemental Specifications. Begin by analyzing the material, process or work proposed in the contract.

Assemble existing specifications prepared for the same or similar subject and obtain specifications for materials and processes prepared by standardizing organizations or State agencies. A study will reduce the time needed for research and preparation of the specifications.

If possible, do not specify brand name or proprietary products. When brand names or proprietary items have to be specified, list a minimum of three acceptable sources for the material or product desired. Sole source procurement is to be avoided. Cover the important properties of materials but do not load the specifications with minor restrictions, which may be difficult or impossible to meet.

Specifications from national technical associations are a valuable source of authoritative information. When specifying standards or test methods, identify them by their identification number (e.g., ASTM A 307, AASHTO T 27, AASHTO M 31M, Federal Specification TT-P-641). Do not include the year portion of the identification number. (Example: When specifying AASHTO T 27-87I use AASHTO T 27 and drop the 87I, which says the specification is an interim specification adopted for use in 1987.) An “M” after the standard number indicates a metric specification and should be included in the reference.

A reference made to a specification, standard or test method adopted by AASHTO, ASTM, GSA or other recognized national technical association, means the approved procedures that are in effect on the date of the contract solicitation.

When adopting requirements taken from other specifications, ensure they are appropriate for the conditions in the current project. The use of a specification on a previous project does not mean it will be satisfactory for the present project. Check the criteria to ensure it is relevant, realistic and applicable for the proposed project. Study every specification to eliminate nonessential requirements and to permit the use of new types of materials, methods or equipment. Do not repeat specification requirements for emphasis. State them firmly and only once.

Do not specifically exclude recycled materials. Recycled materials should be allowed to compete with virgin materials at least on an equal basis. In some cases, providing incentives or relaxed specification limits may encourage the contractor’s use of recycled materials.

For alternative retaining wall systems the contract specifications must identify the procedures fro the FLH review of designs and working drawings submitted by the contractor, similar to the bridge process for reviewing and approving falsework drawings. The information that is required from the contractor for review of wall submittals must be specified in the contract, along with the amount of time required for FLH reviews. The contract must include provisions for additional time needed to permit the working drawings to be reviewed by the A&E firm that did the original design, if appropriate. The specifications must define when the time count begins for both the review of initial submissions, and for subsequent reviews when changes are required. The contract should specify the number of sets of drawings needed by FLH.

6.9.3 Writing Special Contract Requirements

Use the general format for the Standard Specifications when writing specifications for a new item. Most standard specification sections, except Divisions 100 and Division 700, have five major subsections.

1. **Description**. This contains a short condensed statement of the work required. It may include a list of designations, which may be specified in the pay items. Do not use words such as “in accordance with these specifications and in reasonably close conformity with the lines, grades, thickness and typical cross section shown on the plans or established by the contracting officer.”

2. **Material**. Use this subsection to list the materials for the work and their applicable specifications. Wherever possible the Materials subsection should simply consist of an alphabetical listing of materials and references in tabular form. References are usually made to other sections or subsections in the contract specification or applicable specifications for materials as contained in AASHTO, ASTM, etc. The method(s) of sampling and testing and applicable acceptance procedures should be included in the acceptance subsection under Construction Requirements.

3. **Construction Requirements**. Describe the sequence of construction operations, special equipment, controls, limitations, tolerances and acceptance criteria in chronological order. Use multiple subsections with subheadings.

   Use imperative mood, active voice whenever possible. Instead of saying, “The contractor shall build the road.” or “The road shall be built.” say “Build the road.” In sentences using the imperative mood, the contractor is implied. Actions of the government should be written in the active voice using the work “will.” For example, “The government will approve the road.” Subsection 101.01 of the FP-XX makes this interpretation a part of FLH contracts.

   Use sufficient specification requirements to ensure quality of workmanship and satisfactory completion of the work. Minimize specific requirements about methods and equipment to permit improved equipment and to encourage contractors to apply new and advanced ideas and methods in construction. Specify the allowable tolerances and applied penalties, if any, for exceeding these tolerances.

