CALIFORNIA
DEPARTMENT OF TRANSPORTATION

manual change transmittal

TITLE **DIVISION OF DESIGN HIGHWAY DESIGN MANUAL FIFTH EDITION - CHANGE #6**	APPROVED BY MARK LEJA, Chief	NO. 6 Date Issued: June 1, 2004 Page 1 of 4
SUBJECT AREA Table of Contents; List of Figures; List of Tables; Chapters: 20, 60, 80, 100, 200, 300, 400, 500, 600, 830, 840, 850, 900; and, Index	ISSUING UNIT DIVISION OF DESIGN	
SUPERCEDES Table of Contents; List of Figures; List of Tables; Chapters: 20, 60, 80, 100, 200, 300, 400, 500, 600, 830, 840, 850, 900; and, Index – 5TH EDITION, JULY 1995	DISTRIBUTION **ALL HOLDERS OF THE 5TH EDITION, HIGHWAY DESIGN MANUAL**	

The Table of Contents; List of Figures; List of Tables; Chapters: 20, 60, 80, 100, 200, 300, 400, 500, 600, 830, 840, 850, 900; and, the Index of the Highway Design Manual, Fifth Edition, have been revised. Please replace the affected sheets in your Highway Design Manual (HDM) with the enclosed sheets. These revisions and changes are effective July 1, 2004, and shall be applied to on-going projects in accordance with HDM Index 82.5 – Effective Date for Implementing Revisions to Design Standards.

Major revisions have been made within Chapter 600, Design of the Pavement Structural Section; which has been revised in its entirety and, in doing so, has relocated the pavement structural section definitions from Chapter 600 to Chapter 62.

Another major revision relates to the discussion of curbs and dikes within the HDM. The discussion of curbs and dikes has been revised and relocated from Topic 209 to 303.

Additional changes have been made with regards to design speed selection criteria, gore paving, shoulder widths, pedestrian and bicycle issues, and pavement structural section definitions.

Highlights of the other revisions and changes being made in this transmittal are summarized as follows:

General Note All titles and acronyms for Offices, Divisions, Departments, Agencies, and Committees have been updated, as necessary, in the HDM text only where additional revisions and changes were made.

Chapter 20 **Designation of Highway Routes**

21.2 Figure 21.1, Interstate Highway System in California, has been updated to add previously omitted routes.

Chapter 60 **Nomenclature**

62.7 Pavement structural section definitions were updated and moved here from Chapter 600.

Chapter 80 **Application of Design Standards**

82.1 Tables 82.1A and 82.1B have been revised to reflect changes in Chapter 600 and Topics 209, 303, 308, and 504.

82.2 Design standards in Chapter 600 have been delegated to Chief, Office of Pavement Design.

Chapter 100 **Basic Design Policies**

103.2, 110.11, 112.1, 113.3, and 114.3 were revised to reflect changes made in Chapter 600.

105.4 Two advisory standards have been reduced to permissive standards; these accessibility requirements are discussed in Design Information Bulletin (DIB) 82.

Chapter 200 **Geometric Design and Structure Standards**

201.1 In Table 201.1, footnote (2) was reworded to denote advisory standard and direct reader elsewhere.

201.5 Errata: The angle of headlight divergence was corrected from 10^o to 1^o in the diagram of Figure 201.5.

201.6 Errata: The equation for "S" in Figure 201.6 was clarified to minimize misinterpretation.

208.6 Advisory standard has been reduced to permissive standard; this accessibility requirement is discussed in DIB 82.

209 Curb and dike discussion moved to Topic 303.

Chapter 300 **Geometric Cross Section**

301.1 The fact that the traveled way does not include curbs, dikes, gutters, or gutter pans has been reinforced.

302.1 Table 302.1 Notes (4) and (8) have been changed; plus, Note 8 no longer applies to left shoulders.

302.2, 304.1, and 305.5(8) contain updated references to Chapter 600.

303 The discussion of curbs and dikes has been revised and relocated here from Topic 209.

304 Slope guidance has been updated. Advisory standard of 1:4 embankment slopes has been moved here from Topic 309.

305.4 Advisory standard has been removed and reader is directed elsewhere.

307 Figures 307.2, 307.4 and 307.5, contain updated references in Note 4 to dikes.

307.3 Indexes 307.3 and 307.6 have been updated to refer the reader to DIB 79-02.

309.1(2) Reference to embankment steepness has been removed from the advisory standard and moved to Topic 304, and the slope discussion has been moved to Index 304.1.

Chapter 400 **Intersections at Grade**

401.2 Added word "intersection" into first sentence to clarify meaning. Deleted last two sentences.

403.2 Emphasis on bicyclists has been added.

403.8 Consideration of pedestrian convenience and safety has been added.

405.4(2) This index has been revised to correspond to rewritten Topic 303.

405.8 Errata: The larger radius was corrected from 30 m to 8 m.

Chapter 500 **Traffic Interchanges**

504.2(2) This index and Figures 504.2A and B, have been revised to provide guidance on the use of contrasting surface treatments.

504.3(11) and (12) These indexes have been revised to correspond to the rewritten Topic 303.

Chapter 600 **Pavement Structural Section**

General Notes on Chapter 600:

- Technical information regarding basement soils, subbases and bases, Asphalt Concrete materials types, Asphalt Concrete design examples, and pavement structural section rehabilitation have been removed from Chapter 600 and are now available on the Pavement web site at: http://www.dot.ca.gov/hq/oppd/pavement/guidance.htm. Additional details on the revisions of this chapter may also be found on the Pavement web site.
- Deviations from standards which previously required approval from HQ Division of Design in Chapter 600 have been changed to make them consistent with the procedures for mandatory, advisory, and permissive standards as discussed in HDM Topic 82. Proposals to use alternate design procedures from those in Chapter 600, such as mechanistic/empirical design, still require justification to and approval of HQ Division of Design.

Topic 601 – General Considerations

Indexes providing guidance on “Roles and Responsibilities,” “Record Keeping,” “Research and Experimentation,” and on “Other Resources” for pavement information have been written.

Topic 602 – Traffic Data (formerly Topic 603)

- Guidance on using a 40-year service life for high volume corridors has been provided.
- Standards on design life of pavements have been expanded to address CAP-M, Rehabilitation, New Construction, and Widening pavement service life and have been rewritten as mandatory standards. Advisory standards for the pavement service life of temporary pavements and detours have been added.

Topic 603 – Portland Cement Concrete Pavement (formerly Topic 607)

- The use of dowels and tie bars on new or reconstructed PCC pavements has been rewritten as a mandatory design standard.
- Treating low R-value soils with stabilizing agents is emphasized.
- Guidance on perpetuating treated permeable bases when widening has been provided.
- Various revisions have been made to the Traffic Index (TI) parameters.
- PCC shoulder standards have been revised to also permit AC shoulders when a 4.27 m widened slabs is used, and rewritten as mandatory standards.

Topic 604 – Asphalt Concrete Pavement (formerly Topic 608)

- Median and outside shoulders are now to be designed the same way.
- Shoulder structural sections are now recommended to match that of the adjacent lane.

Topic 605 – Selection of Pavement Type for New Construction (formerly Topic 609)

Requirements for conducting an economic analysis have changed.

Topics 606, “Drainage of the Pavement Structural Section,” and 607, “Structure Approach Pavement and Structure Abutment Embankment Design” (formerly Topic 610) have been revised and updated to match the current state-of-the-practice.

Chapter 830 **Roadway Drainage**

834.3(4), 835.3, and 836.1 have been revised to correspond with the changes related to moving the discussion of curbs and dikes from Topic 209 to 303.

836.2(2) and 837.2(2) have been revised to reflect ADA requirements related to gutter cross slope and grates located within pedestrian paths of travel.

Chapter 840 **Subsurface Drainage**

841.5 Revised to reflect changes in Chapter 600.

Chapter 850 **Physical Standards**

854.5 Revised to reflect changes in Chapter 600.

Chapter 900 **Landscape Architecture**

903.53(d) Revised to reflect changes in Chapter 600.

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CHAPTER 20 DESIGNATION OF HIGHWAY ROUTES

Topic 21 - Highway Route Numbers

Index 21.1 - Legislative Route Numbers and Descriptions

The Legislature designates all State highway routes and assigns route numbers. The description and number of each route are contained in Chapter 2, Article 3 of the Streets and Highways Code. These route numbers are used for all administrative purposes.

The Legislature has stated its intent that the routes of the State Highway System serve the State's heavily traveled rural and urban corridors, that they connect the communities and regions of the State, and that they serve the State's economy by connecting centers of commerce, industry, agriculture, mineral wealth, and recreation.

A legislative route description generally runs south to north or west to east. To the extent possible, the number used on each route's guide signs is the same as the legislatively designated route number.

A specific location on any State highway is described by its kilometer post designation (formerly known as post miles). Kilometer posts (KP) start at the west or south county line and end at the east or north county line. Until the corporate database is complete, kilometer posts are determined by soft converting the post mile data. The conversion will be made by multiplying the post miles by 1.6093. All equations, prefixes and suffixes shall be retained. Post mile information is available in the State Highway Log and on post mile maps distributed by the Office of Office Engineer.

21.2 Sign Route Numbers

Each route in the State Highway System is given a unique number for identification and signed with distinctive numbered Interstate, U.S. or California State route shields to guide public travel. Route numbers used on one system are not duplicated on another system. Odd numbered routes are generally south to north and even numbered routes are generally west to east.

(1) *Interstate and Defense Highways.* The Interstate System is a network of freeways of national importance, created by Congress and constructed with Federal-aid Interstate System funds. Routes in the system are signed with the Interstate route shields (See Index 42.2 and Figure 21.1) and the general numbering convention is as follows: routes with one or two-digit numbers are north-south or east-west through routes, routes with three-digit numbers, the first of which is odd, are interstate spur routes. For example, I-110 is a spur route off of I-10. Routes in three-digit numbers, the first of which is even, are loops through or belt routes around cities. I-805 in San Diego is an example of a loop off of I-5. The numbering of Interstate routes was developed by AASHTO with concurrence by the states.

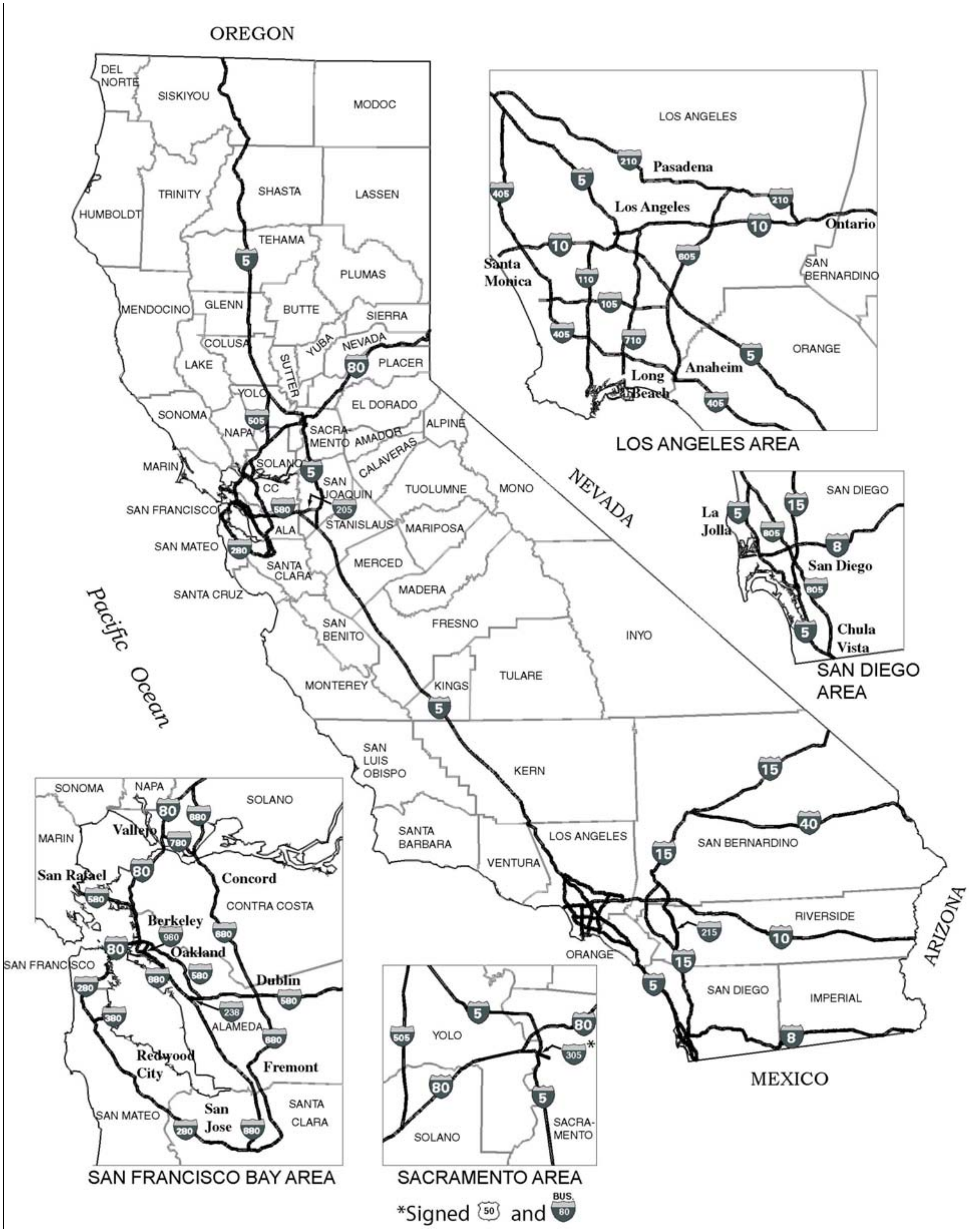
    Renumbering of Interstate routes requires the approval of AASHTO to assure conformity with established numbering procedures. Such revisions also are a system action that must be approved by the Federal Highway Administrator.

    The Transportation System Information Program is responsible for processing requests for changes to the system to AASHTO and FHWA for their consideration.

(2) *United States Numbered Routes.* United States Numbered Routes are a network of State highways of statewide and national importance. These highways can be conventional roadways or freeways.

    The establishment of a U.S. number as a guide for interstate travel over certain roads has no connection with Federal control, any Federal-aid System, or Federal construction financing. The Executive Committee of AASHTO, with the concurrence of the states, has full authority for numbering U.S. routes.

Figure 21.1
Interstate Highway System
in California



the Office of State Landscape Architecture. Highway planting is warranted on new highways where adjacent properties are developed at the time the highway contract is accepted; on existing highways where adjacent properties have been developed at the time the highway contract is accepted for construction of a new interchange or major modification of an existing interchange; and on existing highways where adjacent properties were developed on or before June 30, 1987.

In addition, highway planting may be required to satisfy written agreements or memorandum of understanding between the State and another governmental agency, or mitigate impacts as required in an environmental document or by court order.

If legally required, the allowable maximum cost-per-hectare may be exceeded.

(2) *Revegetation.* Planting of indigenous plants to replace natural vegetation that is damaged or removed as a result of highway construction projects or permit requirements. This work may include provisions for irrigation. Planting to restore existing eroding slope for reduction of maintenance effort, traveler safety and improved water pollution control is included.

(3) *Replacement Planting.* Planting to replace planting (installed by Caltrans or others) that is damaged or removed during highway construction activity, including irrigation modification and/or replacement.

Unless the environmental document or memorandum of understanding with the local agency specifies otherwise, highway planting work including replacement is done as a separate contract from the highway construction work. Exceptions may be permitted with approval of the Office of State Landscape Architecture District Coordinator when justified.

(4) *Highway Planting Restoration.* The renovation or rehabilitation of planting areas and irrigation systems to reduce maintenance expenditures, improve roadside working conditions, reduce water consumption or utilize nonpotable water. Restoration is justified when capital costs can be recovered through maintenance savings within 12 years. Improvement of working conditions, installation of Remote Irrigation Control System (RICS), and conversion to nonpotable water does not require a 12 year payback.

(5) *Erosion Control.* Vegetation, and other materials, such as duff, topsoil, straw, fiber, mulch or compost stabilizing emulsion, protective blankets, etc., placed to stabilize areas disturbed by grading operations, reduce loss of soil due to the action of water or wind, and prevent water pollution.

(6) *Landscaped Freeway.* A designation, as defined in Chapter 6, Title 4 of the California Administrative Code, given to a section of freeway relative to the regulation of outdoor advertising displays.

(7) *Safety Roadside Rest.* A roadside area provided for motorists to stop and rest for short periods. It includes paved parking areas, drinking water, restrooms, tables, benches, telephones, information panels, and may include other facilities (see Topic 903).

(8) *Vista Point.* A paved area beyond the shoulder which permits travelers to safely exit the highway to stop and view a scenic area. In addition to parking areas, trash receptacles, interpretive displays, and in some cases rest rooms, drinking water and telephones may be provided (see Topic 904).

62.6 Right of Way

(1) *Acquisition.* The process of obtaining right of way.

(2) *Air Rights.* The property rights for the control or specific use of a designated airspace involving a highway.

(3) *Appraisal.* An expert opinion of the market value of property including damages and special benefits, if any, as of a specified date, resulting from an analysis of facts.

(4) *Condemnation.* The process by which property is acquired for public purposes

through legal proceedings under power of eminent domain.

(5) *Control of Access.* The condition where the right of owners or occupants of abutting land or other persons to access in connection with a highway is fully or partially controlled by public authority.

(6) *Easement.* A right to use or control the property of another for designated purposes.

(7) *Eminent Domain.* The power to take private property for public use without the owner's consent upon payment of just compensation.

(8) *Encroachment.* Occupancy of project right of way by non-project structures or objects of any kind or character.

(9) *Inverse Condemnation.* The legal process which may be initiated by a property owner to compel the payment of just compensation where the property has been taken or damaged for a public purpose.

(10) *Negotiation.* The process by which property is sought to be acquired for project purposes through mutual agreement upon the terms for transfer of such property.

(11) *Partial Acquisition.* The acquisition of a portion of a parcel of property.

(12) *Relinquishment.* A transfer of the State's right, title, and interest in and to a highway, or portion thereof, to a city or county.

(13) *Right of Access.* The right of an abutting land owner for entrance to or exit from a public road.

(14) *Severance Damages.* Loss in value of the remainder of a parcel which may result from a partial taking of real property and/or from the project.

(15) *Vacation.* The reversion of title to the owner of the underlying fee where an easement for highway purposes is no longer needed.

62.7 Pavement Structural Section

The following list of definitions includes a number of terms that are not commonly used in California. Some are terms which are included in the "AASHTO Guide for the Design of Pavement Structures" and may be used by FHWA, local agencies, consultants, etc., when discussing pavement structural sections. Some are common terms in pavement design and research publications that the PE may want to read.

(1) *Asphalt Treated Permeable Base (ATPB).* A highly permeable open-graded mixture of crushed coarse aggregate and asphalt binder of planned thickness placed as the base layer to assure adequate drainage of the structural section, as well as structural support.

(2) *Base.* A layer of selected, processed, and/or treated aggregate material of planned thickness and quality placed immediately below the pavement and above the subbase or basement soil to support the pavement.

(3) *Basement Soil/Material.* The natural soil or rock material in excavation or embankments underlying the lowest layer of subbase, base, pavement surfacing or other specified layer which is to be placed.

(4) *Borrow.* Natural soil obtained from sources outside the roadway prism to make up a deficiency in excavation quantities.

(5) *Capital Preventive Maintenance (CAP-M).* A maintenance program which funds work that is performed to preserve the existing pavement structural section utilizing strategies that extend pavement service life for a minimum of 5 years. (For more detailed discussion and sample strategies, see CAP-M Guidelines by the Division of Maintenance.)

(6) *Cement Treated Permeable Base (CTPB).* A highly permeable open-graded mixture of coarse aggregate, portland cement, and water placed as the base layer to provide adequate drainage of the structural section, as well as structural support.

(7) *Crack.* Separation of the materials due to natural causes, traffic action, or reflections from an underlying pavement.

(8) *Deflection.* The downward vertical movement of a pavement surface due to the application of a load to the surface.

(9) *Dense Graded Asphalt Concrete (DGAC).* A uniformly graded asphalt concrete mixture (aggregate and paving asphalt), containing a small percentage of voids, used primarily as a surface layer to provide the structural strength needed to distribute loads to underlying layers of the structural section.

(10) *Depression.* Localized low areas of limited size that may or may not be accompanied by cracking.

(11) *Design Period.* The period of time for which traffic is forecasted.

(12) *Dowel Bar.* A load transfer device in a rigid slab usually consisting of a plain round steel bar.

(13) *Edge Drain System.* A drainage system, consisting of a slotted plastic collector pipe encapsulated in treated permeable material and a filter fabric barrier, with unslotted plastic pipe vents, outlets, and cleanouts, designed to drain the structural section of both rigid and flexible pavements.

(14) *Embankment.* A prism of earth that is constructed from excavated or borrowed natural soil and/or rock, extending from original ground to the grading plane, and designed to provide a stable support for the pavement structural section.

(15) *Equivalent Single Axle Loads (ESAL's).* Summation of equivalent 80 kN single axle loads used to convert mixed traffic to design traffic for the design period.

(16) *Flexible Pavement.* A traffic load carrying system that is made up of one or more layers that are designed to transmit and distribute that loading to the underlying roadbed material. The highest quality layer is the surface course (generally asphalt concrete), which is usually underlaid by a lesser quality base, and in turn a subbase. It is called flexible because it can tolerate deflection bending under heavy loads.

(17) *Grading Plane.* The surface of the basement material upon which the lowest layer of subbase, base, pavement surfacing, or other specified layer is placed.

(18) *Hot Recycling.* The use of reclaimed asphalt concrete pavement which is combined with virgin aggregates, asphalt, and sometimes rejuvenating agents at a central hot-mix plant and placed in the structural section in lieu of all new materials.

(19) *Joint Seals.* Pourable, extrudable, or premolded materials that are placed primarily in transverse and longitudinal joints in or along the edge of concrete pavement to deter the entry of water and incompressible materials (such as sand that is broadcast in freeze-thaw areas to improve skid resistance).

(20) *Lean Concrete Base.* Mixture of aggregate, portland cement, water, and optional admixtures, primarily used as a base for portland cement concrete pavement.

(21) *Longitudinal Joint.* A joint normally placed between traffic lanes in rigid pavements to control longitudinal cracking, and the joint between the traveled way and the shoulder.

(22) *Maintenance.* The preservation of the entire roadway, including pavement surface and structural section, shoulders, roadsides, structures, and such traffic control devices as are necessary for its safe and efficient utilization.

(23) *New Construction.* Constructing a new facility or widening an existing facility on land parcels where there are no existing improvements.

(24) *Open Graded Asphalt Concrete (OGAC).* An open graded mixture of aggregate and a relatively high asphalt content which provides good skid resistance and a high permeability. OGAC is designed to accommodate rapid surface drainage and minimize the potential for hydroplaning while providing an effective seal of the underlying asphalt concrete pavement.

(25) *Overlay.* A layer, usually asphalt concrete, placed on existing asphalt or portland cement concrete pavement to restore ride quality, to increase structural strength (load carrying capacity), and to extend the service life.

(26) *Pavement.* The surface layer of the structural section that carries traffic. Except for special or experimental surface layers, the pavement is either portland cement concrete or asphalt concrete. The asphalt concrete layer may include up to a 30 mm layer of Open Graded Asphalt Concrete (OGAC).

(27) *Pavement Rehabilitation.* Work undertaken to extend the service life of an existing facility. This includes placement of additional surfacing and/or other work necessary to return an existing roadway, including shoulders, to a condition of structural or functional adequacy, for the specified service life. This might include the partial or complete removal and replacement of portions of the pavement structural section.

(28) *Pavement Service Life.* The period of time that a newly constructed or rehabilitated pavement structural section is designed to perform before reaching its terminal serviceability or a condition that requires major rehabilitation or reconstruction; this is also referred to as the performance period.

(29) *Pavement Structure.* See Structural Section.

(30) *Performance Period.* See Pavement Service Life.

(31) *Pumping.* The ejection of base and subgrade material, either wet or dry, through joints or cracks, or along edges of rigid slabs resulting from vertical movements of the slab under traffic. This phenomenon is especially pronounced with saturated structural sections.

(32) *Raveling.* Progressive disintegration of the surface downward on asphalt concrete pavement by dislodged aggregate particles and binder. Stripping usually precedes raveling.

(33) *Reconstruction.* Improvements to an existing facility to meet current design standards and/or to provide increased capacity, safety, efficiency, or significant changes to the horizontal or vertical alignments.

(34) *Resurfacing.* An additional surface layer, or the replacement of the surface layer, placed on an existing pavement to restore its riding quality or to increase its structural (load carrying) strength.

(35) *Rigid Pavement.* Primarily portland cement concrete pavement which distributes the superimposed axle loads over a relatively wide area of underlying structural section layers and soil because of its rigidity and high modulus of elasticity.

(36) *Roadbed.* That area between the intersection of the upper surface of the roadway and the side slopes or curb lines. The roadbed rises in elevation as each increment or layer of subbase, base, or pavement is placed. A divided highway with a median so wide as to include areas of undisturbed land is considered as including two separate roadbeds. See also 62.3(4)(c).

(37) *Routine Maintenance (Traditional)***.** Work, performed either by contract or by State forces, that preserves the ride quality, safety characteristics, functional serviceability, and structural integrity of the structural section.

For flexible pavement, this includes strategies to correct for: low skid resistance, cracking, raveling, corrugations, loss of lateral support, wheel grooving, potholes, settlement, heave or distortion, bridge approach settlement, base failure, drip track erosion, and abrupt vertical surface differential.

For rigid pavements, maintenance includes strategies to correct for: low skid resistance, proper drainage, cracking, shoulder drop-off, slab warp, spalling, slab settlement, heave or distortion, bridge approach settlement, base failure, joint separation, checking, joint sealing, and abrupt vertical surface differential.

(38) *Rutting.* Longitudinal depressions that develop in the wheel paths under traffic. This permanent and sometimes progressive deformation is most often caused by unstable pavement, inadequate strength of the underlying foundation, chains or studded tire abrasion, or raveling.

(39) *R-value.* Resistance value of treated or untreated soil or aggregate as determined by the stabilometer test (California Test Method 301). This is a measure of the supporting strength of the basement soil and subsequent layers used in the design of pavement structural sections.

(40) *Serviceability.* A pavement's ability to serve the traffic which uses the facility. The primary measure of serviceability is the Present Serviceability Index (PSI), which ranges from 0 (impassible road) to 5 (perfect road).

(41) *Settlement.* Localized vertical displacement of the pavement structural section due to slippage or consolidation of the underlying basement soil/material, often resulting in pavement cracking, poor ride quality, and deterioration.

(42) *Stripping.* The loss of the adhesive bond between asphalt cement and aggregate, most often caused by the presence of water in asphalt concrete, which may result in raveling, and the loss of stability and load carrying capacity of the asphalt concrete pavement or treated base.

(43) *Structural Section.* The planned, engineering design of layers of specified materials (normally consisting of subbase, base, and pavement surface) placed over the basement soil to support the traffic loads anticipated to be accumulated and applied during the design period. The structural section is also commonly called the pavement structural section.

(44) *Structural Section Drainage System.* Used with both flexible and rigid pavements, consisting of a treated permeable base layer and a collector system which includes a slotted plastic pipe encapsulated in treated permeable material and a filter fabric barrier with unslotted plastic pipe as vents, outlets and cleanouts to rapidly drain the pavement structural section.

(45) *Subbase.* A layer of aggregate, of designed thickness and specified quality, placed on the basement soil as the foundation for a base.

(46) *Subgrade.* The portion of the roadbed on which the pavement structural section is placed.

(47) *Tie Bars.* Deformed steel bars or connectors used to hold the faces of abutting slabs in contact.

62.8 Traffic

(1) *Annual Average Daily Traffic.* The average 24 hour volume, being the total number during a stated period divided by the number of days in that period. Unless otherwise stated, the period is a year. The term is commonly abbreviated as ADT or AADT.

(2) *Delay.* The time lost while traffic is impeded by some element over which the driver has no control.

(3) *Density.* The number of vehicles per kilometer on the traveled way at a given instant.

(4) *Design Vehicles.* See Topic 404.

(5) *Design Volume.* A volume determined for use in design, representing traffic expected to use the highway. Unless otherwise stated, it is an hourly volume.

(6) *Diverging.* The dividing of a single stream of traffic into separate streams.

(7) *Headway.* The time in seconds between consecutive vehicles moving past a point in a given lane, measured front to front.

(8) *Level of Service.* A rating using qualitative measures that characterize operational conditions within a traffic stream and their perception by motorists and passengers.

(9) *Merging.* The converging of separate streams of traffic into a single stream.

(10) *Running Time.* The time the vehicle is in motion.

(11) *Spacing.* The distance between consecutive vehicles in a given lane, measured front to front.

(12) *Speed.*

(a) Design Speed--A speed selected to establish specific minimum geometric design elements for a particular section of highway.

(b) Running Speed--The speed over a specified section of highway, being the distance divided by running time. The average for all traffic, or component thereof, is the summation of distances divided by the summation of running times.

(13) *Traffic Control Devices.*

(a) Traffic Markings--All lines, words, or symbols, except signs, officially placed within the roadway to regulate, warn, or guide traffic.

(b) Traffic Sign--A device mounted on a fixed or portable support, conveying a message or symbol to regulate, warn, or guide traffic.

(c) Traffic Signal--A power operated traffic control device except signs, barricade warning lights, and steady burning electric lamps, by which traffic is regulated, warned, or alternately directed to take specific actions.

(14) *Volume.* The number of vehicles passing a given point during a specified period of time.

(15) *Weaving.* The crossing of traffic streams moving in the same general direction accomplished by merging and diverging.

(16) *Ramp Metering.* A traffic management strategy which utilizes a system of traffic signals on freeway entrance and connector ramps to regulate the volume of traffic entering a freeway corridor in order to maximize the efficiency of the freeway and thereby minimize the total delay in the transportation corridor.

62.9 Drainage

See Chapter 800 for definition of drainage terms.

CHAPTER 80 APPLICATION OF DESIGN STANDARDS

Topic 81 - Project Development Overview

Index 81.1 - Philosophy

The Project Development process seeks to provide a degree of mobility to users of the transportation system that is in balance with other values. In the development of transportation projects, social, economic, and environmental effects must be considered fully along with technical issues so that final decisions are made in the best overall public interest. Attention should be given to such considerations as:

(a) Need for safe and efficient transportation.

(b) Attainment of community goals and objectives.

(c) Needs of low mobility and disadvantaged groups.

(d) Costs of eliminating or minimizing adverse effects on natural resources, environmental values, public services, aesthetic values, and community and individual integrity.

(e) Planning based on realistic financial estimates.

(f) The cost, ease, and safety of maintaining whatever is built.

Proper consideration of these items requires that a facility be viewed from the perspectives of the user, the nearby community, and larger statewide interests. For the user, efficient travel and safety are paramount concerns. At the same time, the community often is more concerned about local aesthetic, social, and economic impacts. The general population, however, tends to be interested in how successfully a project functions as part of the overall transportation system and how large a share of available capital resources it consumes. Therefore, individual projects must be selected for construction on the basis of overall system benefits as well as community goals, plans, and values.

Decisions must also emphasize different transportation modes working together effectively.

The goal is to increase highway mobility and safety in a manner that is compatible with, or which enhances, adjacent community values and plans.

Topic 82 - Application of Standards

82.1 Highway Design Manual Standards

(1) *General.* The highway design criteria and policies in this manual provide a guide for the engineer to exercise sound judgment in applying standards, consistent with the above Project Development philosophy, in the design of projects.

The design standards used for any project should equal or exceed the minimum given in the Manual to the maximum extent feasible, taking into account costs, traffic volumes, traffic and safety benefits, right of way, socio-economic and environmental impacts, etc. The philosophy provides for use of lower standards when such use best satisfies the concerns of a given situation. Because design standards have evolved over many years, many existing highways do not conform fully with current standards. It is not intended that current manual standards be applied retroactively to all existing State highways; such is neither warranted nor economically feasible. However, when warranted, upgrading of existing roadway features such as guardrail, lighting, superelevation, roadbed width, etc., should be considered, either as independent projects or as part of larger projects. A record of the decision not to upgrade the existing non-standard mandatory features shall be provided through the exception process (See Index 82.2).

This manual does not address temporary construction features. It is recognized that the construction conditions encountered are so diverse and variable that it is not practical to set geometric criteria. Guidance for the treatment of temporary construction zones can be found in Chapter 5 of the Traffic Manual, "Manual of Traffic Control" and the Manual on Uniform Traffic Control Devices (MUTCD).

In this manual design standards are categorized in order of importance in development of a safe State highway system operating at selected levels of service commensurate with projected traffic volumes and highway classification.

(2) *Mandatory Standards*. Mandatory design standards are those considered most essential to achievement of overall design objectives. Many pertain to requirements of law or regulations such as those embodied in the FHWA's 13 controlling criteria (see below). Mandatory standards use the word "shall" and are printed in **Boldface** type (see Table 82.1A).

(3) *Advisory Standards*. Advisory design standards are important also, but allow greater flexibility in application to accommodate design constraints or be compatible with local conditions on resurfacing or rehabilitation projects. Advisory standards use the word "should" and are indicated by Underlining (see Table 82.1B).

(4) *Permissive Standards*. All standards other than mandatory or advisory, whether indicated by the use of "should" or "may", are permissive with no requirement for application intended.

(5) *Controlling Criteria.* The FHWA has designated thirteen controlling criteria for selection of design standards of primary importance for highway safety, listed as follows: design speed, lane width, shoulder width, bridge width, horizontal alignment, vertical alignment, grade, stopping sight distance, cross slope, superelevation, horizontal clearance, vertical clearance and bridge structural capacity. All but the last of these criteria are also designated as geometric criteria.

The design standards related to the 12 geometric criteria are designated as mandatory standards in this manual (see Index 82.1(2) and Table 82.1A).

(6) *Other*. In addition to the design standards in this manual, the Traffic Manual contains standards relating to clearzone, signs, delineation, barrier systems, signals, and lighting.

Caution must be exercised when using other Caltrans publications which provide guidelines for the design of highway facilities, such as HOV lanes. These publications do not contain design standards; moreover, the designs suggested in these publications do not always meet Highway Design Manual Standards. Therefore, all other Caltrans publications must be used in conjunction with this manual.

82.2 Approvals for Nonstandard Design

(1) *Mandatory Standards*. **To promote uniform practice on a statewide basis, design features or elements which deviate from the mandatory standards indicated herein shall require the approval of the Chief, Division of Design. This approval authority has been delegated to the Design Coordinators, except the mandatory standards in Chapter 600, which have been delegated to the Chief, Office of Pavement Design, and may involve coordination with the Design Coordinator**.

The current procedures and documentation requirements pertaining to the approval process for exceptions to mandatory design standards are contained in Chapter 21 of the Project Development Procedures Manual (PDPM).

Design exception approval must be obtained prior to District approval of the PSR, or any project initiation document (i.e., PSSR, PEER, combined PSR/PR), other than the PSR-PDS. The text of the project initiation report must include a brief description of the nonstandard features, as well as a reference to all approved Fact Sheets and their approval dates by the Division of Design and/or FHWA (when applicable).

If the need for a design exception is identified after approval of the project's initiation document, the above described consultation and documentation process shall be initiated immediately, and must be completed prior to approval of the next project development report. The text of the project development report (i.e., Draft Project Report, Project Report, Supplemental PR, PAR, etc.) must include the design exception reference normally provided in the project initiation report (see above).

During the construction phase of a project, Fact Sheets must be prepared (by Project Development staff) to document any nonstandard features proposed in a Contract Change Order. Such Change Orders shall not be executed until the proposed design exception has been approved (at least verbally) by the appropriate Caltrans and FHWA (if required) authority (ies). If verbal approval is granted to expedite Change Order execution, the Fact Sheet must be completed and approved immediately thereafter.

The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) allows significant delegation to the states by FHWA to approve and administer portions of the Federal-Aid Transportation Program. California has accepted the maximum delegations offered as outlined in the May 27, 1992 memorandum signed by W.P. Smith. If required, FHWA approval of exceptions to mandatory design standards related to the 13 controlling criteria should be sought as early in the project development process as possible. However, formal approval shall not be requested until the appropriate Project Development Coordinator has approved the design exception.

FHWA approval is not required for exceptions to "Caltrans-only" mandatory standards. Table 82.1A identifies these mandatory standards.

For local facilities crossing the State right of way see Index 308.1.

(2) *Advisory Standards*. The authority to approve exceptions to advisory standards has been delegated to the District Directors. Proposals for exceptions from advisory standards should be discussed with the Project Development Coordinators during development of the approval documentation. The responsibility for the establishment of procedures for review, documentation, and long term retention of approved exceptions from advisory standards has also been delegated to the District Directors.

82.3 Use of FHWA and AASHTO Standards and Policies

The standards in this manual generally conform to the standards and policies set forth in the AASHTO publications, "A Policy on Geometric Design of Highways and Streets" (2001) and "A Policy on Design Standards-Interstate System" (1988). A third AASHTO publication, "Roadside Design Guide" (2002), focuses on creating safer roadsides. These three documents, along with other AASHTO and FHWA publications cited in 23 CFR Ch 1, Part 625, Appendix A, contain most of the current AASHTO policies and standards, and are approved references to be used in conjunction with this manual.

AASHTO policies and standards, which are established as nationwide standards, do not always satisfy California conditions. When standards differ, the instructions in this manual govern, except when necessary for FHWA project approval (Index 108.3, Coordination with the FHWA).

82.4 Mandatory Procedural Requirements

Required procedures and policies for which Caltrans is responsible, relating to project clearances, permits, licenses, required tests, documentation, value engineering, etc., are indicated by use of the word "must". Procedures and actions to be performed by others (subject to notification by Caltrans), or statements of fact are indicated by the word "will".

82.5 Effective Date for Implementing Revisions to Design Standards

Revisions to design standards will be issued with a stated effective date. It is understood that all projects will be designed to current standards unless an exception has been approved in accordance with Index 82.2.

On projects where the project development process has started, the following conditions on the effective date of the new or revised standards will be applied:

- For all projects where the PS&E has not been finalized, the new or revised design standards shall be incorporated unless this would impose a significant delay in the project schedule or a significant increase in the project engineering or construction costs. The Project Development Coordinator will make the final determination on whether to apply the new or previous design standards on a project-by-project basis for roadway features.
- For all projects where the PS&E has been submitted to Headquarters Office Engineer for advertising or the project is under construction, the new or revised standards will be incorporated only if they are identified in the Change Transmittal as requiring special implementation.

For locally-sponsored projects, the Oversight Engineer shall inform the funding sponsor within 15 working days of the effective date of any changes in mandatory or advisory design standards as defined in Index 82.2.

Table 82.1A
Mandatory Standards

CHAPTER 80		**APPLICATION OF DESIGN STANDARDS**
Topic 82		Application of Standards
	Index 82.2	Approvals for Nonstandard Design
CHAPTER 100		**BASIC DESIGN POLICIES**
Topic 101		**Design Speed**
	Index 101.1	Technical Reductions of Design Speed
	101.1	Selection of Design Speed - Local Facilities
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	101.2	Design Speed Standards
Topic 104		**Control of Access**
	Index 104.4	Protection of Access Rights*
CHAPTER 200		**GEOMETRIC DESIGN AND STRUCTURE STANDARDS**
Topic 201		**Sight Distance**
	Index 201.1	Sight Distance Standards
Topic 202		**Superelevation**
	Index 202.2	Standards for Superelevation
	202.7	Superelevation on City Streets and County Roads
Topic 203		**Horizontal Alignment**
	Index 203.1	Horizontal Alignment - Local Facilities
	203.1	Horizontal Alignment and Stopping Sight Distance
	203.2	Standards for Curvature
Topic 204		**Grade**
	Index 204.1	Standards for Grade - Local Facilities
	204.3	Standards for Grade
	204.8	Vertical Falsework Clearances*
Topic 205		**Road Connections and Driveways**
	Index 205.1	Sight Distance Requirements for Access Openings on Expressways
Topic 208		**Bridges and Grade Separation Structures**
	Index 208.1	Bridge Width
	208.10	Bridge Approach Railings*
CHAPTER 300		**GEOMETRIC CROSS SECTION**
Topic 301		**Pavement Standards**
	Index 301.1	Lane Width
	301.2	Cross Slopes
	301.2	Algebraic Differences in Cross Slopes
Topic 302		**Shoulder Standards**
	Index 302.1	Shoulder Width
	302.2	Shoulder Cross Slopes
Topic 305		**Median Standards**
	Index 305.1	Median Width*
Topic 307		**Cross Sections for State Highways**
	Index 307.2	Shoulder Width for Structural Section Support on Two-lane Cross Sections for New Construction
	307.2	Shoulder Standards for Two-lane Cross Sections for New Construction
Topic 308		**Cross Sections for Roads Under Other Jurisdictions**
	Index 308.1	Cross Section Standards for City Streets and County Roads without Connection to State Facilities
	308.1	Minimum Width of 2-lane Structures for City Streets and County Roads without Connection to State Facilities

* Caltrans-only Mandatory Standard

Table 82.1A
Mandatory Standards (Cont.)

	308.1	Cross Section Standards for City Streets and County Roads with Connection to State Facilities
	308.1	Minimum Width of 2-lane Structures for City Streets and County Roads with Connection to State Facilities
Topic 309		**Clearances**
Index	309.1	Horizontal Clearances and Stopping Sight Distance
	309.1	Clear Recovery Zone
	309.2	Vertical Clearances - Major Structures
	309.2	Vertical Clearances - Minor Structures
	309.2	Rural and Single Interstate Routing System
	309.3	Horizontal Tunnel Clearances
	309.3	Vertical Tunnel Clearances
	309.4	Lateral Clearance for Elevated Structures*
	309.5	Structures Across or Adjacent to Railroads - Vertical Clearance
Topic 310		**Frontage Roads**
Index	310.1	Frontage Road Width*
CHAPTER 400		**INTERSECTIONS AT GRADE**
Topic 405		**Intersection Design Standards**
Index	405.1	Driver Set Back
	405.1	Sight Distance at Public Road Intersections
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	405.2	Left-turn Channelization - Lane Width
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CHAPTER 500		**TRAFFIC INTERCHANGES**
Topic 501		**General**
Index	501.3	Interchange Spacing
Topic 504		**Interchange Design Standards**
Index	504.2	Location of Freeway Entrances & Exits
	504.2	Ramp Deceleration Lane and "DL" Distance
	504.3	Ramp Lane Width
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	504.3	Ramp Metering Design Features
	504.3	Lane Drop Taper
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	504.3	Distance Between Ramp Intersection and Local Road Intersection
	504.4	Freeway-to-freeway Connections - Shoulder Width
	504.8	Access Control along Ramps
	504.8	Access Control at Ramp Terminal
	504.8	Access Rights Required Opposite Ramp Terminals
CHAPTER 600		**PAVEMENT STRUCTURAL SECTION**
Topic 602		**Pavement Service Life and Traffic Data**
Index	602.2	Pavement Service Life for CAP-M*
Index	602.2	Pavement Service Life for Pavement Rehabilitation*
Index	602.2	Project Resurfacing Requirements*

* Caltrans-only Mandatory Standard

Table 82.1A
Mandatory Standards (Cont.)

	Index 602.2	Pavement Service Life for New Construction & Reconstruction*
	Index 602.2	Pavement Service Life for Widening*
Topic 603		**Portland Cement Concrete Pavement Structural Section Design**
	Index 603.2	Doweling and Tying Concrete Pavement*
	Index 603.4	Shoulder Structural Section Requirements*
CHAPTER 700		**MISCELLANEOUS STANDARDS**
Topic 701		**Fences**
	Index 701.2	Fences on Freeways and Expressways*
CHAPTER 900		**LANDSCAPE ARCHITECTURE**
Topic 903		**Safety Roadside Rest Area Design Standards**
	Index 903.5	Rest Area Ramp Design
Topic 904		**Vista Point Standards and Guidelines**
	Index 904.3	Vista Point Ramp Design
CHAPTER 1000		**BIKEWAY PLANNING AND DESIGN**
Topic 1002		**General Planning Criteria**
	Index 1002.1	Resurfacing Requirements*
	1002.1	Shoulder Requirements when Adding Lanes*
Topic 1003		**Design Criteria**
	Index 1003.1	Class I Bikeway Widths*
	1003.1	Class I Bikeway Horizontal Clearance*
	1003.1	Class I Bikeway Structure Width*
	1003.1	Class I Bikeway Vertical Clearance*
	1003.1	Physical Barriers Adjacent to Class I Bikeways
	1003.1	Class I Bikeway in Medians*
	1003.1	Class I Bikeway Design Speeds*
	1003.1	No Speed Bumps on Class I Bikeways*
	1003.2	Class II Bikeway Design*
	1003.2	Class II Bikeway Widths Adjacent to Parking Stalls*
	1003.2	Class II Bikeways Adjacent to Parking*
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	1003.2	Class II Bikeways Adjacent to Part-time Parking*
	1003.2	Class II Bikeways Widths in Undeveloped Areas*
	1003.2	Class II Bikeways Delineation*
	1003.2	Class II Bikeways Through Interchange*
	1003.3	Class III Bikeways Through Interchange*
	1003.6	Bicycles Traveling against Traffic*
	1003.6	Bikeway Overcrossing Structures*
	1003.6	Drainage Inlet Grates on Bikeways*
Topic 1004		**Uniform Signs, Markings and Traffic Control Devices**
	Index 1004.1	Uniform Signs, Markings and Traffic Control Devices*
	1004.3	Class II Bikeway Signing*
	1004.3	Class II Bikeway Pavement Markings*
	1004.3	Class II Bikeway Pavement Markers*

* Caltrans-only Mandatory Standard

Table 82.1A
Mandatory Standards (Cont.)

CHAPTER 1100	**HIGHWAY TRAFFIC NOISE ABATEMENT**
Topic 1102	**Design Criteria**
Index 1102.2	Horizontal Clearance to Noise Barrier
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Table 82.1B
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CHAPTER 100		**BASIC DESIGN POLICIES**
Topic 101		**Design Speed**
Index	101.1	Selection of Design Speed - Local Facilities
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Topic 104		**Control of Access**
Index	104.5	Relation of Access Opening to Median Opening
Topic 105		**Pedestrian Facilities**
Index	105.1	Minimum Sidewalk Width
	105.4	New Construction, Two Ramp Design
Topic 107		**Roadside Installations**
Index	107.1	Standards for Roadway Connections
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CHAPTER 200		**GEOMETRIC DESIGN AND STRUCTURE STANDARDS**
Topic 201		**Sight Distance**
Index	201.3	Stopping Sight Distance on Grades
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Topic 202		**Superelevation**
Index	202.2	Superelevation on Same Plane for Rural Two-lane Roads
	202.5	Superelevation Transition
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	202.5	Superelevation in Restrictive Situations
	202.6	Superelevation of Compound Curves
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Topic 203		**Horizontal Alignment**
Index	203.1	Horizontal Alignment - Local Facilities
	203.3	Alignment Consistency and Design Speed
	203.5	Compound Curves
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Topic 204		**Grade**
Index	204.1	Standards for Grade - Local Facilities
	204.3	Standards for Grade
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	204.5	Decision Sight Distance at Climbing Lane Drops
	204.6	Design Speeds for Horizontal and Vertical Curves
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Topic 206		**Pavement Transitions**
Index	206.3	Lane Drop Transitions
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Topic 208		**Bridges and Grade Separation Structures**
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	208.6	Minimum Width of Pedestrian Overcrossings
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Topic 210		**Earth Retaining Systems**
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Table 82.1B
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Topic 301 **Pavement Standards**

Index 301.2 Algebraic Differences of Cross Slopes

Topic 303 **Curbs, Dikes, and Side Gutters**

Index 303.1 Use of Curb with Operating Speeds of 75 km/h and Greater

303.1 Selection of Curb Type

303.3 Selection of Dike Type

Topic 304 **Side Slopes**

Index 304.1 Side Slopes 1:4 or Flatter

304.1 5.5 m Minimum Catch Distance

Topic 305 **Median Standards**

Index 305.1 Median Width

305.2 Median Cross Slopes

Topic 308 **Cross Sections for Roads Under Other Jurisdictions**

Index 308.1 Cross Section Standards for City Streets and County Roads without Connection to State Facilities

308.1 Minimum Shoulder Width Requirements for Bicycles

Topic 309 **Clearances**

Index 309.1 Clear Recovery Zone

309.1 Safety Shaped Barriers at Retaining, Pier, or Abutment Walls

309.5 Structures Across or Adjacent to Railroads - Vertical Clearance

Topic 310 **Frontage Roads**

Index 310.2 Outer Separation - Urban Areas

310.2 Outer Separation - Rural Areas

CHAPTER 400 INTERSECTIONS AT GRADE

Topic 403 **Principles of Channelization**

Index 403.3 Angle of Intersection

Topic 404 **Design Vehicles**

Index 404.3 STAA Truck-turn Template

404.3 California Truck-turn Template

Topic 405 **Intersection Design Standards**

Index 405.1 Corner Sight Distance at Public Road Intersections

405.1 Decision Sight Distance at Intersections

405.5 Emergency Openings and Sight Distance

405.5 Median Opening Locations

CHAPTER 500 TRAFFIC INTERCHANGES

Topic 502 **Interchange Types**

Index 502.2 Isolated Ramps and Partial Interchanges

Topic 504 **Interchange Design Standards**

Index 504.2 Freeway Entrance and Exit Design

504.2 Collector-distributor Deceleration Lane and "DL" Distance

504.2 Paved Width at Gore

504.2 Auxiliary Lanes

504.2 Freeway Exit Design Speed

504.2 Decision Sight Distance at Exits

504.2 Design Speed and Alignment Consistency at Inlet Nose

504.2 Freeway Ramp Grades

504.2 Differences in Pavement Cross Slopes at Freeway Entrances and Exits

504.2 Vertical Curves at Freeway Exits

504.2 Crest Vertical Curves at Freeway Exit Terminal

Table 82.1B
Advisory Standards (Cont.)

504.2	Sag Vertical Curves at Freeway Exit Terminal
504.2	Ascending Entrance Ramps with Sustained Upgrades
504.3	Ramp Design Speed
504.3	Ramp Lane Drop Taper
504.3	Ramp Lane Drops and Auxiliary Lanes
504.3	Metered Single-Lane Entrance Ramps Auxiliary Lane
504.3	Metered Multi-Lane Entrance Ramps Auxiliary Lane
504.3	Ramp Terminals and Grade
504.3	Ramp Terminals and Sight Distance
504.3	Free Right Turns at Ramp Terminals
504.3	Distance between Ramp Intersection and Local Road Intersection
504.3	Entrance Ramp Lane Drop
504.3	Single-Lane Ramp Widening for Passing
504.3	Two-lane Exit Ramps
504.3	Two-lane Exit Ramps and Auxiliary Lanes
504.3	Distance Between Successive On-ramps
504.3	Distance Between Sucessive Exits
504.4	Freeway-to-freeway Connections Design Speed
504.4	Profile Grades on Freeway-to-freeway Connectors
504.4	Single-lane Connector Design
504.4	Single-lane Connector Widening for Passing
504.4	Volumes Requiring Branch Connectors
504.4	Merging Branch Connector Design
504.4	Diverging Branch Connector Design
504.4	Merging Branch Connector Auxiliary Lanes
504.4	Diverging Branch Connector Auxiliary Lanes
504.4	Freeway-to-freeway Connector Lane Drop Tapers
504.5	Auxiliary Lanes
504.6	Mainline Lane Reduction at Interchanges
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Topic 602	**Pavement Service Life and Traffic Data**
Index 602.2	Pavement Service Life for Temporary Pavements and Detours
CHAPTER 700	**MISCELLANEOUS STANDARDS**
Topic 701	**Fences**
Index 701.2	Fences on Freeways and Expressways
CHAPTER 900	**LANDSCAPE ARCHITECTURE**
Topic 902	**Planting design standards**
Index 902.2	Sight Distance and Safety Requirements for Planting
902.2	Clear Recovery Zone and Trees
902.2	Minimum Setback of Trees
Topic 904	**Vista Point Design Standards**
Index 904.3	Vista Point Connection Design

Traffic volumes can be adjusted for the effect of grades and the mix of autos, trucks, and recreational vehicles if a more refined calculation is desired. In those cases, consult the "Highway Capacity Manual", (see reference below).

102.2 References

More detailed data on design capacity are available in the "Highway Capacity Manual", published by the Transportation Research Board.

Topic 103 - Design Designation

103.1 Relation to Design

The design designation is a simple, concise expression of the basic factors controlling the design of a given highway. Following is an example of this expression:

ADT (2000) = 9800 D = 60%

ADT (2020) = 20 000 T = 12%

DHV = 3000 V = 110 km/h

The notation above is explained as follows:

ADT (2000) -- The average daily traffic, in number of vehicles, for the construction year.

ADT (2020) -- The average daily traffic for the future year used as a target in design.

DHV -- The two-way design hourly volume, vehicles.

D -- The percentage of the DHV in the direction of heavier flow.

T -- The character of the traffic. This is expressed by the truck increment (T) as a percent of the DHV (excluding recreational vehicles).

V -- Design speed in km/h.

Within a project, one design designation should be used except when:

(a) The design hourly traffic warrants a change in the number of lanes, or

(b) A decided change in topography dictates a change in design speed.

The design designation should be stated in Project Intiation Documents and Project Reports and should appear on the typical cross section for all new highway construction projects.

103.2 Design Period

Geometric design of new facilities should normally be based on estimated traffic 20 years after completion of construction. With justification, design periods other than 20 years may be approved by the District Director with concurrence by the Headquarters Project Development Coordinator.

Safety, Resurfacing, Restoration, and Rehabilitation (RRR), and operational improvement projects should be designed on the basis of current ADT.

Complimentary to the design period, various components of a project (e.g., drainage facilities, structures, pavement structural section, etc.) have a service life that may differ from the design period. For pavement service life requirements, see Index 602.2.

Topic 104 - Control of Access

104.1 General Policy

Control of access is achieved by acquiring rights of access to the highway from abutting property owners and by permitting ingress and egress only at locations determined by the State.

On freeways, direct access from private property to the highway is prohibited without exception. Abutting ownerships are served by frontage roads or streets connected to interchanges.

104.2 Access Openings

See Index 205.1 for the definition and criteria for location of access openings. The number of access openings on highways with access control should be held to a minimum. (Private property access openings on freeways are not allowed.) Parcels which have access to another public road or street as well as frontage on the expressway are not allowed access to the expressway. In some instances, parcels fronting only on the expressway may be given access to another public road or street by constructing suitable connections if such access can be provided at reasonable cost.

With the exception of extensive highway frontages, access openings to an expressway are limited to one opening per parcel. Wherever possible, one opening should serve two or more parcels. In the case of a large highway frontage under one ownership, the cost of limiting access to one opening may be prohibitive, or the property may be divided by a natural barrier such as a stream or ridge, making it necessary to provide an additional opening. In the latter case, it may be preferable to connect the physically separated portions with a low-cost structure or road rather than permit two openings.

104.3 Frontage Roads

(1) General Policy.

(a) Purpose--Frontage roads are provided on freeways and expressways:

- To control access to the through lanes, thus increasing safety for traffic.
- To provide access to abutting land ownerships.
- Restore continuity of the local street or road systems.
- Provide for nonmotorized traffic that might otherwise desire to use the freeway.
- Provide continuity even though it did not exist before when unreasonable circuity of travel would be incurred due to freeway construction without a frontage road.

(b) Economic Considerations--In general, a frontage road is justified on freeways and expressways if the costs of constructing the frontage road are less than the costs of providing access by other means. Right of way considerations often are a determining factor. Thus, a frontage road would be justified if the investment in construction and extra right of way is less than either the severance damages or the costs of acquiring the affected property in its entirety. Frontage roads may be required to connect parts of a severed property or to serve a landlocked parcel resulting from right of way acquisition.

(c) Access Openings--Direct access to the through lanes is allowable on expressways. When the number of access openings on one side of the expressway exceeds three in 500 m, a frontage road should be provided (see Index 104.2).

(2) New Alignment. Frontage roads generally are not provided on freeways or expressways on new alignment since the abutting property owners never had legal right of access to the new facility. They may be provided, however, on the basis of considerations mentioned in (1) above.

(3) Existing Alignment. Where a freeway or expressway is developed parallel to an existing highway or local street, all or part of the existing roadway often is retained as a frontage road. In such cases, if access to remainders of land on the side of the freeway or expressway right of way opposite the old road cannot be provided by other means, a frontage road must be constructed to serve the landlocked remainders or the remainders must be purchased outright. The decision whether to provide access or purchase should be based on considerations of cost, right of way impacts, street system continuity and similar factors (see (1) above).

(4) Railroad Crossings. Frontage roads on one or both sides of a freeway or expressway on new alignment, owing to safety and cost considerations, frequently are terminated at the railroad right of way.

Any new railroad grade crossings and grade separations, and any relocations or alterations of existing crossings must be cleared with the railroad and approved by the PUC.

(5) Frontage Roads Financed by Others. Frontage roads which are not a State responsibility under this policy may be built by the State upon request of a local political subdivision, a private agency, or an individual. Such a project must be covered by an agreement under which the State is

105.4 Guidelines for the Location and Design of Curb Ramps

(1) *Policy.* On all State highway projects adequate and reasonable access for the safe and convenient movement of physically disabled persons are to be provided across curbs that are constructed or replaced at pedestrian crosswalks. (This includes all marked and unmarked crosswalks, as defined in Section 275 of the Vehicle Code.)

Access should also be provided at bridge sidewalk approaches and at curbs in the vicinity of pedestrian separation structures.

Where a need is identified at an existing curb on a conventional highway, a curb ramp may be constructed either by others under encroachment permit or by the State.

(2) *Location Guidelines.* When locating curb ramps, designers must consider the position of utilities such as power poles, fire hydrants, street lights, traffic signals, and drainage facilities.

On new construction, two ramps should be installed at each corner as shown on the Standard Plans. For retrofit construction, one ramp at the center of the curb return is acceptable, but not desirable. The usage of the one-ramp design should be restricted to those locations where the volume of pedestrians and vehicles making right turns is low. This will reduce the potential frequency of conflicts between turning vehicles and disabled persons entering the common crosswalk area to cross either street.

Ramps and/or curb openings should be provided at midblock crosswalks and where pedestrians cross curbed channelization or median islands at intersections. Often, on traffic signalization, channelization, and similar projects, curbs are proposed to be modified only on portions of an existing intersection. In those cases, consideration should be given to installing retrofit curb ramps on all legs of the intersection.

(3) *Ramp Design.* Curb ramp designs should conform to current Standard Plans. See Index 105.3(3) for review procedures.

Topic 106 - Stage Construction and Utilization of Local Roads

106.1 Stage Construction

(1) *Cost Control Measures.* When funds are limited and costs increase, estimated project costs often exceed the amounts available in spite of the best efforts of the engineering staff. At such times the advantages of reducing initial project costs by some form of staged construction should be considered as an alternative to deferring the entire project. Stage construction may include one or more of the following:

(a) Shorten the proposed improvement, or divide it into segments for construction in successive years;

(b) Reduce number of lanes for initial construction. For example, a 4-lane freeway in a rural area with low current traffic volumes might be staged for two lanes initially with capacity adequate for at least 10 years after construction. Similarly, a freeway might be constructed initially four or six lanes wide with provision for future widening in the median to meet future traffic needs.

(c) Save on pavement design. For AC pavement this most often would be done by reducing the surface course thickness with provision for a future overlay to bring the pavement to full design depth.

(d) Downscope geometric design features. This last expedient should be considered only as a last resort; geometric features such as alignment, grade, sight distance, weaving, or merging distance, are difficult and expensive to change once constructed.

A choice among cost reducing alternatives should be made only after weighing the benefits and disadvantages of each, particularly as they apply to interchange designs, which have a substantial effect on cost. See Index 502.3(2) for design considerations regarding freeway interchanges.

106.2 Utilization of Local Roads

In the construction of freeways or other highways by stages or construction units, it frequently becomes necessary to use portions of the local road system at one or more stages prior to completion of the whole route. Usually the local road is used as a traversable connection between the newly completed segment and the existing State highway.

Where such use of a local road is required, it may be handled by:

(a) Temporarily adopting the local road system as a traversable State highway, or

(b) Designating the local road system as a detour until the next or final stage is constructed.

(1) *Temporary Adoption of Local Roads as State Routes.* Temporary adoption of a local road system as a traversable route requires CTC action. Temporary adoption should be used where, for example, one unit of the freeway construction has been completed and the District wishes to route traffic over the new roadway without waiting for completion of the next succeeding units, and the use of local roads is necessary to connect the freeway with the old State highway. Temporary adoption is useful where construction of the next freeway unit is a number of years in the future.

Such a temporary CTC adoption makes it legally possible to relinquish the old highway portion superseded by relocation.

Normally, the Department will finance any needed improvement required to handle traffic during the period the local road system is a traversable State route. Financing by the local agency is not required. However, adoption of the local road by the CTC must precede State financing and construction of the proposed improvements.

When a local facility is adopted as a traversable route, the Department is responsible for all maintenance costs of the local facility unless otherwise provided for under the terms of a cooperative agreement. The Department normally would not assume maintenance until the road is in use as a connection or, when necessary, until the award of an improvement contract.

Formal concurrence of the local agency must be obtained before an adoption action is presented to the CTC.

If the local agency wants more improvements than are needed to accommodate traffic during the period when the local road is used as a State highway connection, betterments are to be financed by the local agency. In such cases a cooperative agreement would be necessary to define the responsibilities of each party for construction and maintenance.

(2) *Local Roads Used as Detours.* In lieu of temporary adoption by the CTC, a local road may be designated a detour to serve as a connection between the end of State highway construction and the old State highway following completion of a State highway construction unit and pending completion of the next unit. Local road detours are useful if the adjoining construction unit is scheduled in a few years or less and the local road connection is short and direct. Adoption by the CTC is not required when a local road is designated as a temporary detour.

Under Section 93 of the Streets and Highways Code, the Department can finance any needed improvements required to handle detour traffic during the period the local road is used to provide continuity for State highway traffic. A cooperative agreement is usually required to establish terms of financing, construction, maintenance, and liability. If the local agency wants more than the minimum work needed to accommodate traffic on the local road during its use as a State highway, such betterments are to be financed by the local agency.

temporary traffic control plans. However, safety of the public and the workers as well as public convenience demand that designers give careful consideration to the plans for handling traffic even though a different plan may be followed ultimately. It is simpler from a contract administration standpoint to change a plan than to add one where none existed. The special provisions should specify that the contractor may develop alternate traffic control plans if they are as good or better than those provided in the contract PS&E.

See Section 2-30, Traffic, of the Construction Manual for additional factors to be considered in the preparation of traffic control plans.

110.8 Safety Reviews

Formal safety reviews during planning, design and construction have demonstrated that safety-oriented critiques of project plans help to ensure the application of safety standards. An independent team that was not absorbed in the design details of the project is generally able to conduct reviews from a fresh perspective. In many cases, this process leads to highly cost-effective modifications that enhance safety for motorists and highway workers without any material changes in the scope of the project.

(1) *Policy.* During the planning stage all projects shall be reviewed by the District Safety Review Committee prior to approval of the appropriate project initiation document (PSR, PSSR, NBSSR, etc.).

During design, each project with an estimated cost of $750,000 or more must be reviewed by the District Safety Review Committee.

Any project, regardless of cost, requiring a Traffic Control Plan must be reviewed by the District Safety Review Committee. During construction, the detection of the need for safety-related changes is the responsibility of construction personnel, as outlined in the Construction Manual.

Safety concepts that are identified during these safety reviews which directly limit the exposure of employees to traffic shall be incorporated into the project unless deletion is approved by the District Director.

(2) *Procedure.* Each District must have a Safety Review Committee, composed of at least one engineer from the Construction, Design, Maintenance, and Traffic functions and should designate one of the members as chairperson. Committee members should familiarize themselves with current standards and instructions on highway safety so that they can identify items in need of correction.

The Committee should conduct at least two design safety reviews of each major project. The Design Project Engineer has the basic responsibility to notify the committee chairperson when a review is needed. The chairperson should schedule a review and coordinate participation by appropriate committee members.

Reviews should include considerations of such items as:

- Exposure of employees to traffic.
- Traffic control plans.
- Transportation Management Plans.
- Traversability of roadsides.
- Elimination or other appropriate treatment of fixed objects.
- Susceptibility to wrong-way moves.
- Safety of construction and maintenance personnel.
- Sight distance.
- Nonmotorized traffic.
- Guardrail.
- Superelevation, etc.
- Roadside management and maintenance reduction.
- Access to facilities from off of the freeway.
- Maintenance vehicle pull-out locations.

The objective is to identify all elements where safety improvement may be practical and indicate desirable corrective measures. Reviews should be scheduled when the report or plans are far enough along for a review to be fruitful, but early enough to avoid unnecessary delay in the approval of the report or the completion of PS&E.

A simple report should be prepared on the recommendations made by the Safety Committee and the response by the Design Project Engineer. The reports should be included in the project files.

110.9 Value Analysis

The use of Value Analysis techniques should begin early in the project development process and be applied at various milestones throughout the PS&E stage to reduce life-cycle costs. See the Project Development Procedures Manual for additional information.

110.10 Proprietary Items

Although the use of new materials, methods, or products may involve specifying a patented or brand name method, material, or product, use of such proprietary items is discouraged in the interest of promoting competitive bidding. If three or more products or materials are called out for one contract item, they are not considered proprietary.

The use of proprietary items always requires the approval of the Federal Highway Administration (FHWA) Division Office if Federal-aid funds are involved in the project.

Use of proprietary materials can be approved for Caltrans by the DES Deputy Division Chief, Structure Design for those facilities designed by the Division of Structures. Use in District designed facilities can be approved by the District Director or the Deputy District Director, Design if such approval authority has been specifically delegated by the District Director. Copies of all correspondence documenting consideration and approvals of the use of proprietary items must be forwarded to the Division of Design in headquarters, to monitor conformance to this policy.

Caltrans policy and guidelines on the use of proprietary items are covered in the Office Engineer's Plans, Specifications and Estimate (PS&E) Guide under "Trade Names." This policy is based on Public Contract Code, Division 2, Chapter 3, Article 5, Paragraph 3400. It is also virtually coincident with FHWA policy requirements. The use of proprietary materials, methods, or products will not be approved unless:

(a) There is no other known material of equal or better quality that will perform the same function, or

(b) There are overwhelming reasons for using the material or product in the public's interest, which may or may not include cost savings, or

(c) It is essential for synchronization with existing highway or adjoining facilities, or

(d) Such use is on an experimental basis, with a clearly written plan for "follow-up and evaluation."

See Index 601.5(3) for further details.

110.11 Conservation of Materials and Energy

Paving materials such as cement, asphalt, and rock products are becoming more scarce and expensive, and the production processes for these materials consume considerable energy. Increasing evidence of the limitation of nonrenewable resources and increasing worldwide consumption of most of these resources require optimal utilization and careful consideration of alternates such as the substitution of more plentiful or renewable resources and the recycling of existing materials.

(1) PCC Pavement. The crushing and reuse of old PCC pavement as aggregate in new PCC or AC pavement does not now appear to be a cost-effective alternate, primarily because of the availability of good mineral aggregate in most areas of California. However, if this is a feasible option, because of unique project conditions or the potential lack of readily available materials, it may be included in a cost comparison of alternate solutions.

(2) *AC Pavement.* Recycling of existing AC must be considered, in all cases, as an alternative to placing 100% new asphalt concrete. This is discussed in more detail in the "Flexible Pavement Rehabilitation Manual," accessible at the Pavement website: http://www.dot.ca.gov/hq/oppd/pavement/guidance.htm.

(3) *Use of Asphalt Concrete Grindings, Chunks and Pieces.* When constructing transportation facilities, Caltrans frequently uses asphalt in mixed or combined materials such as asphalt concrete (AC) pavement. Caltrans also uses recycled AC grindings and chunks. There is a potential for these materials to reach the waters of the State through erosion or inappropriate placement during construction. Section 5650 of the Fish and Game Code states that it is unlawful to deposit asphalt, other petroleum products, or any material deleterious to fish, plant life, or bird life where they can pass into the waters of the State. In addition, Section 1601 of the Fish and Game Code requires notification to the California Department of Fish and Game (DFG) prior to construction of a project that will result in the disposal or deposition of debris, waste, or other material containing crumbled, flaked, or ground pavement where it can pass into any river, stream, or lake designated by the DFG.

The first step is to determine whether there are waters of the State in proximity to the project that could be affected by the reuse of AC. Waters of the State include: (1) perennial rivers, streams, or lakes that flow or contain water continuously for all or most of the year; or (2) intermittent lakes that contain water from time to time or intermittent rivers or streams that flow from time to time, stopping and starting at intervals, and may disappear and reappear. Ephemeral streams, which are generally exempt under provisions developed by Caltrans and DFG, are those that flow only in direct response to rainfall.

The reuse of AC pavement grindings will normally be consistent with the Fish and Game Code and not require a 1601 Agreement when these materials are placed where they cannot enter the waters of the State. However, there are no set rules as to distances and circumstances applicable to the placement of asphaltic materials adjacent to waters of the State. Placement decisions must be made on case-by-case basis, so that such materials will be placed far enough away from the Waters of the State to prevent weather (erosion) or maintenance operations from dislodging the material into State waters. Site-specific factors (i.e., steep slopes) should be given special care. Generally, when AC pavement grindings are being considered for placement where there is a potential for this material to enter a water body, DFG should be notified to assist in determining whether a 1601 Agreement is appropriate. DFG may require mitigation strategies to prevent the materials from entering the Waters of the State. When in doubt, it is recommended that the DFG be notified.

If there is the potential for reused AC materials to reach Waters of the State through erosion or other means during construction, such work would normally require a 1601 Agreement. Depending on the circumstances, the following mitigation measures should be taken to prevent AC grindings from entering water bodies:

- The reuse of AC pavement grindings as fill material and shoulder backing must conform to the Caltrans Standard Specifications, applicable manuals of instruction, contract provisions, and the MOU described below.
- AC chunks and pieces in embankment must be placed above the water table and covered by at least one foot of material.

A Memorandum of Understanding (MOU) dated January 12, 1993, outlines the interim agreement between the DFG and Caltrans regarding the use of asphaltic materials. This MOU provides a working agreement to facilitate Caltrans' continued use of asphaltic materials and avoid potential conflicts with the Fish and Game Code by describing conditions where use of asphalt road construction material by Caltrans would not conflict with the Fish and Game Code.

Specific Understandings contained in the MOU are:

- Asphalt Use in Embankments

  Caltrans may use AC chunks and pieces in embankments when these materials are placed where they will not enter the Waters of the State.

- Use of AC Pavement Grindings as Shoulder Backing

  Caltrans may use AC pavement grindings as shoulder backing when these materials are placed where they will not enter the Waters of the State.

- Streambed Alteration Agreements

  Caltrans will notify the DFG pursuant to Section 1601 of the Fish and Game Code when a project involving the use of asphaltic materials or crumbled, flaked, or ground pavement will alter or result in the deposition of pavement material into a river, stream, or lake designated by the DFG. When the proposed activity incorporates the agreements reached under Section 1601 of the Fish and Game Code, and is consistent with Section 5650 of the Fish and Game Code and this MOU, the DFG will agree to the use of these materials.

There may be circumstances where agreement between the DFG and Caltrans cannot be reached. Should the two agencies reach an impasse, the agencies enter into a binding arbitration process outlined in Section 1601 of the Fish and Game Code. However, keep in mind that this arbitration process does not exempt Caltrans from complying with the provisions of the Fish and Game Code. Also it should be noted that this process is time consuming, requiring as much as 72 days or more to complete. Negotiations over the placement of AC grindings, chunks, and pieces are to take place at the District level as part of the 1601 Agreement process.

Topic 111 - Material Sites and Disposal Sites

111.1 General Policy

The policies and procedures concerning material sites and disposal sites are listed below.

(a) Materials investigations and environmental studies of local materials sources should be made to the extent necessary to provide a basis for study and design. Location and capacity of available disposal sites should be determined for all projects requiring disposal of more than 7500 m^3 of clean material. Sites for disposal of any significant amount of material in sensitive areas should be considered only where there is no practical alternative.

(b) Factual information obtained from such investigations should be made readily available to prospective bidders and contractors.

(c) The responsibility for interpreting such information rests with the contractor and not with the State.

(d) Generally, the designation of optional material sites or disposal sites will not be included in the special provisions. Mandatory sites must be designated in the special provisions. A disposal site within the highway right of way (not necessarily within the project limits) should be provided when deemed in the best interest of the Department as an alternative to an approved site for disposal of water bearing residues generated by grinding or grooving operations, after approval is obtained from the Regional Water Quality Control Board (RWQCB) having jurisdiction over the area.

(e) Material agreements or other arrangements should be made with owners of material sites whenever the absence of such arrangements would result in restriction of competition in bidding, or in other instances where it is in the State's interest that such arrangements be made.

(f) The general policy of Caltrans is to avoid specifying mandatory sources unless data in support of such sources shows certain and substantial savings to the State. Mandatory sources must not be specified on Federal-aid projects except under exceptional circumstances, and prior approval of the FHWA is required. Supporting data in such cases should be submitted as early as possible. This policy also applies to disposal sites.

(g) It is the policy of Caltrans to cooperate with local authorities to the greatest practicable extent in complying with environmental requirements for all projects. Any corrective measures wanted by the local authorities should be provided through the permit process. Any unusual requirements, conditions, or situations should be submitted to the Division of Design for review (see Indexes 110.2 and 110.3).

(h) The use of any materials site requires compliance with environmental laws and regulations, which is normally a part of the project environmental documentation. If the need for a site occurs after approval of the project environmental document, a separate determination of environmental requirements for the materials site may be required.

(i) If the materials site is outside the project limits and exceeds 0.4 ha in size, or extraction will exceed 765 m^3, it must comply with the Surface Mining and Reclamation Act of 1975 (SMARA) and be included on the current "AB 3098 List" published by the Department of Conservation before material from that site can be used on a State project. There are limited exceptions to this requirement and the District Materials Engineer should be consulted.

111.2 Investigation of Local Materials Sources

(1) Extent of Explorations. Possible sources of materials should be investigated to the extent necessary to assure that the design of each project is based on the most economical use of available materials compatible with good environmental design practices. Where it can be reasonably assumed that all required materials can be most economically obtained from commercial sources on the current "AB 3098 List", it should be unnecessary to investigate other sites. In all other cases material sites should be investigated. Exploration of materials sources should not be restricted to those properties where the owner expresses willingness to enter into agreement with the State. Unless it is definitely known that the owner will under no circumstances permit removal of materials, the site should be considered as a possible source of local materials.

(2) Geotechnical Design Report or Materials Report. The Geotechnical Design Report or Materials Report should include complete information on all sites investigated and should discuss the quality, cost, SMARA status, and availability of materials from commercial plants on the current "AB 3098 List". Sufficient sampling of sites must be performed to indicate the character of the material and the elevation of the ground water surface, and to determine changes in the character of the material, both laterally and vertically. Sampling must be done in such a manner that individual samples can be taken from each horizon or layer. Composite samples of two or more different types of material are unsatisfactory, as there is no assurance that the materials would be so combined if the materials source were actually used. Testing of blends of two or more types of materials is permissible, provided the test report clearly indicates the combination tested. The test report must clearly indicate the location of the sample and the depth represented. The fact that materials sites are not designated in the Special Provisions does

not reduce the importance of thorough exploration and testing.

As tabulations of test data for local materials will be furnished to prospective bidders, and the test reports may be examined by bidders if they so request, it is important that only factual data be shown on the test report and that no conclusions, opinions, or interpretation of the test data be included. Under "Remarks", give only the pertinent factual information regarding the scalping, crushing, blending, or other laboratory processing performed in preparing samples for testing, and omit any comments as to suitability for any purpose. Any discussion of the quality, suitability, or quantity of material in local materials sites necessary for design purposes should be included in the Geotechnical Design Report or Materials Report, and not noted on the test reports. For any potential materials source explored or tested, all boring and test data must be furnished, including those tests which indicate unsuitable or inferior material.

Materials information to be furnished bidders may include data on a materials source previously investigated for the same project or some other project provided all of the following conditions are met:

(a) There has been no change in test procedures subsequent to the time the earlier tests were made.

(b) The materials source has not been altered by stream action, weathering, or other natural processes.

(c) The material sampled and represented by the tests has not been removed.

(d) There has been no change in SMARA status, or inclusion or exclusion on the "AB 3098 List".

It will be necessary for each District to maintain a filing system such that all preliminary test reports for potential materials sites are readily accessible. This will necessitate preparation of test reports covering all preliminary tests of materials. It will also be essential to maintain some type of materials inventory system, whereby sites in the vicinity of any project can be readily identified and the test reports can be immediately accessible. Filing only by numerical or chronological order will not be permissible.

111.3 Materials Information Furnished to Prospective Bidders

(1) Materials Information Compilation. It is the intent that all test data applicable to material sites for a project be furnished to prospective bidders. To obtain uniformity in the "handouts" furnishing this information to prospective bidders, the District Materials Unit should develop the "handout" and the following information must be included:

(a) A cover page entitled, "Materials Information", should show District, County, Route, kilometer post limits, and geographical limits. There should be a note stating where the records, from which the information was compiled, may be inspected. Also, an index, listing investigated material sites, and disposal sites, maps, test reports, tabulation sheets, SMARA status, and agreements is to be shown on the cover page.

(b) A vicinity map showing the location of investigated materials sites and disposal sites in relation to the project.

(c) A map of each material site showing the location and identification of boring or test pits.

(d) A tabulation of the test data for each material site, showing complete information on the location, depth, and processing of each sample tested, together with all test results.

(e) Copies of all options or agreements with owners of the material sites, if such arrangements have been made.

(f) Soil survey sheets or suitable terrain maps showing borings and tests along the highway alignment.

(g) A tabulation of which sites comply with environmental laws and regulations and are included on the current “AB 3098 List”.

(h) Material site grading and reclamation plan and disposal site grading plans, if they have been prepared.

(i) Copies of local use permits and clearances (when they have been obtained by the State) such as environmental clearances, mining permits, Forest Service Fire Regulations, water quality control clearances, etc. If documents are of unusual length, a statement should be included that they have been obtained and are available for inspection at the District office or Sacramento Plans Counter.

Maps, test reports, and other data included in the "Materials Information" must be factual, and should not include any comments, conclusions, or opinions as to the quality, quantity, suitability, depth, or area of the materials in any material site or along the highway.

Reproducible copies of all material to be included in the "Material Information" package should be submitted to the Office Engineer.

The Office Engineer will reproduce the "Materials Information," and copies will be available to prospective bidders upon request in the same manner that plans and special provisions are furnished.

111.4 Materials Arrangements

Materials agreements or other arrangements must be made in accordance with the policy stated under Index 111.1(e).

The determination of when and where materials agreements or other arrangements are to be obtained is the responsibility of the District, see Section 8.25.00.00 of the Right of Way Manual.

The District should also determine the maximum royalty that can be paid economically on the basis of availability of competitive sources.

In preparing agreements, guaranteed quantity provisions should not be included, as the opportunity exists for possible token removal, with the result that the State would be required to pay for the guaranteed quantity even though the material would not actually be removed. Also, requirements that the State perform construction work on the owner's property, such as fences, gates, cattle guards, roads, etc., should be included only when the cost of such items and possible resulting benefits have been properly considered in the derivation of the royalty.

111.5 Procedures for Acquisition of Material Sites and Disposal Sites

These instructions establish procedures to be followed in the purchase of material sites and disposal sites when such purchase is deemed necessary by the District. The steps to be taken are listed in order as follows:

(1) General Procedure.

(a) A District report proposing and establishing the necessity for purchase of the site is required. The report should contain the following information:

- The project or projects on which the site is to be used and programming of proposed construction.
- The location and description of the property, zoning, and site restoration/reclamation proposals including necessary vicinity and site maps.
- The amount and quality of material estimated to be available in the site and amount needed for the project or projects, or amount of excess material to be disposed of and the capacity of the site or sites.
- An economic analysis using the estimated purchase price and value of land after removal of material or deposit of excess material. The total estimated savings over other possible alternatives must be clearly demonstrated. Alternatives must be shown from the standpoint of what would have to be done if the site was not purchased. Alternatives could be

changes in location or grade as well as alternative sources of material.

- A statement as to whether or not the use of the site should be mandatory, with a separate statement regarding the effect for each proposed project for which mandatory use of the site is considered necessary, including complete justification for the mandatory specification (see Index 111.6). Three copies of each map or other attachment, folded letter size, are required for mandatory sites on all Federal-aid projects.
- A statement of the type of environmental documentation.
- Other justification.

Send one copy to the Division of Design and one copy to DES Materials Engineering and Testing Services for information.

(b) If the project or projects are to have Federal aid, the District will prepare a request, with supporting environmental clearance, for FHWA approval to specify the source as mandatory. One copy of this request should be sent to the Office Engineer and one copy to Division of Design.

(c) If the estimated purchase price is over $300,000, the District should include the item in the STIP and corresponding budget.

(d) When the proposed purchase has been approved, the Project Engineer should notify the District Division of Right of Way, District Environmental Division and the District Materials Unit and request that Right of Way purchase the site (or obtain a Materials Agreement; the Materials Unit should assist in the development of the agreement) and the Environmental Division obtain environmental authorization to proceed.

(e) The District must include the cost of purchase in the proper fiscal year program and/or budget as part of the District targets.

(f) After budgeting, the District must submit an expenditure authorization to cover purchase of the site. This could be concurrent if the project is added to the budget during a fiscal year. The expenditure authorization request should be processed through the District Project Management and Administration Units and obtain District Director approval.

(g) After issuance of an expenditure authorization, the District Division of Right of Way will complete purchase of the site.

(2) *Material and Disposal Sites in Federal Lands.* The applicable sections of the Federal Highway Act of 1958 for procurement of borrow or disposal sites, Sections 107(d) and 317, are set forth in Section 8.18.02.00 of the Right of Way Manual; Section 107(d) applies to the Interstate System while Section 317 applies to other Federal-aid highways. Whenever Federal public lands are required for a material or a disposal site, and after preliminary negotiations at the local level with the Federal agency having jurisdiction, the District must submit a letter report to the FHWA. This report should observe the requirements of Index 111.5 of this manual and Section 8.18.02.03 of the Right of Way Manual.

Following submittal of the proposal by the District to the FHWA, the latter, acting on behalf of the State transmits the proposal with a favorable recommendation to the Federal agency having control of the site. See Section 8.18.02.03 of the Right of Way Manual.

111.6 Mandatory Material Sites and Disposal Sites on Federal-aid Projects

The contract provisions must not specify a mandatory site for the disposal of surplus excavated materials unless a particular site is needed for environmental reasons or the site is found to be the most economical for one or more Federal-aid projects. All points listed in Index 111.5(1)(a) and (b) must be covered and one copy of all attachments submitted. Supporting data must be submitted to the FHWA during the project planning phase or early in the project design phase as almost all cases of mandatory sites must go to the FHWA for decision.

Section 635.407 of 23 CFR 635D states in part:

> "The designation of a mandatory material source may be permitted based on environmental considerations, provided the environment would be substantially enhanced without excessive cost."
>
> "The contract provisions ... shall not specify mandatory a site for the disposal of surplus excavated materials unless there is a finding by the State highway agency with the concurrence of the FHWA Division Administrator that such placement is the most economical except that the designation of a mandatory site may be permitted based on environmental considerations, provided the environment would be substantially enhanced without excessive cost."

Topic 112 - Contractor's Yard and Plant Sites

112.1 Policy

The Project Engineer should, during the design phase of a project, consider the need and availability of sites for the contractor's yards and materials plants. This is particularly important in areas where dust, noise, and access problems could limit the contractor in obtaining sites on their own in a timely manner. Asphalt concrete recycling projects pose special problems of material storage, access, and plant location; see Index 110.11. Temporary storage areas should be considered for grooving and grinding projects. As a general rule, the use of material sites designated in the Special Provisions should be optional. Should the materials site be desired, the contractor shall provide notice to the Resident Engineer within a designated time period after approval of the contract (30 days would be a minimum, but not more than 60 days except in unusual situations). All environmental requirements must be satisfied and local permits must be obtained prior to submittal of the PS&E. Right of Way, Permits, and Environmental units must be informed early in the process. The contractor will be allowed to use these sites only for work on the designated project(s).

112.2 Locating a Site

The Project Engineer should consult with District Division of Right of Way concerning appropriately sized parcels currently being held in the airspace inventory, nearby property held by Caltrans for future construction, or as excess land. If such space is available in the vicinity of the project, the District Environmental Division should be consulted to determine what environmental requirements are necessary for the use of these properties for the intended purpose. If sufficient space does not appear to be available for yard or plant, the Project Engineer must see that the appropriate wording is placed in the contract Special Provisions.

Topic 113 - Geotechnical Design Report

113.1 Policy

The Project Engineer must review the project initiation document and Preliminary Geotechnical Design Report, if any, to ascertain the scope of geotechnical involvement for a project. A Geotechnical Design Report (GDR) is to be prepared by the Roadway Geotechnical Engineering Branches of the Division of Engineering Services (DES) Geotechnical Services (or under a consultant contract with technical oversight by DES-GS) for all projects that involve designs for cut slopes, embankments, earthwork, landslide remediation, retaining walls, groundwater studies, erosion control features, subexcavation and any other studies involving geotechnical investigations and engineering geology. A GDR is not required for projects that solely include those design features described in Index 114.1.

113.2 Content

The GDR is to conform to the "Guidelines for Geotechnical Reports" which is prepared by the Office of Structural Foundations.

113.3 Submittal and Review

Final copies of the GDR are to be submitted to the Project Engineer, District Materials Unit, and the Division of Design. For consultant developed reports, the GDR is to be submitted to DES-GS for review and approval. DES-GS will then transmit the approved GDR to the Project Engineer, District Materials Unit, and the Division of Design. Also see Index 607.2.

Topic 114 - Materials Report

114.1 Policy

A Materials Report must be prepared by the District Materials Branch (or under a consultant contract with technical oversight by the District Materials Branch) with assistance from the DES Materials Engineering and Testing Services (METS) for all projects that involve pavement structural section recommendations or pavement studies, culverts or other drainage materials, corrosion studies, or materials or disposal sites.

114.2 Content

The Materials Report is to conform to the guidelines for pavement structural section studies and guidelines for corrosion studies as published by METS. Exceptions may be approved by METS.

114.3 Submittal and Review

A copy of the Draft Materials Report is to be submitted to METS for review and comment by the District Materials Unit. After resolution of the comments from METS, a final copy of the Materials Report is to be submitted to the District Materials Unit, the Project Engineer, the Division of Design, and to METS. Also see Index 607.2.

CHAPTER 200 GEOMETRIC DESIGN AND STRUCTURE STANDARDS

Topic 201 - Sight Distance

Index 201.1 - General

Sight distance is the continuous length of highway ahead visible to the driver. Three types of sight distance are considered here: passing, stopping, and decision. Stopping sight distance is the minimum sight distance to be provided on multilane highways and on 2-lane roads when passing sight distance is not economically obtainable. Stopping sight distance also is to be provided for all elements of interchanges and intersections at grade, including private road connections (see Topic 504, Index 405.1, & Figure 405.7). Decision sight distance is used at major decision points (see Indexes 201.7 and 504.2).

The following table shows the standards for passing and stopping sight distance related to design speed, and these shall be the minimum values used in design.

Table 201.1
Sight Distance Standards

Design Speed(1) (km/h)	Stopping(2) (m)	Passing (m)
30	30	217
40	50	285
50	65	345
60	85	407
70	105	482
80	130	541
90	160	605
100	190	670
110	220	728
120	255	792
130	290	855

(1) See Topic 101 for selection of design speed.
(2) For sustained downgrades, refer to advisory standard in Index 201.3

Chapter 3 of "A Policy on Geometric Design of Highways and Streets," AASHTO, 2001, contains a thorough discussion of the derivation of stopping sight distance.

201.2 Passing Sight Distance

Passing sight distance is the minimum sight distance required for the driver of one vehicle to pass another vehicle safely and comfortably. Passing must be accomplished assuming an oncoming vehicle comes into view and maintains the design speed, without reduction, after the overtaking maneuver is started.

Chapter III of “A Policy on Geometric Design of Highways and Streets,” AASHTO, contains a thorough discussion of the derivation of passing sight distance. In brief, AASHTO states that the sight distance available for passing at any place is the longest distance at which a driver whose eyes are 1070 mm above the pavement surface can see the top of an object 1300 mm high on the road.

In general, 2-lane highways should be designed to provide for passing where possible, especially those routes with high volumes of trucks or recreational vehicles. Passing should be done on tangent horizontal alignments with constant grades or a slight sag vertical curve. Not only are drivers reluctant to pass on a long crest vertical curve, but it is impracticable to design crest vertical curves to provide for passing sight distance because of high cost where crest cuts are involved. Passing sight distance for crest vertical curves is 7 to 17 times longer than the stopping sight distance.

Ordinarily, passing sight distance is provided at locations where combinations of alignment and profile do not require the use of crest vertical curves.

Passing sight distance is considered only on 2-lane roads. At critical locations, a stretch of 3- or 4-lane passing section with stopping sight distance is sometimes more economical than two lanes with passing sight distance.

Passing on sag vertical curves can be accomplished both day and night because headlights can be seen through the entire curve.

See Chapter 6 of the Traffic Manual for criteria relating to barrier striping of no-passing zones. Note, that passing sight distances given in the Traffic Manual are lower than those given in "A Policy on Geometric Design of Highways and Streets," AASHTO. The distances used in the Traffic Manual are not intended for passing sight distance design of horizontal and vertical curves. The shorter distances used in the Traffic Manual are for the passing of slower vehicles than those considered in the AASHTO criteria, such as trucks, bicycles, etc. Consult the Headquarters Traffic Liaison when using the Traffic Manual criteria.

Other means for providing passing opportunities, such as climbing lanes or turnouts, are discussed in Index 204.5.

201.3 Stopping Sight Distance

The minimum stopping sight distance is the distance required by the driver of a vehicle, traveling at a given speed, to bring the vehicle to a stop after an object on the road becomes visible. Stopping sight distance is measured from the driver's eyes, which are assumed to be 1070 mm above the pavement surface, to an object 150 mm high on the road.

<u>The stopping sight distances in Table 201.1 should be increased by 20% on sustained downgrades steeper than 3% and longer than 2 km.</u>

201.4 Stopping Sight Distance at Grade Crests

Figure 201.4 shows graphically the relationships between length of crest vertical curve, design speed, and algebraic difference in grades. Any one factor can be determined when the other two are known.

201.5 Stopping Sight Distance at Grade Sags

From the curves in Figure 201.5, the minimum length of vertical curve which provides headlight sight distance in grade sags for a given design speed can be obtained.

If headlight sight distance is not obtainable at grade sags, lighting may be considered. The Project Development Coordinator and the Traffic Liaison Engineer shall be contacted to review proposed grade sag lighting to determine if such use is appropriate.

201.6 Stopping Sight Distance on Horizontal Curves

Where an object off the pavement such as a bridge pier, building, cut slope, or natural growth restricts sight distance, the minimum radius of curvature is determined by the stopping sight distance.

Available stopping sight distance on horizontal curves is obtained from Figure 201.6. It is assumed that the driver's eye is 1070 mm above the center of the inside lane (inside with respect to curve) and the object is 150 mm high. The line of sight is assumed to intercept the view obstruction at the midpoint of the sight line and 600 mm above the center of the inside lane when the road profile is flat (i.e. no vertical curve). Crest vertical curves can cause additional reductions in sight distance. The clear distance (*m*) is measured from the center of the inside lane to the obstruction. (Note that the clear distance *"m"* is italicized to distinguish it from the "m" used for meters.)

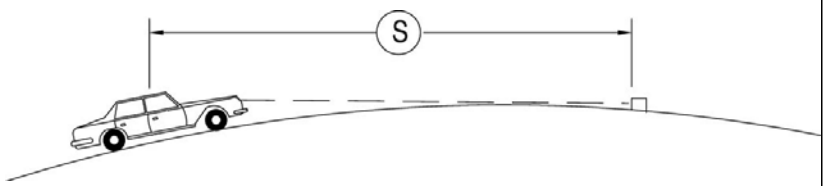
The design objective is to determine the required clear distance from centerline of inside lane to a retaining wall, bridge pier, abutment, cut slope, or other obstruction for a given design speed. Using radius of curvature and minimum sight distance for that design speed, Figure 201.6 gives the clear distance (*m*) from centerline of inside lane to the obstruction.

When the radius of curvature and the clear distance to a fixed obstruction are known, Figure 201.6 also gives the sight distance for these conditions.

See Index 101.1 for technical reductions in design speed caused by partial or momentary horizontal sight distance restrictions. See Index 203.2 for additional comments on glare screens.

Cuts may be widened where vegetation restricting horizontal sight distance is expected to grow on finished slopes. Widening is an economic trade-off that must be evaluated along with other options. See Index 902.2 for sight distance requirements on landscape projects.

Figure 201.4
Stopping Sight Distance on Crest Vertical Curves



Drivers eye height is 1070 mm.
Object height is 150 mm.

L = Curve Length (meters)

A = Algebraic Grade Difference (%)

S = Sight Distance (meters)

V = Design Speed for "S" in km/h

K = Distance in meters required to achieve a 1% change in grade. K value as shown on graph is valid when S < L.

Notes:

- Before using this figure for intersections, branch connections and exits, see Indexes 201.7 and 405.1, and Topic 504.
- See Figure 204.4 for vertical curve formulas.
- See Index 204.4 for minimum length of vertical curve

When S > L	**When S < L**
L = 2S – 405/A	**L = AS^2 /405**

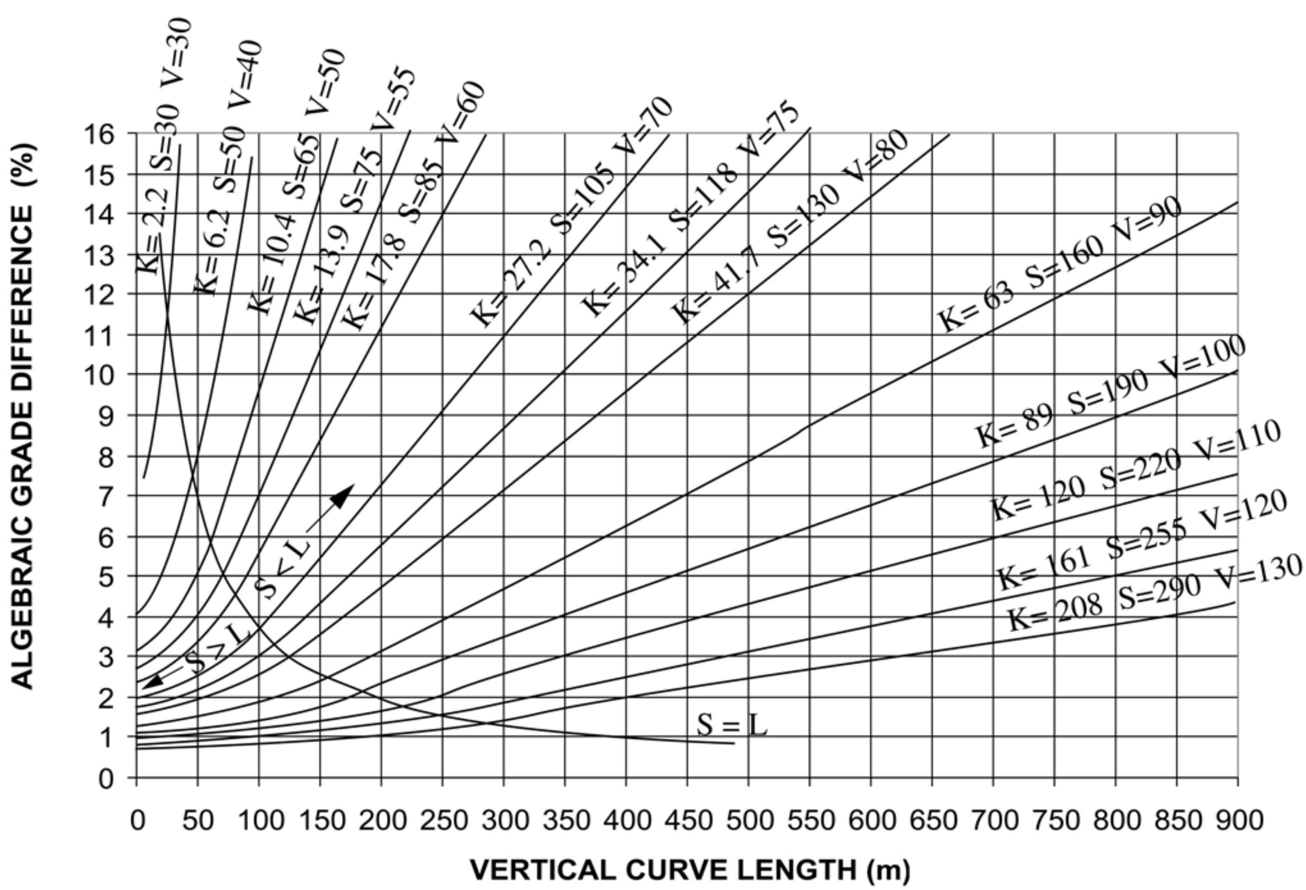
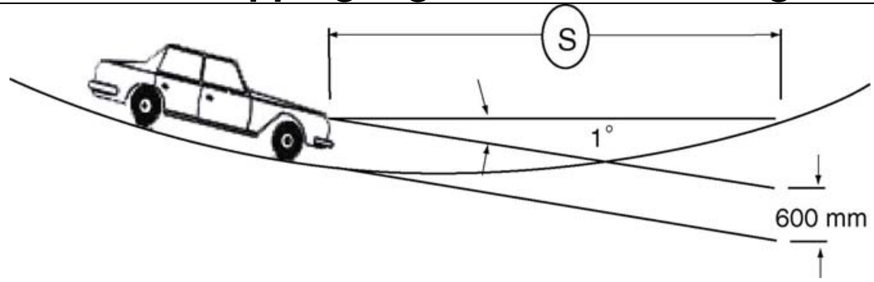


Figure 201.5
Stopping Sight Distance on Sag Vertical Curves



L = Curve Length (meters)
A = Algebraic Grade Difference (%)
S = Sight Distance (meters)
V = Design Speed for "S" in km/h
K = Distance in meters required to achieve a 1% change in grade. K value as shown on graph is valid when S < L.

Notes:

- For sustained downgrades, see Index 201.3.
- Before using this figure for intersections, branch connections and exits, see Indexes 201.7 and 405.1, and Topic 504.
- See Figure 204.4 for vertical curve formulas.
- See Index 204.4 for minimum length of vertical curve.

When S > L	**When S < L**
$L = 2S - (122 + 3.5S)/A$	**$L = AS^2/(122 + 3.5S)$**

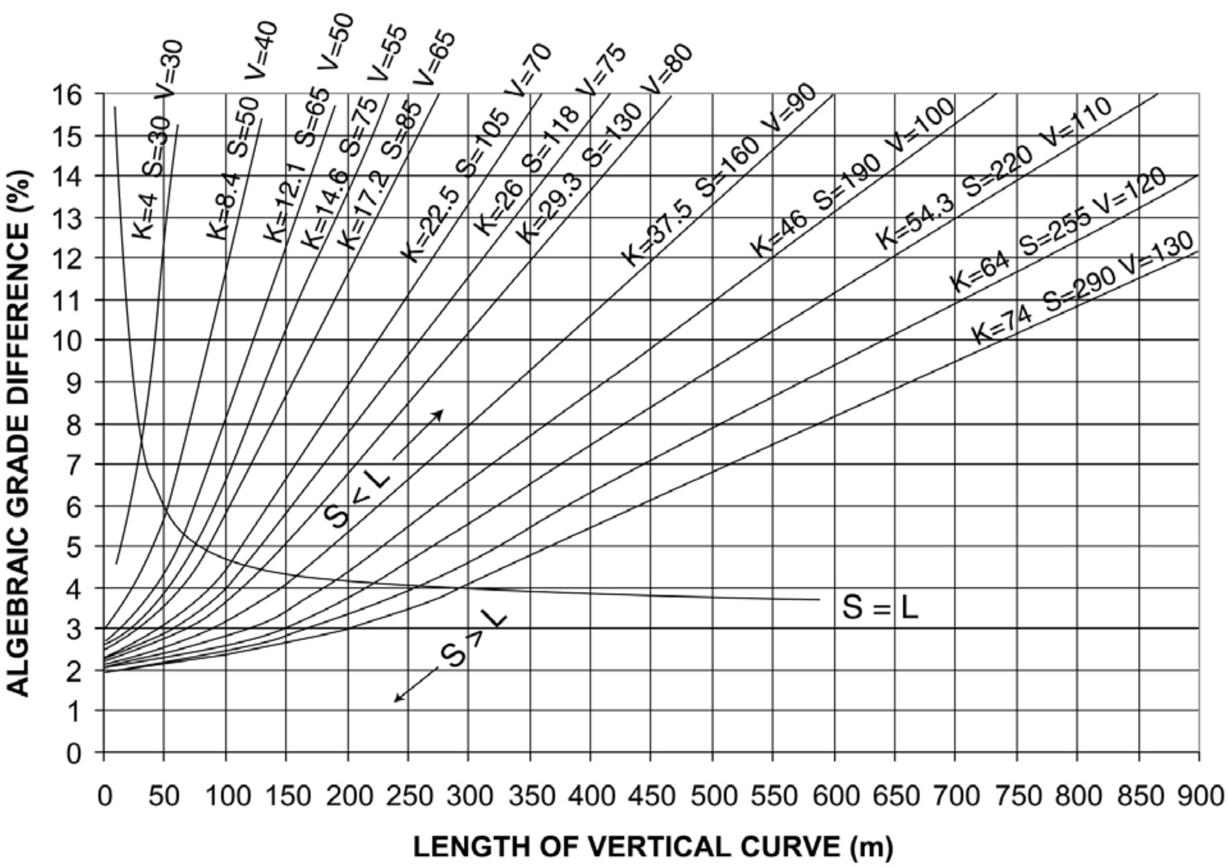
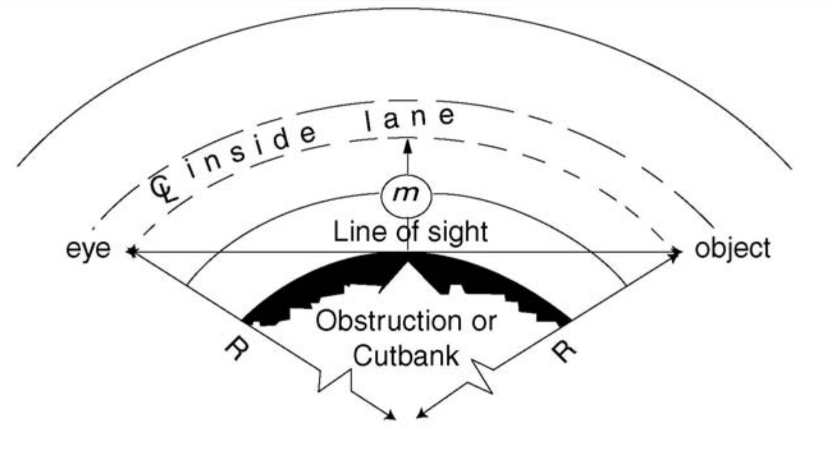


Figure 201.6
Stopping Sight Distance on Horizontal Curves



Line of sight is 600 mm above the centerline inside lane at point of obstruction.