   The last subsection under Construction Requirements is used to describe how the work under that section will be accepted. This usually includes references to the following four methods of acceptance:

   - Subsection 106.02, Visual Inspection;
   - Subsection 106.04, Certification of Compliance;
   - Subsection 106.04, Measured or Tested Conformance; and
   - Subsection 106.05, Statistical Evaluation of Work and Determination of Pay Factor (Value of Work).

4. **Measurement**. Since the contractor performs the measurement under FLH contracts, use the active voice, imperative mood. Specify the components of the completed work item to be measured for payment and the units of measurement to be used. Use the measurement terms and definitions contained in Subsection 109.02 of the FP-XX. Establish where, when and how to measure the work item. List any exception that will or will not be included in the measurements.

5. **Payment**. This subsection should consist of the following wording:

   > *The accepted quantity, measured as provided above, will be paid at the contract price per unit of measurement for the pay items listed below that are shown in the bid schedule. Payment will be full compensation for the work prescribed in this Section. See Subsection 109.05.*

   Follow this wording by a list of the pay item numbers, names and corresponding pay units.

   Pay items with their unit bid prices subject to adjustment under Subsection 106.05 should be included as exceptions in the above paragraph. The subsection will also need to describe the method for adjusting the contract unit bid price.

> Subsection 109.05, Scope of Payment, includes the general rules for measurement and payment of work. There is no need to restate these rules in each individual section. However, all exceptions or needed clarifications of these rules should be stated in the Measurement or Payment subsections or the individual section.

When writing a Special Contract Requirement that adds to a Standard Specification, use the following phrase:

> *Subsection (No.) is supplemented as follows:*

When writing a Special Contract Requirement to delete a Standard Specification for a contract, use the following phrase:

> *Subsection (No.) is deleted.*

When writing a Special Contract Requirement to replace or modify a Standard Specification, use the one of the following phrases:

> *Delete Subsection (No.) and substitute the following:*

or

> *Subsection (No.) is amended as follows:*

6.9.4 Fairness

Specifications should not place all the risk of construction on the contractor. To do so will, in all probability, result in high bid prices. Omissions, ambiguities or inconsistencies in the plans or specifications are not the responsibility of the contractor.

Direct reference to proprietary specifications of national, regional or local trade associations (e.g., Western Pine Association, etc.) should not be placed in the Specifications. Proprietary specifications are subject to change without notice to or acceptance by FHWA.

Avoid the use of trade names in the Specifications and on the plans. Instead, formulate Specifications to obtain the desired results and assure full competition among equivalent materials, equipment and methods. The *Federal Acquisition Regulations* (FARs) do not permit reference in the Specifications and on the plans to single trade name materials (refer to 23 CFR 635.411). In exceptional cases, however, the use of trade name designations are acceptable. These cases require a listing of all, or at least a reasonable number of acceptable materials or products. Generally, list at least three trade names.

A project may require a specific material or product, even though there are other acceptable materials and products. This is an acceptable procedure if the Division Engineer approves the choice as being in the public interest.

A Specification should clearly state the contractor's obligations and known risk. No specification should try to get something for nothing from a contractor by concealing its intent.

6.9.5 Clearness

Write all Specifications in a simple and concise style. Use short sentences, use words in their exact meaning, avoid multi-syllable words and be careful in the use of punctuation and pronouns. Avoid the use of indefinite words and phrases. Each word, each phrase and each sentence in a Specification should clearly convey the same meaning to every reader.

The Specification must describe the work with clarity and precision to prevent different interpretations by the contractor and the contracting officer. Never put anything in the *Specification* that you do not expect to enforce.

Avoid expressing more than one thought in a sentence since this leads to confusion. If a technical word will clearly describe the idea to the contractor, use it exclusively. Do not use synonyms for literary effect. Always use words in their true dictionary or technical meaning. Do not use colloquialisms and slang expressions. Syntax, the orderly or systematic arrangement of words or phrases in a sentence, is very important and the established usage should be maintained.

Punctuate carefully. Recast the sentence if a change in punctuation might change the meaning. The purpose and effect of the Specification should be clear from its language and the language should convey only one meaning.

Use all the words needed to convey clear and correct messages, but use no more. The choice of words is important. They should be plain and well understood.

Exhibit 6.9–A is a listing of words and phrases to avoid when writing specifications.