R = Radius of the centerline of the lane nearest the obstruction (meters).

S = Sight Distance (meters)

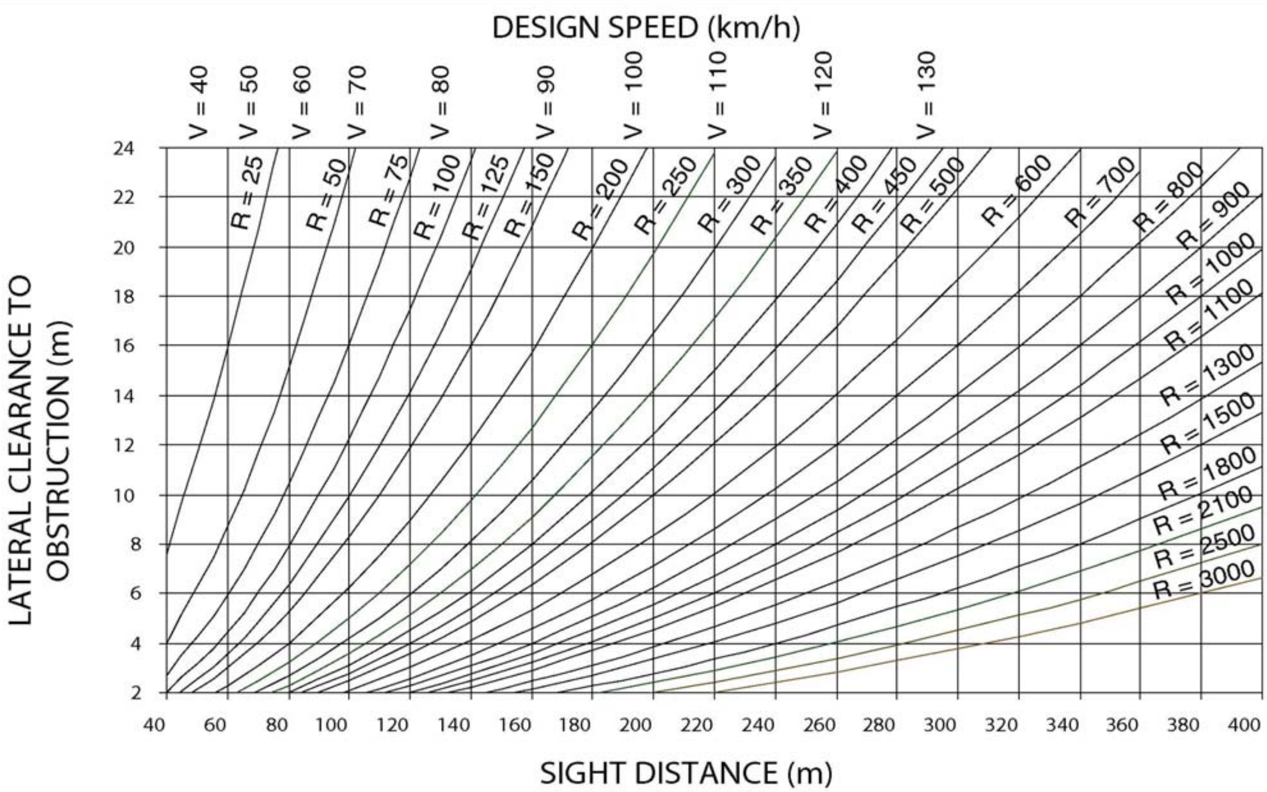
V = Design Speed for "S" in km/h

m = Distance from centerline of the lane nearest the obstruction (meters).

Notes:
- For sustained downgrades, see Index 201.3.
- Formulas apply only when "S" is equal to or less than length of curve.
- Angles in formulas are expressed in degrees.

$$m = R\left[1 - \cos\left(\frac{28.65S}{R}\right)\right]$$

$$S = \frac{R}{28.65}\left[\cos^{-1}\left(\frac{R - m}{R}\right)\right]$$



201.7 Decision Sight Distance

At certain locations, sight distance greater than stopping sight distance is desirable to allow drivers time for decisions without making last minute erratic maneuvers (see Chapter III of "A Policy on Geometric Design of Highways and Streets," AASHTO, for a thorough discussion of the derivation of decision sight distance.)

On freeways and expressways the decision sight distance values in Table 201.7 should be used at lane drops and at off-ramp noses to interchanges, branch connections, roadside rests, vista points, and inspection stations. When determining decision sight distance on horizontal and vertical curves, Figures 201.4, 201.5, and 201.6 can be used. Figure 201.7 is an expanded version of Figure 201.4 and gives the relationship among length of crest vertical curve design speed, and algebraic difference in grades for much longer vertical curves than Figure 201.4.

Decision sight distance is measured using the 1070 mm eye height and 150 mm object height. See Index 504.2 for sight distance at secondary exits on a collector-distributor road.

Table 201.7

Decision Sight Distance

Design Speed (km/h)	Decision Sight Distance (m)
40	110
50	145
60	175
70	200
80	230
90	275
100	315
110	335
120	375

Topic 202 - Superelevation

202.1 Basic Criteria

According to the laws of mechanics, when a vehicle travels on a curve it is forced outward by centrifugal force.

On a superelevated highway, this force is resisted by the vehicle weight component parallel to the superelevated surface and side friction between the tires and pavement. It is impractical to balance centrifugal force by superelevation alone, because for any given curve radius a certain superelevation rate is exactly correct for only one driving speed. At all other speeds there will be a side thrust either outward or inward, relative to the curve center, which must be offset by side friction.

If the vehicle is not skidding, these forces are in equilibrium as represented by the following equation, which is used to design a curve for a comfortable operation at a particular speed:

$$\text{Centrifugal factor} = e + f = \frac{0.0079V^2}{R} = \frac{V^2}{127R}$$

Where:

- e = Superelevation slope in meters per meter
- e_{max} = Maximum superelevation rate for a given condition
- f = Side friction factor
- R = Curve radius in meters
- V = Velocity in kilometers per hour

Standard superelevation rates are designed to hold the portion of the centrifugal force that must be taken up by tire friction within allowable limits. Friction factors as related to speed are shown on Figure 202.2. The factors apply equally to portland cement concrete and bituminous pavements.

The scaled maps accompanying FAA Form 7460-1 should contain the following minimum information.

- Distance from project to nearest runway.
- Elevation of runway thresholds.
- Relationship between the proposed highway horizontal alignment and vertical profile to the nearest runway or heliport primary surface. Include elevations of objects referenced to the elevation of the end of the runway, such as overhead lights, signs, structures, landscaping, and vehicles.

One copy of FAA form 7460-1 should be forwarded to the Division of Design for information and one copy to the Division of Aeronautics for information and land use compatibility review.

Note: The international language for flight is English units. Therefore, all communication with the FAA and Division of Aeronautics, including all mapping, must be in English units, not metric.

Topic 208 - Bridges and Grade Separation Structures

208.1 Bridge Width

(1) *State Highways.* **The clear width of all bridges, including grade separation structures, shall equal the full width of the traveled way and paved shoulders on the approaches with the following exceptions:**

(a) **Bridges to be constructed as replacements on existing 2-lane, 2-way roads shall not have less than a 9.6 m wide roadbed for ADT less than 400, and not less than 12 m for ADT greater than 400. (see Index 307.2).**

(b) **When the approach shoulder width is less than 1.2 m, the minimum offset on each side shall be 1.2 m, and shall be documented in accordance with Index 82.2.**

The width should be measured normal to the center line between faces of curb or railing measured at the gutter line. For offsets to safety shape barriers see Figure 208.1.

For horizontal and vertical clearances, see Topic 309.

(2) *Roads Under Other Jurisdictions.*

(a) Overcrossing Widths--(See Index 308.1.)

(b) Undercrossing Span Lengths--Initial construction should provide for the ultimate requirements. In areas where the local jurisdiction has a definite plan of development, the ultimate right of way width or at least that portion needed for the roadbed and sidewalks should be spanned.

If the undercrossing street or road has no median, one should be provided where necessary to accommodate left-turn lanes or the center piers of the undercrossing structure.

Where it appears that a 2-lane road will be adequate for the foreseeable future, but no right of way width has been established, a minimum span length sufficient for a 12.0 m roadbed should be provided. Additional span length should be provided to permit future sidewalks where there is a foreseeable need. If it is reasonably foreseeable that more than two lanes will be required ultimately, a greater width should be spanned.

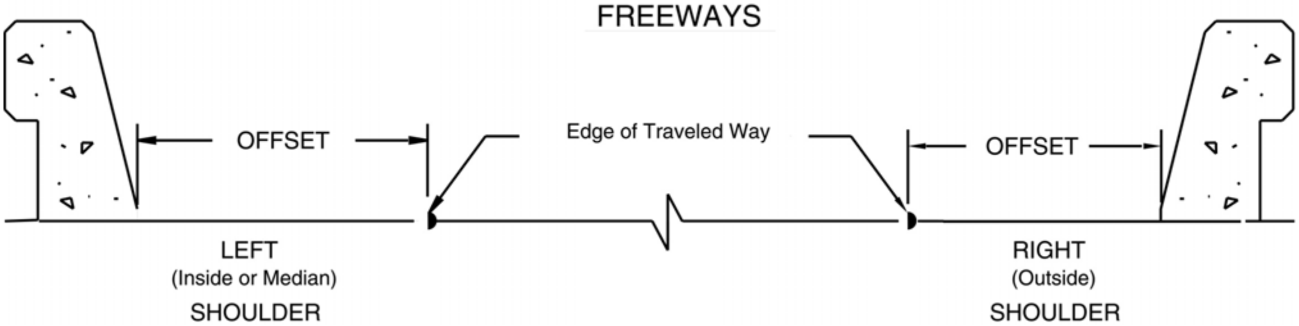
(c) For horizontal and vertical clearances, see Topic 309.

208.2 Cross Slope

The crown is normally centered on the bridge except for one-way bridges where a straight cross slope in one direction should be used. The cross slope should be the same as for the approach pavement (see Index 301.2).

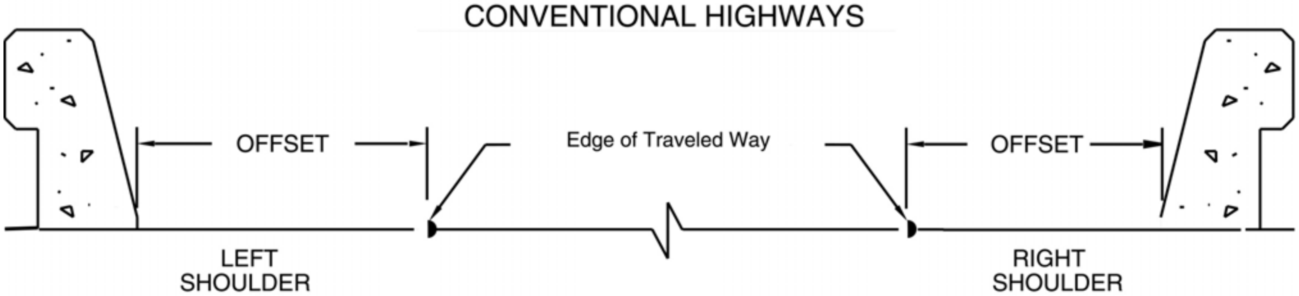
Figure 208.1
Offsets to Safety-Shape Barriers

FREEWAYS



Approach Shoulder Width	Left Shoulder	Right Shoulder
* 0.6 m & 1.2 m (Ramps)	1.2 m	1.2 m
1.5 m	1.5 m	1.5 m
2.4 m	2.4 m	2.4 m
3.0 m	3.0 m	3.0 m

CONVENTIONAL HIGHWAYS



Approach Shoulder Width	Left Shoulder	Right Shoulder
* 0.6 m & 1.2 m	1.2 m	1.2 m
2.4 m	2.4 m	2.4 m

* See Index 208.1(1)(b)

208.3 Median

On multilane divided highways a bridge median that is 10.8 m wide or less should be decked. Exceptions require individual analysis. See Chapter 7 of the Traffic Manual for median barrier warrants.

208.4 Bridge Sidewalks

Bridge sidewalks should be provided where justified by pedestrian traffic (see Figure 208.10B).

208.5 Open End Structures

Embankment end slopes at open end structures should be no steeper than 1:1.5 for all highways.

208.6 Pedestrian Overcrossings and Undercrossings

The minimum width of walkway for pedestrian overcrossings should be 2.4 m.

Determination of the width and height of pedestrian undercrossings requires individual analysis to insure adequate visibility through the structure and approaches (see Index 105.2).

Pedestrian ramps should be provided on all pedestrian separation structures. The ramp should have a maximum longitudinal slope of 8.33% with a maximum rise of 760 mm between landings. The landing should be a minimum of 1525 mm in length.

See Topic 309 for vertical clearances.

208.7 Equestrian Undercrossings

Such structures should normally provide a clear opening 3 m high and 3 m wide. Skewed crossings should be avoided. The structure should be straight so the entire length can be seen from each end. Sustained grades should be a maximum of 10%. Decomposed granite or similar material should be used for the trail surface. While AC is permissible, a PCC surface should be avoided.

208.8 Cattle Passes, Equipment, and Deer Crossings

Private cattle passes and equipment crossings may be constructed when economically justified by a right of way appraisal, as outlined in Section 7.09.09.00 of the Right of Way Manual.

The standard cattle pass should consist of either a standard box culvert with an opening 2.4 m wide and 2.4 m high or a metal pipe 3000 mm in diameter. The invert of metal pipe should be paved with concrete or bituminous paving material.

If equestrian traffic is expected to use the culvert a minimum 3 m wide by 3 m high structure may be provided. However, the user of the facility should be contacted to determine the specific requirements.

If conditions indicate a reasonable need for a larger than standard cattle pass, it may be provided if economically justified by the right of way appraisal.

In some cases the installation of equipment or deer crossings is justified on the basis of public interest or need rather than economics. Examples are:

(a) A deer crossing or other structure for environmental protection purposes.

(b) Equipment crossings for the Forest Service or other governmental agencies or as a right of way obligation.

These facilities should be installed where necessary as determined by consultation with the appropriate affected entities.

A clear line of sight should be provided through the structure.

208.9 Railroad Underpasses and Overheads

Generally, it is desirable to construct overheads rather than underpasses whenever it is necessary for a highway and railroad to cross. Railroads should be carried over highways only when there is no other reasonable alternative.

Some undesirable features of underpasses are:

(a) They create bottlenecks for railroad operations.

(b) It is difficult to widen the highway.

(c) Pumping plants are often required to drain the highway.

(d) They are likely to lead to cost participation controversies for initial and future construction.

(e) Shooflies (temporary tracks) are generally required during construction.

(f) Railroads are concerned about the structure maintenance and liability costs they incur.

Advantages of overheads are:

(a) Railroads can use most of their right of way for maintenance.

(b) Overheads can be widened at a relatively low cost and with little difficulty.

(c) Less damage may be incurred in the event of a derailment.

(d) Agreements for design and maintenance can be reached more easily with railroads.

(e) Initial costs are generally lower.

The State, the railroads, and the public in general can usually benefit from the construction of an overhead structure rather than an underpass.

See Topic 309 for vertical clearances.

208.10 Bridge Barriers and Railings

(1) *General.* There are four classes of railings, each intended to perform a different function.

(a) Vehicular Barrier Railings--The primary function of these railings is to retain and redirect errant vehicles.

(b) Combination Vehicular Barrier and Pedestrian Railings--These railings perform the dual function of retaining both vehicles and pedestrians on the bridge. They consist of two parts--A concrete parapet barrier, generally with a sidewalk, and metal handrailing or fence-type railing.

(c) Pedestrian Railings--These railings prevent pedestrians from accidentally falling from the structure and, in the case of fence-type railing, reduce the risk of objects being dropped on the roadway below. Where the facility is accessible to disabled persons and the profile grade exceeds 5%, a handrail for use by the disabled meeting both the State and Federal regulations must be provided.

(d) Bicycle Railings--These railings retain bicycles and riders on the structure. They may be specifically designed for bicycles, or may be a combination type consisting of a vehicular barrier surmounted by a fence or metal handrail.

(2) *Policies.* To reduce the risk of objects being dropped or thrown upon vehicles, protective screening in the form of fence-type railings should be installed along new overcrossing structure sidewalks in urban areas (Sec.92.6 California Streets and Highways Code). Screening should be considered for the opposite side of structures having one sidewalk. Screening should be installed at such other locations determined to be appropriate.

The approved types of railings for use on bridge structures are listed below and illustrated in Figures 208.10A, B, and C. Railing types not listed are no longer in general use; however, they may be specified in those cases where it is desirable to match an existing condition.

The District should specify in the bridge site data submittal the rail type to be used after consideration has been given to the recommendations of the local agency (where applicable) and the DES-SD.

(3) *Vehicular Barriers.* See Figure 208.10A.

(a) Concrete Barrier Type 732 and 736--These vehicular barriers are for general use adjacent to traffic. Figure 208.1 illustrates the position of the barrier relative to the edge of traveled way.

(c) In other locations where the designer deems it reasonable and appropriate.

(7) *Bridge Approach Railings.* **Approach railings shall be installed at the ends of bridge railings exposed to approach traffic.**

Refer to Chapter 7 of the Traffic Manual for placement and design criteria of guardrail.

Topic 209 – (currently not in use)

Topic 210 - Earth Retaining Systems

210.1 Types and Uses

Earth retaining systems can be divided into five categories:

- State designed systems which involve a Standard Plan,
- State designed systems which require a special design,
- Proprietary systems which have been pre-approved by DES-SD for listing in Special Provisions for specific projects.
- Proprietary systems which are awaiting DES-SD approval.
- Experimental systems.

(1) *State Designed Earth Retaining Systems With Standard Plans.* Standard Plans are available for a variety of earth retaining systems (retaining walls). Loading conditions and foundation requirements are outlined in the Standard Plans. For sites with requirements that are not covered by the Standard Plans, a special design earth retaining system is required. To assure conformance with the Standard Plan requirements and, therefore, completion of the PS&E in a timely fashion, design engineers should request a foundation investigation for all locations at which a retaining wall is being considered. Retaining walls which have Standard Plans are as follows:

(a) Retaining Wall Types 1 and 2 (Concrete Cantilever). These walls have standard design heights up to 10 900 mm, but are most economical below 6000 mm. Concrete cantilever walls accommodate traffic barriers, sound walls, and drainage facilities efficiently.

(b) Retaining Wall Type 3 and 4 (Concrete Counterfort). These walls may be used where minimum wall deflection is desired. When used in conjunction with concrete cantilever walls, there should be an offset in the plane of the wall faces to mask the difference in deflection between the two wall types. The cost of these walls is generally more than for concrete cantilever walls of similar height.

(c) Retaining Wall Type 5 (Concrete L-Type Cantilever). Although more costly than cantilever walls, these walls may be required where site restrictions do not allow for a footing projection beyond the face of the wall stem.

(d) Retaining Wall Type 6 (Concrete Masonry Walls). These walls may be used where the design height of the wall does not exceed 1800 mm. These walls are generally less costly than all other standard design walls or gravity walls. Where traffic is adjacent to the top of the wall, guardrail should be set back as noted in the Standard Plans.

(e) Crib Walls. The following types are available:

- Concrete Crib Wall - This type of crib wall may be used for design heights up to 16 000 mm. Concrete crib walls are suited to coastal areas and higher elevations where salt air and deicing salts may limit the service life of other types of crib walls. Concrete crib walls may be closed face and, therefore, useful where impinging flow is a problem.

- Steel Crib Wall - This type of crib wall may be used for design heights up to 10 900 mm. Steel crib walls are light in weight; easily transported and installed; and, therefore, suited for relatively inaccessible installations and for emergency repairs.
- Timber Crib Wall - This type of crib wall may be used for design heights up to 6600 mm. Timber crib walls have a rustic appearance which makes them suited to a rural environment. When all of the wood members are pressure preservative treated, the service life of timber crib walls is comparable to that of concrete or steel crib walls.

  Timber and concrete crib walls constructed on horizontal alignments with curves or angle points require special details, particularly when the wall face is battered. Because crib wall faces can be climbed, they are not recommended for urban sites where they will be accessible to the public. The economical height for all crib walls is generally less than 9000 mm.

(2) *State Designed Earth Retaining Systems Which Require Special Designs.* Some sites require a special design earth retaining system to accommodate existing and future ground contours, traffic, utilities or other constructed features, site geology, economy, or aesthetics.

Some special design earth retaining systems are as follows:

(a) Standard Plan Walls. The design loadings, heights, and types of walls in the Standard Plans cover frequent applications for earth retaining systems. However, special designs are necessary if the imposed loading exceeds that in the Standard Plans. Railroad live load; building surcharge; loads imposed by sign structures, electroliers, or sound walls are examples. Foundation conditions that require pile support for the wall necessitates a special design. Design is by the DES-SD.

(b) Bulkheads. These systems are also referred to as cantilevered pile, sheet pile, tied-back, anchored pile, or soldier pile walls. These walls are most practical in cut sections and are best suited for situations where excavation for a retaining wall with a footing is impractical because of traffic, utilities, existing buildings, or right of way restrictions. In embankment sections, a bulkhead wall is a practical solution for a roadway widening where design heights are less that 1800 mm. They are also practical for slip-out corrections. Bulkheads can consist of either concrete, steel, or timber sheet piles, or concrete, steel or timber soldier piles either driven or placed in drilled holes and backfilled, with either concrete facing or lagging or timber lagging. Bulkhead walls can be either cantilevered or anchored with tie rod and deadman anchors, ground anchors, or rock anchors. The method of support and anchorage depends on site conditions, design height, and loading imposed. The cost of these walls is variable depending on earth retaining requirements, site geology, aesthetic consideration, and site restraints. Design is by DES-SD.

(c) Concrete or Rock Gravity Walls. These walls are most economical at design heights below 1200 mm. They are constructed at heights between 1200 mm and 1800 mm only for short lengths, and then only if considerable length of the shorter height is involved. These walls can be used in connection with a cantilever wall if long lengths of wall with design heights of less than 1200 mm are required. A Type 50C concrete barrier, which can be found in the Standard Plans, can serve as a gravity retaining wall in locations where a differential in height of up to 900 mm exists between adjoining roadway grades. Design is by DES-SD.

(d) Soil Reinforcement Systems. Soil reinforcement systems consist of facing elements and soil reinforcing elements incorporated into a compacted or in situ soil mass. The reinforced soil mass functions similar to a gravity wall.

Soil reinforcing elements can be any material that provides tensile strength and pullout resistance, and possesses satisfactory creep characteristics and service life. Generally, reinforcing elements are steel, but polymeric and fiberglass systems may be used.

Facing elements for most systems are either reinforced concrete, light guage steel, or treated wood. Polymeric walls may be faced with masonry-like elements or even planted with local grasses. Selection of facing type is governed by aesthetics and service life.

Wall heights of soil reinforcement systems are controlled mainly by bearing capacity of the foundation material and global stability of the site. Wall heights in excess of 18 000 mm are feasible where conditions permit. Foundation investigations for soil reinforcement systems are similar to investigations for conventional retaining walls.

Special details are required when a soil reinforcement system must accommodate drainage structures, overhead sign supports or sound walls on piles within the reinforced soil mass. Concrete traffic barriers require a special design support slab when used at the top of the facing of these systems. These systems can not be used where site restrictions do not allow necessary excavation or placement of the soil reinforcing elements.

Soil reinforcement systems can be classified within two categories typified by the method of construction:

- "Bottom Up Methods" - These soil reinforcement systems involve the placement of reinforcement during construction of an embankment. When conditions permit their use, these systems are generally the most economical choice for wall heights greater than 6000 mm. They may also be the most economical system for wall heights in the 3000 mm to 6000 mm range, depending on specific project requirements.

  Because of the articulated nature of the facing elements these systems use, they can tolerate greater differential settlement than can conventional concrete retaining walls.

  Steel elements used in this method are sized to provide sacrificial steel to offset corrosion; and, additionally, are galvanized for permanent installations.

- "Top Down Methods" - At the time of this revision, soil nailing is the only method of reinforcing undisturbed earth during excavation of a cut slope practiced by Caltrans. This system involves insertion of reinforcement "soil nails" at an angle into undisturbed in situ material during excavation. When site conditions permit its use, soil nailing will generally be the most economic system for all heights.

  Because soil nailing is accomplished concurrent with excavation, and thus results in an unloading of the foundation, there is generally no significant differential movement.

  Steel "soil nails" used in this method are protected against corrosion either by being epoxy coated or encapsulated within a grout filled corrugated plastic sheath, and surrounded by portland cement grout placed during construction.

Soil reinforcement systems are designed by both the state and private firms. Vendor systems are termed "proprietary" and are listed in paragraphs (3) and (4) of this section. Some state designed soil reinforcement systems that require special design are as follows:

- Mechanically Stabilized Embankment (MSE) - This system was developed by the DES-Geotechnical Services (DES-GS) and uses galvanized welded wire mats as soil reinforcing elements. The facing elements are precast concrete. In many cases, this system can be constructed using on-site backfill materials. Design by DES-SD.
- Salvaged Material Retaining Wall - This system was developed by the DES-GS and utilizes C-channel sections as soil reinforcement. Galvanized metal beamguard rail, timber posts or concrete panels are used as facing elements. Often the materials involved can be salvaged from state rehabilitation projects. The District Recycle Coordinator should be consulted as to availability of salvaged materials. Design by DES-GS.
- Soil Nail Wall - This system reinforces either original ground or an existing embankment during the excavation process. Soil nailing is always accomplished from the top down in stages that are typically 1200 mm to 1800 mm in height. After each stage of excavation, corrosion protected soil reinforcing elements, "soil nails", are placed and grouted into holes which have been drilled at angles into the in situ material. The face of each stage of excavation is protected by a layer of reinforced shotcrete. After the full height of wall has been excavated and reinforced, a finish layer of concrete facing is placed either by the shotcreting method or by casting within a face form. Design by DES-SD.
- Tire Anchor Timber (TAT) Wall - This system was developed by the DES-GS and utilizes steel bars with used tire side walls attached by cross bars as soil reinforcing elements. The facing elements are treated timber. TAT walls have a rustic appearance which makes them suited to a rural environment. Design by the DES-GS.

(3) *Proprietary Earth Retaining Systems (Pre-Approved).* These conventional retaining walls, cribwalls, and soil reinforcement systems are designed, manufactured, and marketed by a vendor. These systems are termed proprietary because most of these systems are patented. Pre-approval status means that these systems may be listed in the Special Provisions of the project as an Alternative Earth Retaining System (AERS) when considered appropriate for a particular location. For a proprietary system to be given pre-approval status, the vendor must submit standard plans and design calculations to DES-SD for their review and approval. Preapproved proprietary earth retaining systems are as follows:

(a) Reinforced Earth (RE). This French, patented soil reinforcement system is marketed by the Reinforced Earth Company. Reinforced Earth utilizes steel strips as soil reinforcing elements and precast concrete face panels.

(b) Reinforced Soil Embankment (RSE). This patented soil reinforcement system is marketed by The Hilfiker Company. RSE walls utilize welded wire mat soil reinforcement and precast concrete face panels.

(c) Welded Wire Walls. This patented soil reinforcement system is marketed by The Hilfiker Company. Welded Wire Walls are constructed using welded wire mat units which are both the soil reinforcement and the facing element.

(d) Retained Earth Walls. This patented soil reinforcement system is marketed by the Foster Geotechnical Corporation. Like MSE walls, retained earth walls use welded wire mat soil reinforcement and precast concrete face panels.

(e) Criblock Walls. This patented concrete cribwall system is marketed by Retaining Walls Company.

(f) Port-O-Wall. This system is marketed by Port-O-Wall Enterprises. This system consists of cantilevered precast concrete stem panels supported by a cast-in-place concrete footing.

(g) MSE Plus. This patented soil reinforcement system is marketed by the SSL Company. MSE Plus uses welded wire mat soil reinforcement and precast concrete face panels.

(h) Evergreen Retaining Wall System. This system is marketed by the Quickset Corporation. Evergreen Wall is composed of prefabricated concrete elements placed on top of each other which are then filled with earth and planted.

It should be noted that this list includes only those systems which were pre-approved by DES-SD at the time of this revision. New systems will be added to the list as they are submitted, evaluated, and approved.

(4) Proprietary Earth Retaining Systems (Pending). The systems in this category have been submitted by a vendor to the DES-SD for evaluation. They will undergo thorough review and any necessary testing and with the approval of DES-SD, they will be added to the list of pre-approved proprietary earth retaining systems and can be listed in the Special Provisions under Alternative Earth Retaining Systems.

In most cases, proprietary systems will be listed in the Special Provisions for a project under Alternative Earth Retaining Systems. However, if a proprietary system is the only retaining system deemed appropriate for a project and, therefore, the only system contained in the project documents, the construction of that system must be designated experimental construction in accordance with existing contract agreements concerning sole source purchases.

(5) Experimental State Designed Earth Retaining Systems. Every earth retaining system must undergo a thorough evaluation before becoming accepted for routine use. Newly introduced designs or untried combinations of proprietary and non-proprietary designs or products are, therefore, considered experimental. Evaluation of the system may take the form of either a Category 1 or a Category 2 Experimental Construction Project. Category 1 projects are administered by either the DES-GS or DES-SD. Category 2 projects are administered through the DES, Value Analysis and Resource Conservation Branch, and require a minimum of paperwork. The evaluation process in both cases is federally funded. Once a system has been evaluated the experimental status will be changed.

Some earth retaining systems which are considered experimental are as follows:

(a) Fabric or Plastic Reinforced Walls. These systems utilize geotextiles or plastics as the soil reinforcing elements. The face of these walls can be left exposed if the fabric has been treated to prevent decay from ultra-violet rays. Concrete panels, mortarless masonry, tar emulsion, or air blown mortar may be used as facing materials or the face may be seeded if a more aesthetic treatment is preferred. Design is by DES-GS.

(b) Mortarless Masonry Gravity Walls. Each of these systems utilizes the friction and shear developed between facing units and the combined weight of the units to retain the backfill. Some of these systems have been used as erosion protection at abutments and on embankments. They can be used as an aesthetic treatment for facing fabric and plastic soil reinforced walls. All of these systems require a batter. Design is by the DES-GS.

It should be noted that this list includes only those systems which are being evaluated by the Office of Structural Foundations at the time of this revision. New systems will be added to the list as they are considered.

210.2 Alternative Earth Retaining Systems (AERS)

The Alternative Earth Retaining Systems procedure encourages competitive bidding and potentially results in cost savings. Therefore, AERS should be considered in preparing all project documents involving earth retaining systems.

DES-SD initiated the AERS procedure in 1982. Implementation of the procedure means that various earth retaining systems are presented in the contract bid package and are, therefore, able to be considered for use by a contractor. Under this procedure, a fully detailed State designed earth retaining system will be provided for each location, and will be used as the basis for payment. Additional systems may be presented in the contract documents as alternatives to the fully detailed State design and can be considered for use at specified locations. The fully detailed State designed earth retaining system which is used as the basis for payment may be either a Standard Plan system or a special design system. Additional (or alternative) systems may be State designed systems, pre-approved proprietary systems, an experimental system, or any combination thereof. The State designed alternative systems, both Standard Plan walls and special design systems, will be fully detailed on the plans. The alternative systems which are pre-approved proprietary systems will be listed in the Special Provisions as Alternative Earth Retaining Systems.

Implementation of the AERS process requires the involvement of the District Design Engineer, DES-SD, and the DES-GS. The District Design Engineer should submit pertinent site information (site plans, typical sections, etc.) to both the DES-GS and DES-SD for feasibility studies as early as possible in the project design stage.

Under the AERS procedure, parts of the PS&E package which pertain to the earth retaining systems will be prepared as follows:

- Project plans for the State designed systems can be prepared by the District Design Engineer (Standard Plan systems), the DES-GS (special design soil reinforcement systems and experimental systems), or DES-SD (Standard Plan systems and special design systems).
- Pre-approved proprietary systems will be listed in the Special Provisions.
- Specifications and Estimates for the fully detailed State designed system, which will be used as the basis for payment, will be prepared by DES-SD.

The earth retaining systems under this procedure will be measured and paid for by the square meter area of the face of the earth retaining system which has been indicated to be the basis of payment. Should an Alternative Earth Retaining System be constructed, payment will be made based on the measurements of the State designed system which was designated as basis of payment. The contract price paid per square meter is for all items of work involved and includes excavation, backfill, drainage system, reinforcing steel, concrete, soil reinforcement, and facing. Any barrier, fence, or railing involved is measured and paid for as separate items.

210.3 Cost Reduction Incentive Proposals (CRIP)

The contractor may submit a proposal for an earth retaining system under Section 5-1.14 of the Standard Specifications, Cost Reduction Incentive. The proposed system may modify or replace the earth retaining system permitted by the contract. This gives vendors of proprietary earth retaining systems a method for having their system used prior to having pre-approval of a standard plan submittal for that system. CRIP submittals are administered by the Resident Engineer. Contract Change Orders are not to be processed until the CRIP is approved by Headquarters Construction with review assistance provided by other functional units.

210.4 Aesthetic Consideration

The profile of the top of wall should be designed to be as pleasing as the site conditions permit. All changes in the slope at the top of cast-in-place concrete walls should be rounded with vertical curves at least 6000 mm long. Small dips in the top of the wall should be eliminated. Sharp dips should be improved by using vertical curves, slopes, steps, or combinations thereof. Side slopes may be flattened or other adjustments made to provide a pleasing profile.

Where walls are highly visible, special surface treatment or provisions for landscaping should be considered. Aesthetic treatment of walls should be referred to DES-SD for study by the Transportation Architecture Branch.

Walls should not have indentations or protrusions less than 1800 mm above grade large enough to snag errant vehicles.

When alternative wall types are provided on projects with more than one wall site, any restriction as to the combination of wall types should be specified in the Special Provisions.

210.5 Safety Railing, Fences, and Concrete Barriers

Cable railing should be installed for employee protection in areas where employees may work adjacent to and above vertical faces of retaining walls, wingwalls, abutments, etc. where the vertical fall is 1220 mm or more.

If cable railing is required on a wall which is less than 1370 mm tall and that wall is located within the clear recovery zone, then the cable railing should be placed behind the wall. See Standard Plans for details of cable railing.

Special designs for safety railing may be considered where aesthetic values of the area warrant special treatment.

Concrete barriers may be mounted on top of retaining walls. Details for concrete barriers mounted on top of retaining walls Type 1 through 5 are shown in the Standard Plans. A special design traffic slab is required if a concrete barrier is to be used at the top of crib walls and most special design earth retaining systems. DES-SD should be contacted for preparation of the plans involved in the special design.

Retaining walls joining right of way fences should be a minimum of 1800 mm clear height.

210.6 Design Responsibility

DES-SD has primary responsibility for the structural design and preparation of the contract documents (PS&E) for earth retaining systems in the Standard Plans and for the special designs involving bulkheads, concrete and rock gravity walls, pile support systems, Mechanically Stabilized Embankment, and soil nail walls. The DES-GS has primary responsibility for the geotechnical design of soil nail walls. DES-SD prepares the Specifications and Engineer's Estimate for contracts where the Alternative Earth Retaining Systems (AERS) procedure is used. DES-SD reviews and approves standard plan submittals for proprietary earth retaining systems submitted by vendors. DES-SD and the DES-GS assist Headquarters Construction in evaluating the Cost Reduction Incentive Proposals (CRIP) submitted by contractors.

Districts may prepare contract plans, specifications, and engineer's estimate for Standard Plan retaining walls provided the foundation conditions and site requirements permit their use. A foundation investigation is required for all earth retaining structures. Project plans, specifications, and estimates for Tire Anchored Timber walls, Salvaged Material walls, and experimental walls will be prepared by the Districts with the assistance of the DES-GS. Earth retaining systems can be included in the PS&E as either Highway or Structure items.

Requests for the special design of a retaining system should be submitted at least 9 months before the PS&E is due. At least 3 months is required to conduct a foundation investigation for a retaining structure. A site plan, index map, cross sections, vertical and horizontal alignment, and utility and drainage requirements should be sent along with the request.

DES-Geotechnical Services has responsibility for making foundation recommendations for all earth retaining systems. They assist the District Design Engineer with preparation of contract documents for special designs of Tire Anchor Timber walls, Salvage Material walls, and experimental earth retaining systems.

Both the DES-GS and DES-SD have responsibility for making feasibility studies for Alternative Earth Retaining Systems. The District should submit project site information (site plans, typical sections, etc.) to both of them as early in the planning stages as possible so that determination of the most appropriate earth retaining systems to use can be made.

210.7 Guidelines for Plan Preparation

(1) Type Selection. Wall type selection should be based on considerations set forth in Index 210.1. Both State designed earth retaining systems and proprietary earth retaining systems may meet the requirements for a project. Therefore, to promote competitive bidding which can result in cost savings, all appropriate earth retaining systems should be included in the contract documents.

(2) Foundation Investigations. A foundation investigation should be requested from the DES-Geotechnical Services for all sites involving an earth retaining system. All log of test boring sheets accompanying the foundation reports must be included with the contract plans.

The following guidelines should be used to prepare the contract plans for earth retaining systems which are found in the Standard Plans:

(a) Loads. All wall types selected must be capable of supporting the field surcharge conditions. The design surcharges can be found in the Standard Plans. Deviance from these loadings will require a special design.

(b) Footing Steps. For economy and ease of construction of wall Types 1 through 6, the following criteria should be used for layout of footing steps.

- Distance between steps should be in multiples of 2400 mm.
- A minimum number of steps should be used even if a slightly higher wall is necessary. Small steps, less than 300 mm in height, should be avoided unless the distance between steps is 29 200 mm or more. The maximum height of steps should be held to 1200 mm. If the footing thickness changes between steps, the bottom of footing elevation should be adjusted so that the top of footing remains at the same elevation.

(c) Sloping Footings. The following criteria should be used for layout of sloping footings.

- The maximum permissible slope for reinforced concrete retaining walls is 3%. Maximum footing slope for masonry walls is 2%.
- When sloping footings are used, form and joint lines are permitted to be perpendicular and parallel to the footing for ease of construction.
- In cases where vertical electroliers or fence posts are required on top of a wall, the form and joint lines must also be vertical. A sloping footing should not be used in this situation since efficiency of construction would be lost.
- Sloping footing grades should be constant for the entire length of the wall. Breaks in footing grade will complicate forming and result in loss of economy. If breaks in footing grade are necessary, a level stepped footing should be used for the entire wall.
- When the top of wall profile of crib walls is constant for the entire length, the bottom of wall profile may be

sloped to avoid steps in the top of wall. In this case, all steps to compensate for changes of wall height and original ground profile would be made in the bottom of wall. The maximum permissible slope is 6%. If vertical electroliers or fence posts are required on top of the wall, the crib wall should not be sloped. Sloping crib walls are permissible with guard railing with vertical posts.

(d) Wall Joints. General details for required wall joints on wall Types 1, 1A, 2, and 5 are shown on Standard Plan B0-3. Expansion joints, Bridge Detail 3-3, should be shown at maximum intervals of 29 200 mm. Shorter spaces should be in multiples of 2400 mm. Expansion joints should not be placed near an angle point in the wall alignment. When concrete barriers are used on top of retaining walls, the waterstop in the expansion joint must be extended 150 mm into the barrier. This detail should be shown or noted on the wall plans. Weakened plane joints, Bridge Detail 3-2, should be shown at nearly equal spaces between joints.

(e) Drainage. Gutters should be used behind walls in areas where it is necessary to carry off surface water or to prevent scour. Low points in wall vertical alignment or areas between return walls must be drained by downspouts passing through the walls. Standard Plan B3-9 shows typical drainage details. Special design of surface water drainage facilities may be necessary depending on the amount of surface water anticipated. Where ground water is likely to occur in any quantity, special provisions must be made to intercept the flow to prevent inundation of the backfill and unsightly continuous flow through weep holes.

(f) Quantities. When the AERS procedure is not implemented, wall quantities for each item of work are usually set up for payment. The quantities for concrete, expansion joint waterstop, structure excavation, structure backfill, pervious backfill material, concrete barrier or railing, and gutter concrete must be tabulated also. Quantities should be tabulated on the plans for each wall.

The following guidelines should be used to prepare the contract plans for soil reinforcement systems:

(a) Leveling Slabs. Most soil reinforcement systems do not require extensive foundation preparation. It may be necessary, however, to design a concrete leveling slab on which to construct the face elements. A reinforced concrete slab will be required in areas prone to consolidation or frost disturbance.

- Steps in the leveling slab should be the same height as the height of the facing elements or thickness of the soil layer between the soil reinforcement.
- Distance between steps in the leveling slabs should be in increments equivalent to the length of individual facing elements.
- A minimum number of steps should be used even if a slightly higher wall is necessary.

(b) Drainage. Gutters should be used behind walls in areas where it is necessary to carry off surface water or to prevent scour. Low points in wall vertical alignment or areas between return walls must be drained by downspouts passing through the walls. Special design of surface water drainage facilities will be necessary and should be prepared by DES-SD. Where ground water is likely to occur in any quantity, special provisions must be made to intercept the flow to prevent inundation of the backfill.

(c) Quantities. When the AERS procedure is not implemented, quantities for each item of work are usually set up for payment.

Bid items must include, but not be limited to: excavation and backfill for the embedment depth, soil reinforcement, facing elements, and concrete for slab construction. Additional bid items for inclusion are any drainage system, pervious backfill, concrete barrier, railings, and concrete gutters. Quantities should be tabulated on the plans for each wall.

The following miscellaneous details are applicable to all earth retaining systems:

(a) Utilities. Provisions must be made to relocate or otherwise accommodate utilities conflicting with the retaining wall. A utility opening for a Type 1 wall is shown in the Standard Plans. Any other utility openings will require special design details and should be reviewed by DES-SD.

(b) Electroliers and Signs. Details for mounting electroliers and signs on earth retaining systems are designed by DES-SD. Requests for preparation of details should be made at least 3 months in advance of PS&E. To accommodate the base plates for overhead signs, a local enlargement may affect the horizontal clearance to both the edge of pavement and the right of way line. The enlargement should be considered at the time of establishing the wall layout. For mounting details, furnish DES-SD a complete cross section of the roadway at the sign and the layout and profile of the earth retaining system.

(c) Fence and Railing Post Pockets. Post pocket details shown for cable railing in the Standard Plans may also be used for mounting chain link fence on top of retaining walls. Special details may be necessary to accommodate the reinforcement in soil reinforcement systems.

(d) Return Walls. Return walls should be considered for use on the ends of the walls to provide a finished appearance. Return walls are necessary when wall offsets are used or when the top of wall is stepped. Return walls for soil reinforcement systems will require special designs to accommodate the overlapping of reinforcing elements.

All special wall details such as sign bases, utility openings, drainage features, fences, and concrete barriers should be shown on the plan sheet of the wall concerned or included on a separate sheet with the wall plan sheets. As a minimum, these details should be cross referenced on the wall sheets to the sheets on which they are shown.

CHAPTER 300
GEOMETRIC CROSS SECTION

Topic 301 - Traveled Way Standards

Index 301.1 - Traveled Way Width

The traveled way width is determined by the number of lanes demanded by the design hourly volume. The traveled way width does not include curbs, dikes, gutters, or gutter pans. **The basic lane width for new construction on two-lane and multilane highways, ramps, collector roads, and other appurtenant roadways shall be 3.6 m.** For roads with curve radii of 90 m or less, widening due to offtracking should be considered. See Index 404.1 and Table 504.3A. For roads under other jurisdictions, see Topic 308.

301.2 Cross Slopes

(1) *General.* The purpose of sloping on roadway cross sections is to provide a mechanism to direct water (usually from precipitation) off the traveled way. Undesirable accumulations of water can lead to hydroplaning or other problems which can increase accident potential. See Topics 831 and 833 for hydroplaning considerations.

(2) *Standards.*

(a) **The standard cross slope to be used for new construction on the traveled way for all types of surfaces shall be 2%.**

(b) **For resurfacing or widening when necessary to match existing cross slopes, the minimum shall be 1.5% and the maximum shall be 3 percent.** However, the cross slope on 2-lane and multilane AC highways should be increased to 2% if the cost is reasonable.

(c) **On unpaved roadway surfaces, including gravel and penetration treated earth, the cross slope shall be 2.5% to 5.0%.**

On undivided highways with two or more lanes in a normal tangent section, the high point of the crown should be centered on the pavement and the pavement sloped toward the edges on a uniform grade.

For rehabilitation and widening projects, the maximum algebraic difference in cross slope between adjacent lanes of opposing traffic for either 2-lane or undivided multilane highways should be 6%. **For new construction, the maximum shall be 4%.**

On divided highway roadbeds, the high point of crown may be centered at, or left of, the center of the traveled way, and preferably over a lane line (tent sections). This strategy may be employed when adding lanes on the inside of divided highways, or when widening an existing "crowned" 2-lane highway to a 4-lane divided highway by utilizing the existing 2-lane pavement as one of the divided highway roadbeds.

The maximum algebraic difference in cross slope between same direction traffic lanes of divided highway roadbeds should be 4%.

The maximum difference in cross slope between the traveled way and the shoulder should not exceed 8%. This applies to new construction as well as pavement overlay projects.

At freeway entrances and exits, the maximum difference in cross slope between adjacent lanes, or between lanes and gore areas, should not exceed 5%.

Topic 302 - Shoulder Standards

302.1 Width

The shoulder widths given in Table 302.1 shall be the minimum continuous usable width of paved shoulder. For new construction, and major reconstruction projects on conventional highways, adequate width should be provided to permit shared use by motorists and bicyclists.

See Index 308.1 for shoulder width requirements on city streets or county roads. See shoulder definition, Index 62.1(7).

See Index 1102.2 for shoulder width requirements next to noise Barriers.

Table 302.1
Standards for Paved
Shoulder Width

	Paved Shoulder Width (m) Left	Right (8)
Freeways & Expressways		
2 lanes (1)	--	2.4 (6)
4 lanes (1)	1.5	3.0
6 or more lanes (1)	3.0	3.0
Auxiliary lanes	--	3.0
Freeway-to-freeway connections		
Single and two-lane connections	1.5	3.0
Three-lane connections	3.0	3.0
Single-lane ramps	1.2 (2)	2.4
Multilane ramps	1.2 (2)	2.4 (3)
Multilane undivided	--	3.0
Collector-Distributor	1.5	3.0
Conventional Highways		
Multilane divided		
4-lanes	1.5	2.4
6-lanes or more	2.4	2.4
Urban areas with speeds less than 75 km/h and curbed medians	0.6 (4)	2.4 (7)
Multilane undivided	--	2.4 (7)
2-lane		
RRR	See Table 307.3	
New construction	See Table 307.2	
Slow-moving vehicle lane	--	1.2 (5)
Local Facilities		
Frontage roads	See Index 310.1	
Local facilities crossing State facilities	See Index 308.1	

NOTES:

(1) Total number of lanes in both directions including separate roadways (see Index 305.6). If a lane is added to one side of a 4-lane facility (such as a truck climbing lane) then that side shall have 3.0 m left and right shoulders. See Index 62.1.

(2) May be reduced to 0.6 m. 1.2 m preferred in urban areas and/or when ramp is metered. See Index 504.3.

(3) In restrictive situations, may be reduced to 0.6 m or 1.2 m (preferred in urban areas) in the 2-lane section of a non-metered ramp which transitions from a single lane. May be reduced to 0.6 m in ramp sections having 3 or more lanes. See Index 504.3.

(4) For posted speeds less than 60 km/h, shoulder may be omitted (see Index 303.5(5)) except where drainage flows toward the curbed median.

(5) On right side of climbing or passing lane section only. See Index 1003.2 if bike lanes are present.

(6) 3.0 m shoulders preferred.

(7) Where parking is allowed, 3.0 m to 3.6 m shoulders preferred.

(8) Shoulders adjacent to abutment walls, retaining walls in cut locations, and noise barriers shall be 3.0 m.

302.2 Cross Slopes

(1) *General* - **When a roadway crosses a bridge structure, the shoulders shall be in the same plane as the adjacent traveled way**.

(2) *Left Shoulders* - **In depressed median sections, shoulders to the left of traffic shall be sloped at 2% away from the traveled way.**

In paved median sections, shoulders to the left of traffic shall be designed in the plane of the traveled way. Maintenance paving beyond the edge of shoulder should be treated as appropriate for the site, but consideration needs to be given to the added runoff and the increased water depth on the pavement (see discussion in Index 831.4 (5) "Hydroplaning").

(3) *Right Shoulders*- In normal tangent sections, **shoulders to the right of traffic shall be sloped at 2% to 5% away from the traveled way.**

The above flexibility in the design of the right shoulder allows the designer the ability to conform to regional needs. Designers shall consider the following during shoulder cross slope design.

- In most areas a 5% right shoulder cross slope is desired to most expeditiously remove water from the pavement and to allow gutters to carry a maximum water volume between drainage inlets. The shoulders must have adequate drainage interception to control the "water spread" as discussed in Table 831.3 and Index 831.4. Conveyance of water from the total area transferring drainage and rainwater across each lane and the quantity of intercepting drainage shall also be a consideration in the selection of shoulder cross slope. Hydroplaning is discussed in Index 831.4 (5).

- In locations with snow removal operations it is desirable for right shoulders to slope away from traffic in the same plane as the traveled way. This design permits the snowplowing crew to remove snow from the lanes and the shoulders with the least number of passes.

- If shoulders are PCC and the District plans to convert shoulders into through lanes within the 20 years following construction, then shoulders are to be built in the plane of the traveled way and to lane standards for width and structural section. (See Index 603.4).

- If use of the highway by pedestrians is expected in areas where sidewalks are not to be constructed, new shoulder cross slope and drainage design should accommodate pedestrians and consideration should be given to pedestrian and bicycle needs on reconstruction of existing shoulders. This decision should involve the local agency and must be consistent with the design guidance provided in Topic 105 and in Design Information Bulletin 82, "Pedestrian Accessibility Guidelines for Highway Projects" for people with disabilities.

Shoulder slopes for super elevated curves are discussed under Index 202.2.

See Index 307.2 for shoulder slopes on 2-lane roads with 0.6 m and 1.2 m shoulders.

Topic 303 - Curbs, Dikes, and Side Gutters

303.1 General Policy

Curb (including curb with gutter pan), dike, and side gutter all serve specific purposes in the design of the roadway cross section. Curb is primarily used for channelization, access control, separation between pedestrians and vehicles, and to enhance delineation. Dike is specifically intended for drainage and erosion control where stormwater runoff cannot be cost effectively conveyed beyond the pavement by other means. Curb with gutter pan serves the purpose of both curb and dike. Side gutter is intended to prevent runoff from a cut slope on the high side of a superelevated roadway from running across the pavement and is discussed further in Index 834.3.

Aside from their positive aspects in performing certain functions, curbs and dikes can have undesirable effects. In general, curbs and dikes should present the least potential obstruction, yet perform their intended function. As operating speeds increase, lower curb and dike height is desirable. Curbs and dikes are not considered traffic barriers.

On urban and suburban conventional highways where right of way is costly and/or difficult to acquire, it is appropriate to consider the use of a "closed" highway cross section with curb, or curb with gutter pan. There are also some situations where curb is appropriate in freeway settings. The following criteria describe typical situations where curb or curb with gutter pan may be appropriate:

(a) Where needed for channelization, delineation, or other means of improving traffic flow and safety.

(b) At ramp connections with local streets for the delineation of pedestrians walkways and continuity of construction at a local facility.

(c) As a replacement of existing curb with gutter pan and sidewalk.

(d) On frontage roads on the side adjacent to the freeway to deter vehicular damage to the freeway fence.

(e) When appropriate to conform to local arterial street standards.

(f) Where it may be necessary to solve or mitigate operational deficiencies through control or restriction of access of traffic movements to abutting properties or traveled ways.

(g) In freeway entrance ramp gore areas (at the inlet nose) when the gore cross slope exceeds standards.

(h) At separation islands between a freeway and a collector-distributor to provide a positive separation between mainline traffic and collector-distributor traffic.

(i) Where sidewalk is appropriate.

(j) As a tool for traffic calming where operating speeds are 65 km/h or less.

(k) To deter vehicular damage of traffic signal standards.

Dike is appropriate where controlling drainage is not feasible via sheet flow or where it is necessary to contain/direct runoff to interception devices. On cut slopes, dike also protects the toe of slope from erosion. Dike may also be necessary to protect adjacent areas from flooding.

<u>The use of curb should be avoided on facilities with operating speeds greater than or equal to 75 km/h, except as noted in Table 303.1. For projects where the use of curb is appropriate, it should be the type shown in Table 303.1.</u>

303.2 Curb Types and Uses

Depending on their intended function, one of two general classifications of curb design are selected as appropriate. The two general classifications are vertical and sloped. Vertical curbs are actually nearly vertical (approximate batter of 4:1) and vary in height from 150 to 200 mm. Sloped curbs (approximate batter of 1.5:1 or flatter) vary in height from 80 to 150 mm.

Sloped curbs are more easily mounted by motor vehicles than vertical curbs. Since curbs are not generally adequate to prevent a vehicle from leaving the roadway, a suitable traffic barrier should be provided where redirection of vehicles is needed. Where curb is placed to deter vehicles from intentionally entering the area behind the curb (e.g., truck offtracking), in most cases the curb will not prevent an errant vehicle from mounting the curb.

Table 303.1
Selection of Curb Type

Location	Operating Speeds (km/h)		
	≤ 65	> 65 to < 75	≥ 75
Freeways and Expressways			
Collector-distributor Roads	See Index 504.3(11)		
Ramps			
Conventional Highways			
- Frontage Roads (1)	A or B-150	B-150	B-100
- Traffic Signals	A or B-150	B-150	B-100
- Raised Traffic & Median Islands(2)	A or B-150	B-150	B-100 or D
- Adjacent to Sidewalks & Pedestrian Refuge Islands	A (3)	A-150	B-150
- Bulb outs/curb extensions	A (3)	NA	NA
- Bridges (4)	H, A3, or B3	H or B3	B3

(1) Based on the operating speed along the frontage road.
(2) See Design Information Bulletin Number 80-01, “Roundabouts” for information on curbs at roundabouts.
(3) Type A curb includes types A1-150, A2-150, A1-200, and A2-200.
(4) Type H curb typically used in conjunction with Type A curbs next to sidewalks on approach roadway. Type A3 curbs typically used with corresponding Type A curbs on median island of approach roadway. Type B3 curbs typically used with corresponding Type B curbs on approach roadway.

Curb with gutter pan may be provided to enhance the visibility of the curb and thus improve delineation. This is most effective where the adjacent pavement is a contrasting color or material. B2-100 and B4 curbs are appropriate for enhancing delineation. Where curb with gutter pan is intended as delineation and has no drainage function, the gutter pan should be in the same plane as the adjacent pavement.

The curb sections provided on the Standard Plans are approved types to be used as stated below. The following types are vertical curb:

(1) *Types A1-150, A2-150, and A3-150.* These curbs are 150 mm high. Their main function is to provide a more positive deterrent to vehicles than is provided by sloped curb. Specifically, they are used to separate pedestrians from vehicles, to control parking of vehicles, and to deter vehicular damage of traffic signal standards. They may also be used as raised median islands in low speed environments (operating speed ≤ 65 km/h). These curbs do not constitute a positive barrier as they can be mounted except at low speeds and flat angles of approach.

(2) *Types A1-200, A2-200, and A3-200.* These 200 mm high curbs may be used in lieu of 150 mm curbs when requested by local authorities, if the curb criteria stated under Index 303.1 are satisfied and operating speeds are 65 km/h or less. This type of curb may impede curbside passenger loading and may make it more difficult to comply with curb ramp design (see Design Information Bulletin Number 82, “Pedestrian Accessibility Guidelines for Highway Projects”).

(3) *Type H Curb.* This type may be used on bridges with operating speeds less than 75 km/h where it is desired to match the approach roadway curb. Type H curb is often incorporated into bridge barrier/sidewalk combination railings (See Index 208.10(4)).

These types are sloped curbs:

(4) *Types B1, B2, and B3 Curbs and Curbs with Gutter Pan.* Types B1-150, B2-150, and B3-150 are 150 mm high. Type B1-100, B2-100, and B3-100 are 100 mm high. Since all have a 1.5:1 slope or flatter on the face, they are mounted more easily than Type A curbs. Typical uses of these curbs are for channelization including raised median islands. B2 curb with gutter pan also serves as drainage control.

(5) *Type B4 Curb.* Type B4 curb with gutter pan is 80 mm high and is typically used on ramp gores as described under Index 504.3(11). It may also be appropriate where a lower curb is desirable.

(6) *Type D Curb.* Type D curb is 100 or 150 mm high and is typically used for raised traffic islands, collector-distributor separation islands, or raised medians when operating speeds equal or exceed 75 km/h.

(7) *Type E Curb.* This essentially is a rolled gutter used only in special drainage situations.

Curbs with gutter pans, along with the shoulder, may provide the principal drainage system for the roadway. Inlets are provided in the gutter pan or curb, or both.

Gutter pans are typically 0.6 m wide but may be 0.3 to 1.2 m in width, with a cross slope of typically 8.33 percent to increase the hydraulic capacity. Gutter pan cross slopes often need to be modified at curb ramps in order to meet accessibility requirements. See Design Information Bulletin Number 82, "Pedestrian Accessibility Guidelines for Highway Projects" for accessibility standards. Warping of the gutter pan should be limited to the portion within 0.6 to 0.9 m of the gutter flow line to minimize adverse driving effects.

Curbs and gutter pans are cross section elements considered entirely outside the traveled way, see Index 301.1.

Where bicycles are permitted and the shoulder width is 1.2 m, gutter pan width should be reduced to 0.3 m, so 0.9 m is provided between the traffic lane and the longitudinal joint at the gutter pan. For mandatory requirements regarding drainage inlet grates for bicycles, see Index 1003.6(3).

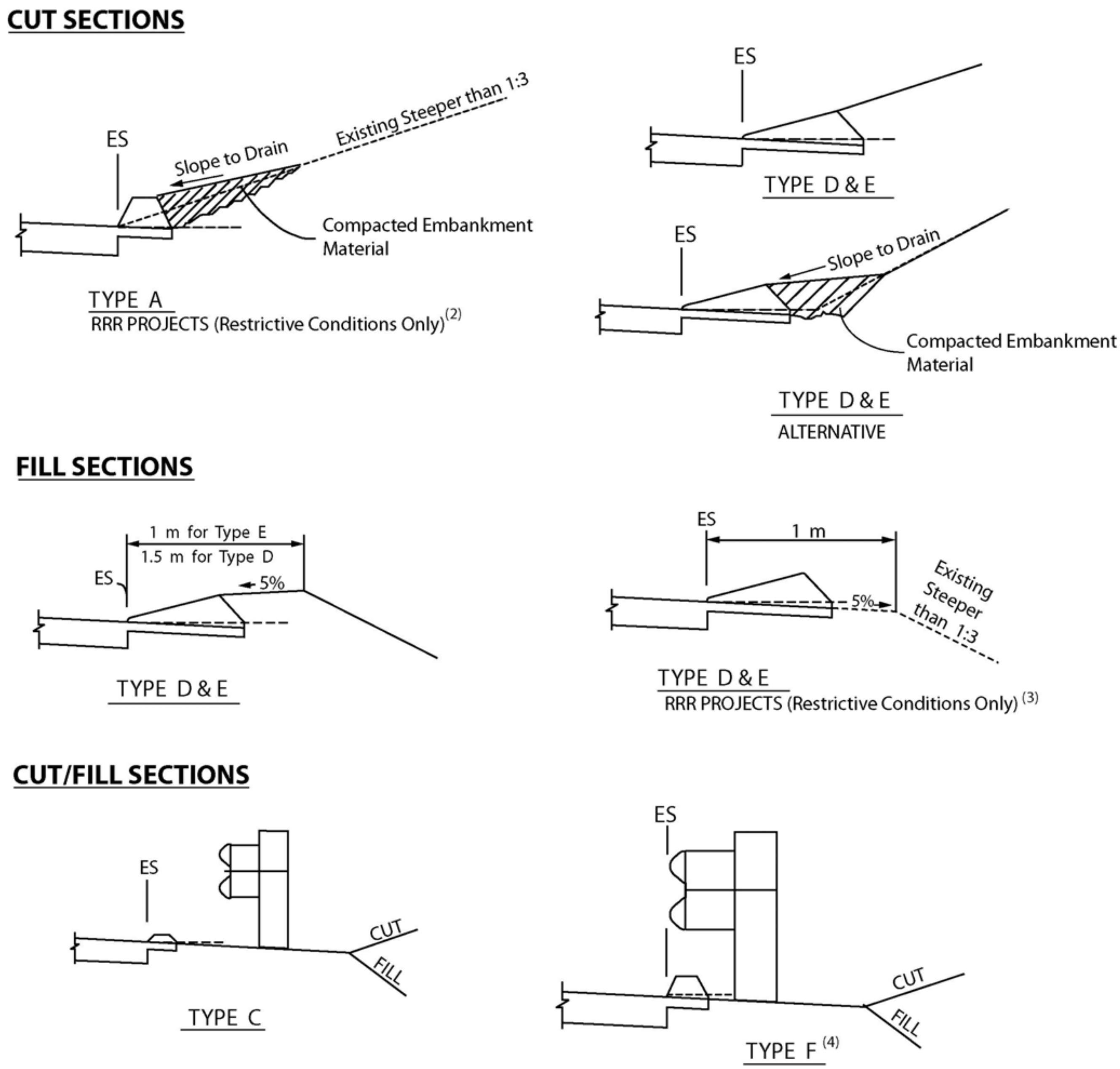
303.3 Dike Types and Uses

Use of dike is intended for drainage control and should not be used in place of curb. Dikes placed adjoining the shoulder, as shown in Figures 307.2, 307.4, and 307.5, provide a paved triangular gutter within the shoulder area. The dike sections provided on the Standard Plans are approved types to be used as stated below. Dikes should be selected as illustrated in Figure 303.3. Dikes should be designed so that roadway runoff is contained within the limits specified in Index 831.3. For most situations Type E dike is the preferred dike type as discussed below.

(1) *Type A Dike.* The use of Type A dike should be avoided. For RRR projects, Type A dike may be used in cut sections with slopes steeper than 1:3 and where existing conditions do not allow for construction of the wider Type D or E dikes. Compacted embankment material should be placed behind the back of dike as shown in Figure 303.3.

(2) *Type C Dike.* This low dike, 50 mm in height, may be used to confine small concentrations of runoff. The capacity of the shoulder gutter formed by this dike is small. Due to this limited capacity, the need for installing an inlet immediately upstream of the beginning of this dike type should be evaluated. This low dike can be traversed by a vehicle and allows the area beyond the surfaced shoulder to be used as an emergency recovery and parking area. The Type C dike is the only dike that may be used in front of guardrail. In such cases, it is not necessary to place compacted embankment material behind Type C dike.

Figure 303.3
Dike Type Selection and Placement(1)



Notes:
(1) See Standard Plans for additional information and details.
(2) See Index 303.3(1) for restrictive conditions.
(3) See Index 303.3(3) and Index 303.3(4) for restrictive conditions for Type D and Type E respectively.
(4) Use under MBGR when dike is necessary for drainage control.

(3) *Type D Dike.* This 150 mm high dike provides about the same capacity as the Type A dike but has the same shape as the Type E dike. The quantity of material in the Type D dike is more than twice that of a Type E dike. It should only be used where there is a need to contain higher volumes of drainage. Compacted embankment material should be placed behind the back of dike as shown in Figure 303.3. For RRR projects that do not widen pavement, compacted embankment material may be omitted on existing fill slopes steeper than 1:3 when there is insufficient room to place the embankment material.

(4) *Type E Dike.* This 100 mm high dike provides more capacity than the Type C dike. Because Type E dike is easier to construct than Type D dike, and has greater drainage capacity than Type C dike, it is the preferred dike type for most installations. Compacted embankment material should be placed behind the back of dike as shown in Figure 303.3. For RRR projects that do not widen pavement, compacted embankment material may be omitted on existing fill slopes steeper than 1:3 where there is insufficient room to place the embankment material.

(5) *Type F Dike.* This 100 mm high dike is to be used where dike is necessary for drainage underneath a guardrail installation. This dike is placed directly under the face of metal beam guardrail installations.

303.4 Side Gutters

For information on side gutters, see Index 834.3.

303.5 Position of Curbs and Dikes

Curbs located at the edge of the traveled way may have some effect on lateral position and speed of moving vehicles, depending on the curb configuration and appearance. Curbs with low, sloped faces may encourage drivers to operate relatively close to them. Curbs with vertical faces may encourage drivers to slow down and/or shy away from them and, therefore, it may be desirable to incorporate some additional roadway width.

All dimensions to curbs (i.e., offsets) are from the near edge of traveled way to face of curb. All dimensions to dikes are from the near edge of traveled way to flow line. Curb and dike offsets should be in accordance with the following:

(1) *Through Lanes.* The offset from the edge of traveled way to the face of curb or dike flow line should be no less than the shoulder width, as set forth in Table 302.1.

(2) *Channelization.* Island curbs used to channelize intersection traffic movements should be positioned as described in Index 405.4.

(3) *Separate Turning Lanes.* Curb offsets to the right of right turn lanes in urban areas may be reduced to 0.6 m if design exception approval for nonstandard shoulder width has been obtained in accordance with Index 82.2. No curb offset is required to the left of left turn lanes in urban areas unless there is a gutter pan.

(4) *Median Openings.* Median openings (Figure 405.5) should not be separated with curb unless necessary to delineate areas occupied by traffic signal standards.

(5) *Urban Conventional Highways.* When the posted speed is less than 60 km/h, no median curb offset is required if there is no gutter pan.

(6) *Bridges and Grade Separation Structures.* When both roadbeds of a curbed divided highway are carried across a single structure, the median curbs on the structure should be in the same location as on adjacent roadways.

(7) *Approach Nose.* The approach nose of islands should also be designed utilizing a parabolic flare, as discussed in Index 405.4.

303.6 Curbs and Dikes on Frontage Roads and Streets

Continuous curbs or dikes are not necessarily required on all frontage roads. Where curbs or dikes are necessary for drainage control or other reasons, they should be consistent with the guidelines established in this topic and placed as shown on Figure 307.4. Local curb standards should be used when requested by local authorities for roads and streets that will be relinquished to them.

Topic 304 - Side Slopes

304.1 Side Slope Standards

Slopes should be designed as flat as is reasonable. The factors affecting slope design are as follows:

(a) *Safety.* Flatter slopes provide better recovery for errant vehicles that have run off the road. A cross slope of 1:6 or flatter is suggested for high speed roadways whenever it is achievable. Cross slopes of 1:10 are desirable.

Recoverable slopes are embankment (fill) slopes 1:4 or flatter. Motorists who encroach on recoverable slopes can generally stop their vehicles or slow them enough to return to the traveled way safely.

A slope which is between 1:3 and 1:4 is considered traversable, but not recoverable. Since a high percentage of vehicles will reach the toe of these slopes, the recovery area should be extended beyond the toe of slope. The AASHTO "Roadside Design Guide" should be consulted for methods of determining the preferred extent of the runout area.

Embankment slopes steeper than 1:3 are considered non-recoverable and non-traversable. For new construction, widening, or where slopes are otherwise being modified, embankment slopes should be 1:4 or flatter. District Traffic, Chapter 7 of the Traffic Manual, and the AASHTO "Roadside Design Guide" should be consulted for methods of determining the preferred treatment.

Regardless of slope steepness, it is desirable to round the top of slopes so an encroaching vehicle remains in contact with the ground. Likewise, the toe of slopes should be rounded to prevent vehicles from nosing into the ground.

(b) *Erosion Control.* Slope designs steeper than 1:4 must be approved by the District Landscape Architect in order to assure compliance with the regulations affecting Stormwater Pollution contained in the Federal Clean Water Act (see Index 82.4). Slope steepness and length are two of the most important factors affecting the erodability of a slope. Slopes should be designed as flat as possible to prevent erosion. However, since there are other factors such as soil type, climate, and exposure to the sun, District Landscape Architecture and the District Stormwater Coordinator must be contacted for erosion control requirements.

(c) *Structural Integrity.* Slopes steeper than 1:2 require approval of District Maintenance. The Geotechnical Design Report (See Topic 113) will recommend a minimum slope required to prevent slope failure due to soil cohesiveness, loading, slip planes and other global stability type failures. There are other important issues found in the Geotechnical Design Report affecting slope design such as the consistency of the soil likely to be exposed in cuts, identification of the presence of ground water, and recommendations for rock fall.

(d) *Economics.* Economic factors such as purchasing right of way, imported borrow, and environmental impacts frequently play a role in the decision of slope length and steepness. In some cases, the cost of stabilizing, planting, and maintaining steep slopes may exceed the cost of additional grading and right of way to provide a flatter slope.

(e) *Aesthetics.* Flat, smooth, well transitioned slopes are visually more satisfying than steep, obvious cuts and fills. In addition, flatter slopes are more easily revegetated, which provides for a more scenic landscape. Contact District Landscape

Architecture when preparing a contour grading plan.

In light grading where normal slopes catch in a distance less than 5.5 m from the edge of the shoulder, a uniform catch point, at least 5.5 m from the edge of the shoulder, should be used. This is done not only to improve errant vehicle recovery and aesthetics, but also to reduce grading costs. Uniform slopes wider than 5.5 m can be constructed with large production equipment thereby reducing earthwork costs.

Transition slopes should be provided between adjoining cuts and fills. Such slopes should intersect the ground at the uniform catch point line.

In areas where heavy snowfall can be expected, consideration should be given to snow removal problems and snow storage in slope design. It is considered advisable to use flatter slopes in cuts on the southerly side of the roadway where this will provide additional exposure of the pavement to the sun.

304.2 Clearance From Slope to Right of Way Line

The minimum clearance from the right of way line to catch point of a cut or fill slope should be 3 m for all types of cross sections. When feasible, at least 5 m should be provided.

Following are minimum clearances recommended for cuts higher than 10 m:

(a) 6 m for cuts from 10 m to 15 m high.

(b) 7.5 m for cuts from 15 m to 25 m high.

(c) One-third the cut height for cuts above 25 m, but not to exceed a width of 15 m.

The foregoing clearance standards should apply to all types of cross sections.

304.3 Slope Benches and Cut Widening

The necessity for benches, their width, and vertical spacing should be finalized only after an adequate materials investigation. Since greater traffic benefits are realized from widening a cut than from benching the slope, benches above grade should be used only where necessary. Benches above grade should be used for such purposes as installation of horizontal drains, control of surface erosion, or intercepting falling rocks. Design of the bench should be compatible with the geotechnical features of the site.

Benches should be at least 6 m wide and sloped to form a valley at least 0.3 m deep with the low point a minimum of 1.5 m from the toe of the upper slope. Access for maintenance equipment should be provided to the lowest bench, and if feasible to all higher benches.

In cuts over 45 m in height, with slopes steeper than 1:1.5, a bench above grade may be desirable to intercept rolling rocks. The Office of Structural Foundations should be consulted for assistance in recommending special designs to contain falling and/or rolling rocks.

Cut widening may be necessary:

(a) To provide for drainage along the toe of the slope.

(b) To intercept and store loose material resulting from slides, rock fall, and erosion.

(c) For snow storage in special cases.

(d) To allow for planting.

Where the widened area is greater than that required for the normal gutter or ditch, it should be flush with the edge of the shoulder and sloped upward or downward on a gentle slope, preferably 1:20 in areas of no snow; and downward on a 1:10 slope in snow areas.

304.4 Contour Grading and Slope Rounding

Pleasing aesthetic roadside effects can be developed with smooth flowing contours. Contour grading is an important factor in roadside design, safe vehicle recovery (see Index 304.1), erosion control, planting, and maintenance of planting and vegetation. Contour grading plans should be prepared to facilitate anticipated roadside treatment. These plans should show flattening of slopes where right of way permits.

The tops and ends of all cut slopes should be rounded where the material is other than solid rock. A layer of earth overlying a rock cut also should be rounded.

304.5 Stepped Slopes

Stepped cut slopes should be used to encourage material revegetation from the adjacent plants. Stepped slopes are a series of small benches 0.3 m to 0.6 m wide. Generally, stepped slopes can be used in rippable material on slopes 1:2 or steeper. Steps may be specified for slopes as flat as 1:3. Steps are provided to capture loose material, seed, and moisture. Topsoil should be reapplied to stepped slopes to encourage revegetation.

For appearance, steps on small cuts viewed from the roadway should be cut parallel to the road grade. Runoff is minimized on steps cut parallel to roads with grades up to 10%, as long as the natural ravel from construction is left on the steps. Steps less than one-half full should not be cleaned.

High cuts viewed from surrounding areas should be analyzed before a decision is made to form steps parallel to the roadway or horizontal. In some cases, horizontal steps may be more desirable. Special study is also necessary when a sag occurs in the vertical alignment within the cut. In all cases at the ends of cuts, the steps should wrap around the rounded transition.

The detail or contract special provisions should allow about a 20% variation, expressed in terms of millimeters. Some irregularity will improve the appearance of the slope by making it appear more natural.

In designing step width, the material's weathering characteristics should be considered. Widths over approximately 0.6 m should be avoided because of prominence and excessive time to achieve a weathered and natural appearance. Contact the Office of Structural Foundations if questions arise about the width of steps.

Topic 305 - Median Standards

305.1 Width

Median width is expressed as the dimension between inside edges of traveled way, including the inside shoulder. This width is dependent upon the type of facility, costs, topography, and right of way. Consideration may be given to the possible need to construct a wider median than prescribed in Cases (1), (2), and (3), below, in order to provide for future expansion to accommodate:

(a) Other modes of transportation.

(b) Traffic needs more than 20 years after completion of construction.

Any recommendation to provide additional median width should be identified and documented as early as possible and must be justified in a Project Study Report and/or Project Report. Attention should be given to such items as initial costs, future costs for outside widening, the likelihood of future needs for added mixed flow or High Occupancy Vehicle (HOV) lanes, traffic interruption, future mass transit needs and right of way considerations. (For instance, increasing median width may add little to the cost of a project where an entire city block must be acquired in any event.)

If additional width is justified, the minimum median widths provided below should be increased accordingly.

<u>Minimum median widths for the design year (as described below) should be used in order to accommodate the ultimate highway facility (type and number of lanes):</u>

(1) Freeways and Expressways.

(a) Urban Areas. Where HOV lanes or transit facilities are planned, the minimum median width should be 18.6 m. Where there is little or no likelihood of HOV lanes or transit facilities planned for the future, the minimum median width should 13.8 m. However, where physical and economic limitations are such that a 13.8 m median cannot be provided at reasonable cost, <u>the minimum median</u>

width for freeways and expressways in urban areas should be 10.8 m.

(b) Suburban Areas. The minimum median width for freeways and expressways in suburban areas should be 18.6 m. Suburban areas can be described as those where there is a strong possibility that the surrounding properties will be converted into urban type development during or beyond the design year. The additional median width will provide for construction of mixed flow lanes, HOV lanes, or transit facilities.

(c) Rural Areas. The minimum median width for freeways and expressways in rural areas should be 18.6 m.

(2) *Conventional Highways.* Appropriate median widths for non-controlled access highways vary widely with the type of facility being designed. In city street conditions the minimum median width for multilane conventional highways should be 3.6 m. This median width will provide room for left turn pockets at intersections, and/or the construction of two way left turn lanes. Where medians are provided for proposed future two way left turn lanes, median widths up to 4.8 m may be provided to conform with local agency standards (see Index 405.2). **In rural areas the minimum median width for multilane conventional highways shall be 3.6 m.** This provides the minimum space necessary to accommodate a median barrier and 1.5 m shoulders. Whenever possible, and where it is appropriate, this minimum width should be increased to 9.0 m or greater.

At locations where a climbing or passing lane is added to a 2-lane conventional highway, a 1.2 m median (or "soft barrier") between opposing traffic lanes should be used.

(3) *Facilities under Restrictive Conditions.* Where certain restrictive conditions, including steep mountainous terrain, extreme right of way costs, and/or significant environmental factors are encountered, the basic median widths above may not be attainable. Where such conditions exist, a narrower median, down to the limits given below, may be allowed with adequate justification. (See Index 307.5.)

(a) Freeways and Expressways. **In areas where restrictive conditions prevail the minimum median width shall be 6.6 m.**

(b) Conventional Highways. Median widths should be consistent with requirements for two way left turn lanes or the need to construct median barriers (as discussed in Index 305.1(2)), but may be reduced or eliminated entirely in extreme situations.

The above stated minimum median widths should be increased at spot locations to accommodate the construction of bridge piers or other planned highway features while maintaining standard cross section elements such as inside shoulder width and horizontal clearance. If a bridge pier is to be located in a tangent section, the additional width should be developed between adjacent horizontal curves; if it is to be located in a curve, then the additional width should be developed within the limits of the curve. Provisions should be made for piers 2 m wide or wider. Median widths in areas of multilevel interchanges or other major structures should be coordinated with the DOS.

Consideration should also be given to increasing the median width at unsignalized intersections on expressways and divided highways in order to provide a refuge area for large trucks attempting to cross the State route.

In any case, the median width should be the maximum attainable at reasonable cost based on an individual analysis of each project.

See Indexes 603.4 and 604.4 for median structural section requirements.

305.2 Median Cross Slopes

Unsurfaced medians up to 20 m wide should be sloped downward from the adjoining shoulders to form a shallow valley in the center. Cross slopes should be 1:10 or flatter; 1:20 being preferred. Slopes as steep as 1:6 are acceptable in exceptional cases when necessary for drainage, stage construction, etc. Cross slopes in medians 20 m and wider should be treated as separate roadways (Index 305.6).

Paved medians, including those bordered by curbs, should be crowned at the center, sloping towards the sides at the slope of the adjacent pavement.

305.3 Median Barriers

See Chapter 7 of the Traffic Manual.

305.4 Median Curbs

See Topic 303 for curb types and usage in medians and Index 405.5(1) for curbs in median openings.

305.5 Paved Medians

(1) Freeways.

(a) 6 or More Lanes--Medians 9.0 m wide or less should be paved.

(b) 4 Lanes--Medians 6.6 m or less in width should be paved. Medians between 6.6 m and 9.0 m wide, should be paved only if a barrier is installed. With a barrier, medians wider than 9.0 m should not normally be paved.

Where medians are paved, each half generally should be paved in the same plane as the adjacent traveled way.

(2) Nonfreeways. Unplanted curbed medians generally are to be surfaced with 50 mm of asphalt concrete.

For additional information on median cross slopes see Index 305.2.

305.6 Separate Roadways

(1) General Policy. Separate grade lines are not considered appropriate for medians less than 20 m wide (see Index 204.7).

(2) Median Design. The cross sections shown in Figure 305.6 with a 6.9 m graded area left of traffic are examples of median treatment to provide maneuvering room for out-of-control vehicles. This optional treatment may be used where extra recovery area is desired (see Index 307.6).

See Index 302.1 for shoulder widths and Index 302.2 for shoulder cross slopes.

Topic 306 - Right of Way

306.1 General Standards

The right of way widths for State highways, including frontage roads to be relinquished, should provide for all cross section elements including median, traffic lanes, outside shoulders, recovery areas, slopes, outer separations, ramps, walls, and other essential highway appurtenances. For minimum clearance from the right of way line to the catch point of a cut or fill slope, see Index 304.2. Fixed minimum widths of right of way, except for 2-lane highways, are not specified because dimensions of cross-sectional elements may require narrow widths, and right of way need not be of constant width. The minimum right of way width on new construction for 2-lane highways should be 40 m.

306.2 Right of Way Through the Public Domain

Right of way widths to be obtained or reserved for highway purposes through lands of the United States Government or the State of California are determined by laws and regulations of the agencies concerned.

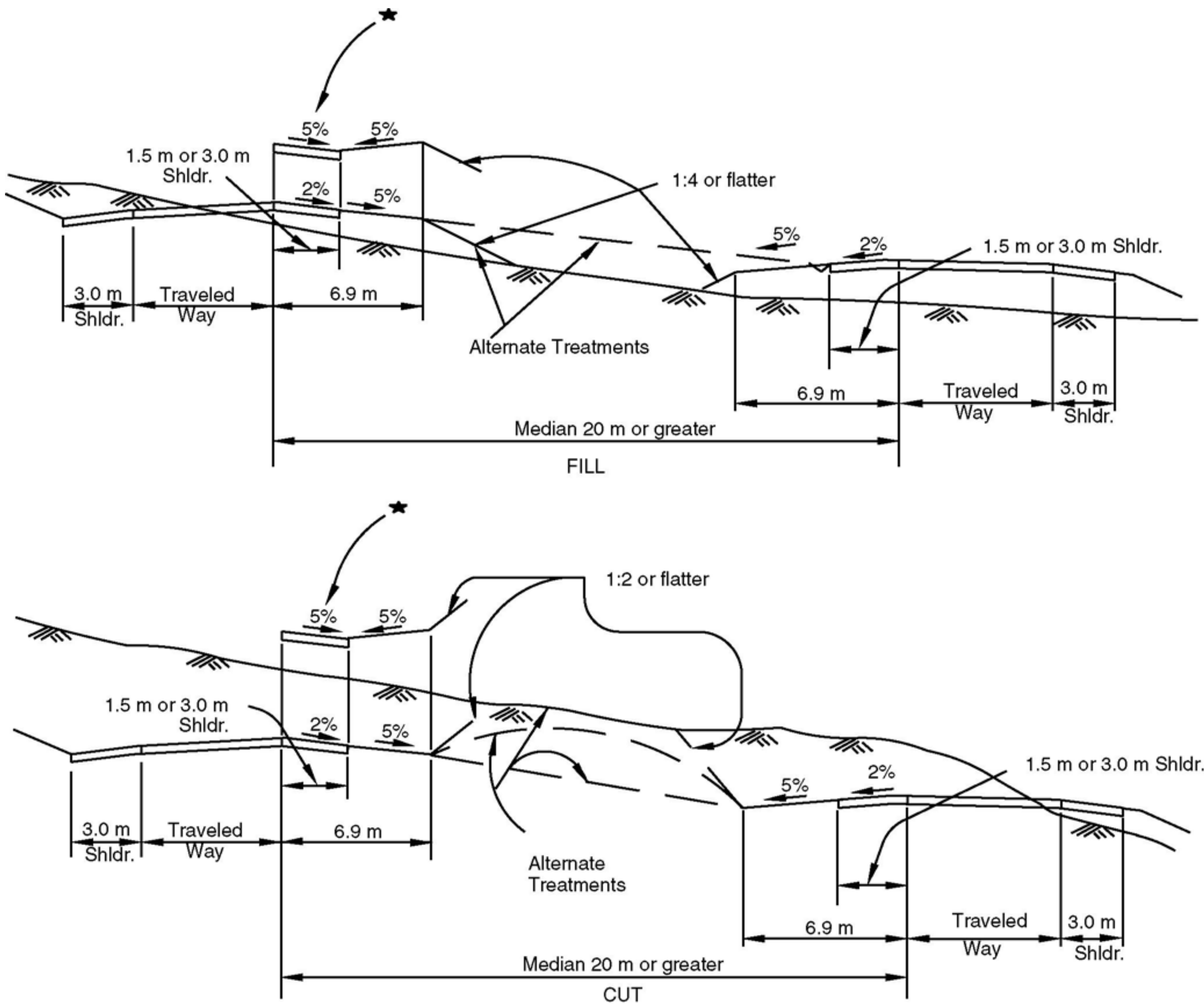
Topic 307 - Cross Sections for State Highways

307.1 Warrants

The selection of a cross section is based upon traffic, terrain, safety, and other considerations. For 2-lane roads the roadbed width is influenced by the factors discussed under Index 307.2. The roadbed width for multilane facilities should be adequate to provide capacity for the design hourly volume based upon capacity considerations discussed under Index 102.1.

Figure 305.6

Optional Median Design for Freeways with Separate Roadways



NOTES:

Left Paved Shoulder Width
- 3.0 m for 6 and 8 lanes
- 1.5 m for 4 lanes

Side Slopes
- See Index 304.1

★ Superelevated section

307.2 Two-lane Cross Sections for New Construction

These standards are to be used for highways on new alignment as well as on existing highways where the width, alignment, grade, or other geometric features are being upgraded.

A 2-lane, 2-way roadbed consists of a 7.2 m wide traveled way plus paved shoulders. **In order to provide structural support, the minimum paved width of each shoulder shall be 0.6 m.** Development and maintenance of 1.2 m paved shoulders should be considered when bicyclists are present. See Topic 1003 for information on bicycle design criteria and Figure 307.2 for typical 2-lane cross sections.

Shoulder widths based on design year traffic volumes shall conform to the standards given in Table 307.2.

On 2-lane roads with 1.2 m shoulders, the shoulder slope may be increased to 7% for additional drainage capacity where a dike is used. With 0.6 m shoulders the shoulder slope should be 2% without a dike, but may be increased to a maximum of 9% for additional drainage capacity with a dike.

Shoulder widths of 1.2 m or less should be constructed in accordance with the "All Paved Cross Section" of Figure 307.2 in order to provide essentially the same structural section throughout the full roadbed width.

Minimum width of 2-lane State highways functionally classified as collectors may be as given in Table V1-4 of "A Policy on Geometric Design of Highways and Streets", AASHTO. Up-to-date information on the functional classification of State highways may be obtained from Headquarters Office of Highway System Engineering.

Table 307.2

Shoulder Widths for Two-lane Roadbed New Construction Projects

Two-way ADT (Design Year)	Shoulder Width(1) (m)
Less than 400	0.6 or 1.2(2)
Over 400	2.4

(1) See Index 1003.2 for shoulder requirements when bike lanes are present.

(2) Bridge width is to be 9.6 m minimum (see Index 208.1).

307.3 Two-lane Cross Sections for RRR Projects

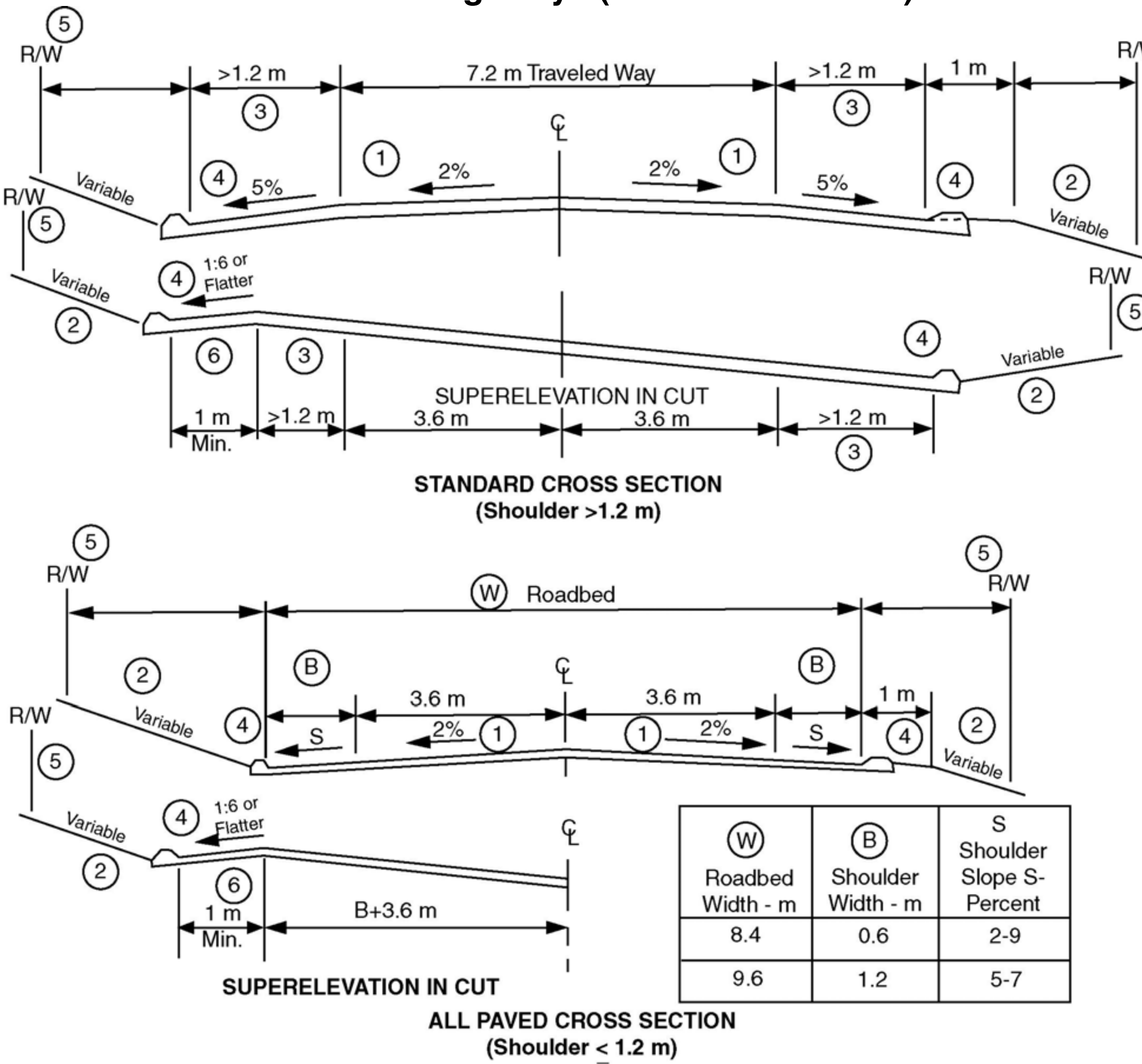
Standards and guidelines for two-lane cross sections on RRR projects are found in Design Information Bulletin Number 79-02 (DIB 79-02), "Geometric Design Criteria for Resurfacing, Restoration, and Rehabilitation (RRR) and Certain Safety, Storm Damage, Protective Betterment, and Operational Improvement Projects." DIB 79-02 can be found on the HQ Division of Design website under Design Information Bulletins at: http://www.dot.ca.gov/hq/oppd/dib/dib79-02.htm.

The purpose of RRR projects is to preserve and extend the service life of existing highways for a minimum of ten years and enhance highway safety. DIB 79-02 focuses on geometric design criteria developed for RRR projects. The designer must always emphasize implementation of cost-effective safety improvements where practical.

RRR design criteria apply to all structure and roadway RRR projects on two-lane conventional highways and three-lane conventional highways not classified as multilane conventional highways.

RRR design criteria also apply to certain storm damage, protective betterment, operational, and safety nonfreeway improvement projects that are considered spot locations as described in detail in DIB 79-02.

Figure 307.2
Geometric Cross Sections for Two-lane Highways (New Construction)



(W) Roadbed Width - m	(B) Shoulder Width - m	S Shoulder Slope S-Percent
8.4	0.6	2-9
9.6	1.2	5-7

NOTES	
(1) CROSS SLOPES	See Index 302.2
(2) SIDE SLOPES	See Index 304.1
(3) SHOULDER WIDTH	See Index 302.1
(4) DIKES	See Index 303.3
(5) RIGHT OF WAY	See Index 306.1
(6) SIDE GUTTERS	See Index 834.3(3)

RRR criteria apply to geometric design features such as lane and shoulder widths, horizontal and vertical alignment, stopping sight distance, structure width, cross slope, superelevation, side slope, clear recovery zone, and intersections. They may also apply to such features as curb ramps, pavement edge drop, dike, curb and gutter, sidewalk, and drainage.

307.4 Multilane Divided Cross Sections

The general geometric features of multilane divided cross sections are shown in Figure 307.4.

Divided highways may be designed as two separate one-way roads where appropriate to fit the terrain. Economy, pleasing appearance, and safety are factors to be considered in this determination. The alignment of each roadway may be independent of the other (see Indexes 204.8 and 305.6). Optional median designs may be as shown on Figure 305.6.

307.5 Multilane All Paved Cross Sections with Special Median Widths

A multilane cross section with a narrow median is illustrated in Figure 307.5. This section is appropriate in special circumstances where a wider median would not be justified. It should not be considered as an alternative to sections with the median widths set forth under Index 305.1. It may be used under the following conditions:

(a) Widening of existing facilities.

(b) Locations where large excavation quantities would result if a multilane roadway cross section with a basic median width were used. Examples are steep mountainous terrain and unstable mountainous areas.

(c) As an alternate cross section on 2-lane roads having frequent sight distance restrictions.

The median width should be selected in accordance with the criteria set forth in Index 305.1(3).

In general, the outside shoulder should be 2.4 m wide (3.0 m on freeways and expressways) as mandated in Table 302.1. Where large excavation quantities or other factors generate unreasonable costs, 1.2 m shoulders may be considered. However, a design exception is required except where 4-lane passing sections are constructed on 2-lane highways. Where the roadbed width does not contain 2.4 m shoulders, emergency parking areas clear of the traveled way should be provided by using daylighted cuts and other widened areas which develop during construction.

307.6 Multilane Cross Sections for RRR Projects

RRR projects on freeways, expressways, and multilane conventional highways are generally required to meet new construction standards.

For additional information, see Design Information Bulletin Number 79-02, "Geometric Design Criteria for Resurfacing, Restoration, and Rehabilitation (RRR) and Certain Safety, Storm Damage, Protective Betterment, and Operational Improvement Projects."

Topic 308 - Cross Sections for Roads Under Other Jurisdictions

308.1 City Streets and County Roads

The width of local roads and streets that are to be reconstructed as part of a freeway project should conform to AASHTO standards if the local road or street is a Federal-aid route. Otherwise the cross section should match the width of the city street or county road adjoining the reconstructed portion, or the cross section should satisfy the local agency's minimum standard for new construction.

Where a local facility within the State right of way crosses over or under a freeway or expressway but has no connection to the State facility, the minimum design standards for the cross section of the local facility within the State's right of way shall be those found in AASHTO. <u>If the local agency has standards that exceed AASHTO standards, then the local agency standards should apply.</u>

AASHTO standards for local roads and streets are given in "A Policy on Geometric Design of Highways and Streets," AASHTO.

Figure 307.4
Geometric Cross Sections for Freeways and Expressways

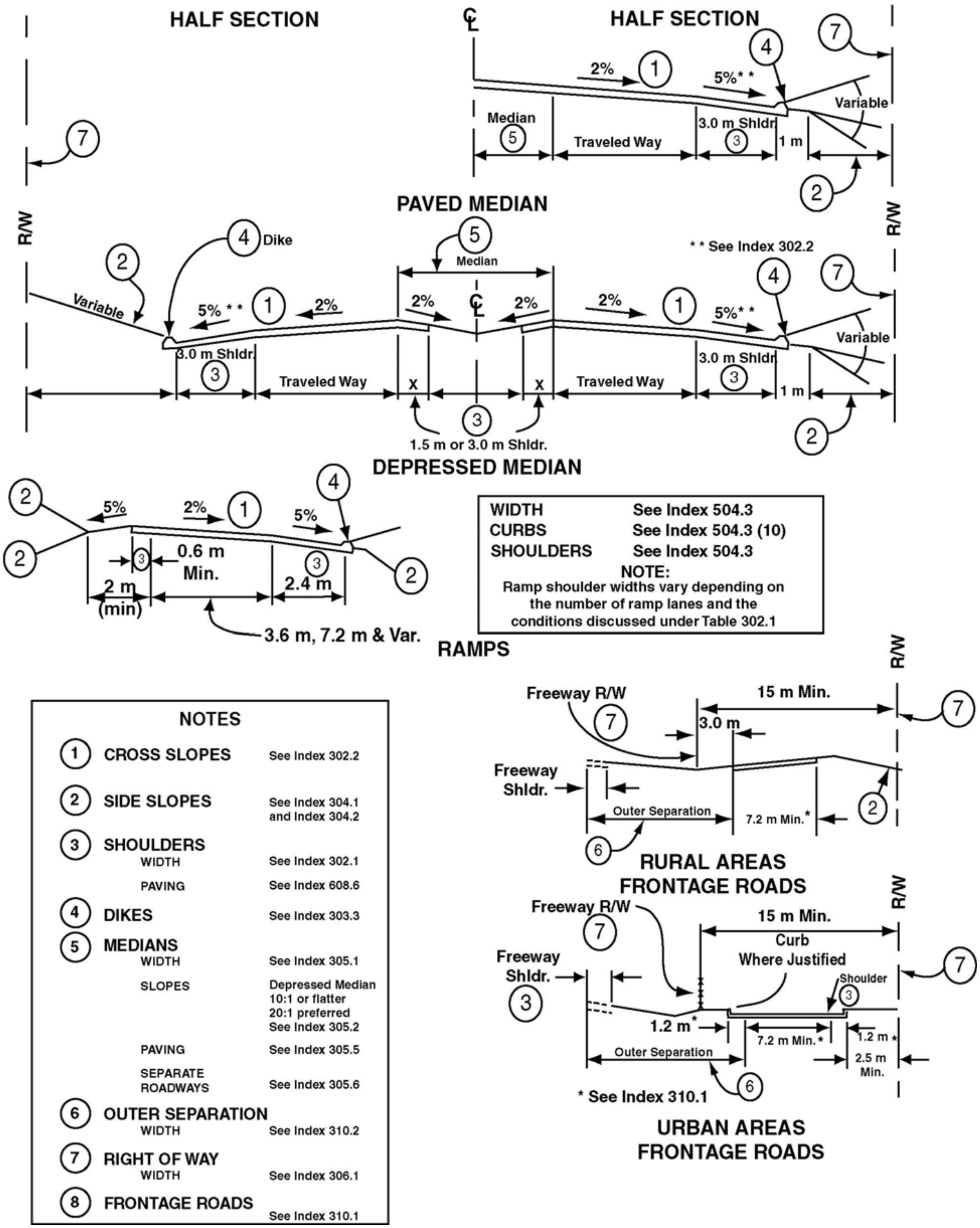
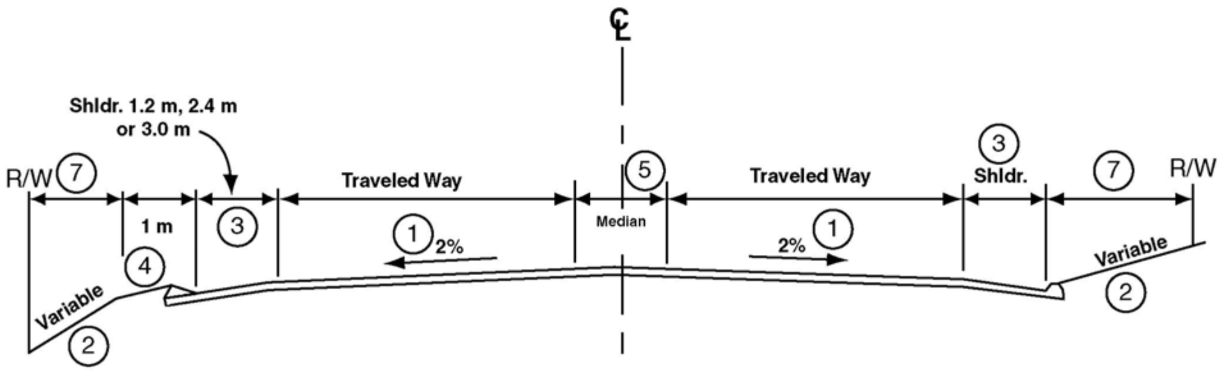
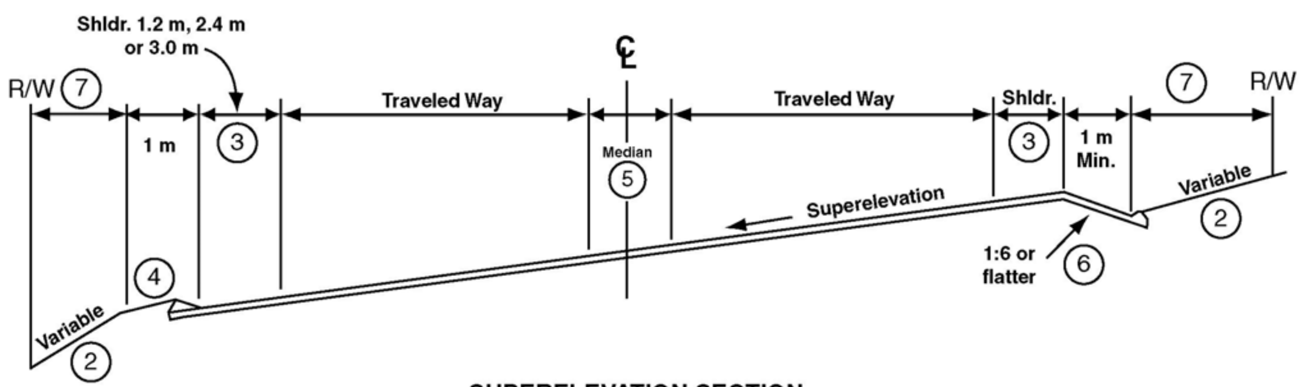


Figure 307.5
Geometric Cross Sections for All Paved Multilane Highways



TANGENT SECTION



SUPERELEVATION SECTION

NOTES

(1)	CROSS SLOPES	See Index 302.2
(2)	SIDE SLOPES	See Index 304.1
(3)	SHOULDERS	See Index 307.5
(4)	DIKES	See Index 303.3
(5)	MEDIANS	See Index 305.1 (3)
(6)	SIDE GUTTERS	See Index 834.3 (3)
(7)	RIGHT OF WAY	See Index 306.1

It is important to note that "A Policy on Geometric Design of Highways and Streets," AASHTO, standards are based on functional classification and not on a Federal-aid System.