In addition to the words and phrases listed in Exhibit 6.9–A, use the following words in the proper context:

1. **Shall/Will**. Use the imperative mood, active voice when the contractor is the subject of a requirement, command or order, to avoid the use of “shall.” Use “will” when the government or contracting officer is the subject.

2. **May**. Use may when either the contractor or government is the subject and either or both have options or alternatives.

3. **Amount/Quantity**. Use amount when money is the subject. Use quantity when volume, mass or other unit of measurement is the subject.

4. **Bidder/Contractor**. Do not use bidder in the Specifications. Use contractor exclusively. Bidder is reserved for use in the Notice to Bidders, press releases, amendments and other similar non-specification portions.

Do not use the words said, same, aforesaid, hereinabove, hereinafter, former, latter, whatsoever or similar words of reference or emphasis. Do not use the expressions and/or, as per, or, etc.

Exhibit 6.9–A CORRECT USAGE OF WORDS AND PHRASES

Do Not Use	Use
Any	All
In the event that	If or when
It is intended	Shall
Subsequent to	After
In order to	To
It shall be incumbent upon	Shall
It shall be the responsibility of the contractor	The contractor shall
It shall be the duty	Shall
Is hereby authorized	May
For the purpose of	For
Must	Shall
If the contractor so elects he may	The contractor may
At the option of the contractor	The contractor may
Is hereby amended	Is amended
Is hereby deleted	Is deleted
By means of	By
Absolutely essential	Essential
Enclosed herewith	Enclosed
At a later date	Later
Prior to	Before
In accordance with	By, under, according to
Through the use of	By
Until such time	Until
In order to	To
Engineer	Contracting officer (CO)

Avoid such terms as “as directed by the contracting officer,” “to the satisfaction of the engineer,” or “satisfactory to the engineer”. This type of phrase may be used sparingly, such as in unit price items where action taken by the contracting officer will definitely not involve changes in cost to the contractor.

6.9.6 Completeness

Each Specification must be complete and will complement and substantiate the applicable Typical Sections, dimensions and details shown on the plans. The Specification should furnish all information necessary to enable a bidder to prepare a complete and responsible bid and to enable the contractor to construct the project properly. The Specification should never fail to give the bidders and the contractor explicit and definite instructions. However, there is no place in a Specification for instructions to the contracting officer.

Do not attempt to explain the reasons for requirements. This information or instructions associated with the enforcement or specifications properly belongs in the *Construction Manual* or in a design narrative and not in the Specifications.

Specifications should specify materials, construction methods, sequence of work, the method of measurement and the basis of payment. Notes on the plans should explain and clarify the design features. Cover a requirement only once. Information or data that is shown on the plans should not be shown in the Specifications.

There should be no uncertainty by the contractor or contracting officer about the desired quality or acceptability of the work. Use only essential facts, essential words and essential phrases. Omit needless words and phrases. If a word has the same meaning as a phrase, use the word.

6.9.7 Correctness

Specifications should be accurate and factual. Sources of data used in the Specification must be reliable and current. Careless statements or statements based on unreliable data are frequently the cause of contract administration problems and contractor's claims. Legalistic words and phrases may shorten or clarify Specifications, but ensure that the usage is correct and that alternate interpretations cannot contradict the intended meaning.

There are many publications available for providing instruction on the preparation of specifications. The majority of the Standard Specifications begin as Special Contract Requirements, which gradually change through use until the intent and meaning is the same to both the contractor and contracting officer.

A good guide for determining the success of a specification is to review the bid tabulations for the item in question. When the range of bidding is close, it indicates that all contractors are reading the Specification in the same context. Conversely, a wide range of bidding may indicate confusion and ambiguity in the Specification.

6.10 CONTRACT ASSEMBLY

Refer to the PDDM.

The contract assembly, often called solicitation package, is the end product of the designer's efforts. The PS&E package is an integral part of this assembly. Before the Federal Lands

Highway Division offices can solicit bids for a construction contract, they need to describe the articles, works or services for a desired bid. This involves preparing plan drawings, supplemented by Specifications and a schedule of quantities, and combining them with appropriate regulations and clauses into a contract assembly.

6.11 QUALITY CONTROL AND QUALITY ASSURANCE

Refer to the PDDM.