Chapters 5, 6, and 7 of "A Policy on Geometric Design of Highways and Streets," AASHTO, 2001, list standards for the following six functional classes:

- Local rural roads
- Local urban streets
- Rural collectors
- Urban collectors
- Rural arterials
- Urban arterials

"A Policy on Geometric Design of Highways and Streets," AASHTO, gives minimum lane and shoulder widths. When selecting a cross section, the effects on capacity of commercial vehicles and grades should be considered as discussed under Topic 102 and in the "Highway Capacity Manual," 2000.

The minimum width of 2-lane overcrossing structures shall not be less than 8.4 m curb to curb. Also see Index 208.1(2) and Index 307.3.

If the local agency has definite plans to widen the local street either concurrently or within 5 years following freeway construction, the reconstruction to be accomplished by the State should generally conform to the widening planned by the local agency. Stage construction should be considered where the planned widening will occur beyond the 5-year period following freeway construction or where the local agency has a master plan indicating an ultimate width greater than the existing facility. Where an undercrossing is involved, the initial structure construction should provide for ultimate requirements.

Where a local facility crosses over or under a freeway or expressway and connects to the State facility (such as ramp terminal intersections), the minimum design standards for the cross section of the local facility shall be at least equal to those for a conventional highway with the exception that the outside shoulder width shall match the approach roadway, but not less than 1.2 m (shoulder width should not be less than 1.5 m where curbs with 600 mm gutter pans are proposed and bicycle use is expected). **The minimum width for two-lane overcrossings at interchanges shall be 12.0 m curb-to-curb.**

Topic 309 - Clearances

309.1 Horizontal Clearances

(1) *General.* The horizontal clearance to all fixed roadside objects including bridge piers, abutments, retaining walls, and noise barriers should be based on engineering judgment with the objective of maximizing the distance between fixed objects and the edge of traveled way. Engineering judgment should be exercised in order to balance the achievement of horizontal clearance objectives with the prudent expenditure of available funds.

Certain yielding objects, such as sand filled barrels, metal beam guard rail, breakaway wood posts, etc. may encroach within the clear recovery zone (see Index 309.1(2)). While these objects are designed to reduce the severity of accidents, efforts should be made to maximize the distance between any object and the edge of traveled way.

Clearances are measured from the edge of the traveled way to the nearest point on the obstruction (usually the bottom). **Horizontal clearances greater than those cited below under subsection (3) - "Minimum Clearances" shall be provided where necessary to meet horizontal stopping sight distance requirements to median barriers, bridge rails, bridge columns, retaining walls, cut slopes, and noise barriers.** See discussion on ".. technical reductions in design speed .." under Topic 101.

(2) *Clear Recovery Zone (CRZ).* The roadside environment can and should be made as safe as practical. A clear recovery zone is an unobstructed, relatively flat (1:4 or flatter) or gently sloping area beyond the edge of the traveled way which affords the drivers of errant vehicles the opportunity to regain

control. The AASHTO "Roadside Design Guide" provides detailed design guidance for creating a forgiving roadside environment. See also Index 304.1 regarding side slopes and Chapter 7 of the Traffic Manual.

The following clear recovery zone widths are the minimum desirable for the type of facility indicated. Consideration should be given to increasing these widths based on traffic volumes, operating speeds, terrain, and costs associated with a particular highway facility:

- Freeways and Expressways - 9 m
- Conventional Highways (no curbs) - 6 m
- Conventional Highways (with curbs)* - 0.5 m

* This clear zone is measured from the face of curb to the obstruction.

<u>Fixed objects closer to the edge of traveled way than the distances listed above should be eliminated, moved, redesigned to be made yielding, or shielded in accordance with the following guidelines:</u>

(a) Fixed objects should be eliminated or moved outside the clear recovery zone to a location where they are unlikely to be hit.

(b) If sign posts 150 mm or more in any dimension or light standards cannot be eliminated or moved outside the clear recovery zone, they should be made yielding with a breakaway feature.

(c) If a fixed object cannot be eliminated, moved outside the clear recovery zone, or modified to be made yielding, it should be shielded by guardrail or a crash cushion.

Shielding must be in conformance with the guidance found in Chapter 7 of the Traffic Manual. For input on the need for shielding at a specific location, consult District Traffic.

When the planting of trees is being considered, see the additional discussion and standards in Chapter 900.

Where compliance with the above stated clear recovery zone guidelines is impractical, the minimum horizontal clearance cited below shall apply to the unshielded fixed object.

(3) *Minimum Clearances.* **The following minimum horizontal clearances shall apply to fixed objects that are closer to the edge of traveled way than the clear recovery zone distances listed above:**

(a) **The minimum horizontal clearance to fixed objects, such as bridge rails and safety-shaped concrete barriers, on all freeway and expressway facilities, including auxiliary lanes, ramps, and collector roads, shall be equal to the standard shoulder width of the highway facility as stated in Table 302.1. A minimum clearance of 1.2 m shall be provided where the standard shoulder width is less than 1.2 m.** Approach rail connections to bridge rail may require special treatment to maintain the standard shoulder width.

(b) **The minimum horizontal clearance to walls, such as abutment walls, retaining walls in cut locations, and noise barriers on all freeway and expressway facilities, including auxiliary lanes, ramps and collector roads, shall not be less than 3.0 m.**

(c) **On two-lane highways, frontage roads, city streets and county roads (all without curbs), the minimum horizontal clearance shall be the standard shoulder width as listed in Tables 302.1 and 307.2, except that a minimum clearance of 1.2 m shall be provided where the standard shoulder width is less than 1.2 m.** For RRR projects, widths are shown in Table 307.3.

On curbed highway sections, a minimum clearance of 1 m should be provided along the curb returns of intersections and near the edges of driveways to allow for design vehicle offtracking (see Topic 404). Where sidewalks are located immediately adjacent to curbs, fixed objects should be located beyond the back of sidewalk to provide an unobstructed area for pedestrians.

In areas without curbs, safety shaped barrier face should be constructed integrally at the base of any retaining, pier, or abutment wall which faces traffic and is 4.5 m or less from the edge of traveled way (right or left of traffic and measured from the face of wall). See Index 1102.2 for the treatment of noise barriers.

The minimum width of roadway openings between temporary K-rail on bridge deck widening projects should be obtained from the District Permit Engineer. The Regional Permit Manager should be consulted on the use of the route by overwidth loads.

See Chapter 7 of the Traffic Manual for other requirements pertaining to clear recovery zone, guardrail at fixed objects and embankments, and crash cushions.

309.2 Vertical Clearances

(1) *Major Structures.*

(a) Freeways and Expressways, All construction except overlay projects -- **5.1 m shall be the minimum vertical clearance over the roadbed of the State facility (e.g., main lanes, shoulders, ramps, collector-distributor roads, speed change lanes, etc.).**

(b) Freeways and Expressways, Overlay Projects -- **4.9 m shall be the minimum vertical clearance over the roadbed of the State facility.**

(c) Conventional Highways, Parkways, and Local Facilities, All Projects -- **4.6 m shall be the minimum vertical clearance over the traveled way and 4.5 m shall be the minimum vertical clearance over the shoulders of all portions of the roadbed.**

(2) *Minor Structures.* **Pedestrian over-crossings shall have a minimum vertical clearance 0.5 m greater than the standard for major structures for the State facility in question.**

Sign structures shall have a vertical clearance of 5.5 m over the roadbed of the State facility.

(3) *Rural Interstates and Single Routing in Urban Areas:* This subset of the Interstate System is composed of all rural Interstates and a single routing in urban areas, and is a modification to what has previously been referred to as the 42 000 km Priority Network. Those routes described in Table 309.2B and Figure 309.2 are given special attention in regards to minimum vertical clearance as a result of agreements between the FHWA and the Department of Defense. **Vertical clearance for structures on this system shall meet the standards listed above for freeways and expressways.** In addition to the standards listed above, vertical clearances of less than 4.9 m over any portion of this system will be subjected to extensive review by FHWA and must be approved by the Military Traffic Management Command Traffic Engineering Agency (MTMCTEA) in Washington D. C. Documentation in the form of a Design Exception Fact Sheet must be submitted to FHWA to obtain approval for less than 4.9 m of vertical clearance. Vertical clearances of less than 4.9 m over any Interstate will require FHWA/MTMCTE notification. See Robert L. Buckley's memo dated March 30, 2000 to District Directors for more information on this subset of the Interstate system.

(4) *General Information.* The standards listed above and summarized in Table 309.2A are the minimum allowable on the State Highway system for the facility and project type listed. For the purposes of these vertical clearance standards, all projects on the freeway and expressway system other than overlay projects shall be considered to be covered by the "new construction" standard.

Table 309.2A
Vertical Clearances

	Traveled Way	Shoulder
Freeways and Expressways, New Construction, Lane Additions, Reconstruction and Modification	5.1 m	5.1 m
Freeways and Expressways, Overlay Projects	4.9 m	4.9 m
All Projects on Conventional Highways and Local Facilities	4.6 m	4.5 m
Sign Structures	5.5 m	5.5 m
Pedestrian and Minor Structures	Standard + 0.5 m See 309.2(2)	
Structures on the Rural and Single Interstate Routing System	See 309.2(3)	

Figure 309.2
Department of Defense
Rural and Single Interstate Routes

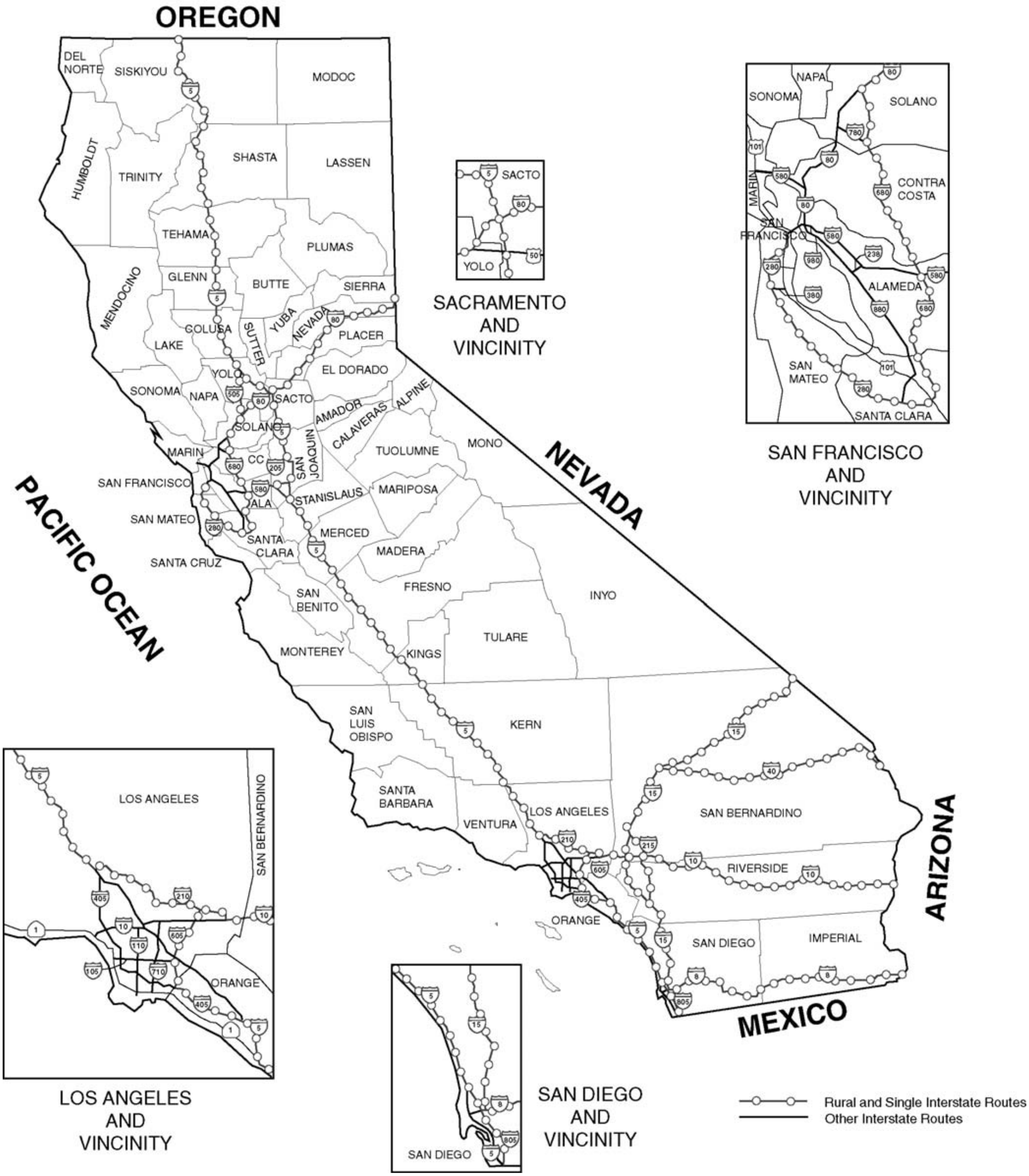


Table 309.2B
California Routes on the Rural and Single Interstate Routing System

ROUTE	FROM	TO
I-5	U. S. Border	I-805 just N. of U. S. Border
I-5	I-805 N. of San Diego	I-405 near El Toro
I-5	I-210 N. of Los Angeles	Oregon State Line
I-8	I-805 near San Diego	Arizona State Line
I-10	I-210 near Pomona	Arizona State Line
I-15	I-8 near San Diego	Nevada State Line
I-40	Junction at I-15 near Barstow	Arizona State Line
I-80	I-680 near Cordelia	Nevada State Line
I-205	Junction at I-580	Junction at I-5
I-210	I-5 N. of Los Angeles	I-10 near Pomona
I-215	I-15 near Temecula	I-15 near Devore
I-280	Junction at I-680 in San Jose	At or near south city limits of San Francisco to provide access to Hunter's Point
I-405	I-5 near El Toro	Palo Verde Avenue just N. of I-605
I-505	Junction at I-80	Junction at I-5
I-580	I-680 near Dublin	Junction at I-5
I-605	I-405 near Seal Beach	I-210
I-680	Junction at I-280 in San Jose	I-80 near Cordelia
I-805	I-5 just N. of U. S. Border	I-5 N. of San Diego

When approved by a design exception (see HDM Index 82.2) clearances less than the values given above may be allowed on a case by case basis given adequate justification based upon engineering judgment, economic, environmental or right of way considerations. Typical instances where lesser values may be approved are where the structure is protected by existing lower structures on either side or where a project includes an existing structure that would not be feasible to modify to the current standard. In no case should vertical clearance be reduced below 4.6 m over the traveled way or 4.5 m over the shoulders over any portion of a State highway facility.

Efforts should be made to avoid decreasing the existing vertical clearance whenever possible and consideration should be given to the feasibility of increasing vertical clearance on projects involving structural section removal and replacement. Any project that would reduce vertical clearances below 5.1 m or lead to an increase in the vertical clearance should be brought to the attention of the Project Development Coordinator, the District Permit Engineer and the Regional Permit Manager at the earliest possible date.

The Regional Permit Manager should be informed of any changes (temporary or permanent) in vertical clearance.

(5) *Federal Aid Participation.* Federal-aid participation is normally limited to the following maximum vertical clearances unless there are external controls such as the need to provide for falsework clearance or the vertical clearance is controlled by an adjacent structure in a multi-structure interchange:

(a) Highway Facilities.

- 5.3 m over freeways and expressways.
- 4.8 m over other highways (4.7 m over shoulders).
- For pedestrian structures, 0.7 m greater than the above values.

(b) Railroad Facilities.

- 7.1 m over the top of rails for non-electrified rail systems.
- 7.4 m over the top of rails for existing or proposed 25 kv electrification.
- 8.0 m over the top of rails for existing or proposed 50 kv electrification.

These clearances include an allowance for future ballasting of the rail facility. The cost of reconstructing or modifying any existing railroad-highway grade separation structure solely to accommodate electrification will not be eligible for Federal-aid highway fund participation. Where a rail system is not currently electrified, the railroad must have a plan adopted which specifies the intent to electrify the subject rail segment within a reasonable time frame in order to provide clearances in excess of 7.1 m.

Any exceptions to the clearances listed above should be reviewed with the FHWA early in the design phase to ensure that they will participate in the structure costs. All excess clearances should be documented in the project files as to reasons and appropriate concurrences.

309.3 Tunnel Clearances

(1) *Horizontal Clearances.* Tunnel construction is so infrequent and costly that the width should be considered on an individual basis. For the minimum width standards for freeway tunnels see Index 309.1.

Normally, the minimum horizontal clearance on freeways should include the full roadbed width of the approaches.

In one-way tunnels on conventional highways the minimum side clearance from the edge of the traveled way shall be 1.5 m on the left and 2.0 m on the right. For two-way tunnels, this clearance shall be 2.0 m on each side.

(2) *Vertical Clearances.* **The minimum vertical clearance shall be 4.6 m measured at any point over the traveled way and 4.5 m above the gutter at the curb line. On**

freeways and expressways, the vertical clearance listed in Index 309.2(1)(a) shall be used. Cost weighed against the probability of over-height vehicles will be the determining factors.

309.4 Lateral Clearance for Elevated Structures

Adequate clearance must be provided for maintenance, repair, construction, or reconstruction of adjacent buildings and of the structure; to avoid damage to the structure from a building fire or to buildings from a vehicle fire; to permit operation of equipment for fire fighting and other emergency teams. **The minimum horizontal clearance between elevated highway structures, such as freeway viaducts and ramps, and adjoining buildings or other structures, shall be 4.6 m for single-deck structures and 6.1 m for double-deck structures. Spot encroachments on this clearance shall be approved in accordance with Index 82.2.**

309.5 Structures Across or Adjacent to Railroads

Regulations governing clearances on railroads and street railroads with reference to side and overhead structures, parallel tracks, crossings of public roads, highways, and streets are established by the PUC.

(1) *Normal Horizontal and Vertical Clearances.* Although General Order No. 26-D specifies a minimum vertical clearance of 6.86 m above tracks on which freight cars not exceeding a height of 4.72 m are transported, a minimum of 7.01 m should be used in design to allow for reballasting and normal maintenance of track. Railroads on which freight cars are not operated, should have a minimum vertical clearance of 5.79 m. In establishing the grade line, the District should consult the DES to obtain the depth of structures and false work requirements, if any (see Index 204.6(4)).

At underpasses, General Order No. 26-D establishes a minimum vertical clearance of 4.27 m above any public road, highway or street. **However, the greater clearances specified under Index 309.2 shall be used.**

All curbs, including median curbs, should be designed with 3.05 m of clearance from the track centerline measured normal thereto.

The principal clearances which affect the design of highway structures and curbs are summarized in Tables 309.5A and B. It should be noted that collision walls may be required for the clearances given in Columns (3) and (4) of Table 309.5B. Usually, no collision walls are required if the clearance 3.05 m or more on tangent track and 3.35 m or more on curved track.

Table 309.5A
Minimum Vertical Clearances Above Highest Rail

Type of Structure	Type of Operation	
	Normal Freight	No Freight Cars Operated
Highway overhead and other structures including through railroad bridges.	7.01 m	5.79 m

(2) *Off-track Maintenance Clearance.* The 5.49 m horizontal clearance is intended for sections of railroad where the railroad company is using or definitely plans to use off-track maintenance equipment. This clearance is provided on one side of the railroad right of way.

On Federal-aid projects, where site conditions are such that off-track maintenance clearance at an overpass is obtained at additional cost, Federal-aid funds may participate in the costs of such overhead designs that provide up to 5.49 m horizontal clearance on one side of the track. In such cases, the railroad is required to present a statement that off-track maintenance equipment is being used, or is definitely planned to be used, along that section of the railroad right of way crossed by the overhead structure.

Table 309.5B

Minimum Horizontal Clearances to Centerline of Nearest Track

Type of Structure	Off-track Maintenance Clearance	Tangent Track Clearance	Normal Curved Track(1) Clearance	Curved Track Clearances When Space is Limited(1)	
				Curves of 0° to 12°	Curves of 12° or more
Through railroad bridge	None	2.44 m(2)(4)	2.74 m(2)(4)		
Highway overhead and other structures	5.49 m clear to face of pier or abutment on side railroad requires for equipment road.	2.59 m(4)	2.90 m(4)	2.59 m (Min.)(3)	2.59 m + 0.013 m(3) per degree of curve.
Curbs		3.05 m			

(1) The minimum, in general, is 0.30 m greater than for tangent track.

(2) With approval of P.U.C.

(3) Greater clearance necessary if walkway is required.

(4) Collision walls may be required. See Index 309.5(1).

(3) *Walkway Clearances Adjacent to Railroads.* All plans involving construction adjacent to railroads should be such that there is no encroachment on the walkway adjoining the track. Walkway requirements are set forth in General Order No. 118 of the PUC. Where excavations encroach into walkway areas, the contractor is required to construct a temporary walkway with handrail as set forth in the contract special provisions.

(4) *Approval.* All plans involving clearances from a railroad track must be submitted to the railroad for approval as to railroad interests. Such clearances are also subject to approval by the PUC.

To avoid delays, early consideration must be given to railroad problems when design is started on a project.

Topic 310 - Frontage Roads

310.1 Cross Section

Frontage roads are normally relinquished to local agencies. When Caltrans and a county or city enter into an agreement (cooperative agreement, freeway agreement, or other type of binding agreement), the CTC may relinquish to the county or city any frontage or service road or outer highway within that city or county. The relinquished right of way (called a collateral facility) should be at least 12.2 m wide and have been constructed as part of a State highway project, but not as a part of the main State highway. Index 308.1 gives width criteria for city streets and county roads. These widths are also applicable to frontage roads. **However, the minimum paved cross section for urban frontage roads shall be two 3.6 m lanes with 1.2 m outside shoulders.** (See Chapter 1000 for shoulder requirements when bicycles are present.) **The minimum paved cross section for rural frontage roads shall be 7.2 m.**

310.2 Outer Separation

In urban areas and in mountainous terrain, the width of the outer separation should be a minimum of 8 m from edge of traveled way to edge of traveled way. A greater width may be used where it is obtainable at reasonable additional cost, for example, on an urban highway centered on a city block and paralleling the street grid.

In rural areas, other than mountainous terrain, the outer separation should be a minimum of 12 m wide from edge of traveled way to edge of traveled way.

See Figure 307.4 for cross sections of outer separation and frontage road.

310.3 Headlight Glare

Care should be taken in design of new frontage roads to avoid the potential for headlight glare interfering with the vision of motorists traveling in opposite directions on the frontage roads and in the outer freeway lanes. The preferred measures to prevent headlight glare interference on new construction are wider outer separations, revised alignment and raised or lowered profiles.

CHAPTER 400
INTERSECTIONS AT GRADE

Topic 401 - Factors Affecting Design

Index 401.1 - General

At-grade intersections must handle a variety of conflicts among vehicles, pedestrians, and bicycles. These recurring conflicts, a unique characteristic of intersections, play a major role in the preparation of design standards and guidelines. Arriving, departing, merging, turning, and crossing paths of moving traffic have to be accommodated within a relatively small area.

401.2 The Driver

The assumption of certain driver skills is a factor in intersection design. A driver's perception and reaction time set the standards for sight distance and length of transitions.

401.3 The Vehicle

Size and maneuverability of vehicles are factors that influence the design of an intersection.

Table 401.3 compares vehicle characteristics to intersection design elements.

A design vehicle is a convenient means of representing a particular segment of the vehicle population. See Topic 404 for a further discussion of the uses of design vehicles.

401.4 The Environment

In highly developed urban areas, street parking, pedestrians, and transit buses add to the complexity of a busy intersection.

Industrial development may require special attention to the movement of large trucks.

Residential areas may have school children and bicycles to accommodate (see Indexes 105.1 and 1003.2).

Table 401.3

Vehicle Characteristics	Intersection Design Element Affected
Length	Length of storage lane
Width	Lane width
Height	Clearance to overhead signs and signals
Wheel base	Corner radius and width of turning lanes
Acceleration	Tapers and length of acceleration lane
Deceleration	Tapers and length of deceleration lane

Rural intersections in farm areas with low traffic volumes may have special visibility problems or require shadowing of left-turn vehicles from high speed approach traffic.

401.5 The Pedestrian

Pedestrian considerations are an integral part of intersection design because of their potential conflict with motor vehicles. Such factors include pedestrian volumes, their age and physical abilities, etc. Geometric features which may affect the pedestrian should be taken into account. See Topic 105 Pedestrian Facilities and Chapters 6 and 10 of the Traffic Manual.

401.6 The Bicyclist

The presence of bicyclists on State routes should be considered early in design. Chapter 1000 gives information on bikeway planning and design criteria.

Topic 402 - Operational Features Affecting Design

402.1 Capacity

Adequate capacity to handle peak period traffic demands is a basic goal of intersection design.

(1) *Unsignalized Intersections.* Chapter 10 of the "Highway Capacity Manual", gives methodology for capacity analysis of unsignalized intersections controlled by stop or yield signs. The assumption is made that major street traffic is not affected by the minor street movement. Unsignalized intersections generally become candidates for signalization when traffic backups begin to develop on the cross street. See Chapter 9 of the Traffic Manual for signal warrants.

(2) *Signalized Intersections.* See Topic 406 for analysis of simple signalized intersections, including ramps. The analysis of complex signalized intersections should be referred to the District Traffic Branch.

402.2 Accidents

(1) *General.* Intersections have a higher potential for conflicts compared to other sections of the highway. At an intersection continuity of travel is interrupted, traffic streams cross, and many types of turning movements occur.

The type of traffic control affects the type of accidents. Signalized intersections tend to have more rear enders and same-direction sideswipes than stop-controlled intersections. The latter tend to have more angle or crossing accidents due to a lack of positive control.

(2) *Undesirable Geometric Features.*

- Inadequate approach sight distance.
- Inadequate corner sight distance.
- Steep grades.
- Inappropriate traffic control.
- Five or more approaches.
- Presence of curves within intersections.

Topic 403 - Principles of Channelization

403.1 Preference to Major Movements

The provision of direct free-flowing high-standard alignment to give preference to major movements is good channelization practice. This may require some degree of control of the minor movements such as stopping, funneling, or even eliminating them. These controlling measures should conform to natural paths of movement and should be introduced gradually to promote smooth and efficient operation.

403.2 Areas of Conflict

Large multilane undivided intersectional areas are usually undesirable. The hazards of conflicting movements are magnified when drivers and bicyclists are unable to anticipate movements of other traffic within these areas. Channelization reduces areas of conflict by separating or regulating traffic movements into definite paths of travel by the use of pavement markings or traffic islands.

Large areas of intersectional conflicts are characteristic of skewed intersection angles. Therefore, angles of intersection approaching 90° will aid in reducing conflict areas.

403.3 Angle of Intersection

A right angle intersection provides the most favorable conditions for intersecting and turning traffic movements. Specifically, a right angle (90 degrees) provides:

- The shortest crossing distance for motor vehicles, bicycles, and pedestrians.
- Sight lines which optimize corner sight distance and the abilitiy of drivers to judge the relative position and speed of approach vehicles.

Minor deviations from right angles are generally acceptable provided that the potentially detrimental impact on visibility and turning movements for large trucks (see Topic 404) can be mitigated. However, large deviations from right angles may decrease visibility, hamper certain turning operations, and will increase the size of the intersection and therefore crossing distances for bicyclists and pedestrians. When a right angle cannot be provided due to physical constraints, the interior angle should be designed as close to 90 degrees as is practical, but should not be less than 75 degrees. Mitigation should be considered for the affected intersection design features. (See Figure 403.3). A 75 degree angle does not unreasonably increase the crossing distance or generally decrease visibility.

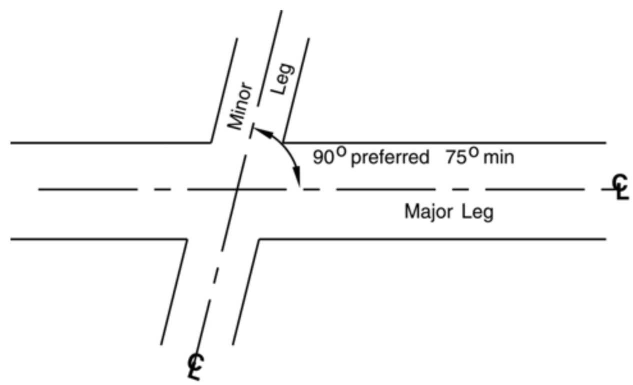
When existing intersection angles are less than 75 degrees, the following retrofit improvement strategies should be considered:

- Realign the subordinate intersection legs if the new alignment and intersection location(s) can be designed without introducing new geometric or operational deficiencies.
- Provide acceleration lanes for difficult turning movements due to radius or limited visibility.
- Restrict problematic turning movements; e.g. for minor road left turns with potentially limited visibility.

For additional guidance on the above and other improvement strategies, consult the Design Reviewer or Traffic Liaison.

Particular attention should be given to skewed angles on curved alignment with regards to sight distance and visibility. Crossroads skewed to the left have more restricted visibility for drivers of vans and trucks than crossroads skewed to the right. In addition, severely skewed intersection angles, coupled with steep downgrades (generally over 4%) can increase the potential for high centered vehicles to overturn where the vehicle is on a downgrade and must make a turn greater than 90 degrees onto a crossroad. These factors should be considered in the design of skewed intersections.

Figure 403.3
Angle of Intersection
(Minor Leg Skewed to the Right)



403.4 Points of Conflict

Channelization separates and clearly defines points of conflict within the intersection. Drivers should be exposed to only one conflict or confronted with one decision at a time.

403.5 Speed-change Areas

Speed-change areas for vehicles entering or leaving main streams of traffic are beneficial to the safety and efficiency of an intersection. Entering traffic merges most efficiently with through traffic when the merging angle is less than 15 degrees and when speed differentials are at a minimum.

Speed-change areas for diverging traffic should provide adequate length clear of the through lanes to permit vehicles to decelerate after leaving the through lanes.

403.6 Turning Traffic

A separate turning lane removes turning movements from the intersection area. Abrupt changes in alignment or sight distance should be avoided, particularly where traffic turns into a separate turning lane from a high-standard through facility.

403.7 Refuge Areas

The shadowing effect of traffic islands may be used to provide refuge areas for turning and crossing vehicles. Adequate shadowing provides refuge for a vehicle waiting to cross or enter an uncontrolled traffic stream. Similarly, channelization also may provide a safer crossing of two or more traffic streams by permitting drivers to select a time gap in one traffic stream at a time.

Traffic islands also may serve the same purposes for pedestrians and disabled persons.

403.8 Prohibited Turns

Traffic islands may be used to divert traffic streams in desired directions and prevent undesirable movements. Care should be taken that islands used for this purpose accommodate convenient and safe pedestrian crossings, drainage, and striping options. See Topic 303.

403.9 Effective Signal Control

At intersections with complex turning movements, channelization is required for effective signal control. Channelization permits the sorting of approaching traffic which may move through the intersection during separate signal phases. This requirement is of particular importance when traffic-actuated signal controls are employed.

403.10 Installation of Traffic Control Devices

Channelization may provide locations for the installation of essential traffic control devices, such as stop and directional signs. See Index 405.4 for information about the design of traffic islands.

403.11 Summary

- Give preference to the major move(s).
- Reduce areas of conflict.
- Cross traffic at right angles or skew no more than 75 degrees. (90 degrees preferred.)
- Separate points of conflict.
- Provide speed-change areas and separate turning lanes where appropriate.
- Provide adequate width to shadow turning traffic.
- Restrict undesirable moves with traffic islands.
- Coordinate channelization with effective signal control.
- Install signs in traffic islands when necessary, but avoid built-in hazards.

403.12 Precautions

- Striping is usually preferable to curbed islands, especially adjacent to high-speed traffic where curbing can be an obstruction to out-of-control vehicles.
- Where curbing must be used, first consideration should be given to mountable curbs. Barrier curbs are usually justified only where protection of pedestrians is a primary consideration.
- Avoid complex intersections that present multiple choices of movement to the driver.
- Traffic safety should be considered. Accident records provide a valuable guide to the type of channelization needed.

Topic 404 - Design Vehicles

404.1 Offtracking

Any vehicle whether car, bus, truck, or combination tractor semi-trailer while turning a curve covers a wider path than the width of the vehicle. The front steering axle can generally follow a circular curve, but the following axles (and trailers) will swing inside toward the center of the curve. Some terminology is vital to understanding the engineering concepts. *Tracking width* is the distance measured along the curve radius from the outside front steering tire track to the inside rear tire track as they traverse around a curve. *Offtracking* is the difference between the tracking width and the vehicle axle width. *Swept width* is the total path width needed by the vehicle body to traverse a curve. Swept width always exceeds tracking width. Therefore a swept width is the preferred vehicle performance reference for design of tight curves on narrow mountainous roads and tight intersections with obstructions.

Table 405.1A
Corner Sight Distance
(7-1/2 Second Criteria)

Design Speed (km/h)	Corner Sight Distance (m)
40	90
50	110
60	130
70	150
80	170
90	190
100	210
110	230

Table 405.1B
Application of Sight Distance Requirements

Intersection Types	Sight Distance		
	Stopping	Corner	Decision
Private Roads	X	X(1)	
Public Streets and Roads	X	X	
Signalized Intersections	X	(2)	
State Route Intersections & Route Direction Changes, with or without Signals	X	X	X

(1) Using stopping sight distance between an eye height of 1070 mm and an object height of 1300 mm. See Index 405.1(2)(a) for setback requirements.

(2) Apply corner sight distance requirements at signalized intersections whenever possible due to unanticipated violations of the signals or malfunctions of the signals. See Index 405.1(2)(b).

405.2 Left-turn Channelization

(1) General. The purpose of a left-turn lane is to expedite the movement of through traffic, control the movement of turning traffic, increase the capacity of the intersection, and improve safety characteristics.

The District Traffic Branch normally establishes the need for left-turn lanes. See "Guidelines for Reconstruction of Intersections," August 1985, published by the California Division of Transportation Operations.

(2) Design Elements.

(a) Lane Width -- **The lane width for both single and double left-turn lanes on State highways shall be 3.6 m.** Under certain circumstances (listed below), left-turn lane widths of 3.3 m or as narrow as 3.0 m may be used on RRR or other projects on existing State highways and on roads or streets under other jurisdictions when supported by an approved design exception pursuant to Index 82.2. When considering lane width reductions adjacent to curbed medians, refer to Index 303.5 for guidance on effective roadway width; which may vary depending on drivers' lateral positioning and shy distance from raised curbs.

- On high speed rural highways or moderate speed suburban highways where width is restricted, the minimum width of single or dual left-turn lanes may be reduced to 3.3 m.
- In severely constrained situations on low to moderate speed urban highways where large trucks are not expected, the minimum width of single left-turn lanes may be reduced to 3.0 m. When double left-turn lanes are warranted under these same circumstances the width of each lane shall be no less than 3.3 m. This added width is needed to assure adequate clearance between turning vehicles.

(b) Approach Taper -- On a conventional highway without a median, an approach taper provides space for a left-turn lane by moving traffic laterally to the right. The approach taper is unnecessary where a median is available for the full width of the left-turn lane. Length of the approach taper is given by the formula on Figures 405.2A, B and C.

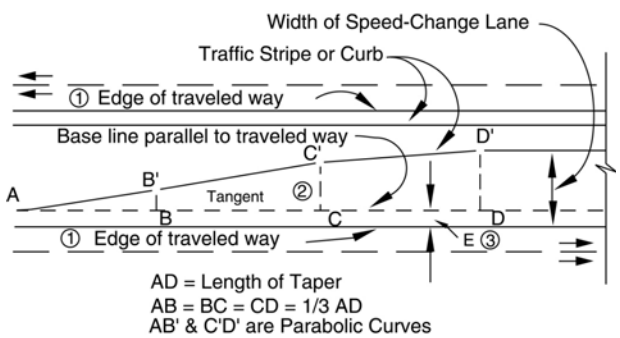
Figure 405.2A shows a standard left-turn channelization design in which all widening is to the right of approaching traffic and the deceleration lane (see below) begins at the end of the approach taper. This design should be used in all situations where space is available, usually in rural and semi-rural areas or in urban areas with high traffic speeds and/or volumes.

Figures 405.2B and 405.2C show alternate designs foreshortened with the deceleration lane beginning at the 2/3 point of the approach taper so that part of the deceleration takes place in the through traffic lane. Figure 405.2C is shortened further by widening half (or other appropriate fraction) on each side. These designs may be used in urban areas where constraints exist, speeds are moderate and traffic volumes are relatively low.

(c) Bay Taper -- A reversing curve along the left edge of the traveled way directs traffic into the left-turn lane. The length of this bay taper should be short to clearly delineate the left-turn move and to discourage through traffic from drifting into the left-turn lane. Table 405.2A gives offset data for design of bay tapers. In urban areas, lengths of 18 m and 27 m are normally used. Where space is restricted and speeds are low, a 18 m bay taper is appropriate. On rural high-speed highways, a 36 m length is considered appropriate.

(d) Deceleration Lane Length -- Design speed of the roadway approaching the intersection should be the basis for determining deceleration lane length. It is desirable that deceleration take place entirely off the through traffic lanes. Deceleration lane lengths are given in Table 405.2B; the bay taper length is included. Where partial deceleration is permitted on the through lanes, as in Figures 405.2B and 405.2C, design speeds in Table 405.2B may be reduced 15 to 30 km/h for a lower entry speed. In urban areas where cross streets are closely spaced and deceleration lengths cannot be achieved, the District Traffic branch should be consulted for guidance.

Table 405.2A
Bay Taper for Median Speed-change Lanes



	LENGTH OF TAPER - meters			OFFSET DISTANCE			
	18	27	36	DD' = 3.0 m	DD' = 3.3 m	DD' = 3.6 m	
	Distance From Point "A"						
	-	-	-	0	0	0	
	1.5	2.25	3.0	0.048	0.051	0.057	
	3.0	4.5	6.0	0.186	0.207	0.225	
	4.5	6.75	9.0	0.423	0.465	0.507	
B'	6	9	12	0.75	0.825	0.90	B'
	9	13.5	18	1.50	1.65	1.80	
C'	12	18	24	2.25	2.475	2.70	C'
	13.5	20.25	27	2.58	2.84	3.10	
	15	22.5	30	2.81	3.09	3.38	
	16.5	24.75	33	2.95	3.25	3.54	
	18	27	36	3.0	3.3	3.6	

NOTES:

(1) The table gives offsets from a base line parallel to the edge of traveled way at intervals measured from point "A". Add "E" for measurements from edge of traveled way.

(2) Where edge of traveled way is a curve, neither base line nor taper between B & C will be a tangent. Use proportional offsets from B to C.

(3) The offset "E" is usually 0.6 m along edge of traveled way for curbed medians; Use "E" = 0 m for striped medians.

Table 405.2B
Deceleration Lane Length

Design Speed (km/h)	Length to Stop (m)
50	75
60	94
70	113
80	132
90	150
100	169

(e) Storage Length--At unsignalized intersections, storage length may be based on the number of turning vehicles likely to arrive in an average 2-minute period during the peak hour. As a minimum, space for 2 passenger cars should be provided at 7.5 m per car. If the peak hour truck traffic is 10 % or more, space for one passenger car and one truck should be provided.

At signalized intersections, the storage length may be based on one and one-half to two times the average number of vehicles that would store per signal cycle depending on cycle length, signal phasing, and arrival and departure rates. As a minimum, storage length should be calculated the same manner as unsignalized intersection. The District Traffic Branch should be consulted for this information.

When determining storage length, the end of the left turn lane is typically placed at least 1 m, but not more than 10 m, from the nearest edge of shoulder of the intersecting roadway. Although often set by the placement of a crosswalk stripe or limit line, the end of the storage lane should always be located so that the appropriate turning template can be accommodated.

(3) Double Left-turn Lanes. At signalized intersections on multilane conventional highways and on multilane ramp terminals, double left-turn lanes should be considered if the left-turn demand is 300 vehicles per hour or more. The lane widths and other design elements of left-turn lanes given under Index 405.2(2) apply to double as well as single left-turn lanes.

The design of double left-turn lanes can be accomplished by adding one or two lanes in the median. See "Guidelines for Reconstruction of Intersections", published by Headquarters, Division of Traffic Operations, for the various treatments of double left-turn lanes.

(4) Two-way Left-turn Lane (TWLTL). The TWLTL consists of a striped lane in the median of an arterial and is devised to address the special capacity and safety problems associated with high-density strip development. It can be used on 2-lane highways as well as multilane highways. Normally, the District Traffic Operations Branch should determine the need for a TWLTL.

The minimum width for a TWLTL shall be 3.6 m (see Index 301.1). The preferred width is 4.2 m. Wider TWLTL's are occasionally provided to conform with local agency standards. However, TWLTL's wider than 4.2 m are not recommended, and in no case should the width of a TWLTL exceed 4.8 m. Additional width may encourage drivers in opposite directions to use the TWLTL simultaneously.

405.3 Right-turn Channelization

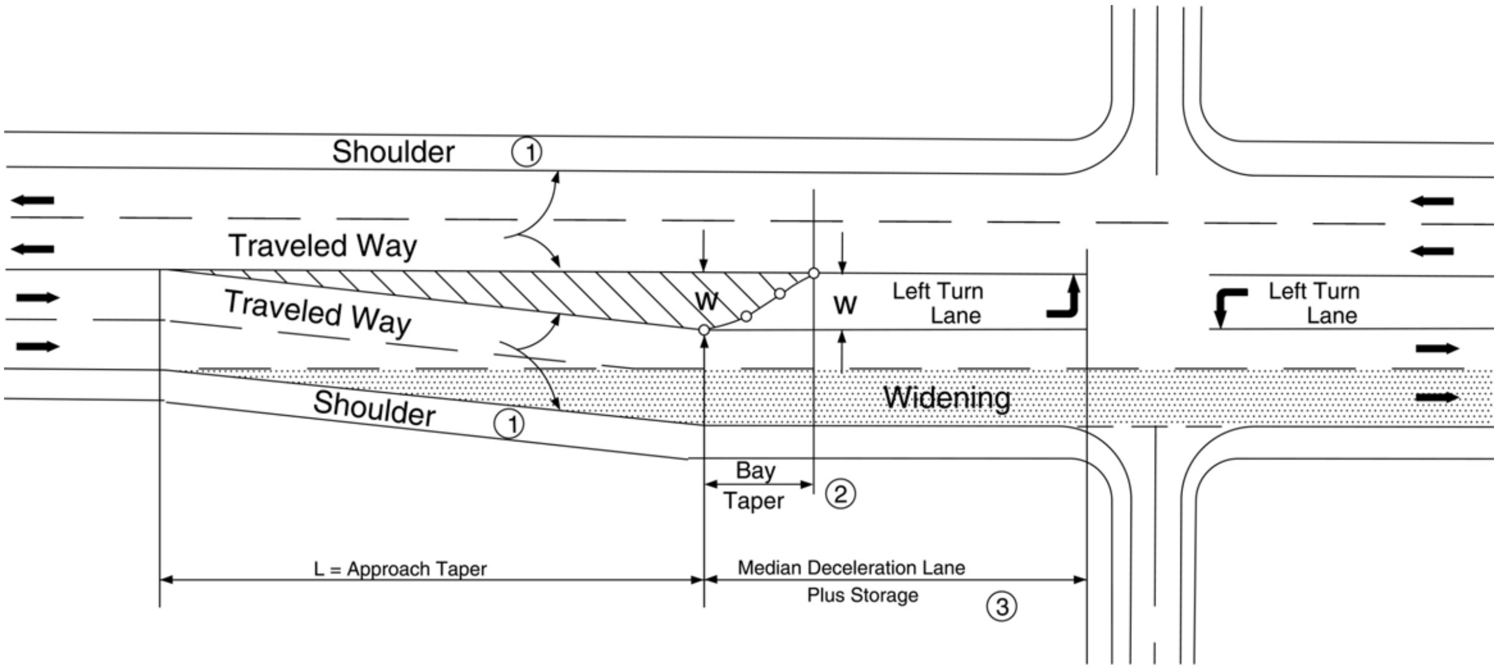
(1) General. For right-turning traffic, delays are less critical and conflicts less severe than for left-turning traffic. Nevertheless, right-turn lanes can be justified on the basis of capacity, analysis, and accident experience.

In rural areas a history of high speed rear-end accidents may warrant the addition of a right-turn lane.

In urban areas other factors may contribute to the need such as:

- High volumes of right-turning traffic causing backup and delay on the through lanes.
- Pedestrians conflicting with right turning vehicles.
- Frequent rear-end and sideswipe accidents involving right-turning vehicles.

Figure 405.2A
Standard Left-turn Channelization



EQUATION: L = Use $(2/3)WV$, for $V \geq 70$ km/h ④
Or $WV^2/150$, for $V < 70$ km/h

Where L = Length of Approach Taper - meters
V = Design Speed - km/h
W = Width of Median Lane - meters

NOTES:

① Where width is restricted, shoulder width may be reduced and parking restricted with an approved design exception pursuant to Index 82.2.
For bicycle use, a minimum 1.2 m shoulder is required (1.5 m if gutter is present).

② Bay taper length = 18 m to 36 m. (See Table 405.2A)

③ For deceleration lane length see Table 405.2B.

④ Where both sides of roadway are widened, use a fraction of "W" that is proportional to widening on each side.

(2) Design Elements.

(a) Lane and Shoulder Width--**The basic lane width for right turn lanes shall be 3.6 m. Shoulder width shall be a minimum of 1.2 m.** Whenever possible, consideration should be given to increasing the shoulder width to 2.4 m to facilitate the passage of bicycle traffic and provide space for vehicle breakdowns. Although not desirable, lane and shoulder widths less than those given above can be considered for right turn lanes under the following conditions and with the approval of a design exception pursuant to Index 82.2.

- On high speed rural highways or moderate speed suburban highways where width is restricted, consideration may be given to reducing the lane width to 3.3 m with approval of a design exception.
- On low to moderate speed roadways in severely constrained situations, consideration may be given to reducing the minimum lane width to 3.0 m with approval of a design exception.
- Shoulder widths may also be considered for reduction under constricted situations. Whenever possible, at least a 0.6 m offset should be provided where the right turn lane is adjacent to a curb. Entire omission of the shoulder should only be considered in the most severely constricted situations and where an 3.3 m lane can be constructed. Gutter pans can be included within a shoulder, but cannot be included as part of the lane width.

Additional right of way for a future right-turn lane should be considered when an intersection is being designed.

(b) Tapers--Approach tapers are usually unnecessary since main line traffic need not be shifted laterally to provide space for the right-turn lane. If, in some rare instances, a lateral shift were needed, the approach taper would use the same formula as for a left-turn lane. Bay tapers are treated as a mirror image of the left-turn bay taper.

(c) Deceleration Lane Length--The conditions and principles of left-turn lane deceleration apply to right-turn deceleration. Where full deceleration is desired off the high-speed through lanes, the lengths in Table 405.2B should be used. Where partial deceleration is permitted on the through lanes because of limited right of way or other constraints, average running speeds in Table 405.2B may be reduced 15 to 30 km/h for a lower entry speed. For example, if the main line speed is 80 km/h and a 20 km/h deceleration is permitted on the through lanes, the deceleration length may be that required for 60 km/h.

(d) Storage Length--Right-turn storage length is determined in the same manner as left-turn storage length. See Index 405.2(2)(e).

(3) Right-turn Lanes at Off-ramp Intersections. Diamond off-ramps with a free right turn at the local street and separate right-turn off-ramps around the outside of a loop will cause problems as traffic volumes increase. Serious conflicts occur when the right-turning vehicle must weave across multiple lanes on the local street in order to turn left at a major cross street close to the ramp terminal. Also, rear-end accidents can occur as right-turning drivers slow down or stop waiting for a gap in local street traffic. Free right turns usually end up with yield, stop, or signal controls thus defeating their purpose of increasing intersection capacity.

Free right turns should generally be avoided unless there is room for a generous acceleration lane or a lane addition on the local street. See Index 504.3(2) for additional information.

405.4 Traffic Islands

A traffic island is an area between traffic lanes for control of vehicle movements or for pedestrian refuge. An island may be designated by paint, raised pavement markers, curbs, pavement edge, or other devices. Examples of traffic island designs are shown on Figure 405.4.

Traffic islands usually serve more than one function, but may be generally classified in three separate types:

(a) Channelizing islands which are designed to confine specific traffic movements into definite channels;

(b) Divisional islands which serve to separate traffic moving in the same or opposite direction; and

(c) Refuge islands to aid and protect pedestrians crossing the roadway. If a divisional island is located in an urban area where pedestrians are present, portions of each island can be considered a refuge island.

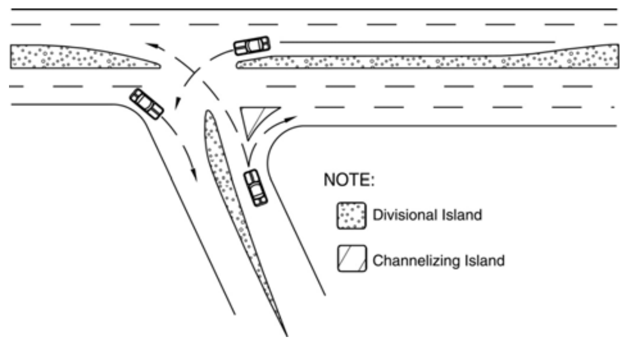
Traffic islands are also used to discourage or prohibit undesirable movements.

(1) *Design of Traffic Islands.* Island sizes and shapes vary from one intersection to another. They should be large enough to command attention. Channelizing islands should not be less than 5 m^2 in area, preferably 7 m^2. Curbed, elongated divisional islands should not be less than 1.2 m wide and 6 m long.

The approach end of each island should be offset 1 m to the left and 1.5 m to the right of approaching traffic, using standard 1:15 parabolic flares, and clearly delineated so that it does not surprise the motorist. These offsets are in addition to the normal 0.6 m left and 2.4 m right shoulder widths. Table 405.4 gives standard parabolic flares to be used in island design. On curved alignment, parabolic flares may be omitted for small triangular traffic islands whose sides are less than 7.5 m long.

The approach nose of a divisional island should be highly visible day and night with appropriate use of signs (reflectorized or illuminated) and object markers. The approach nose should be offset 1 m from the through traffic to minimize accidental impacts.

Figure 405.4
Traffic Island Designs



(2) *Delineation of Traffic Islands.* Generally, islands should present the least potential conflict to approaching vehicles and yet perform their intended function. When curbs are used, Type B is preferable except where a Type A curb is needed for traffic control or pedestrian refuge (see Index 303.2). Islands may be designated as follows:

(a) Raised paved areas outlined by curbs.

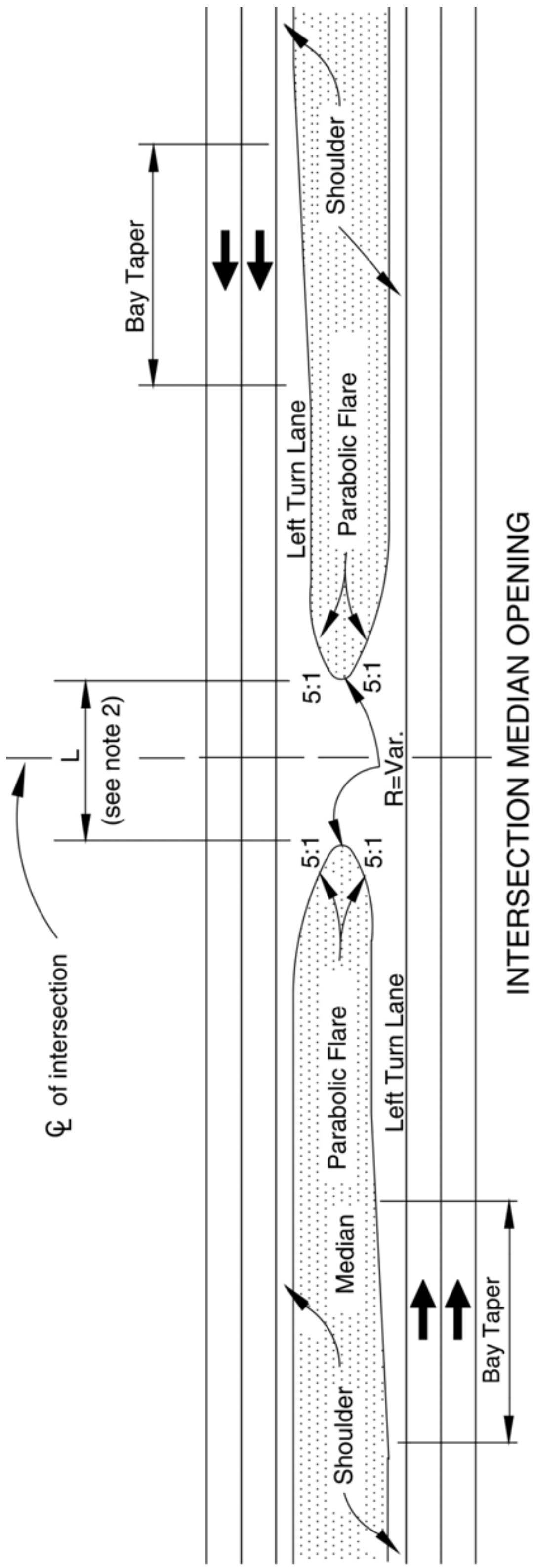
(b) Flush paved areas outlined by pavement markings.

(c) Unpaved areas (small unpaved areas should be avoided).

On facilities with speeds over 75 km/h, the use of any type of curb is discouraged. Where curbs are to be used, they should be located at or outside of the shoulder edge, as discussed in Index 303.5.

In rural areas, painted channelization supplemented with raised pavement markers would be more appropriate than a raised curbed channelization. The design is as forgiving as possible and decreases the consequence of a driver's failure to detect or recognize the curbed island.

Figure 405.5
Typical Design for Median Openings



NOTES:

1 - For length of bay taper, see Table 405.2A.

2 - L = Length of median opening: varies with width of median and angle of intersecting road. Usually for 90 intersection, L=18 m for median of 6.6 m and wider. L=21 m for median narrower than 6.6 m

3 - See Index 405.2.

405.7 Public Road Intersections

The basic design to be used at right-angle public road intersections on the State Highway System is shown in Figure 405.7. The essential elements are sight distance (see Index 405.1) and the treatment of the right-turn on and off the main highway. Encroachment into opposing traffic lanes by the turning vehicle should be avoided or minimized.

(1) *Right-turn Onto the Main Highway.* The combination of a circular curve joined by a 2:1 taper on the crossroads and a 22.5 m taper on the main highway is designed to fit the wheel paths of the appropriate turning template chosen by the designer.

    It is desirable to keep the right turn as tight as practical, so the stop or yield sign on the minor leg can be placed close to the intersection.

(2) *Right-turn Off the Main Highway.* The combination of a circular curve joined by a 45 m taper on the main highway and a 4:1 taper on the crossroads is designed to fit the wheel paths of the appropriate turning template and to move the rear of the vehicle off the main highway. Deceleration and storage lanes may be provided when necessary (see Index 405.3).

(3) *Alternate Designs.* Offsets are given in Figure 405.7 for right angle intersections. For skew angles, roadway curvature, and possibly other reasons, variations to the right-angle design are permitted, but the basic rule is still to approximate the wheel paths of the design vehicle.

    A three-center curve is an alternate treatment that may be used at the discretion of the designer.

405.8 City Street Returns and Corner Radii

The pavement width and corner radius at city street intersections is determined by the type of vehicle to be accommodated taking into consideration the amount of available right of way, the roadway width, the number of lanes on the intersecting street, and the number of pedestrians.

At urban intersections, the California truck or the Bus Design Vehicle template may be used to determine the corner radius. Where STAA truck access is anticipated, the STAA Design Vehicle template may be used giving consideration to factors mentioned above. (See Index 404.3.)

Smaller radii of 5 to 8 m are appropriate at minor cross streets where few trucks are turning. Local agency standards may be appropriate in urban and suburban areas.

Encroachment into opposing traffic lanes should be avoided.

405.9 Widening of 2-lane Roads at Signalized Intersections

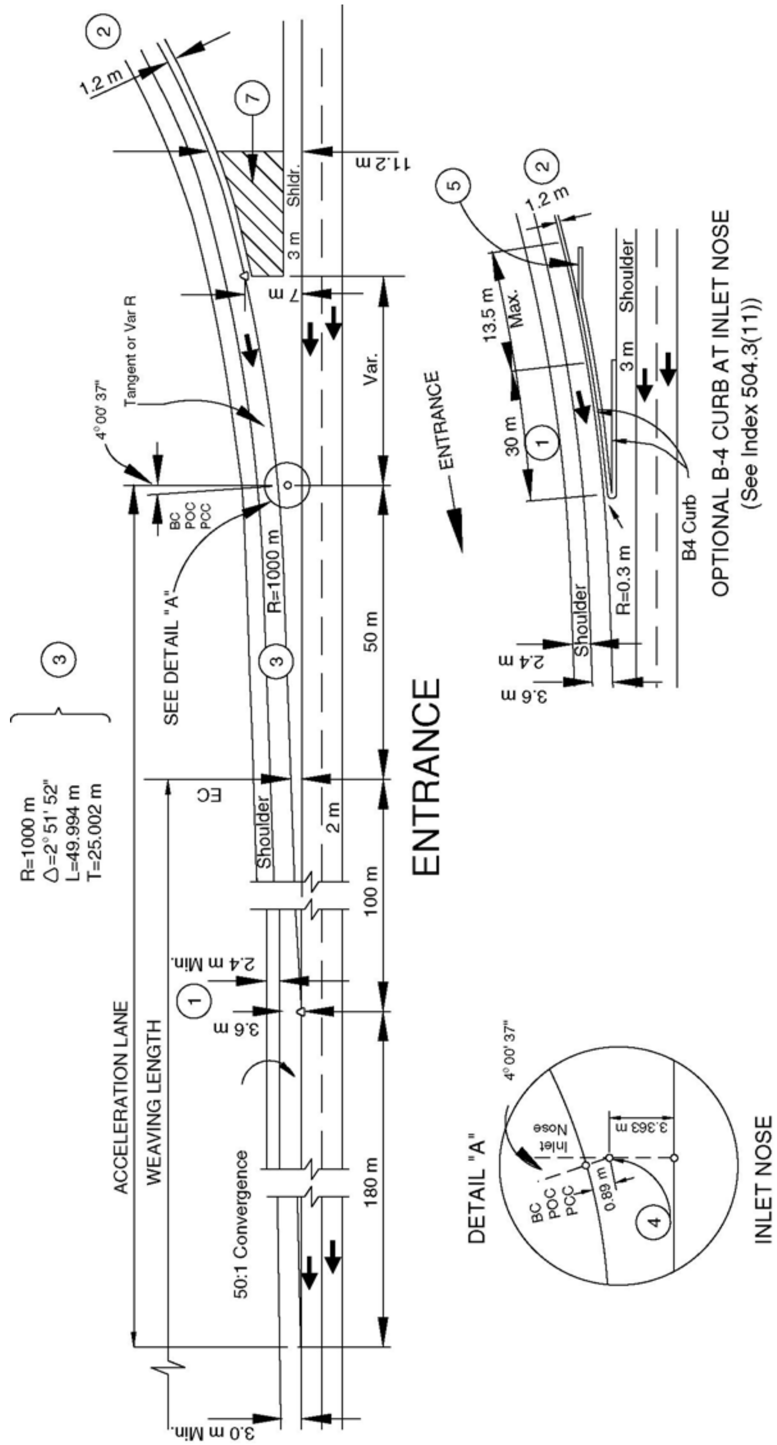
Two-lane state highways may be widened at intersections to 4-lanes whenever signals are installed. Sometimes it may be necessary to widen the intersecting road. The minimum design is shown in Figure 405.9. More elaborate treatment may be warranted by the volume and pattern of traffic movements. Unusual turning movement patterns may possibly call for a different shape of widening.

Topic 406 - Ramp Intersection Capacity Analysis

The following procedure for ramp intersection analysis may be used to estimate the capacity of any signalized intersection where the phasing is relatively simple. It is useful in analyzing the need for additional turning and through traffic lanes.

(a) Ramp Intersection Analysis--For the typical local street interchange there is usually a critical intersection of a ramp and the crossroads that establishes the capacity of the interchange. The capacity of a point where lanes of traffic intersect is 1500 vehicles per hour. This is expressed as intersecting lane vehicles per hour (ILV/hr). Table 406 gives values of ILV/hr for various traffic flow conditions.

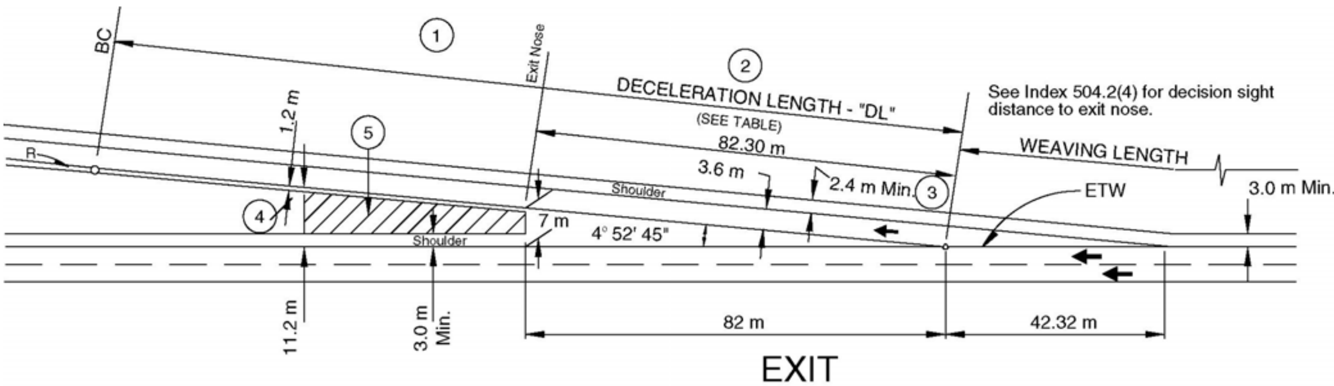
Figure 504.2A
Single Lane Freeway Entrance



NOTES:

1. On freeway to freeway connections the right paved shoulder shall be 3 m. - Table 302.1
2. On single- and two-lane freeway to freeway connections the left paved shoulder shall be 1.5 m. - Table 302.1
3. When freeway is not on tangent alignment, select radius to approximate same degree of convergence(see Index 504.2(3)).
4. Locate as if it were to be center of a 0.3 m radius curb nose.
5. 1:15 Flare, 15 m long - Table 405.4.
6. 2% superelevation may be acceptable for the 1000 m radius curve on entrance ramps.
7. Contrasting surface treatment (See Index 504.2(2)) (permissive standard)

Figure 504.2B
Single Lane Freeway Exit



R (m)	Min. DL (m) ②
Less than 90	180
90 - 149	150
150 - 299	130
300 & over	82.3

NOTES:

1. Minimum length between exit nose and end of ramp is 160 m for full stop at end of ramp.
2. "DL" distance should be lengthened for descending, short radius curves, or if entered from a sustained downgrade.
3. On freeway to freeway connections the right paved shoulder shall be 3 m. - Table 302.1
4. On single- and two-lane freeway to freeway connections the left paved shoulder shall be 1.5 m. - Table 302.1
5. Contrasting surface treatment (See Index 504.2(2)) (permissive standard)

The exit nose shown on Figure 504.2B may be located downstream of the 7 m dimension; however, the maximum paved width between the mainline and ramp shoulder edges should be 6 m. Also, see pavement cross slope requirements in Index 504.2(5).

Contrasting surface treatment beyond the gore pavement may be considered on both entrance and exit ramps as shown on Figures 504.2A and 504.2B. This treatment can both enhance aesthetics and minimize maintenance efforts. It should be designed so that a driver will be able to identify and differentiate the contrasting surface treatment from the pavement areas that are intended for regular or occasional vehicular use (e.g., traveled way, shoulders, paved gore, etc.). Consult with the District Landscape Architect, District Materials Engineer, and District Maintenance Engineer to determine the appropriate contrasting surface treatment of the facility at a specific location.

Refer to the HOV Guidelines for additional information specific to direct connections to HOV lanes.

(3) *Location on a Curve.* Freeway entrances and exits should be located on tangent sections wherever possible in order to provide maximum sight distance and optimum traffic operation. Where curve locations are necessary, the ramp entrance and exit tapers should be curved also. The radius of the exit taper should be about the same as the freeway edge of traveled way in order to develop the same degree of divergence as the standard design (see Figure 504.2C).

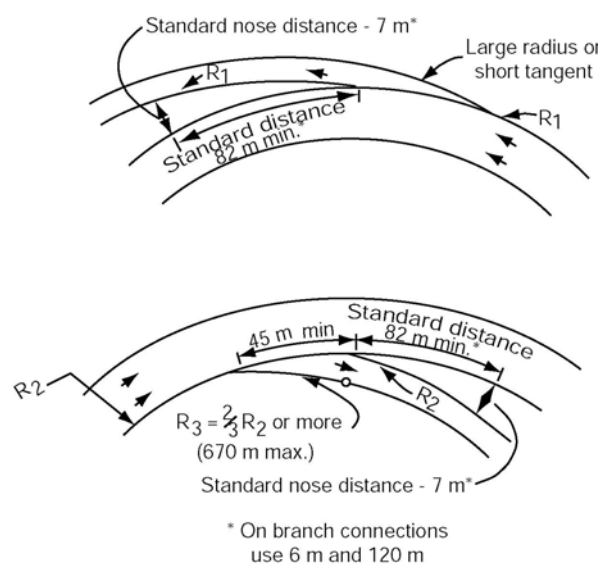
On entrance ramps the distance from the inlet nose (4.25-meter point) to the end of the acceleration lane taper should equal the sum of the distances shown on Figure 504.2A. The 50:1 taper may be curved to fit the conditions, and the 1000 m radius curve may be adjusted (see Figure 504.2A, note 5).

When an exit must be located where physical restrictions to visibility cannot be corrected by cut widening or object removal, an auxiliary lane in advance of the exit should be provided. The length of auxiliary lane should be a minimum 180 m, 300 m preferred.

(4) *Design Speed Considerations.* In the design of interchanges it is important to provide vertical and horizontal alignment standards which are consistent with driving conditions expected on branch connections. Sight distance on crest vertical curves should be consistent with expected approach speeds.

(a) Freeway Exit--The design speed at the exit nose should be 80 km/h or greater for both ramps and branch connections.

Figure 504.2C
Location of Freeway Ramps on a Curve



Decision sight distance given in Table 201.7 should be provided at freeway exits and branch connectors. At secondary exits on collector-distributor roads, a minimum of 190 m of decision sight distance should be provided. In all cases, sight distance is measured to the center of ramp lane right of the nose.

(b) Freeway Entrance--The design speed at the inlet nose should be consistent with approach alignment standards. If the approach is a branch connection or diamond ramp with high alignment standards, the design speed should be at least 80 km/h.

(c) Ramps--See Index 504.3(1)(a).

(d) Freeway-to-Freeway Connections -- See Index 504.4(2).

(5) Grades. Grades for freeway entrances and exits are controlled primarily by the requirements of sight distance. Ramp profile grades should not exceed 8% with the exception of descending entrance ramps and ascending exit ramps, where a 1% steeper grade is allowed. However, the 1% steeper grade should be avoided on descending loops to minimize overdriving of the ramp (see Index 504.3 (8)).

Profile grade considerations are of particular concern through entrance and exit gore areas. In some instances the profile of the ramp or connector, or a combination of profile and cross slope, is sufficiently different than that of the freeway through lanes that grade breaks across the gore may become necessary. Where adjacent lanes or lanes and paved gore areas at freeway entrances and exits are not in the same plane, the algebraic difference in pavement cross slope should not exceed 5% (see Index 301.2). The paved gore area is typically that area between the diverging or converging edge of traveled ways and the 7 meter point.

In addition to the effects of terrain, grade lines are also controlled by structure clearances (see Indexes 204.6 and 309.2). Grade lines for overcrossing and undercrossing roadways should conform to the requirements of HDM Topic 104 Roads Under Other Jurisdictions.

(a) Freeway Exits--Vertical curves located just beyond the exit nose should be designed with a minimum 80 km/h stopping sight distance. Beyond this point, progressively lower design speeds may be used to accommodate loop ramps and other geometric features.

Ascending off-ramps should join the crossroads on a reasonably flat grade to expedite truck starts from a stopped condition. If the ramp ends in a crest vertical curve, the last 15 m of the ramp should be on a 5% grade or less. There may be cases where a drainage feature is necessary to prevent crossroads water from draining onto the ramp.

On descending off-ramps, the sag vertical curve at the ramp terminal should be a minimum of 30 m in length.

(b) Freeway Entrances--Entrance profiles should approximately parallel the profile of the freeway for at least 30 m prior to the inlet nose to provide intervisibility in merging situations. The vertical curve at the inlet nose should be consistent with approach alignment standards.

Where truck volumes (three-axle or more) exceed 20 per hour on ascending entrance ramps to freeways and expressways with sustained upgrades exceeding 2%, a 450 m length of auxiliary lane should be provided in order to insure satisfactory operating conditions. Additional length may be warranted based on the thorough analysis of the site specific grades, traffic volumes, and calculated speeds; and after consultation with representatives of the Headquarters Division of Traffic Operations and the Division of Design. Also, see Index 204.5 "Sustained Grades".

504.3 Ramps

(1) General.

(a) Design Speed -- When ramps terminate at an intersection at which all traffic is expected to make a turning movement, the minimum design speed along the ramp should be 40 km/h. When a "through" movement is provided at the ramp terminus, the minimum ramp design speed should meet or exceed the design speed of the highway facility for which the through movement is provided. The design speed along the ramp will vary depending on alignment and controls at each end of the ramp. An acceptable approach is to set design speeds of 40 km/h and 80 km/h at the ramp terminus and exit nose, respectively, the appropriate design speed for any intermediate point on the ramp is then based on its location relative to those two points. When short radius curves with relatively lower design speeds are used, the vertical sight distance should be consistent with approach vehicle speeds. See Index 504.2(4) for additional information regarding design speed for ramps.

(b) Lane Width--**Ramp lanes shall be a minimum of 3.6 m in width. Where ramps have curve radii of 90 m or less, measured along the outside ETW for single lane ramps or along the outside lane line for multilane ramps, with a central angle greater than 60 degrees, the single ramp lane, or the lane furthest to the right if the ramp is multilane, shall be widened in accordance with Table 504.3A in order to accommodate large truck wheel paths** (see Topic 404). Consideration may be given to widening more than one lane on a multilane ramp with short radius curves if there is a likelihood of considerable bus or truck usage of that lane.

Table 504.3A
Ramp Widening for Trucks

Ramp Radius (m)	Widening (m)	Lane Width (m)
<40	2.0	5.6
40 - 44	1.6	5.2
45 - 54	1.3	4.9
55 - 64	0.9	4.5
65 - 74	0.6	4.2
75 - 90	0.3	3.9
>90	0	3.6

(c) Shoulder Width--**Shoulder widths for ramps shall be as indicated in Table 302.1.** Typical ramp shoulder widths are 1.2 m on the left and 2.4 m on the right.

(d) Lane Drops--Typically, lane drops are to be accomplished over a distance equal to 2/3WV. Where ramps are metered, the recommended lane drop taper past the meter limit line is 50 to 1. Where conditions preclude the use of a 50 to 1 taper, the lane should be dropped using a taper of no less than 30 to 1. **However, the lane drop taper past the limit line shall not be less than 15 to 1.**

Lane drop tapers should not extend beyond the 2-meter point (the beginning of the weaving length) without the provision of an auxiliary lane.

(e) Lane Additions -- Lane additions to ramps are usually accomplished by use of a 36 m bay taper. See Table 405.2A for the geometrics of bay tapers.

(2) Ramp Metering

All geometric designs for ramp metering installations must be discussed with the Project Development Coordinator or Design Reviewer from the Division of Design. **Design features or elements which deviate from the mandatory standards require the approvals described in Index 82.2.** Before beginning any ramp meter design, the designer must contact the District Traffic Operations Branch responsible for ramp metering for direction in the application of procedural requirements of the Division of Traffic Operations.

Geometric ramp design for new facilities should normally be based upon the projected peak-hour traffic volumes 20 years after completion of construction, except as stated in Index 103.2.

Geometric ramp design for operational improvement projects for ramp meters should be based on current peak-hour traffic volume (this is considered to be data that is less than two years old). If this data is not available it should be obtained before proceeding with design. Peak hour traffic data from the annual Traffic Volumes book is not adequate for this application.

The design advice and typical designs that follow should not be directly applied to ramp meter installation projects, especially retrofit designs, without giving consideration to "customizing" the geometric design features to meet site and traffic conditions (i.e., design highway volume, geometry, speeds, etc.). Every effort should be made by the designer to exceed the recommended minimum standards provided herein, where conditions are not restrictive.

(a) Metered Single-Lane Entrance Ramps

Geometrics for a single-lane ramp meter should be provided for volumes up to 900 vehicles per hour (vph) (see Figures 504.3A and 504.3B). Where truck volumes (3-axle or more) are 5% or greater on ascending entrance ramps to freeways with sustained upgrades exceeding 3% (i.e., at least throughout the merge area), a minimum 150 m length of auxiliary lane should be provided beyond the ramp convergence point. For additional guidance see Table X-5 of “A Policy on Geometric Design of Highways and Streets”, AASHTO.

A multi-lane ramp segment may be provided to increase vehicle storage within the available ramp length (see 504.3(2)(d) Storage Length) and/or to create a preferential lane for HOVs, as required in Section 504.3(2)(h).

(b) Metered Multi-Lane Entrance Ramps

When entrance ramp volumes exceed 900 vph, and/or when an HOV lane is determined to be necessary, a two or three lane ramp segment should be provided. Figures 504.3C, 504.3D and 504.3E illustrate typical designs for metered two-lane ramps; and Figures 504.3F and 504.3G illustrate typical designs for metered three lane ramps. On two-lane loop ramps, normally only the right lane needs to be widened to accommodate design vehicle off-tracking. See 504.3(1)(b).

Three-lane metered ramps are typically needed to serve peak (i.e., commute) hour traffic along urban and suburban freeway corridors. The adverse effects of bus and truck traffic on the operation of these ramps (i.e., off-tracking, sight restriction, acceleration characteristics on upgrades, etc.) is minimized when the ramp alignment is tangential or consists of curve radii not less the 90 m.

The recommended widths for metered ramps are shown in Table 504.3B.

On local street entrance ramps, the multi-lane segment should transition to a single lane width between the ramp meter limit line and the 2 m separation point (from the mainline edge of traveled way). See Figures 504.3C, 504.3D, 504.3E, 504.3F, 504.3G, 504.3H and 504.3I.

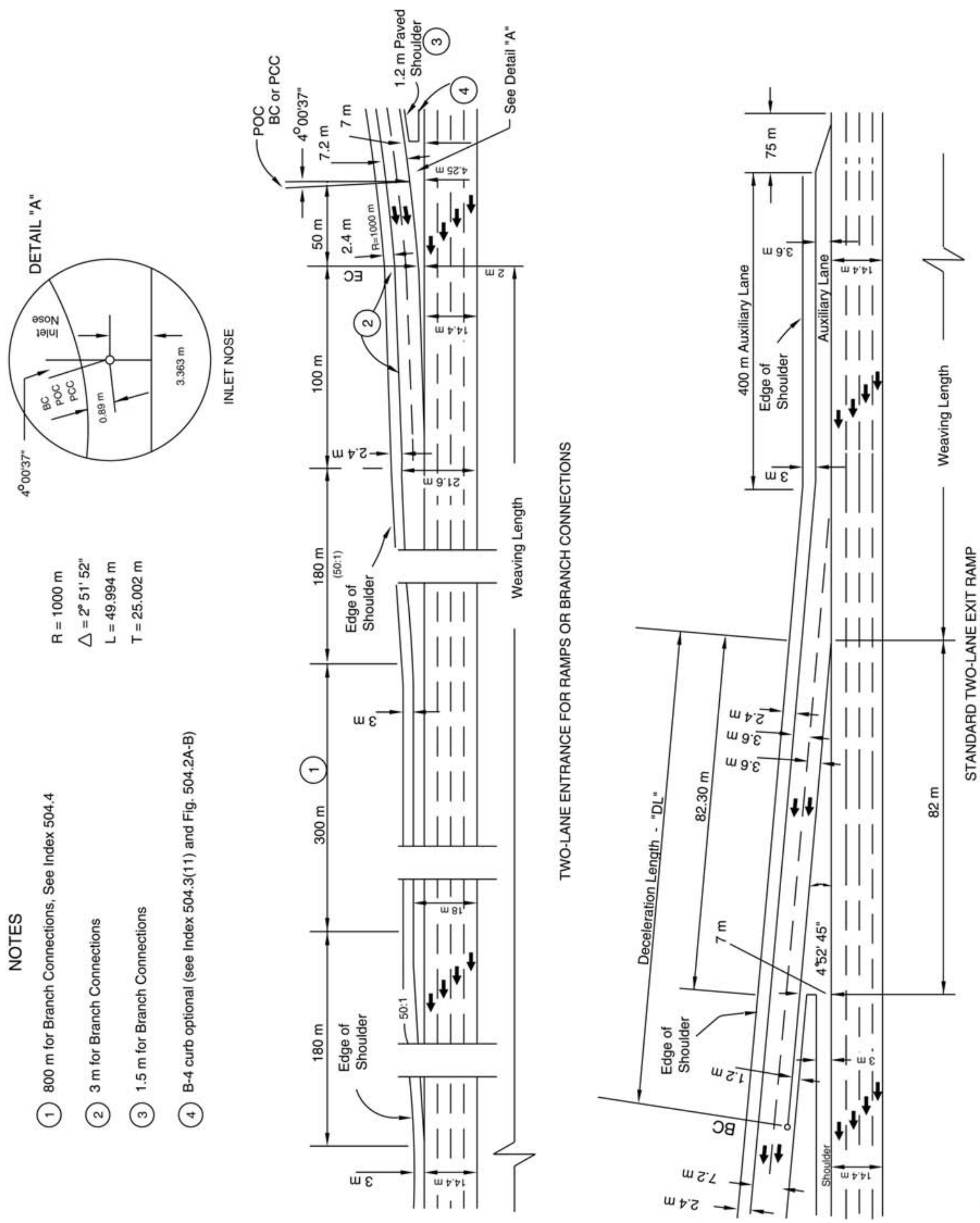
Table 504.3B
Pavement Widths

Metered Ramp	Traveled Way	Inside Shoulder	Outside Shoulder
1-lane	3.6 m	1.2 m	2.4 m
2-lane	7.2 m	1.2 m	2.4 m
3-lane	10.8 m	0.6 m	0.6 m

The lane drop transition should be accomplished with a taper of 50:1 unless a lesser taper is warranted by site and/or project specific conditions which control the ramp geometry and/or anticipated maximum speed of ramp traffic. For example, "loop" entrance ramps would normally not allow traffic to attain speeds which would warrant a 50:1 lane drop taper. Also, in retrofit situations, existing physical, environmental or right of way constraints may make it impractical to provide a 50:1 taper, especially if the maximum anticipated approach speed will be less than 80 km/h. Therefore, depending on approach geometrics and speed, the lane drop transition should be accomplished with a taper of between 30 and 50:1. **However, the lane drop taper past the limit line shall not be less than 15 to 1.**

Figure 504.3L

Two-Lane Entrance and Exit Ramps



will typically only be used where adequate capacity exists on the effected corridor of the through facility in the design year. Where capacity is limited, consideration should be given to extending the auxiliary lane to the next interchange or adding additional lanes to the freeway. For most situations, the multiple ramp lanes taper to a single lane prior to the 2-meter separation point (where merging is considered to begin). A thorough investigation of ramp volumes versus through facility volumes must be made for off-peak as well as peak periods if metering of the ramp is anticipated. Early discussion with the Headquarters Traffic Liason and Project Development Coordinator or Design Reviewer is recommended whenever two lane entrance ramps are being considered.

(8) *Loop Ramps.* Normally, loop ramps should have one lane and shoulders unless a second lane is needed for capacity or ramp metering purposes. Consideration should be given to providing a directional ramp when loop volumes exceed 1500 vehicles per hour. If two lanes are provided, normally only the right lane needs to be widened for trucks. See Topic 404 for additional discussion on lane widths and design of ramp intersections to accommodate the design vehicle. See Index 504.3(1) for a discussion on ramp widening for trucks.

Radii for loop ramps should normally range from 45 m to 60 m. Increasing the radii beyond 60 m is typically not cost effective as the slight increase in design speed is usually outweighed by the increased right of way requirements and the increased travel distance. Curve radii of less than 35 m should also be avoided. Extremely tight curves lead to increased off-tracking by trucks and increase the potential for vehicles to enter the curve with excessive speed.

Of particular concern in the design of loop ramps are the constraints imposed on large trucks. Research indicates that trucks often enter loops with excessive speed, either due to inadequate deceleration on exit ramps or due to driver efforts to maintain speed on entrance ramps to facilitate acceleration and merging. Where the loop is of short radius and is also on a steep descent (over 6%), it is important to develop the standard 2/3 full superelevation rate by the beginning of the curve (see Index 504.2(5)). On loop entrance ramps this can often be facilitated by beginning the ramp with a short tangent (20 m to 30 m) that diverges from the cross street at an angle of 4 to 9 degrees. Consideration should be given to developing additional tangent length if conditions allow.

The ramp lane structural section should be provided on shoulders for curves with a radius less than 90 m (see Indexes 603.6 and 604.5).

(9) *Distance Between Successive On-ramps***.** The minimum distance between two successive on-ramps to a freeway lane should be the distance needed to provide the standard on-ramp acceleration taper shown on Figure 504.2A. This distance should be about 300 m unless the upstream ramp adds an auxiliary lane in which case the downstream ramp should merge with the auxiliary lane in a standard 50:1 convergence. The distance between on-ramp noses will then be controlled by interchange geometry.

(10) *Distance Between Successive Exits.* The minimum distance between successive exit ramps for guide signing should be 300 m on the freeway and 180 m on collector-distributor roads.

(11) *Curbs.* Curbs should not be used on ramps except in the following locations:

(a) A Type B-100 or Type D curb (see Index 303.2) may be used on both sides of the separation between freeway lanes and a parallel collector-distributor road.

(b) A B4 curb may be used as shown in Figure 504.2A to control drainage or where the gore cross slope would be greater than allowed in Index 504.2(5). When the optional B4 curb is used at the entrance ramp inlet nose, the shoulder adjacent to the curb should be the same width as the ramp shoulder approaching the curb. The B4 gutter pan can be included as part of the shoulder width. As stated in Index 405.4(2), curbs are typically discouraged where design speeds are over 75 km/h. The appropriateness of curbs at gore areas must be determined on a case-by-case basis.

(c) Curbs may be used where necessary at the ramp connection with the local street for the protection of pedestrians, for channelization, and to provide compatibility with the local facility.

(d) The Type E curb may be used only in special drainage situations, for example, where drainage parallels and flows against the face of a retaining wall.

In general, curbs should not be used on the high side of ramps or in off-ramp gore areas except at collector-distributor roads. The offtracking of trucks should be analyzed when considering curbs on ramps.

(12) *Dikes.* Dikes may be used where necessary to control drainage. For additional information see Index 303.3.

504.4 Freeway-to-Freeway Connections

(1) *General*. All of the design criteria discussed in Indexes 501.3, 504.2 and 504.3 apply to freeway to freeway connectors, except as discussed or modified below.

(2) *Design Speed*. The design speed for single lane directional and all branch connections should be a minimum of 80 km/h. When smaller radius curves, with lower design speeds, are used the vertical sight distance should be consistent with approaching vehicle speeds. Design speed for loop connectors should be consistent with Index 504.2(4).

(3) *Grades*. The maximum profile grade on freeway-to-freeway connections should not exceed 6%. Flatter grades and longer vertical curves than those used on ramps are needed to obtain increased stopping sight distance for higher design speeds.

(4) *Shoulder Width.*

(a) Single-lane and Two-lane Connections--**The width of shoulders on single-lane and two-lane (except as described below) freeway-to-freeway connectors shall be 1.5 m on the left and 3.0 m on the right. A single lane freeway-to-freeway connector that has been widened to two lanes solely to provide passing opportunities and not due to capacity requirements shall have a 1.5 m left shoulder and at least a 1.5 m right shoulder** (see Index 504.4(5)).

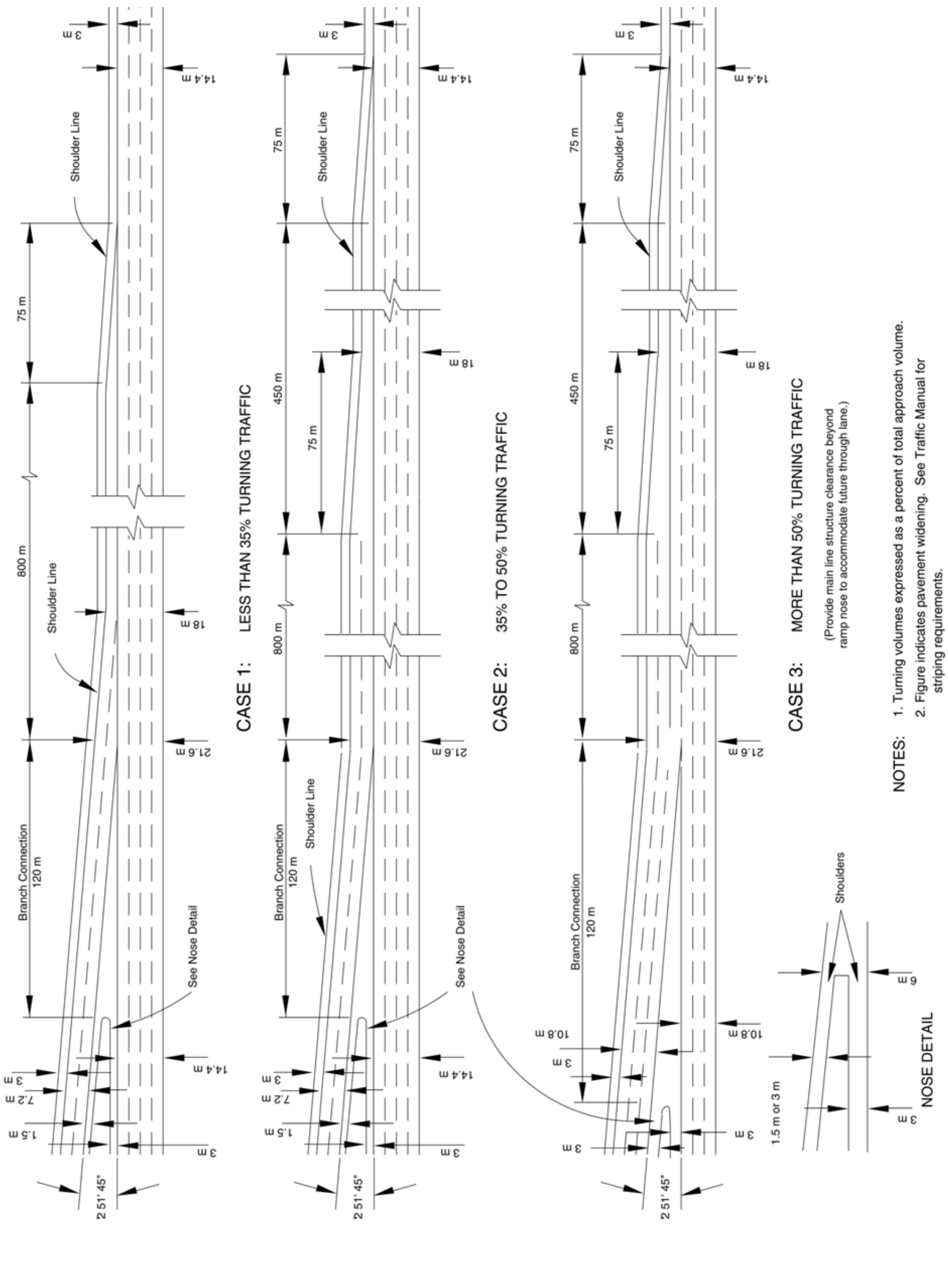
(b) Three-lane Connections--**The width of shoulders on three-lane connectors shall be 3.0 m on both the left and right sides.**

(5) *Single-lane Connections.* Freeway-to-freeway connectors may be single lane or multilane. Where design year volume is between 900 and 1500 equivalent passenger cars per hour, initial construction should provide a single lane connection with the capability of adding an additional lane. Single lane directional connectors should be designed using the general configurations shown on Figure 504.2A and 504.2B, but utilizing the flatter divergence angle shown in Figure 504.4. Single lane loop connectors may use a diverge angle of as much as that shown on Figure 504.2B for ramps, if necessary. The choice will depend upon interchange configuration and driver expectancy. Single lane connectors in excess of 300 m in length should be widened to two lanes to provide for passing maneuvers (see Index 504.4(4)).

(6) *Branch Connections*. A branch connection is defined as a multilane connection between two freeways. A branch connection should be provided when the design year volume exceeds 1500 equivalent passenger cars per hour.

Merging branch connections should be designed as shown in Figure 504.3L. Diverging branch connections should be designed as shown in Figure 504.4. The diverging branch connection leaves the main

Figure 504.4
Diverging Branch Connections



CHAPTER 600 PAVEMENT STRUCTURAL SECTION

Topic 601 - General Considerations

Index 601.1 - Introduction

Pavement structural section design is determined by a combination of pavement, base, and subbase layers that are best suited to specific project conditions. In California, this combination of materials placed in layers above the top of the basement soil (the grading plane) is most often referred to as the "structural section." The AASHTO "Guide for Design of Pavement Structures" refers to it as the "pavement structure." “Pavement,” the uppermost surface layer of the structural section that carries the traffic, is normally either portland cement concrete or asphalt concrete. The asphalt concrete pavement layer may include a layer of open graded asphalt concrete.

It is impossible to reduce the design of the structural section into exact mathematical formulas based entirely on theory because of the many variables involved. The design guidelines and standards included herein are based on a wide range of information including: theory; test track studies; experimental sections; research on materials, methods, and equipment; and, perhaps most important of all, the observation of structural section performance throughout the state and the nation. The final structural section design must be based on a thorough investigation of specific project conditions including materials, environmental conditions, projected traffic, cost effectiveness, and on the performance of other project structural sections under similar conditions in the same area.

601.2 Structural Section Design Objectives

Structural sections are to be designed using the standards and guidance described herein. This will assure adequate strength, consistency, and durability to carry the predicted traffic loads for the design life of each project. Pavement type selection may be dictated by specific project conditions such as:

- Predicted uneven foundation settlements
- Maintaining or changing grade profile
- Highly expansive basement soils
- Groundwater
- Availability of materials
- Type of pavement on existing adjacent lanes or facilities
- Corridor continuity
- Traffic considerations
- Maintenance considerations
- Climate impacts
- Stage construction
- Size of project
- Other factors

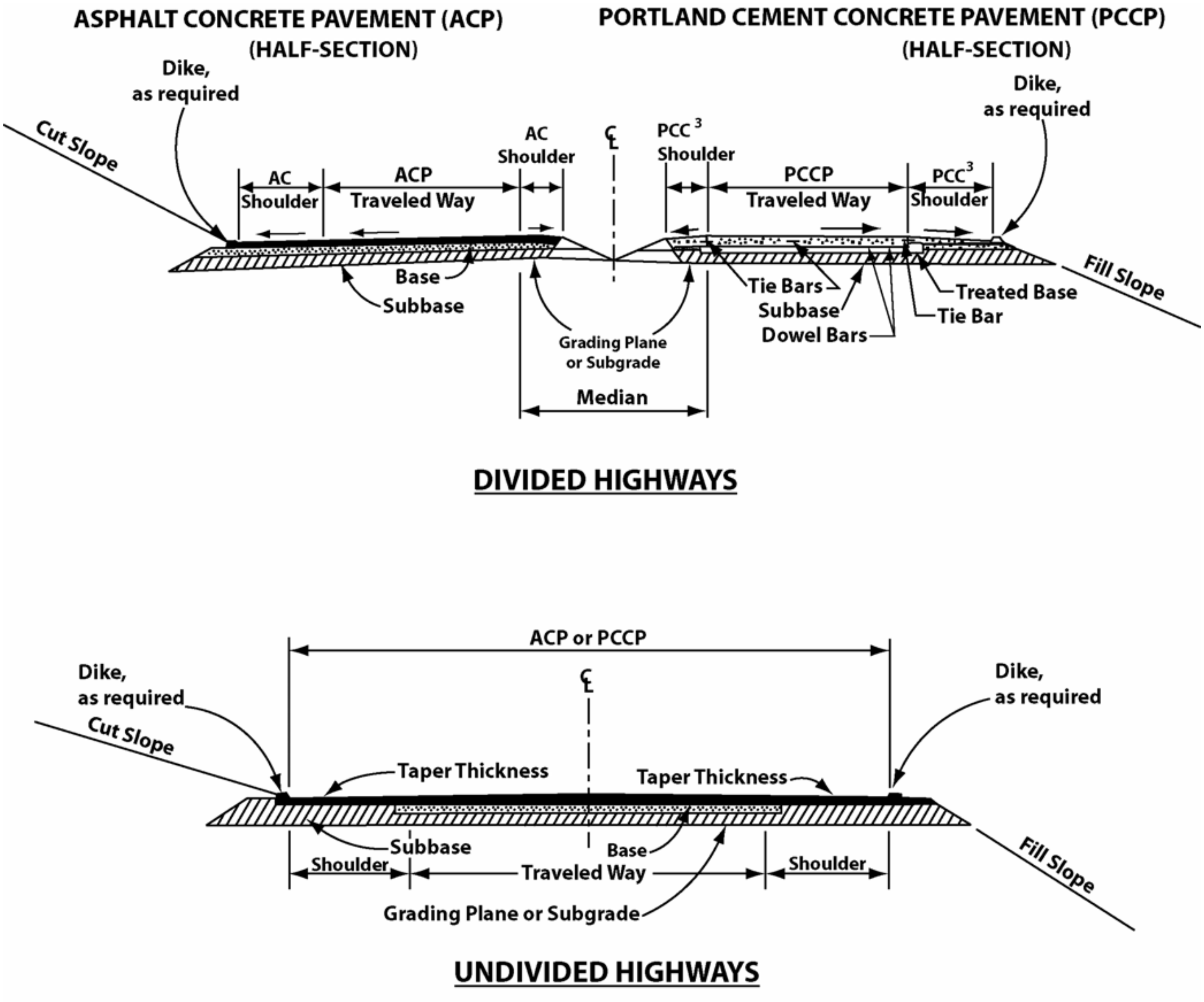
If the pavement type is not dictated by any of these factors, alternative designs (flexible and rigid) must be considered for each project. The final decision on pavement type should be the most economical design based on “life-cycle costs” which include initial cost, maintenance cost, traffic delay cost, and rehabilitation cost. Topic 605 discusses pavement type selection and economic analysis in more detail. The various basic structural elements of the roadway are shown diagrammatically in Figure 601.2.

601.3 Roles and Responsibilities

The roles and responsibilities listed below apply only to the design of the pavement structural section.

(1) *Project Engineer (PE)* - The registered civil engineer in responsible charge of appropriate project development documents (i.e., PSR, Project Report, etc.) and project design; is responsible for project technical decisions, design quality, and estimates; obtains input and recommendations from the District Materials Engineer and other subject matter experts (as appropriate) regarding pavement structural section design and details; selects pavement

Figure 601.2
Basic Structural Elements of the Roadway[1,2]



Notes:

1. These illustrations are only to show nomenclature and are not to be used for geometric cross section details. For these, see Chapter 300.

2. Structural section drainage elements, both on divided and undivided highways, are illustrated and discussed under Topic 606.

3. AC shoulders may be used when justified per Index 603.4.

structural section, final rehabilitation strategy, and pavement design details; and clearly conveys this information on the project plans and specifications for a Contractor to bid and build the project.

(2) *District Materials Engineer (DME)* - Responsible for Materials information, when requested, for each project; prepares the Materials Report for each project; provides recommendations to and in continuous consultation with the Project Engineer and Resident Engineer throughout planning, design, and construction; coordinates Materials information with Caltrans functional units, Material Engineering and Testing Services (METS), Headquarters functional units, local agencies, industry, and consultants.

(3) *Pavement Program Steering Committee (PPSC)* - Provides leadership and commitment to assure safe, effective, and environmentally sensitive highway pavement structural sections that improve mobility across California. Responsible for assuring structural section pavement initiatives, policies, and standards that reflect departmental goals; provides clear direction and priorities on pavement structural section initiatives; implements pavement structural section policies, standards, and specifications. Members include Headquarters Division Chiefs and some District Directors.

(4) *Pavement Standards Team (PST)* - Multifunctional group consisting of METS, Design, Construction, Maintenance, Research and Innovation, Office Engineer, and selected District Materials Engineer representatives; provides structural section related policies, procedures, and practices to ensure quality of structural section features regarding design, construction, maintenance, and rehabilitation; develops and maintains structural section standards, specifications, and procedures; provides recommendations to the PPSC; approves nonstandard specifications. The chairperson of this team is the single focal point of contact for pavement related issues.

(5) *Materials Engineering and Testing Services (METS)* - A subdivision of the Division of Engineering Services, METS is responsible for conducting standard and specialized laboratory and field testing, inspections, giving expert advice on all phases of transportation engineering involving materials and manufactured products; provides technical expertise for the development of statewide standards, guidelines, and procedure manuals; works closely with the District Materials Engineers and Resident Engineers to investigate ongoing field problems and/or disputes.

(6) *Division of Design (DOD)* - Responsible for statewide consistency in the project design process. The Office of State Pavement Design (OSPD) is part of the DOD. OSPD is responsible for communicating and maintaining pavement structural section design standards, policies, procedures, and practices that are used statewide.

601.4 Research and Experimentation

Research and experimentation are continuing in order to provide improved design methods and standards, which take advantage of new technology, materials, and methods. Submittal of new ideas by Headquarters and District staff, especially those involved in the design, construction, maintenance, and materials engineering of the structural section, is encouraged. Suggested research should be sent to the Division of Research and Innovation in Sacramento. The Pavement Standards Team must approve experimental construction features before completing the final design phase of a project (refer to Index 601.5(2)). District Maintenance should also be engaged in the discussion involving experimental construction features.

Suggestions for research studies and changes in design standards may also be submitted to the Pavement Standards Team (PST).

601.5 Record Keeping

The following are instructions for the retention of pavement structural section design information:

(1) *Selection of Pavement Type.* One complete copy of the documentation for the type of pavement approved by the District Director should be retained in permanent District Project History files as well as subsequent updates of construction changes to the structural section. The documentation must contain the design period, R-values of the basement soil, the R-value(s) selected for the structural section(s) design, and the lane traffic index (TI) for each design. In addition, it must include the data required by the instructions set forth under Topic 605 for selection of pavement type, including a life-cycle cost analysis.

A life-cycle cost analysis should be completed for pavement type selection on new construction projects with TI $\geq$ 10 unless the pavement type is dictated by specific project conditions as discussed in Index 601.2.

(2) *"Special" Designs.* "Special" designs to satisfy unique project specific conditions or for research purposes must be fully justified and submitted to DOD Office of Pavement Design for approval. "Special" designs are defined as those designs which involve products or strategies for which the Department has not developed a standard special provision or for designs which propose the use of products or strategies which reduce the structural sections to less than what is determined by this manual and accompanying technical guidance. The submittals must be in duplicate and include the proposed structural section design(s) and a location strip map. The letter of transmittal should include the design period, the R-value(s) of the basement soil(s), the R-value(s) selected for the structural section(s) design, the lane TI for each structural section, and justification for the "special" design(s). DOD will act as the Headquarters focal point to obtain concurrence, as required, of PST representatives prior to DOD granting approval of the "special" designs.

(3) *Proprietary Items.* The use of new materials, methods, or products may involve specifying a patented or brand name method, material, or product. The use of proprietary items is discouraged in the interest of promoting competitive bidding.

When proprietary items are needed and beneficial to the State, their use must be approved by the District Director or by the Deputy District Director of Design if such approval authority has been specifically delegated by the District Director. The Deputy Division Chief of Engineering Services, Structure Design, approves the use of proprietary materials on structures and other design elements under their jurisdiction. The use of proprietary items requires approval (i.e., Public Interest Finding) by the Federal Highway Administration (FHWA) Division Office if the project is on the Interstate System of the National Highway System (NHS). Caltrans' policy and guidelines on the use of proprietary items are covered in the Office Engineer's Ready to List and Construction Contract Award Guide (RTL Guide) under "Trade Names." This policy is based on Public Contract Code, Division 2, Chapter 3, Article 5, Paragraph 3400. It is also consistent with FHWA regulatory requirements. The use of proprietary materials, methods, or products will not be approved unless:

(a) There is no other known material of equal or better quality that will perform the same function, or

(b) There are overwhelming reasons for using the material or product in the public's interest, which may or may not include savings, or

(c) It is essential for synchronization with existing highway or adjoining facilities, or

(d) Such use is on an experimental basis, with a clearly written plan for "follow-up and evaluation."

In addition to the RTL Guide requirements, the FHWA requires that the following information be documented when a proprietary item is specified in the design of a pavement structural section:

(a) If it must be constructed on or immediately adjacent to an existing facility: year the existing facility was constructed and the original structural section details,

(b) Traffic data (Average Daily Traffic (ADT), Peak Hour Flow, Annual Average Daily Truck Traffic (AADTT), TI),

(c) Accident data,

(d) Construction cost of the project,

(e) As applicable, name of FHWA representative who reviewed the proposed project per stewardship, and

(f) Tentative advertising schedule.

If the proprietary item is to be used experimentally and there is Federal participation, the request for FHWA approval must be submitted to the Chief, Office of CTC Highway Appearances, Highway Encroachments, and Resource Conservation, Division of Design. The request must include a Construction Evaluated Work Plan (CEWP), which indicates specific functional managers, and units, which have been assigned responsibility for objective follow-up, evaluation, and documentation of the effectiveness of the proprietary item. See Section 3-404 Scope of Work ("Construction-Evaluated Research") of the Construction Manual for further details on the work plan and the approval procedure.

Technical assistance is available from the Division of Engineering Services – Materials Engineering and Testing Services (METS) and the Division of Design (DOD) to assist with designs that utilize new materials, methods, and products.

(4) Subsequent Revisions. Any subsequent changes in structural sections must be documented and processed in accordance with the appropriate instructions stated above and with proper reference to the original design.

601.6 Other Resources

The following resources provide additional information on pavement design. Much of this information can be found on the Pavement website at http://www.dot.ca.gov/hq/oppd/pavement/index.htm.

(1) Standard Plans. Generally, these are collections of commonly used design details intended to provide consistency for Contractors and designers in defining the scope of work for projects and assist in the biddability of the project contract plans.

(2) Standard Specifications and Standard Special Provisions. The Standard Specifications provide material descriptions, materials quality and workmanship requirements, contract administration terms and definitions, and measurement and payment clauses for items entering the project. The Standard Special Provisions are additional specification standards used to modify the Standard Specifications for those items entering the project and include descriptions, quality requirements, and measurement and payment.

(3) Pavement Technical Guidance. Pavement Technical Guidance is a collection of supplemental guidance and manuals regarding pavement design which is intended to assist designers, materials engineers, specialists, construction oversight personnel, and maintenance workers in making informed decisions on pavement structural section issues. Information includes, but is not limited to, aids for assistance in decision making, rigid and flexible pavement structural section rehabilitation strategies, and guidelines for the use of various products and materials. These Technical Guidance documents may be accessed on the Pavement website at: http://www.dot.ca.gov/hq/oppd/pavement/guidance.htm.

(4) The AASHTO "Guide for Design of Pavement Structures." The AASHTO "Guide for Design of Pavement Structures," although not adopted by Caltrans, is a comprehensive reference guide that provides background that is helpful to those involved in design of pavement structural sections. This reference is on file in the Division of Design and a copy should be available in each District. Design procedures included in the AASHTO Guide are used by FHWA to check the adequacy of the specific

structural sections adopted for Caltrans projects, as well as the procedures and standards included in Chapter 600 of this manual. The AASHTO Guide was developed by a team of nationally recognized pavement structural section design experts with detailed input from several states, including California.

(5) *Supplemental District Guidance.* Some Districts have developed additional structural section guidance to address local issues. Such guidance only supplements and does not replace the Headquarters guidance found in this manual, the Pavement Technical Guidance, the standard plans, specifications, and special provisions. Supplemental District Guidance can be obtained by contacting the District Materials Engineer.

Topic 602 – Pavement Service Life and Traffic Data

602.1 Introduction

This topic discusses the factors to be considered and procedures to be followed in developing an estimate of traffic loading for design of the "pavement structure" or the structural section for specific projects.

Pavement structural sections are designed to carry the projected truck traffic expected to occur during the pavement service life. This truck traffic is the primary factor affecting pavement life. Passenger cars, pickups, and two-axle trucks are considered to be negligible.

Truck traffic information that is required for structural section design includes axle loads, axle configurations, and number of applications. A mixed truck traffic stream of different axle loads and axle configurations are converted to an equivalent number of 80 kN axle loads for the design life. Finally, this sum is converted to a Traffic Index or TI (Topic 602.4), which is used to select a standard portland cement concrete pavement structural section (Topic 603) or design an asphalt concrete pavement structural section (Topic 604).

Because of the complexity involved in developing travel forecasts, Districts typically have established a unit specifically responsible for providing travel forecasting information. These units are responsible for developing traffic projections (including trucks and equivalent single axle loads) for the planning and designing of State highways. The District Office Chief responsible for travel forecasting should notify the Headquarters Office of Travel Forecasting and Analysis (OTFA) in the Division of Transportation Systems Information if there is a significant difference between the traffic used to determine ESAL's and the traffic forecast by the regional agency in urban areas. The notification should include the reasons for the deviation so that OTFA may offer recommendations or provide consultation relative to the chosen methodology.

602.2 Pavement Service Life

Pavement Service Life is the period of time that a newly constructed or rehabilitated pavement structural section is designed to perform before reaching its terminal serviceablility or a condition that requires major rehabilitation or reconstruction; this is also referred to as the performance period. The selected pavement service life varies depending on the characteristics of the highway facility, the objective of the project, and the severity of traffic. The strategy or structural section selected for any project needs to provide the minimum pavement service life that meets the objective of the project as described below.

On resurfacing projects, the entire paved shoulder and traveled way shall be resurfaced. Not only does this help provide a smoother finished surface, it also benefits bicyclists and pedestrians when they are allowed to use the shoulder.

(1) *Capital Preventive Maintenance (CAP-M) Projects.* **The pavement service life for CAP-M projects shall be a minimum of 5 years to meet FHWA funding criteria.** CAP-M guidelines are available by contacting Headquarters Maintenance, Pavement Maintenance Managers. Additional information and guidance may be found in the Project Development Procedures Manual (PDPM) Appendix H at the following website address: http://www.dot.ca.gov/hq/oppd/pdpm/pdpm.htm.

(2) *Pavement Rehabilitation Projects.* **The minimum pavement service life for rehabilitation projects shall be at least 10 years.** Longer service lives of 15, 20, and even 30 years may be more appropriate when the cost of the additional work is only incrementally higher. A Life-cycle Cost Analysis (LCCA) can be an effective tool in determining the most cost effective service life. LCCA is discussed further in Index 605.3. A pavement service life longer than 10 years needs concurrence from the District Maintenance Engineer and the Headquarters Rehabilitation Program Manager. For corridors with at least a current Annual Average Daily Traffic (AADT) of 150 000 or Annual Average Daily Truck Traffic (AADTT) of 15 000, it is recommended that a minimum pavement service life of 30-40 years be used.

(3) *New Construction and Reconstruction.* **The minimum pavement service life must be no less than the project design period (see Index 103.2) or 20 years, whichever is greater. Where a project will meet either of the following criteria, the minimum pavement service life shall be 40 years:**

- The projected AADT 20 years after completion of construction equals or exceeds 150 000.
- The projected AADTT will equal or exceed 15 000 trucks 20 years after the completion of construction.

The development of a 30 or 40 year TI may be difficult. District Transportation Planning and/or Traffic Operations should be involved in determining a realistic and appropriate TI. Refer to Index 62.7 for the definition of new construction and reconstruction.

(4) *Widening.* Additional consideration is needed when determining the service life for pavement widening. Factors to consider include the remaining service life of the existing pavement, planned future projects, and future corridor plans for any additional lane widening and shoulders. **At a minimum, the pavement service life for widenings shall match the adjacent roadway's pavement service life, but not be less than the pavement service life required for new construction and reconstruction as noted in Index 602.2(3).** See Index 604.4 for shoulder design considerations if future roadway widening is a potential. An economic analysis is recommended to assist in project decisions.

To minimize traffic handling, it may be advantageous to combine a widening project with needed rehabilitation. For example, grinding the adjoining PCC lane next to the proposed widening can improve constructability and provide a smoother pavement surface for the widening. The Project Development Procedures Manual Chapter 8, Section 7 provides additional guidance on widening adjacent to existing facilities.

(5) *Temporary Pavements and Detours.* <u>During construction, lane detours should be designed to accommodate the anticipated traffic during construction.</u> This period of time may be several years and it is important to determine the traffic index based on the truck traffic the pavement will actually experience.

602.3 Truck Traffic Projection

(1) *Mainline Traffic*. Considerable judgment is required to develop realistic traffic volume projections.

Truck traffic volume and loading projections on State Highways can come from weigh-in-motion (WIM) stations, the Vehicle Classification Program, and the Truck Weight Studies. Traffic and truck volume projections and loading can be obtained from District Traffic or Planning.

The Division of Design uses information from the Truck Weight Study to develop 80 kilonewton (kN) Equivalent Single Axle Load (ESAL) constants that represent the estimated total accumulated ESAL, for each of the four axle configurations, during the design service life. The current 10-, 20-, and 40-year ESAL Constants are shown in Table 602.3A.

Table 602.3A
ESAL Constants

Vehicle Type	10-year Constants	20-year Constants	40-year + Constants
2-axle trucks	690	1380	2760
3-axle trucks	1840	3680	7360
4-axle trucks	2940	5880	11 760
5-axle trucks or more	6890	13 780	27 560

The ESAL constants are used as multipliers of the expanded AADTT to determine the total design period ESAL's and in turn the TI. The ESAL's and the resulting TI are the same magnitude for both AC and PCC pavement design alternatives.

The distribution of truck traffic by lanes must be considered in the structural section design for all multilane facilities. Truck traffic is generally lightest in the median lanes and heaviest in the outside lanes. Because of the uncertainties and the variability of lane distribution of trucks, lane distribution factors have been established for design purposes as shown in Table 602.3B.

Finally, an expansion factor is developed for each axle classification. In its simplest form, the expansion is a straight-line projection of the AADTT data. When using the straight-line projection the data is projected to find the AADTT at the middle of the design period, thus representing the average AADTT for each axle classification for the design period. The expanded AADTT, for each axle classification, is multiplied by the appropriate lane distribution factor (fraction of the total AADTT) to arrive at the expanded AADTT for the lane. The lane AADTT is multiplied by the design period ESAL constant for each corresponding axle classification. Finally, the summation of these totals equals the total one-way ESAL's for the lane, which is converted into the TI for the lane (See Table 602.4B Example).

Table 602.3B
Lane Distribution Factors for Multilane Roads

Number of Lanes in One Direction	Factors to be Applied to Expanded Average Daily Trucks			
	Lane 1	Lane 2	Lane 3	Lane 4
One	1.0	-	-	-
Two	1.0	1.0	-	-
Three	0.2	0.8	0.8	-
Four	0.2	0.2	0.8	0.8

NOTES:

1. Lane 1 is next to the centerline or median.
2. For more than four lanes in one direction, use a factor of 0.8 for the outer two lanes and any auxiliary/collector lanes and a factor of 0.2 for all other lanes.

When other than a straight-line projection of available truck traffic data is used for design purposes, the procedure to be followed in developing traffic projections will vary. It will be dependent on a coordinated effort of the District's Planning and Traffic Divisions working closely with the Regional Agencies.

(2) *Shoulder Traffic.* See Index 603.4 and 604.4 for PCC and AC shoulder design respectively.

(3) *Ramp Traffic.* Estimating future truck traffic on ramps is more difficult than on through traffic lanes. The relative effect of the commercial and industrial development in an area is much greater on ramp truck traffic than it is on mainline truck traffic.

As an alternative to estimating and projecting an AADTT to determine the ramp TI, ramps may be classified and designed as follows:

(a) Light Traffic Ramps - Ramps serving undeveloped and residential areas with light to no truck traffic should be designed for a TI of 8.0.

(b) Medium Traffic Ramps - Ramps in metropolitan areas, business districts, or where increased truck traffic is quite likely to develop because of anticipated commercial development within the design period should be designed for a TI of 10.0.

(c) Heavy Traffic Ramps - Ramps that serve weigh stations, industrial areas, truck terminals, and/or maritime shipping facilities should be designed for a TI of 12.0 for a pavement service life of 20 years or less and 14.0 for a pavement service life of greater than 20 years.

When ramps are widened to handle truck offtracking, the full structural section, based on the ramp TI, should be extended to the inner edge of the required widening, see 504.3(1)(b).

(4) Auxiliary Lane Traffic. Because of structural section drainage considerations, the auxiliary lane structural section should perpetuate any drainage layer of the existing adjacent lane.

(5) Freeway-to-Freeway Connectors. TI's for connectors should be determined the same way as for mainline traffic.

602.4 Traffic Index

The Traffic Index or TI is a measure of the number of ESAL's expected in the design lane over the design period. The TI does not vary linearly with the ESAL's but rather according to the following exponential formula and as illustrated in Table 602.4A.

TI = 9.0 x (ESAL/106)0.119

Where:

TI = Traffic Index

ESAL = Total number of 80 kN Equivalent Single Axle Loads

Table 602.4B illustrates the determination of the TI for outside and median lanes of an 8-lane freeway. The expanded AADTT and the TI's shown in Table 602.4B are not intended to be used in the design for a specific project.

Topic 603 - Portland Cement Concrete Pavement Structural Section Design

603.1 Introduction

Portland cement concrete (PCC) pavement, or rigid pavement, should be considered as a potential alternative for all state highway facilities. PCC pavement should always be considered on Interstate and other interregional freeways. Standard structural sections are included herein for a range from very high to relatively low volumes of traffic. Truck traffic and soil conditions are the principal factors considered in selecting the structural section, however life-cycle economics and other pertinent or overriding factors may ultimately determine the pavement type to be used on any given project.

603.2 Design Procedure for Rigid Pavement

(1) Tie Bars and Dowel Bars.

New or reconstructed PCC pavements shall be doweled and tied except as noted below:

- Interior lane replacements (lanes not adjacent to a shoulder) should be undoweled if all adjacent lanes are undoweled.
- PCC shoulders being placed or reconstructed next to an undoweled PCC lane can be undoweled.
- PCC pavement should not be tied to adjacent PCC pavement with tie bars when the spacing of transverse joints of adjacent slabs is not the same.
- No more than 15 m width of PCC should be tied together with tie bars to preclude random cracks from occurring due to the pavement acting as one large PCC slab.

For slab replacements, the placement of dowel bars and tie bars should be determined on a project by project basis based on proposed service life, construction work windows, existence of dowel bars and tie bars in adjacent slabs, condition of adjacent slabs, and other

Table 602.4A
Conversion of ESAL to Traffic Index

ESAL	TI*	ESAL	TI*	ESAL	TI*
48		164 000		9 490 000	
	3.0		7.5		12.0
194		288 000		13 500 000	
	3.5		8.0		12.5
646		487 000		18 900 000	
	4.0		8.5		13.0
1850		798 000		26 100 000	
	4.5		9.0		13.5
4710		1 270 000		35 600 000	
	5.0		9.5		14.0
10 900		1 980 000		48 100 000	
	5.5		10.0		14.5
23 500		3 020 000		64 300 000	
	6.0		10.5		15.0
47 300		4 500 000		84 700 000	
	6.5		11.0		15.5
89 800		6 600 000		112 000 000	
	7.0		11.5		
164 000		9 490 000			

*NOTE:
The determination of the TI closer than 0.5 is not justified. No interpolations should be made.

Table 602.4B
Example Determination of the 20 Year Traffic Index for an 8-lane Freeway

		Outside Lanes		Median Lanes	
(1) Vehicle Type	(2) ESAL 20 Year Constants	(3) Expanded Annual Average Daily Truck Traffic	(4) Total 20 Year ESAL (Col.2 x Col.3)	(5) Expanded Annual Average Daily Truck Traffic	(6) Total 20 Year ESAL (Col.2 x Col.5)
2-axle trucks	1380	935	1 290 300	235	324 300
3-axle trucks	3680	550	2 024 000	140	515 200
4-axle trucks	5880	225	1 323 000	55	323 400
5-axle or more	13 780	1025	14 124 500	255	3 513 900
Totals	----	----	18 761 800	----	4 676 800
Traffic Index (TI) for 20 Year Design, From Table 602.4A = 12.5					11.0

pertinent factors. Further information on slab replacement design, see "Slab Replacement Guides" and companion documents on the Pavement website http://www.dot.ca.gov/hq/oppd/pavement/guidance.htm.

Dowel bars are smooth round bars that act as a load transfer device across a pavement joint. Tie bars are deformed bars or connectors that are used to hold the faces of abutting PCC slabs in contact. PCC shoulders used with PCC pavement are to be tied to the adjacent lane with tie bars, see Figure 603.2. Further details regarding dowel bars and tie bars can be found in the Standard Plans and Pavement Technical Guidance on the Pavement website.

(2) *Structural Section Thickness.*

Standard structural section thicknesses shown in Table 603.2 should be used in the design for new, widening, and reconstruction projects. Structural section element thicknesses vary with Traffic Index (TI) and R-value of the basement soil material. Procedures for developing the TI are described in Topic 602. The R-Value for the basement soil to be used is contained in the project Materials Report or available from the District Materials Engineer. With an expansive basement soil (Plasticity Index > 12) and/or basement soil R-value < 10, an asphalt concrete, or flexible pavement, structural section should be specified. If based on engineering analysis, the R-value of the basement soil can be raised above 10 by treatment, to a minimum depth of 200 mm, with an approved stabilizing agent such as lime, cement, asphalt, or fly ash, PCC pavement can be specified.

The final selection of which of the five bases, as shown in Table 603.2, should be used on a given project depends on specific factors relative to the available materials, terrain, environmental conditions, and past performance of PCC pavement under similar project or area conditions. When the TI is greater than 10, only lean concrete base or asphalt concrete base is allowed, except on widening projects where existing pavement structural sections having treated permeable base, the treated permeable base should be perpetuated along the same plane. Questions on selection of base material for rehabilitation projects may be directed to the Office of Pavement Rehabilitation in METS. Questions concerning structural section features for new construction and reconstruction projects may be directed to the Division of Design. Consultation with the District Materials Engineer should be an ongoing process for the project. The Office of Rigid Pavement Materials and Structural Concrete is also available to provide forensic studies and project specific consultation.

(3) *Drainage.*

Structural sections should be designed to promote free drainage whenever possible. Alternative designs are provided, as shown in Figure 606.2. Incorporation of a treated permeable base daylighting to the edge of embankment may be considered; otherwise, an edge drain collector and outlet system may provide positive drainage of the structural section. The climatic region of the project site should be a factor in selection of a drainable or dense base layer under the PCC pavement. A dense non-erodible base (lean concrete base or asphalt concrete base) may also be considered with or without an edge drain collector and outlet system as discussed in Topic 606.

When placing PCC over a lean concrete base, it is important to avoid bonding between the two layers. Bonding can cause cracks and joints in the lean concrete base to reflect through the PCC, which will lead to premature cracking failure. Several methods are available for preventing bonding including application of wax curing compound, slurry seals, or placing a 30 mm interlayer of AC. Application rates may be found in the Standard Specifications. For specific project recommendations on how to prevent bonding between PCC and lean concrete base, consult the District Materials Engineer.

Alternative combinations are diagramed in Table 603.2. Details of structural section drainage systems are provided in Topic 606 and the Standard Plans.

Table 603.2
PCC Pavement Structural Section Thickness Guidelines (mm)[4]

TI	PCC[1] Pavement	Base[3] (LCB, ACB)	Aggregate Subbase (AS)	Treated Permeable Base (ATPB, CTPB)	Aggregate Base (AB)	Aggregate Subbase (AS)
	Basement Soil R-value 10-40					
8 or less	205	105	120	105	105	105
8.5-10	215	105	105	105	105	105
10.5-12	230	120	185	--	--	--
12.5-13.5	270[2]	150	215	--	--	--
14+	300[2]	150	215	--	--	--
	Basement Soil R-value > 40					
TI	PCC[1] Pavement	Base[3] (LCB, ACB)	Aggregate Subbase (AS)	Treated Permeable Base (ATPB, CTPB)	Aggregate Base (AB)	Aggregate Subbase (AS)
8 or less	205	105	--	105	105	--
8.5-10	215	120	--	105	120	--
10.5-12	230	120	--	--	--	--
12.5-13.5	270[2]	150	--	--	--	--
14+	300[2]	150	--	--	--	--

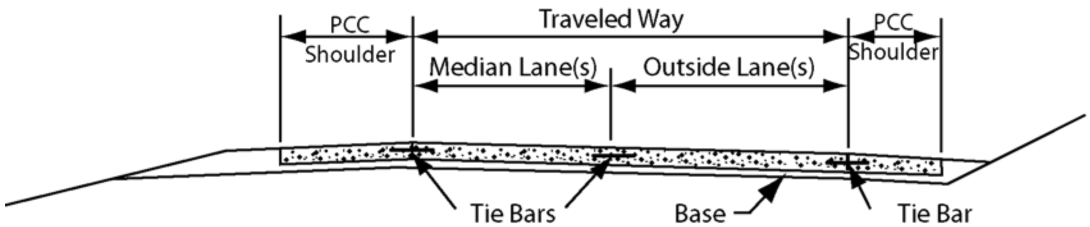
NOTES :

1. Additional thickness should be considered where chains are used for winter weather driving. Consult District Materials Engineer for recommendations.
2. Includes 10 mm of sacrificial thickness for future grinding.
3. In desert environment, where large temperature differentials occur, use ACB or, for LCB, place a minimum 25 mm AC between the LCB and PCC pavement layers.
4. The thicknesses shown in this table are only applicable for PCC pavement that includes either tied PCC shoulders or widened slab (see Index 603.4) and whose adjacent lanes are PCC pavement.

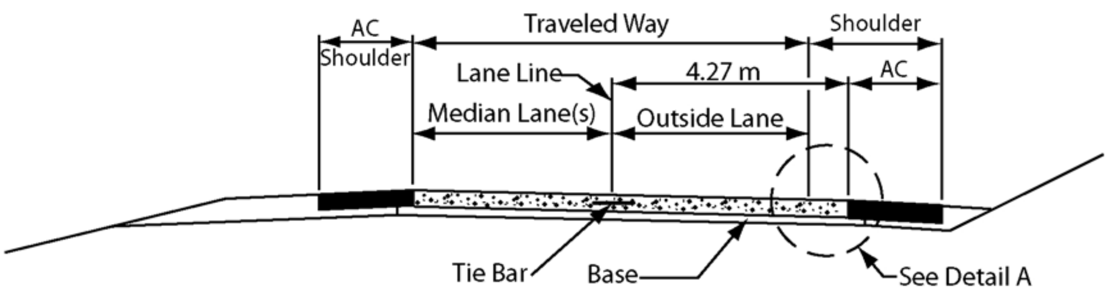
<u>Legend</u>

LCB	= Lean Concrete Base	PCC	= Portland Cement Concrete
ACB	= Asphalt Concrete Base	CTPB	= Cement Treated Permeable Base
ATPB	= Asphalt Treated Permeable Base	AS	= Aggregate Subbase
AB	= Aggregate Base		

Figure 603.2
Portland Cement Concrete Pavement Details

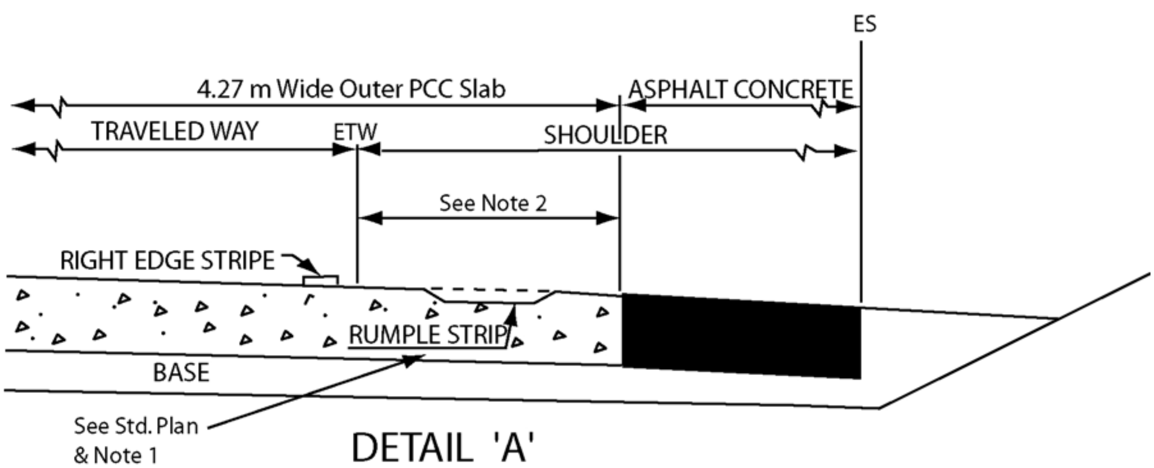


CONCRETE SHOULDERS



ASPHALT CONCRETE SHOULDERS

NOTE: These illustrations are only to show nomenclature and are not to be used for geometric cross section details.



DETAIL 'A'

NOTE:
1. Use of Rumble Strips is determined in consultation with District Traffic Operations.
2. 670 mm for 3.6 meter lane.
   610 mm for 3.66 meter lane.

603.3 Structural Section Geometry

On projects with three or more lanes in one direction, the PCC pavement thickness should be constant for the median and outside lanes. When PCC shoulders are specified, a hinge point may be required at the median edge of the traveled way to minimize drainage across the pavement.

603.4 Shoulders

It is recommended that the shoulders be constructed of the same material as the mainline pavement in order to facilitate construction, improve pavement performance, and reduce maintenance cost. However, shoulders adjacent to PCC traffic lanes can be either PCC or AC with the following conditions:

(a) **PCC shoulders shall be used for:**

- **PCC pavements constructed in mountainous areas that experience chain control (above 1300 m elevation)**
- **Paved buffers between PCC High Occupancy Vehicle (HOV) lanes and PCC mixed flow lanes**
- **PCC ramps to and from truck inspection stations**

(b) **When AC shoulders are used, a widened concrete slab (4.27 m) shall be used in the outside lane, HOV lane(s), and truck bypass lanes (see Figure 603.2).** A rumble strip or a raised pavement marking is recommended next to the pavement edge line of widened concrete slabs to discourage trucks from driving on the outside 0.6 meters of the slab. The use of rumble strips or raised markings requires approval from District Traffic Operations.

These conditions apply to all PCC paving projects including new construction, reconstruction, widening, adjacent lane replacements, and shoulder replacements. Typically existing AC shoulders next to PCC pavement are not replaced for rehabilitation projects that involve only grinding, dowel bar retrofits, and intermittent slab replacements unless the AC shoulder needs to be rehabilitated or replaced as part of the project.

Tied PCC shoulders or widened slabs increase the service life of PCC pavement by reducing edge stresses from trucks, buses, and other vehicles. PCC shoulders have the added benefit of reducing future maintenance costs and worker exposure.

The structural section selected must meet the pavement service life standards in Index 602.2. In selecting whether to construct PCC or AC shoulders the following factors should be considered:

(a) Life-cycle cost of the shoulder

(b) Construction cost of the shoulder

(c) Ability and safety of maintenance crews to maintain the shoulder. In confined areas, such as in front of retaining walls or narrow shoulders, and on high volume roadways (AADT > 150,000) consideration should be given to providing a shoulder design that requires the least amount of maintenance, even if it is more expensive to construct.

(d) Future plans to widen the facility or convert the shoulder to a traffic lane

(e) Width of shoulder. When shoulder widths are less than 1.5 meters, tied PCC shoulders are preferable to a widened concrete slab and narrow AC shoulder (≤0.9 m).

The structural section for the PCC shoulder should match the structural section of the adjacent traffic lane. Cross slopes should meet the requirements found in Index 302.2. If the future conversion of the shoulder to a traffic lane is anticipated within the pavement service life of the pavement, it is preferred that the shoulder width match the width of the future lane. Special delineation of concrete shoulders may be required to deter the use of the shoulder as a traveled lane. District Traffic Operations should be consulted to determine the potential need for anything more than the standard edge stripe.

In those instances where AC shoulders are used with PCC pavement, the minimum AC thickness should be determined in accordance with Index 604.4

603.5 Freeway-to-Freeway Connectors and Ramps

PCC should be considered for all freeway-to-freeway connectors and ramps near major commercial or industrial areas, truck terminals, and truck weighing and inspection facilities (TI $\geq$12.0) Heavy trucks cause deterioration by repeated heavy loading on the outside edge of pavement, at the corners, or at the midpoint of the slab leading to flexure of the pavement. Distress is compounded on AC ramps by the dissolving action of oil drippings combined with the braking of trucks. At a minimum, PCC pavement should be used as exit ramp termini on AC ramps where a significant volume of trucks is anticipated (see Index 603.6).

When the entire new ramp is concrete, it is recommended to utilize the same base and thickness as that to be used under the traveled way, especially when concrete shoulders are utilized. If the base is Treated Permeable Base (TPB) under the traveled way and shoulder, TPB should be utilized in the ramp area.

For ramp reconstruction, consider recycling the existing base and subbase layers. In some situations, underground water from landscape irrigation or other sources may tend to saturate the existing slow-draining layers, thereby creating the potential for pumping and pavement damage. In this case, the design should provide for removal of such water by a TPB drainage layer when reconstruction is required or by using other positive drainage features which minimize maintenance (e.g., daylighting the structural section layers).

603.6 Ramp Termini

PCC pavement is placed at ramp termini instead of AC to preclude pavement failure due to high truck traffic (TI > 12), vehicular braking, turning movements, and oil dripping from vehicles. The length of PCC pavement to be placed at the termini will depend on the geometric alignment of the ramp, ramp grades, and the length of queues of stopped traffic. The PCC pavement should extend to the first set of signal loops on signalized intersections. A length of 45 m should be considered the minimum on unsignalized intersections. Special care should be taken to assure skid resistance in conformance with current standard specifications in the braking area, especially where oil drippage is concentrated.

The PCC pavement for the termini of AC exit ramps should meet the minimum TI requirements found in Table 603.2 except that the minimum TI used should be 12.5. Special attention should be given to base type selection to assure continuity and adequacy of drainage. District Traffic Operations should be consulted for recommendations regarding construction windows to mitigate traffic impacts.

603.7 Pavement Joints

In Portland cement concrete pavement, there are longitudinal and transverse construction joints, longitudinal and transverse weakened plane joints, and transverse pressure relief joints. Required spacing for transverse joints is found in the Standard Plans and Standard Specifications. Dowel bars are required in all transverse joints along with tie bars for longitudinal joints as discussed in Index 603.2(1). Joints are sawed into the new pavement. Additional PCC pavement joint and slab saw cutting requirements are available on the Pavement Technical Guidance page of the Pavement website http://www.dot.ca.gov/hq/oppd/pavement/guidance.htm, Standard Specifications, Standard Special Provisions, and the Standard Plans.

Joints should be sealed to prevent incompressible materials from filling the joints and causing the concrete to spall. Seals also limit the entry of water that could otherwise degrade the underlying structural section layers. Various products or systems for sealing joints are available or are being developed. Each one differs in cost and service life. The need to specify the sealing of joints should be discussed in the Materials Report or by contacting the District Materials Engineer. For additional information on various joint seal products, consult the Pavement Technical Guidance on the Pavement website http://www.dot.ca.gov/hq/oppd/pavement/guidance.htm, Standard Specifications, Standard Special Provisions, Standard Plans, or contact your District Materials Engineer or METS Office of Rigid Pavement Materials and Structural Concrete.

603.8 PCC Pavement Maintenance and Rehabilitation

Pavement maintenance and rehabilitation is the use of a single or combination of several preventive or corrective strategies, which will provide the best overall solution to extend the pavement service life for a predetermined number of years. The choice of strategies depends primarily on the pavement condition, traffic impacts, life-cycle cost considerations, and apparent rate of deterioration. The Materials Report should discuss any historical problems observed in the performance of PCC pavement constructed with aggregates found near the proposed project and subjected to similar physical and environmental conditions. The use of rapid strength concrete in the replacement of concrete slabs should be given consideration to minimize traffic impacts and open the facility to traffic in a minimal amount of time. The rate of deterioration is based on experience, field observation, and a review of successive annual Pavement Condition Survey Reports provided by Caltrans Division of Maintenance. The selection of the appropriate strategy may be based upon constructability, cost, deflection testing (if load transfer is a concern), materials testing, ride quality, safety, visual inspection of pavement distress, and other factors based upon project needs.

Pavement Scoping Team reviews are scheduled and coordinated by the District, with final approval by the District Director. See the Project Development Procedures Manual for further procedures and details.

PCC pavement structural section rehabilitation strategies may be found on the Design Pavement website under Technical Guidance at: http://www.dot.ca.gov/hq/oppd/pavement/guidance.htm.

Topic 604 - Asphalt Concrete Pavement Structural Section Design

604.1 Introduction

Asphalt concrete (AC) pavement should be considered as a potential alternative for all state highway facilities since it adjusts readily to differential settlement that is likely to occur where the roadway is constructed on relatively flexible or variable quality basement soil. Asphalt concrete is readily repaired or recycled and should be considered when traffic impacts must be minimized.

Asphalt concrete structural sections may be constructed from new or recycled materials including rubberized asphalt concrete (RAC), cold or hot recycling, cold foam in-place recycling, and pulverization, to name a few. Additionally, different asphalt binders have been developed to address different climatic and environmental constraints. The Pavement website includes discussions of the various asphalt pavement types and their applicability. The site may be found at: http://www.dot.ca.gov/hq/oppd/pavement/guidance.htm.

604.2 Design Data Requirements and Sources

The data needed to design a structural section are R-value of the basement soil and the Traffic Index (TI) for the design period. The R-value is a measure of the resistance to deformation of the basement soil under saturated soil conditions and wheel loading. The R-value method of design is based on two separate measurements:

(1) The R-value determines the thickness of cover or structural section required to prevent plastic deformation of the soil under imposed wheel loads.

(2) The expansion pressure test determines the thickness or weight of cover required to maintain the compaction of the soil.

Fine grained and sandy soils may exhibit high R-values (greater than 50) and on occasion, the R-value test may not provide sufficient thickness of cover. Local experience with these soils should govern in assigning a design R-value. The determination of R-Value for basement soils is provided under California Test Method (CTM) 301. Further discussion may be found on the Division of Design's Pavement website under Technical Guidance located at the following link: http://www.dot.ca.gov/hq/oppd/pavement/guidance.htm.

The R-Values of materials to be used on a project are contained in the Materials Report. The R-Value of basement soils within a project may vary substantially but cost and constructability should be considered in specifying one R-value for the project.

Judgment based on experience should still be exercised to assure a reasonably "balanced design" which will avoid excessive costs resulting from over conservatism.

If the range of R-value is small or if most of the values are in a narrow range with some scattered higher values, the lowest R-value should be selected for the structural section design. The lowest R-value should not, however, necessarily govern the structural section design throughout the length of long projects. If there are a few exceptionally low R-values and they represent a relatively small volume of basement soil or they are concentrated in a small area, it may be possible to specify placing this material in the bottom of an embankment or in the slope area outside the structural section limits. Occasionally lime treatment of a short length may be cost effective.

The placement of geotextiles below the structural section will provide subgrade enhancement by bridging soft areas and providing a separation between soft pumpable subgrade fines and high quality subbase or base materials.

Where changing geological formations and soil types are encountered along the length of a project, it may be cost-effective to design more than one structural section to accommodate major differences in R-value that extend over a considerable length. Care should be exercised, however, to avoid multiple variations in the structural section design that may actually result in increased construction costs that exceed potential materials cost savings.

Design of the flexible pavement structural section is based on a relationship between the "gravel equivalent" (GE) of the structural section materials, the Traffic Index (TI), and the R-value (R) of the underlying material. This relationship was developed by the Department through research and field experimentation and is represented by the following equation:

$$GE = 0.975\,(TI)(100-R)$$

Gravel equivalency (GE) may be defined as the required gravel thickness needed to carry a load compared to a different material's ability to carry the same load. Gravel factor (G_f) is the relative strength of a material to gravel. Gravel factors for the various types of base materials are provided in Table 604.2. The relationship between the two is that the GE may be divided by the G_f to obtain the material's thickness as follows:

$$\text{Thickness (t)} = \frac{GE}{G_f}$$

Structural section safety factors are utilized to compensate for construction tolerances allowed by the contract specifications. For structural sections that include base and/or subbase, a safety factor of 60 mm is added to the GE requirement for the AC layer. Since the safety factor is not intended to increase the GE of the structural section, a compensating thickness is subtracted from the subbase layer (or base layer if there is no subbase). For structural sections that are full depth AC, a safety factor of 30 mm is added to the required GE of the AC and is not removed. When determining the appropriate safety factor to be added, ACB and ATPB should be considered as part of the AC layer.

604.3 Structural Section Design Procedures for New and Reconstruction Projects

A computer program for flexible pavement structural section design is available from METS' Office of Pavement Rehabilitation or the District Materials Engineer. The use of this program is recommended because it automatically employs the rules of the flexible pavement design procedure and enables the designer to compare numerous combinations of materials in seeking the most economical structural section. Numerous examples of flexible structural section design solutions are available on the Division of Design's Pavement website located at: http://www.dot.ca.gov/hq/oppd/pavement/guidance.htm.

The procedures and rules governing flexible structural section design are:

(1) The TI is determined to the nearest 0.5.

Table 604.2
Gravel Factor and R-Values for Subbases and Bases

Type of Material	Abbreviation	Gravel Factor (G_f)	Design R-Value
Aggregate Subbase	AS-Class 1	1.0	60
	AS-Class 2	1.0	50
	AS-Class 3	1.0	40
	AS-Class 4	1.0	specify
	AS-Class 5	1.0	specify
Aggregate Base	AB-Class 2	1.1	78
	AB-Class 3	1.1[2]	specify
Asphalt Treated Permeable Base	ATPB	1.4	NA
Cement Treated Base	CTB-Class A	1.7	NA
	CTB-Class B	1.2	80
Cement Treated Permeable Base	CTPB	1.7	NA
Lean Concrete Base	LCB	1.9	NA
Lime Treated Subbase	LTS	$0.9 + \frac{UCS}{6.9}$	NA

Notes:

1. For Asphalt Concrete Base (ACB), see Pavement Technical Guidance at: http://www.dot.ca.gov/hq/oppd/pavement/guidance.htm
2. Must conform to the quality requirements of AB-Class 2.

Legend:

NA = Not Applicable

UCS = Unconfined Compressive Strength in MPa

(2) The following standard design equation is applied to calculate the gravel equivalent (GE) requirement of the entire structural section or each layer:

$$GE = 0.975(TI)(100-R)$$

where:

GE = gravel equivalent in mm

TI = traffic index (See Index 602.4)

R = R-value of the basement material. This may also be the R-value of the material below the layer for which the GE is being calculated.

(3) GE values for each type of material are found in Table 604.3 by layer thicknesses. The G_f of asphalt concrete increases for any given TI as follows:

$t \leq 150$ mm:	$G_f = \frac{5.67}{(TI)^{1/2}}$
$t > 150$ mm:	$G_f = (1.04)\frac{(t)^{1/3}}{(TI)^{1/2}}$

(4) Design – The GE to be provided by each type of material in the structural section is determined for each layer, starting with the AC and proceeding downward. The thickness of each material layer is calculated by dividing the GE by the appropriate gravel factor from Table 604.3. When selecting the design layer thickness, the value is rounded to the nearest 15 mm. A value midway between 15 mm increments is rounded to the next higher value.

The following design example illustrates the general methodology to be followed.

(a) AC/Untreated Base/Aggregate Subbase:

AC Layer: Calculate the initial $GE_{(AC)}$ from standard design equation using the R-value of the aggregate base material (AB) and add the safety factor to get the required $GE_{(AC)}$. Refer to Table 604.3 and select the closest GE layer thickness. A GE value midway between two GE values should be rounded to the next higher value. Finally, determine the $GE_{(AC)}$ value from Table 604.3 that the design layer thickness provides or corresponds to.

Untreated Base Layer: Calculate the initial $GE_{(AC+AB)}$ from the standard design equation using the R-value of the subbase material and add the safety factor. From this, subtract the $GE_{(AC)}$ taken from Table 604.3 to get the required $GE_{(AB)}$ (i.e., $GE_{(AB)} = GE_{(AC+AB)} - GE_{(AC)}$). Refer to Table 604.3 and select the closest layer thickness. Determine the adjusted $GE_{(AB)}$ that the design layer thickness provides.

Untreated Subbase Layer: Calculate the $GE_{(total)}$ (without the safety factor) for the entire structural section using the standard design equation with the R-value of the basement material. Then subtract the $GE_{(AC+AB)}$, as taken from Table 604.3, provided by the AC layer and AB layer ($GE_{(AS)} = GE_{(total)} - GE_{(AC+AB)}$). Finally, refer to Table 604.3 and select the closest layer thickness. (In this way, the GE of the subbase is decreased by the amount of the safety factor.) This thickness is also the adjusted $GE_{(AS)}$ that the subbase provides since the G_f for the subbase is 1.0.

Finally, summarize the structural layer thicknesses and adjusted GE's to easily check that all the requirements are satisfied.

(b) Full Depth AC:

Full depth AC (FDAC) is asphalt concrete used for the entire structural section in lieu of base and subbase. Considerations regarding worker safety, short construction windows, the amount of area to be paved, or temporary repairs may make it desirable to reduce the total thickness of the structural section by placing full depth AC. FDAC also is less affected by moisture or frost, provides no moisture build up in the subgrade, provides no permeable layers to entrap water, and is a more uniform structural section. Use the standard design equation with the R-value of the basement material to calculate the initial GE for the entire structural section. Increase this by adding the safety factor (indicated in Index 604.2) to obtain the required GE of the AC. Then refer to Table 604.3, select the closest layer thickness for AC, and determine the adjusted GE that it provides. The GE of the safety factor is not removed in this design.

An asphalt concrete base (ACB) may be utilized for part of the full depth AC pavement since ACB is considered part of the pavement design. The dense graded AC surface layer should have a minimum thickness of 45 mm.

A treated permeable base (TPB) layer may be placed below full depth AC or within the AC layer on widening projects to perpetuate, or match, an existing treated permeable base layer for continuity of drainage. Reduce the GE of the AC by the amount of GE provided by the TPB. In no case should the initial GE of the AC layer over the TPB be less than 40% of the GE required over the subbase as calculated by the standard design equation. When there is no subbase, use 50 for the R-value for this calculation. In cases where a working table will be used, the GE of the working table is subtracted from the GE of the AC as well. A working table is a minimum thickness of material, asphalt, base, or subbase, used to place construction equipment and achieve compaction requirements when compaction is difficult or impossible to meet.

(5) Base and subbase materials, other than ATPB, should each have a minimum thickness of 105 mm. When the calculated thickness of base or subbase material is less than the desired 105 mm minimum thickness, either (a) increase the thickness to the minimum without changing the thickness of the overlying layers or (b) eliminate the layer and increase the thickness of the overlying layers to compensate for the reduction in GE.

(6) When Lime Treated Subbase (LTS) is used as a subbase it is substituted for all, or part, of the required AS layer. The design thickness of the base and AC surfacing layers are determined as though AS is the planned subbase material. The LTS is then substituted for the AS.

Since AS has a G_f of 1.0, the actual thickness and the GE are equal. When LTS is substituted for the AS, the actual thickness is determined by dividing the GE by the appropriate G_f based on unconfined compressive strength. The gravel factor for LTS is calculated from the Unconfined Compressive Strength (UCS) of the treated soil measured in MPa using the formula:

$$G_f = 0.9 + \frac{UCS}{6.9}$$

Generally, the layer thickness of LTS should be limited, with 200 mm as the minimum and 600 mm as the maximum thickness. An asphalt concrete layer placed directly on the LTS should have a thickness of at least 75mm.

Because the lime treatment of the basement soil may be less expensive than the base material, the calculated base thickness can be reduced and the LTS thickness increased because of cost considerations. The base layer thickness is reduced by the corresponding gravel equivalency provided by the lime treated basement soil or subbase.

A subbase layer or even a base layer may be omitted if the R-value of the basement soil is relatively high. Lime treatment (or stabilization) may in some cases increase the R-value of a soil so that the subbase or even the base layer may be omitted.

(7) The thickness of other structural section layers (other than AC, ATPB, and CTPB) determined by the procedures described herein may be adjusted to accommodate construction practice and to minimize cost provided the minimum GE and construction requirements are satisfied.

(8) Alternate Designs. The design thickness determined by the procedures provided in Index 604.3(4) are not intended to prohibit other combinations and thickness of materials. Adjustments to the thickness of the various materials (other than AC, ATPB, and CTPB) may be made to accommodate construction

Table 604.3
Gravel Equivalents of Structural Layers (mm)

	ASPHALT CONCRETE (DGAC)											BASE AND SUBBASE					
	Traffic Index (TI)																
	5 & below	5.5 6.0	6.5 7.0	7.5 8.0	8.5 9.0	9.5 10.0	10.5 11.0	11.5 12.0	12.5 13.0	13.5 14.0	14.5 & up	ACB; LCB	CTPB; CTB (Cl. A)	ATPB	CTB (Cl. B)	AB	AS
Actual Thickness of Layer	Gravel Factor (G_f)																
	← G_f varies with TI[4] →											← G_f constant →					
(mm)	2.54	2.32	2.14	2.01	1.89	1.79	1.71	1.64	1.57	1.52	1.46	1.9	1.7	1.4	1.2	1.1	1.0
30	76	70	64	60	57	54	51	49	47	46	44	--	--	--	--	--	--
45	114	104	96	90	85	81	77	74	71	68	66	--	--	--	--	--	--
60	152	139	128	121	113	107	103	98	94	91	88	--	--	--	--	--	--
75	191	174	161	151	142	134	128	123	118	114	110	--	--	105[2]	--	--	--
90	229	209	193	181	170	161	154	148	141	137	131	--	--	126	--	--	--
105	267	244	225	211	198	188	180	172	165	160	153	200	180[2]	147	126	116	105
120	305	278	257	241	227	215	205	197	188	182	175	228	204	168	144	132	120
135	343	313	289	271	255	242	231	221	212	205	197	257	230	189	162	149	135
150	381	348	321	302	284	269	257	246	236	228	219	285	255	210	180	165	150
165	421	392	362	338	318	301	287	275	264	254	247	314	281	231	198	182	165
180	473	441	407	380	357	338	322	308	296	285	278	342	306	252	216	198	180
195	526	490	453	422	397	377	359	343	329	317	309	371	332	273	234	215	195
210	--	541	500	466	439	416	396	379	363	350	341	399	357	--	252	231	210
225	--	593	548	511	481	456	434	415	399	384	374	428	383	--	270	248	225
240	--	647	597	557	524	497	473	452	434	418	407	456	408	--	288	264	240
255	--	--	647	604	568	538	513	491	471	453	442	485	434	--	306	281	255
270	--	--	698	652	613	581	553	529	508	489	477	513	459	--	324	297	270
285	--	--	--	701	659	625	595	569	546	526	512	542	485	--	342	314	285
300	--	--	--	750	706	669	637	609	585	563	548	570	510	--	360	330	300
315	--	--	--	801	753	714	680	650	624	601	585	599	536	--	378	347	315
330	--	--	--	--	802	759	723	692	664	639	623	--	--	--	--	--	330
345	--	--	--	--	851	806	767	734	705	679	661	--	--	--	--	--	345
360	--	--	--	--	900	853	812	777	746	718	699	--	--	--	--	--	360
375	--	--	--	--	--	901	858	820	787	758	738	--	--	--	--	--	375
390	--	--	--	--	--	949	904	864	830	799	778	--	--	--	--	--	390
405	--	--	--	--	--	998	950	909	873	840	818	--	--	--	--	--	--
420	--	--	--	--	--	--	997	954	916	882	859	--	--	--	--	--	--
435	--	--	--	--	--	--	1045	1000	960	924	900	--	--	--	--	--	--
450	--	--	--	--	--	--	1094	1046	1004	967	942	--	--	--	--	--	--
465	--	--	--	--	--	--	--	1093	1049	1010	984	--	--	--	--	--	--
480	--	--	--	--	--	--	--	1140	1094	1054	1026	--	--	--	--	--	--
495	--	--	--	--	--	--	--	1188	1140	1098	1069	--	--	--	--	--	--
510	--	--	--	--	--	--	--	--	1187	1143	1113	--	--	--	--	--	--
525	--	--	--	--	--	--	--	--	1233	1188	1156	--	--	--	--	--	--
540	--	--	--	--	--	--	--	--	1280	1233	1201	--	--	--	--	--	--
555	--	--	--	--	--	--	--	--	--	1279	1245	--	--	--	--	--	--
570	--	--	--	--	--	--	--	--	--	1325	1290	--	--	--	--	--	--
585	--	--	--	--	--	--	--	--	--	1372	1336	--	--	--	--	--	--
600	--	--	--	--	--	--	--	--	--	--	1382	--	--	--	--	--	--

Notes:

1. Standard layer thicknesses of 75 mm and 105 mm have been adopted respectively for ATPB and CTPB. These in turn correspond respectively to GEs of 105 mm and 180 mm. A thicker TPB drainage layer may be considered only under a unique combination of conditions.
2. DGAC G_f also increases as the thickness increases, if the thickness is greater than 150mm - See Index 604.3(3).
3. Rubberized layer thicknesses may be found in the Flexible Pavement Rehabilitation Manual, Table 3 and 4.
4. Open Graded Asphalt Concrete is a surface wearing course and provides no structural value.

restrictions or practices, and minimize costs, provided the minimum GE requirements, including safety factors, of the basement soil and each layer in the structural section are satisfied.

At times, experimental designs and/or alternative materials are proposed. These should be designed, constructed, and evaluated in cooperation with METS and the District Materials Engineer. Refer to Index 601.5(2) for further discussion.

Alternative design examples are provided in the Design Pavement website found at: http://www.dot.ca.gov/hq/oppd/pavement/guidance.htm

604.4 Shoulder Structural Section Design

The structural section design of median and outside shoulders is based on the same method described for the traveled way in Index 604.3.

(1) *Traffic Index (TI).*

Where possible, it is recommended that the TI for the shoulder should match that of the adjacent traffic lane except that the thickness of the base or AC pavement may vary to account for the different cross slope between the shoulder and traffic lane. At a minimum the design for an AC shoulder is based on no less than 2% of the projected ESAL's in the adjacent lane; however, a TI less than 5.0 should not be used.

In an area where there are sustained steep grades (over 4%) without a truck climbing lane, the potential for slow moving trucks to encroach on the shoulder should be investigated. If said encroachment results in the ESAL's exceeding 2%, the shoulder structural section should be designed to accommodate the larger ESAL value.

(2) *Grading Plane.*

Normally, there is no break in the grading plane under the pavement shoulder contact joint. The shoulder structural section can be designed with or without an aggregate subbase (AS) layer, depending on the comparative initial cost of aggregate base (AB) versus AS.

The total GE of the shoulder section is usually more than required due to the thickness of AB and/or AS.

(3) *Future Conversion to Lane.*

On new facilities, if the future conversion of the shoulder to a traffic lane is within the pavement service life, the shoulder structural section should be equal to that of the adjacent traveled way.

If a decision has been made to convert an existing shoulder to a portion of a traffic lane, a deflection study must be made to determine the structural adequacy of the in-place material. The condition of the existing shoulder must also be evaluated for undulating grade, rolled-up AC at the PCC joint, surface cracking, raveling, brittleness, oxidation, etc.

The converted facility must provide a roadway that is structurally adequate for the proposed pavement service life. This is to eliminate or minimize the likelihood of excessive maintenance or rehabilitation being required in a relatively short period of time because of inadequate structural strength and deterioration of the existing AC.

(4) *Medians.*

In addition to the information in Index 305.5(2), when a median is 4.2 m wide or less on multi-lane undivided cross sections, the median structural section should be equivalent to the adjacent lanes.

604.5 Ramp Structural Section Design

Structural section design for AC ramps is based on the same method used for the traveled way, as described in Index 604.3. Refer to Index 602.3(3) for determination of design traffic for ramps.

(1) *Structural Section Drainage.* Provisions for positive, rapid drainage of the structural section is very important, as stated in Topic 606, on ramps as well as main lanes. However, including drainage systems in ramp structural sections can sometimes create drainage problems such as accumulation of water in the subgrade of descending ramps approaching local street intersections in flat terrain. Such

situations, where there may be no cost effective way to provide positive drainage outlets, call for careful evaluation of local conditions and judgment in determining whether a drainage system should be included or not in each AC ramp structural section.

(2) *Shoulder Structural Section.* Ramp shoulder structural sections are to be designed in accordance with Index 604.4 except where ramp widening is required to handle truck off-tracking, see Index 404.1. In such cases, the full ramp structural section should extend to the outer shoulder edge of the widened ramp, see Index 504.3(1)(b).

For the design of ramp termini, see Index 603.6.

604.6 Structural Section Design for Roadside Rests and Parking Lots

Following the standard pavement structural section design procedure for roadside rests and park and ride lots is not practicable because of the unpredictability of traffic. Therefore, standard sections, based on anticipated typical load, have been adopted. However, if project site specific traffic information is available, it should be used with the standard design procedure.

(1) *Roadside Rest Pavement Design.* Table 604.6A gives recommended thicknesses for the elements of structural sections to be used on entrance and exit ramps, roads, truck parking areas - including maintenance stations, facilities, maintenance pull-out areas, and auto parking areas in safety roadside rests. The surface of the parking areas in safety roadside rests should be crowned or sloped to minimize the amount of surface water penetrating into the structural section. Drainage facilities for the surface runoff should be provided.

TI assumptions have been made which are the basis for Table 604.6A. The structural sections are minimal, to keep initial costs down, but are reasonable because additional AC surfacing can be added later, if needed, and generally without incurring exposure to traffic or traffic handling problems. When stage construction is used to minimize initial costs, the full subbase and base thicknesses should be placed in the initial construction. Table 604.6A considers R-value of the basement soil as the only variable under each traffic usage classification. Safety factors were applied in the ramp design but not for the other areas.

(2) *Park and Ride Lot Pavement Design.* The layer thicknesses shown in Table 604.6B are based on successful practice. These designs are minimal to keep initial costs down, but are considered reasonable since additional AC surfacing can be added later, if needed, without the exposure to traffic or traffic-handling problems typically encountered on a roadway.

The surface of Park and Ride Lots should be crowned or sloped to minimize the amount of surface water penetrating into the structural section. Drainage facilities for the surface runoff should be provided. A 9.5 mm or 12.5 mm maximum AC mix is recommended to provide a relatively low permeability. The AC pavement should be placed in one lift to provide maximum density.

Table 604.6A, Structural Sections for Roadside Rests, should be used in designing the structural section for areas of park and ride lots that will be used by buses and/or trucks. Unique conditions may require other special considerations.

Coal tar pitch emulsion treatment should not be applied to park and ride lots. However, a fog seal coat may be required after placing the AC, particularly if the facility will not be used immediately after construction.

604.7 Asphalt Concrete Pavement Maintenance and Rehabilitation

Policies and procedures governing AC pavement rehabilitation are contained in the Department's "Flexible Pavement Rehabilitation Manual," available from METS' Office of Pavement Rehabilitation or the District Materials Engineer. The "Flexible Pavement Rehabilitation Manual" may be accessed at: http://www.dot.ca.gov /hq/oppd/pavement/guidance.htm.

Table 604.6A
Structural Sections for Roadside Rests
(Thickness of Layers[1] in mm)

Usage	TI	Material (Class)[3]	R-value of Basement Soil 50 & Over	45-49	40-44	35-39	30-34	25-29	20-24	15-19-	10-14	5-9
Ramps & Truck Roads	8.0	AC	75	90	90	105	75	75	75	75	75	75
		CTB(A)	180	180	210	210	180	180	180	180	180	180
		AS(2)	0	0	0	0	105	120	165	195	240	270
		AC	105	105	105	105	105	105	105	105	105	105
		AB(2)	195	240	270	330	195	195	195	195	195	195
		AS(2)	0	0	0	0	105	150	195	225	270	300
		AC[2]	195	210	225	240	255	270	285	285	285	300
Truck Parking Areas	6.0	AC	60	60	60	60	60	60	60	60	60	60
		AB(2)	135	165	195	210	135	135	135	135	135	135
		AS(2)	0	0	0	0	120	150	165	195	225	255
		AC[2]	120	135	150	165	165	180	195	195	210	210
Auto Roads	5.5	AC	60	60	60	60	60	60	60	60	60	60
		AB(2)	120	135	165	180	210	120	120	120	120	120
		AS(2)	0	0	0	0	0	120	150	180	210	225
		AC[2]	120	120	135	150	150	165	180	180	195	195
Auto Parking Areas	5.0	AC	45	45	45	45	45	45	45	45	45	45
		AB(2)	120	150	165	195	210	120	120	120	120	120
		AS(2)	0	0	0	0	0	105	135	165	180	210
		AC[2]	90	105	120	120	135	135	150	165	165	180

Notes:
1. AC thicknesses of 75 mm or less must be placed in one lift.
2. Full Depth AC option (No base or subbase).
3. Structural section material options listed for each Usage, TI, and R-value are equivalent. The option chosen is the Project Engineer's decision based on recommendations from the District Materials Engineer, economics, and material availability.

Table 604.6B
Structural Sections for Park and Ride Lots

	Thickness of Layers	
R-Value Basement Soil	AC* (mm)	AB (mm)
≥ 40	45	0
< 40	75	0
	45	105
≥ 40 and < 60	Penetration Treatment, using a liquid asphalt or dust palliative on compacted roadbed material. See Standard Specifications Section 93 or Section 18.	

* Place in one lift.

The Division of Maintenance has committed dedicated funding to pavement preservation. This pavement preservation funding implements a preventive maintenance program as a Departmental business practice. Preventive maintenance is applied to roadway surfaces in good condition. This effectively provides additional service life by minimizing the effects of weathering and reducing maintenance costs. For further information, contact the HQ Division of Maintenance.

Refer to the Maintenance Manual for preventive maintenance strategies and to the CAP-M guidelines for capital preventive maintenance strategies. CAP-M guidelines are available by contacting Headquarters Maintenance, Pavement Maintenance Managers.

Topic 605 - Selection of Pavement Type

605.1 Introduction

The two types of pavement generally considered for new construction are rigid and flexible pavements as typified by Portland cement concrete (PCC) pavement and asphalt concrete (AC) pavement, respectively. There is no formula or clear-cut procedure which will produce a definite answer as to which pavement type is the most appropriate. In addition, because physical conditions are so variable and the influence of other factors differs significantly from location to location, projects must be studied individually. Therefore, the Project Engineer must consider the factors in Index 605.2, make certain assumptions, and use engineering judgment based on the best information available when determining which type or strategy to specify.

605.2 Pavement Type/Strategy Determination

The choice of pavement type or strategy should consider the following factors, which are listed and discussed in Appendix B of the 1993 AASHTO Guide for Design of Pavement Structures. These factors should be considered and addressed specifically in all project approval documents (PR, PSSR, etc.).

Primary factors listed are:

- Traffic,
- Soils characteristics,
- Weather,
- Construction considerations,
- Recycling, and
- Cost comparisons (initial and life-cycle).

No significance is attached to the order in which the factors are listed.

Secondary factors which may be pertinent, should also be considered and addressed. These factors include:

- Performance of similar pavements in the project area,
- Adjacent existing pavements,
- Conservation of materials and energy,
- Availability of local materials or contractor capabilities,
- Traffic and worker safety,
- Incorporation of experimental features,
- Stimulation of competition, and
- Municipal preference, participating local government preference, and recognition of local industry.

Pavement type selection may be dictated by specific project conditions such as:

- Predicted uneven foundation settlements or expansive soils dictate the use of AC,
- Groundwater or periodic inundation suggest the use of PCC pavement,
- Short freeway to freeway connections made between pavements of the same type,
- Existing pavement widening with a similar material,
- Traffic considerations,
- Stage construction, and
- Size of project less than 6.5 lane kilometers.

Another consideration that may have a possible effect on the final decision is the presence of grade controls, such as:

- median barriers,
- drainage facilities,
- curbs and dikes
- lateral and overhead clearances, and
- structures which may limit the structural section design or rehabilitation strategies.

The pavement type selection should consider how these appurtenant features might affect the pavement structural section.

The new construction design and rehabilitation strategy should also minimize the exposure and maximize the safety of construction or maintenance forces and their equipment.

The final decision on pavement type should be the most economical design based on a life-cycle cost analysis (LCCA) which includes initial cost, maintenance cost, traffic delay cost and rehabilitation cost. At a minimum, a life-cycle cost analysis should be done for pavement type selection with TI $\geq$ 10 unless the pavement type is dictated by specific project conditions (see Index 601.2 for examples).

After considering the various governing factors, alternative structural sections should be developed for economic analysis. If a detailed life-cycle cost analysis is not performed, a less comprehensive analysis must still be completed. This analysis is basically to determine the most economical structural section utilizing available structural section materials.

If a detailed LCCA is performed, it should follow the procedure in Index 605.3.

605.3 Life-Cycle Cost Analysis (LCCA)

LCCA comparisons must be made between properly designed, viable structural sections that would be approved for construction if selected. The structural section chosen in the economic comparison should be included in the final plans unless a revision is subsequently approved. In this event, a short memorandum is prepared referring to the original documentation, stating the details of the change, the reasons for the change, and the revised life-cycle costs. See Index 601.5 for documentation requirements.

(1) General. The economic comparison of structural sections should be based on total expected life-cycle cost. The following general guidelines should be used:

(a) The structural sections to be compared should be shown by sketches so that quantities can be computed and checked.

(b) A 35-year economic life-cycle period should be used for each project that is designed for a 20-year life. This assumes that the pavement structural section will be maintained and rehabilitated to carry the projected traffic over a 35-year period. The chart below provides for other analysis periods for different pavement service lives.

Pavement Service Life (years)	Economic Analysis Period (years)
10	20
20	35
30	45
40	50

(c) A discount rate of 4% is used to convert costs to present worth.

(d) Life-cycle costs are to be computed for the entire pavement structural section, including shoulders, for a length of one kilometer in one direction of travel on divided highways. The entire structural section is included for 2-lane roadways. Use one half of the normal maintenance cost per kilometer for divided highways.

(2) PCC Pavement Structural Section. The life-cycle cost analysis for a PCC pavement structural section should include the following items as appropriate:

(a) Initial Costs.

- PCC pavement,
- Treated base (LCB, ACB, ATPB, CTPB)
- Aggregate base (AB),
- Aggregate subbase (AS),
- PCC shoulders,
- Shoulder base,
- Shoulder subbase,
- Structural section drainage system (TPB layer under PCC pavement and/or edge drains), and
- Joint seals.

(b) Maintenance Costs.

- Maintenance records should be obtained for cost data, including seal joints and cracks, undersealing to fill voids, repairing spalls, occasional slab replacement, etc., and
- Traffic delay.

(c) Rehabilitation Costs.

- Replacing slabs in truck lanes in year 15,
- Placing AC overlay (preceded by slab cracking and seating) in year 25,
- Engineering cost (preliminary and construction charges as percent of rehabilitation costs),
- Appurtenant and supplemental work (all work to be done to appurtenant drainage, safety, and other features made necessary by the rehabilitation work),
- Traffic delay (obtain cost data from District Division of Planning),
- Detours (may be included in appurtenant and supplemental work), and
- Salvage value (estimated remaining service life of pavement or value of structural section materials).

(3) AC Pavement Structural Section. The life-cycle cost analysis for an AC pavement structural section should include the following items:

(a) Initial Cost.

- AC pavement,
- Base (ACB, CTB, ATPB, CTPB, AB),
- Aggregate subbase (AS),
- AC shoulders,
- Shoulder base,
- Shoulder subbase, and
- Structural section drainage system (TPB under AC pavement and/or edge drains)

(b) Maintenance Cost.

- Maintenance records should be obtained for cost data, including thin AC blanket, chip seals, patching, sealing cracks, etc., and
- Traffic delay.

(c) Rehabilitation Cost.

- AC overlay for all lanes and shoulders once every 12 years,
- Engineering cost (preliminary and construction charges as percent of rehabilitation costs determined from past district records),
- Appurtenant and supplemental work (all work to be done to appurtenant drainage, safety, and other features made necessary by the rehabilitation work),
- Traffic delay (obtain costs from District Division of Planning),
- Detours (may be included in appurtenant and supplemental work), and
- Salvage value (estimated remaining service life of pavement or value of structural section materials).

(4) Present Worth Cost Calculation.

PWC = IC + [(RC + EC + SC + DC) x PWF No.1] + (MC x PWF No. 2) - (SV x PWF No. 3)

Where:

PWC = Present worth cost
IC = Initial costs
RC = Rehabilitation costs
EC = Engineering cost
SC = Supplemental work costs
DC = Traffic delay costs
PWF = Present worth factor
MC = Maintenance costs
SV = Salvage value

It is imperative that careful attention is given to the calculations involved and the data used in the calculations to ensure the most realistic and factual comparison between pavement types.

An economic life-cycle cost comparison outline for a 35-year period is presented in Table 605.3.

Topic 606 - Drainage of the Pavement Structural Section

606.1 Introduction

Distress in both flexible and rigid pavements is generally caused by exposure to heavy truck traffic when the pavement structural section is in a saturated condition. Saturation of the structural section or underlying foundation materials, or both, generally results in a decrease in strength or ability to support truck axle loads. Potential problems associated with saturation of the structural section and the subgrade foundation include:

- Pumping action,
- Differential expansion (swelling) of expansive subgrade soils,
- Frost damage in freeze-thaw areas,
- Erosion and piping of fine materials creating voids which result in the loss of subgrade support,
- Icing of pavement surface from upward seepage,
- Stripping of asphalt concrete aggregates, and
- Accelerated oxidation of asphalt binder.

Water can enter the structural section as surface water through cracks, joints, and pavement infiltration, and as groundwater from an intercepted aquifer, a high water table, or a localized spring. Both sources of water should be considered and provisions should be made to handle both. The structural section drainage system, which is designed to handle surface water inflow, is generally separate from the subsurface drainage system that is designed to accommodate encroaching sub-surface water. Local rainfall data should be used in the design of the roadway drainage system as discussed in Chapter 830 of this manual.

Table 605.3
Life-Cycle Economic Comparison of Pavement Types
(Variable-Year Analysis Period and 4% Discount Rate)

ALTERNATIVE 1			Cost Per Kilometer With Shoulders
Initial Cost =			$(_A_)
Rehabilitation Costs in Year _____:			
Repair Cost =		$(_b_)	
Engineering	$(_b_)(0.1225) =	$(___)	
Appurtenant and Supplemental Work	$(_b_)(0.1350) =	$(___)	
Traffic Delay =		$(___)	
		$(_c_)	
Present Worth Cost of Rehabilitation Work in Year ____		$(_c_) (PWF) =	$(_C_)
Rehabilitation Costs in Year _____: ****			
Repair Cost =		$(_d_)	
Engineering	$(_d_)(0.1225) =	$(___)	
Appurtenant and Supplemental Work	$(_d_)(0.1350) =	$(___)	
Traffic Delay =		$(___)	
		$(_e_)	
Present Worth Cost of Rehabilitation Work in Year ____		$(_e_) (PWF) =	$(_E_)
Annual/Average Maintenance over ____ years (See Index 605.3(2)(b))		$(_*_)(16.3742)=	$(_F_)
Subtotal (A+C+E+F)			$(___)
Less Salvage Value (of rehabilitation)**		(Variable Ratio) $(_c_)(PWF) =	- $(___)
PCC Pavement Net Present Worth Cost			$(___)
ALTERNATIVE 2			Cost Per Kilometer With Shoulders
Initial Cost =			$(_G_)
Rehabilitation Costs in Year _____:			
Repair Cost =		$(_h_)	
Engineering	$(_h_)(0.1225) =	$(___)	
Appurtenant and Supplemental Work	$(_h_)(0.1350) =	$(___)	
Traffic Delay =		$(___)	
		$(_i_)	
Present Worth Cost of Rehabilitation Work in Year ____		$(_i_) (PWF) =	$(_I_)
Present Worth Cost of Rehabilitation Work in Year ____		$(_i_) (PWF) =	$(_J_)
Annual/Average Maintenance over ___ years (See Index 605.3(3)(b))		$(_*_)(16.3742)=	$(_K_)
Subtotal (G+I+J+K)			$(___)
Less Salvage Value (of Resurfacing) **		(Variable Ratio) $(_i_)(PWF) =	- $(___)
ALT2 Net Present Worth Cost			$(___)
Savings Per Kilometer Using (ALT1/ALT2) [Circle appropriate alternative]			$(___)

NOTES
- * As an initial estimate, use the average annual district maintenance cost for the respective type of pavement (use WIMS Data).
- ** Salvage Value Assumptions: **For purposes of this example**, the original PCC pavement is expected to require some type of rehabilitation work at 15 and 25 years. At the end of the 35-year comparison, the second rehabilitation is expected to serve 2 years longer. This provides a salvage value of 2/12 the cost of the second rehabilitation. The original AC pavement is expected to require resurfacing or recycling in 12 and 24 years, and the AC overlay or recycling is assumed to last 12 years for a total service of 36 years.
- *** The above format is an example of an outline for guidance only. Actual rehabilitation strategies for a specific project should be used. Refer to Pavement website – "LCCA" for further discussion.
- **** Repeat as necessary over pavement analysis period.

The estimated sub-surface water inflow can be determined by a combination of field investigations, analytical techniques, and graphical methods. "Subsurface Drainage" is discussed in Chapter 840. The Materials Report contains findings on subsurface conditions and recommendations for design. The District Materials Engineer and Division of Design can provide assistance in developing appropriate features in the plans and specifications to address the problem of water in the structural section.

606.2 Structural Section Drainage Practices

(1) *New Construction Projects*. The structural section should include a layer of Treated Permeable Base (TPB) under the pavement except in areas where the mean annual rainfall is very low (less than 125 mm) or where the basement soil is free draining (a permeability greater than 3.53 x 10^{-4}m/s). The surface of the traveled way and shoulders should employ materials that will prevent surface water intrusion and any joints should be sealed. If sufficient right of way is available, it is desirable to grade the roadbed to allow for a free draining outlet for the structural section. The TPB, AB and AS layers of the structural section extend the full width of the roadbed (see Figure 606.2).

(2) *Widening and Reconstruction Projects.* The widened structural section layers should conform to the existing structural section layers to perpetuate existing drainage. The widened layers should extend the full width of the roadbed to a free outlet, if feasible, as in new construction. (See Figure 606.2). Joints should be sealed as discussed in Index 603.7.

(3) *Rehabilitation Projects.* The surface of the traveled way and shoulders should employ methods and materials that will help prevent surface water intrusion and any joints should be sealed. Existing structural section drainage should be perpetuated or restored, if feasible.

606.3 Drainage Components and Related Design Considerations

The basic components of a pavement structural section drainage system are:

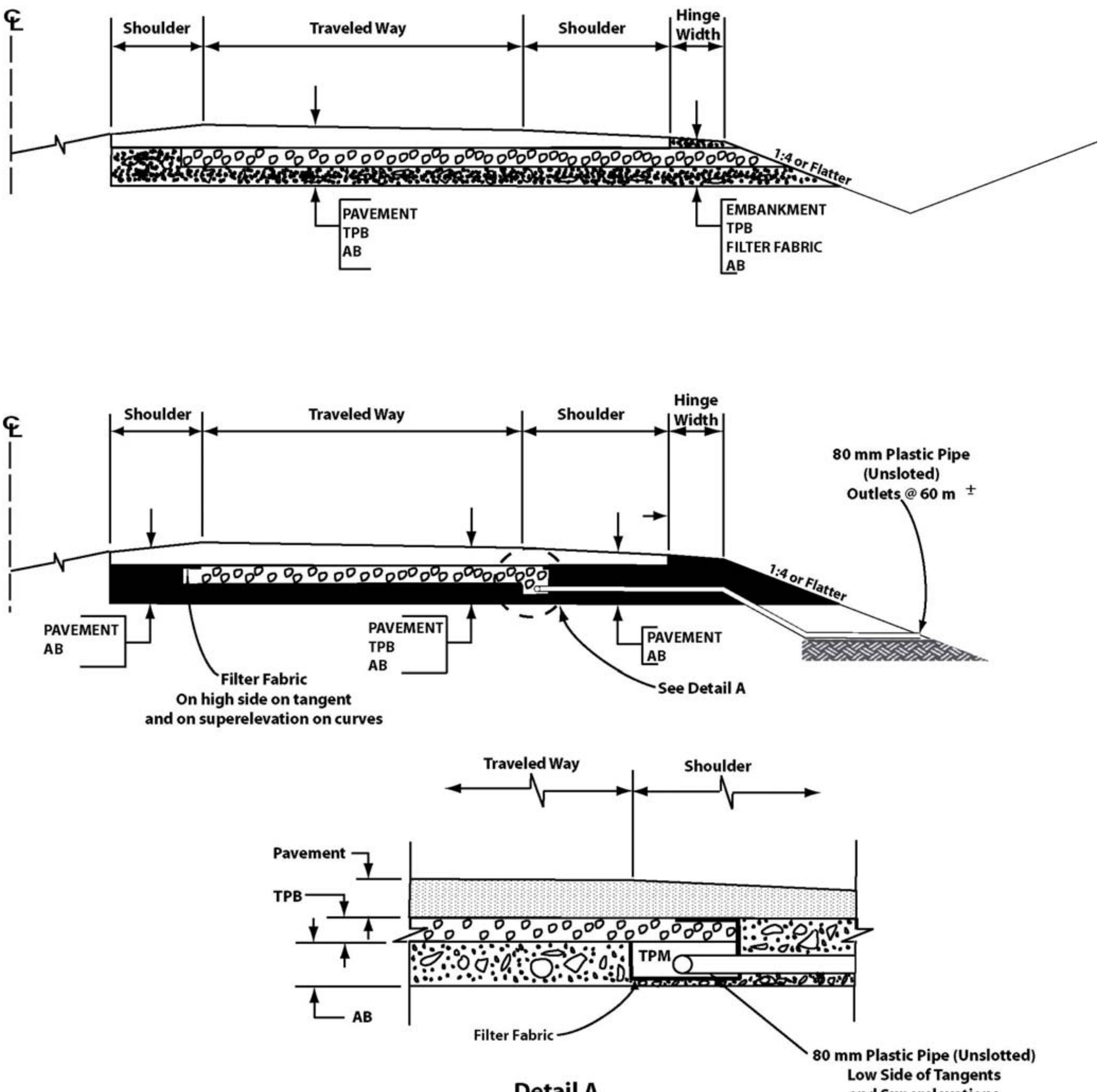
- Drainage layer.
- Collector system.
- Outlets, vents, and cleanouts.
- Filter Fabric (Selected for project specific soil conditions)
- Storm Water Management

(1) *Drainage Layer*. A drainage layer consisting of either 75 mm of asphalt treated permeable base (ATPB) or 105 mm of cement treated permeable base (CTPB) should be placed immediately below the pavement for interception of surface water that enters the structural section. The drainage layer, base, and subbase should extend the full width of the roadbed (see Figure 606.2). If constraints exist, then the drainage layer should utilize a collector system of edge drains and collector pipes (see Figure 606.2).

When there is concern that the infiltrating surface water may saturate and soften the underlying subbase or subgrade (due either to exposure during construction operations or under service conditions) a filter fabric or other suitable membrane should be utilized. It should be applied to the base, subbase, or subgrade on which the TPB layer is placed to prevent migration of fines and contamination of the TPB layer by the underlying material.

Either of the standard ATPB or CTPB layers (75 mm or 105 mm respectively) will generally provide greater drainage capacity than is needed. The standard thicknesses are based primarily on constructability with an added allowance to compensate for construction tolerances. If material other than ATPB or CTPB with a different permeability is used, it is necessary to check the permeability and adequacy of the layer thickness.

Figure 606.2
Typical Section with Treated Permeable Base Drainage Layer



Detail A

See Std. Plans D99A-D99D For Additional Information

NOTES:

1. Section shown is a half-section of a divided highway. An edge drain collector and outlet system should be provided if insufficient Right of Way precludes a retention basin.

2. This figure is only intended to show typical pavement structural section details, for geometric cross section details, see Chapter 300.

When using TPB, special attention should be given to drainage details wherever water flowing in the TPB encounters impermeable abutting structural section layers, a bridge approach slab, a sleeper slab, a pavement end anchor, or a pressure relief joint. In any of these cases, a cross drain interceptor should be provided.

Details of cross drain interceptors at various locations are shown in Figure 606.3A. The cross drain outlets should be tied into the longitudinal edge drain collector and outlet system with provision for maintenance access to allow cleaning.

When TPB is encountered as a drainage layer in widening of a facility, the TPB should be perpetuated so water is not trapped within the structural section.

(2) *Structural Section Design Considerations.* The standard flexible pavement design procedure, as covered under Index 604.4, is followed to develop AC pavement structural sections which incorporate a drainage layer to accommodate surface infiltration. A gravel factor (G_f) of 1.4 is used for ATPB with a standard thickness of 75 mm. A standard thickness of 105 mm is used for CTPB with a G_f of 1.7. Because of their relative rigidity, no R-value is assigned to either ATPB or CTPB and the design is handled in the same manner as Class A CTB. For design examples see Structural Section Design Examples on the Design Pavement website http://www.dot.ca.gov/hq/oppd/pavement/guidance.htm.

(3) *Collector System.* Where it is not practical to drain water out of the structural section by other means, an 80 mm slotted plastic pipe edge drain should be installed in a longitudinal collector trench as shown in Figure 606.2. In areas where the profile grade is equal to or greater than 4%, intermediate cross drain interceptors, as shown in Figure 606.3B should be provided at an approximate spacing of 150 m. This will limit the longitudinal seepage distance in the drainage layer, minimizing the drainage time and preventing the buildup of a hydrostatic head under the surface layer. Cross drain interceptor trenches must be sloped to drain.

In addition, cross drains need to be provided at the low-end terminal of TPB projects, as shown in Figure 606.3B. Care should be taken to coordinate the cross drains with the longitudinal structural section drainage system. Drainage layers in roadway intersections and interchanges may require additional collector trenches, pipes, and outlets to assure rapid drainage of the structural section.

A standard longitudinal collector trench width of 0.3 m has been adopted for new construction to accommodate compaction and consolidation of the TPB alongside and above the 80 mm slotted plastic pipe. The TPB type (cement or asphalt treated) for use in the collector trenches will be at the contractor's option.

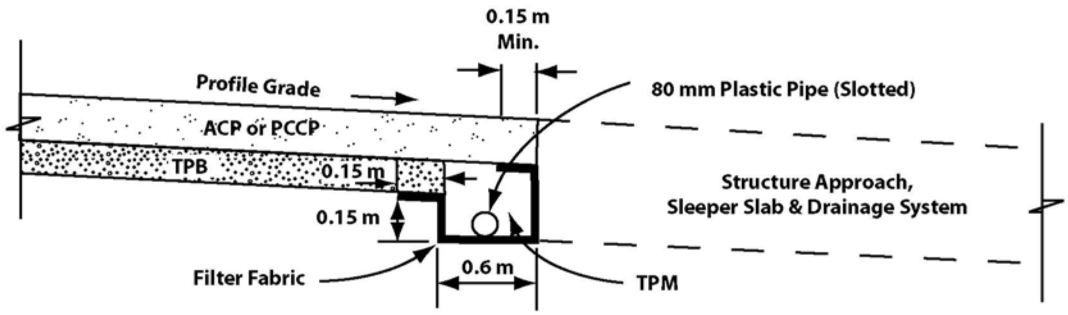
Filter fabric should be placed as shown in Figures 606.2 and 606.3A, respectively, to provide protection against clogging of the TPM by intrusion of fines. Filter fabric should be selected based upon project specific materials conditions to ensure continuous flow of water and preclude clogging of the filter fabric openings. Consult with METS' Office of Pavement Rehabilitation to assist in selecting the most appropriate filter fabric for the project.

On curvilinear alignments, superelevation of the roadway may create depressions at the low side of pavement where the collected water cannot be drained away. An adjustment to the profile grade may be necessary to eliminate these depressions. Refer to Chapter 200 for superelevation design guidelines.

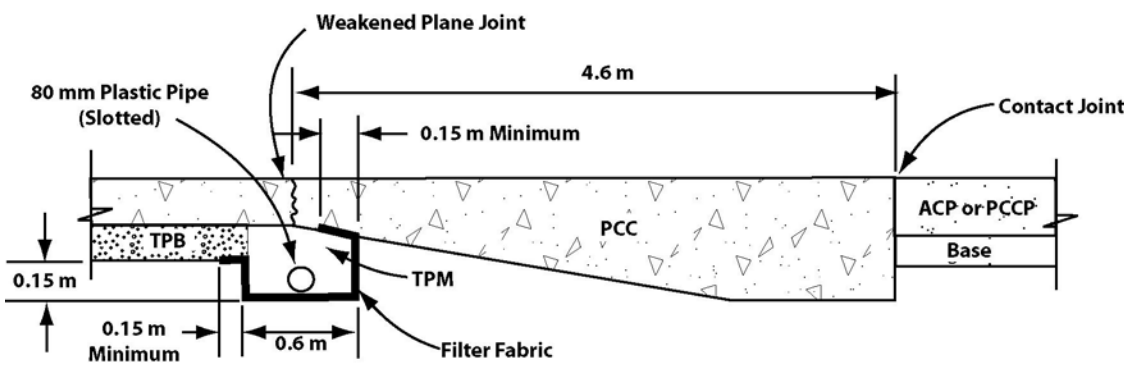
When a superelevation cross slope begins to drain the water through the TPB to the low side of pavement in cut sections, an edge drain system may be considered to direct water to an area where ponding will not occur.

(4) *Outlet Pipes.* When edge drains are used, plastic pipe (unslotted) outlets should be provided at proper intervals for the pavement structural section drainage system to be free draining. The spacing of outlets (including

Figure 606.3A
Cross Drain Interceptor Details
For Use with Treated Permeable Base

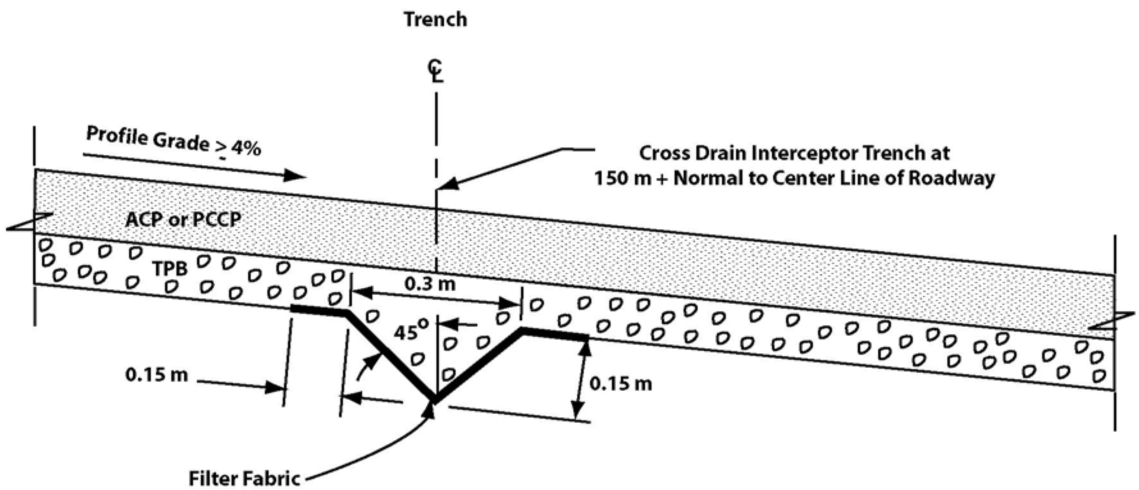


AT STRUCTURE APPROACH
(LONGITUDINAL SECTION)

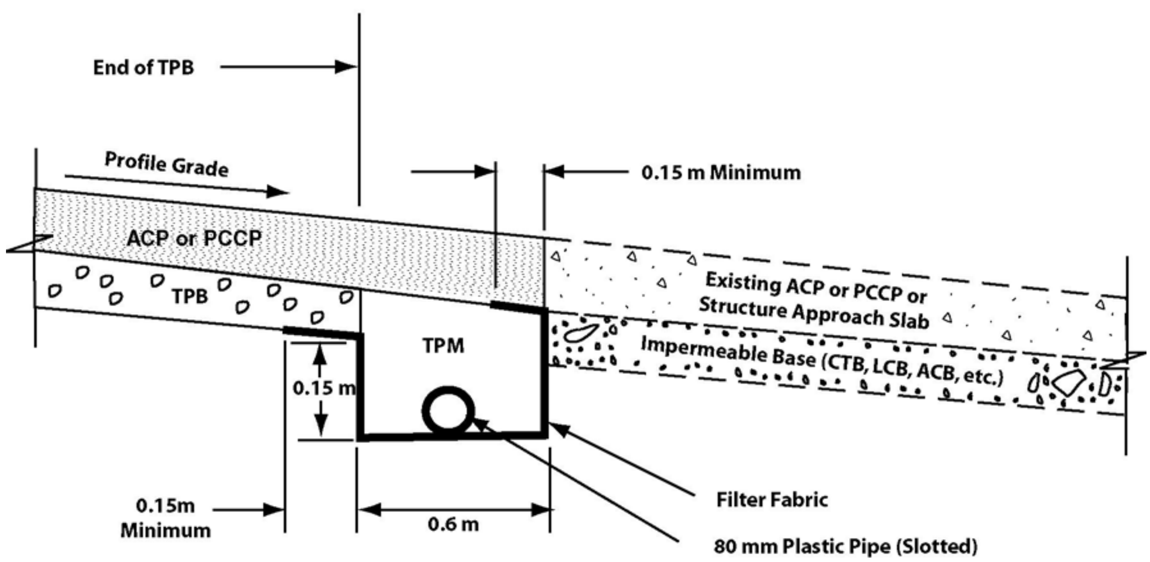


AT END ANCHOR
(LONGITUDINAL SECTION)

Figure 606.3B
Cross Drain Interceptor Trenches



Intermediate Cross Drain
(Longitudinal Section)



Terminal Cross Drain
(Longitudinal Section)

vents and cleanouts) should be approximately 60 m (75 m maximum). Outlets should be placed on the low side of superelevations or blockages such as bridge structures.

The trench for the outlet pipe must be backfilled with material of low permeability, or provided with a cut-off wall or diaphragm, to prevent piping.

The outlets must be daylighted, connected to culverts or drainage structures, or discharged into gutters or drainage ditches. The area under the exposed end of a daylighted outlet should have a splash block or be paved to prevent erosion and the growth of vegetation, which will impede flows from the outlet. Ready access to outlets, and the provision of intervening cleanouts when outlet spacing exceeds a maximum distance of 75 m, should be provided to facilitate cleaning of the structural section drainage system. Typical details are shown on the Standard Plans for Edge Drain Outlet and Vent Details.

The end of each outlet pipe should be indicated by an appropriate marker to facilitate location and identification for maintenance purposes and to reduce the likelihood of damage by vehicles and equipment. Consult the District Division of Maintenance for the preferred method of identification.

(5) *Storm Water Management.* Drainage emanating from either the pavement surface or from subsurface drains (edge drains, underdrains, and daylighting of the structural section layers) is to be handled in accordance with the procedures provided in Chapter 800 of the HDM for conveyance and with the procedures in the Project Planning and Design Guide (PPDG) for treatment consideration. Storm water Best Management Practices (BMP's) are to be incorporated in the design of projects as prescribed in the PPDG.

Topic 607 - Structure Approach Pavement and Structure Abutment Embankment Design

607.1 Introduction

The ultimate goal of structure approach slab design is to provide a smooth transition between a pavement that is generally supported on a yielding medium (soil that is subject to consolidation and settlement) and a structure, which is supported on a relatively unyielding foundation (piling or spread footings).

The approaches to any structure, new or existing, often present unique geometric, drainage, structural section, and traffic situations that require special design considerations.

Adequate information must be available early in the project development process if all factors affecting the selection and design of a structure approach system are to be properly assessed. A field review will often reveal existing conditions, which must be taken into consideration during the design.

These design guidelines must be followed in the design of all projects involving new construction, reconstruction, or rehabilitation of structure approaches. They are not, however, a substitute for engineering knowledge, experience, or judgment.

607.2 Functional Area Responsibilities

(1) *Project Engineer* - The Project Engineer (PE) is responsible for the Plans, Specifications, and Estimate (PS&E) of all structure approach contract items below the grading plane, except for the contiguous drainage system components placed within the abutments and wingwalls. The PE is responsible for PS&E of drainage outside the abutments and wingwalls. The PE is also responsible for coordinating and reviewing the adequacy of all drainage ties between the structure approach drainage features and other new or existing drainage facilities.

The PE should contact the Structures District Liaison Engineer as early as possible in the project development process to facilitate project scheduling. The PE must provide pertinent site information and traffic staging plans to DES and may submit recommendations concerning the need for concrete approach systems. Close coordination between the District staff and DES staff is necessary for the proper selection and design of a structure approach system.

(2) *Division of Engineering Services* – The DES is responsible for the PS&E of all structure approach contract items above the grading plane and for the drainage system components placed within the abutments and wingwalls. Coordination between DES and the District should be as discussed in Index 607.2(1). Questions concerning approach slab design should be directed to DES. Figures 607.4, 607.5A and 607.5B show diagrammatically the structure approach features which are DES responsibilities. When the construction or rehabilitation of a concrete pavement approach is necessary, the DES is responsible for selecting the type of concrete approach system to be used. On new construction projects, the DES is responsible for determining whether or not a concrete pavement approach system is used at each bridge site. On rehabilitation projects, the Pavement Rehabilitation Scoping Team will recommend whether or not replacement or construction of a PCC approach slab(s) is necessary. The Pavement Rehabilitation Scoping Team is comprised of the Project Engineer, District Maintenance, other District functional unit representatives, Headquarters Program Advisors and others as needed.

(3) *Office of Structural Foundations (OSF)* - Provides the Districts, Structures, and Headquarters with expertise in foundation investigations. Prepares Geotechnical Design Reports recommending estimates of settlement by areas, specific recommendations for foundation treatment, and a history of the performance of structure abutment foundations and embankments in the same area. The OSF Structure Foundation Branch on new construction projects should perform a foundation investigation and analysis. At the request of the DES, the OSF Roadway Geotechnical Engineering Branch will prepare a Geotechnical Design Report based upon its studies and information supplied by the District. The report should include a summary of field investigations, estimate of settlement by areas, specific recommendations for foundation treatment, and a history of the performance of structure abutment foundations and embankments in the same area. All foundation and embankment recommendations by the OSF Branches must be carefully followed in development of the project PS&E or documented as to why they were not followed.

(4) *District Materials Engineer* - Responsible for materials information requested for each project from Planning through Maintenance. Prepares the District Materials Report for each project. Continuous consultation with the PE and Construction should take place. Coordinates Materials information with Caltrans functional units, METS, Headquarters functional units, local agencies, industry, and consultants. The District Materials Unit is responsible for conducting a preliminary soils investigation, which addresses the quality of the materials available in and under the roadway prism for constructing the project. Poor quality material, such as expansive soils, must be precluded from structure abutment embankments. If sufficient quality roadway excavation material is unavailable for constructing structure abutment embankments, the designer may specify select material, local borrow or imported borrow to satisfy the design requirements.

(5) *Traffic Operations* - Recommends Traffic Management Plans (TMP's) and assists in the determination of construction windows. On approach slab rehabilitation projects, complete investigations by the District Division of Traffic Operations will be necessary to assess the impact of lane closures and detours on the traveling public.

607.3 Structure Approach Embankment

Structure approach embankment is that portion of the fill material within approximately 50 m longitudinally of the structure. Refer to Figure 607.3 for limits, the Standard Specifications, and other requirements.

Quality requirements for embankment material are normally specified only in the case of imported borrow. When select material or local borrow for use in structure abutment embankments is shown on the plans, the Resident Engineer (RE) is responsible for assuring the adequacy of the quantity and quality of the specified material. The RE File should include adequate information and guidance to assist the RE in fulfilling this responsibility.

607.4 Structure Approach Pavement Systems

Concrete pavement structure approach systems are used on all Portland cement concrete (PCC) pavements and on multilane asphalt concrete (AC) pavements located within currently designated urbanized areas. Urbanized areas are identified, by kilometer post, in the Route Segment Report, Project Management Control System (PMCS) Data Base and State Highway Inventory. The current boundaries of urbanized areas are also shown on the official State Highway Map.

There are several pavement slab alternatives that may be considered in the design of a structure approach pavement system. These alternatives are designated Types 14, 9, and 3 structure approach systems. Standard details and special provisions have been developed for each type of approach system. DES will select the appropriate alternate and provide applicable details, specifications, and an estimate of cost for inclusion in the PS&E package. It is recommended that dowel bars be placed at the transverse joint of PCC pavement where the pavement and approach slab meet to ensure load transfer at the joint. The thinner of either the pavement or the approach slab will govern placement of the dowel at half the thickness of the thinner slab.

On all new construction projects, regardless of the type of structure approach selected, provisions for positive drainage of the approach system are to be incorporated into the design. (See Structures Design Standard Details for requirements.)

On rehabilitation projects, provisions for positive drainage of the structural section must be incorporated into the structure approach design.

On new construction projects, overcrossing structures constructed in conjunction with the State highway facility should receive the same considerations as the highway mainline.

A brief discussion of the types of structure approach pavement systems follows:

(1) *Type 14 Structure Approach System (Approach and Sleeper Slabs/Drainage).* The Type 14 system includes a 9 m long reinforced concrete pavement slab and a 4.5 m long structure approach sleeper slab (see Figure 607.4). The structure approach system extends laterally across all traffic lanes and shoulder areas. The approach slab is designed to either cantilever over (preferred) or extend to the inside faces of both abutment wingwalls.

    The Type 14 approach system is used only on new construction with structures having diaphragm type abutments. It is primarily used on PCC pavement but may be used on AC pavement if warranted by special site conditions.

(2) *Type 9 Structure Approach Pavement System (Approach Slab/Drainage).* This approach slab is a 9 m long reinforced concrete pavement slab which rests on and is tied to the structure abutment backwall or paving notch. The slab extends laterally across all traffic lanes and shoulder areas. The approach slab is designed to either cantilever over or extend to the inside faces of both abutment wingwalls.

Figure 607. 3
Limits of Structure Approach Embankment Material

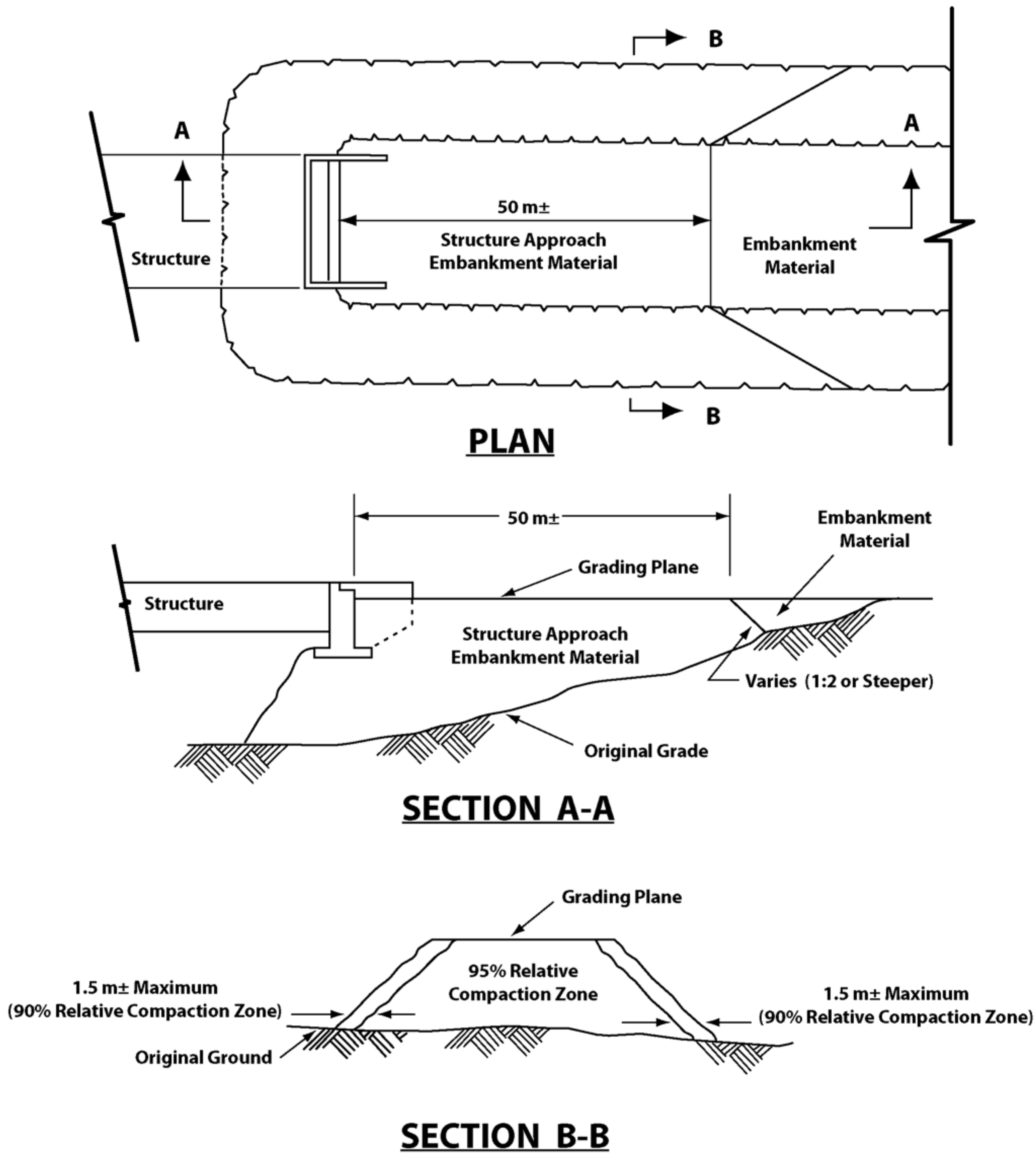
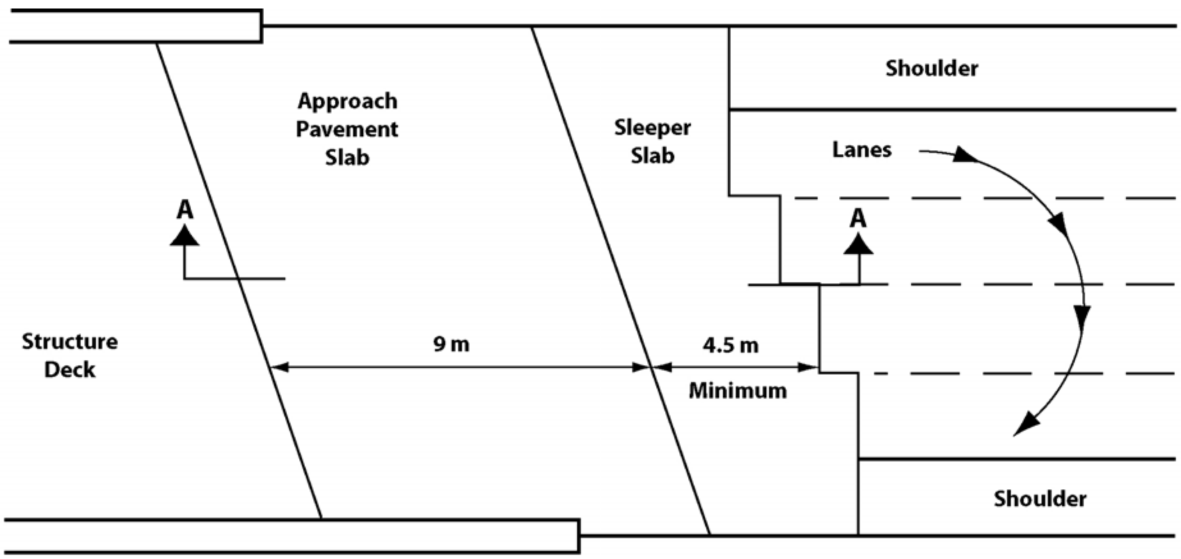
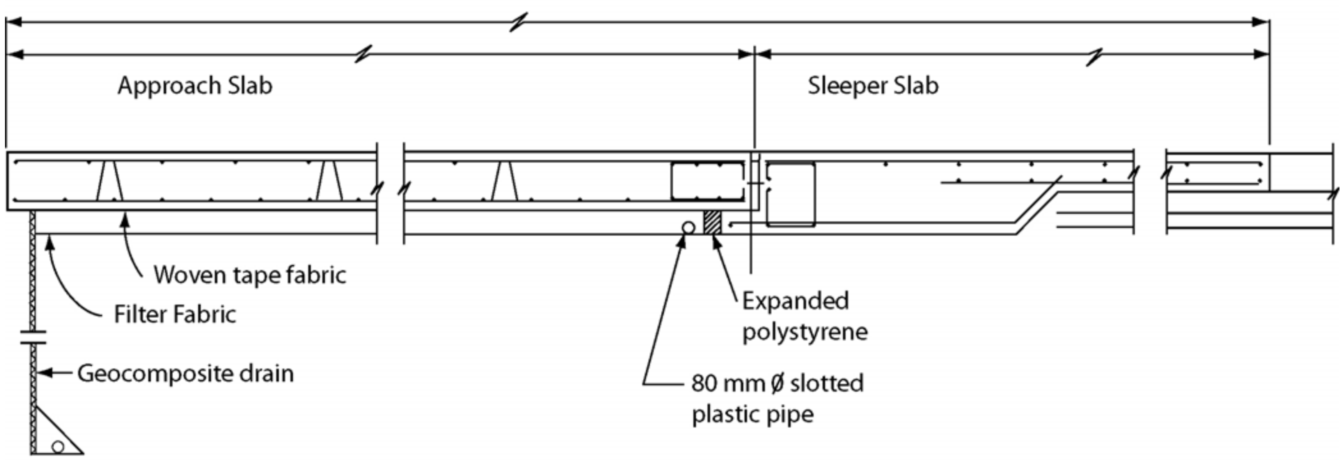


Figure 607.4
Type 14 Structure Approach Layout



Plan View



SECTION A-A

The Type 9 system is the design standard for new construction at structures with seat type abutments. The Type 9 system is also adaptable to diaphragm type abutments where the Type 14 approach system may be inappropriate. The Type 9 slab is the standard rehabilitation treatment at structures with either diaphragm or seat type abutments.

(3) *Type 3 Structure Approach Pavement System - Earthquake Zones (Seismic Ramp Slab).* The Type 3 structure approach slab, 3 m in length, is used only on AC pavement located within areas of high magnitude seismic activity. This approach slab is designed to provide a ramp to accommodate the passage of motor vehicles over the structure in the event that an earthquake creates settlement of the structure abutment embankment and approach pavement. The Type 3 seismic ramp slab is provided when both the following conditions (a) and (b) exist or when the following condition (c) exists:

(a) Peak rock acceleration is estimated to be 0.6 x gravity or greater, as documented in the Geotechnical Design Report, District Materials Report or Foundation Report.

(b) Approach embankment or fill height exceeds 3 m.

(c) Geologic conditions, as documented in the Geotechnical Design Report, District Materials Report, or Foundation Report, indicate the need for a seismic approach ramp.

If an alternate and convenient route is available for use by emergency vehicles, the use of the Type - 3 structure approach system is not necessary.

607.5 Structure Approach Pavement System - New Construction

(1) *Foundation and Embankment Design.* The structural stability and overall performance of the structure approach system depends, to a significant degree, upon the long-term settlement/consolidation of the approach foundation and structure abutment embankment. A design that minimizes this post construction settlement/ consolidation is essential. Factors that influence settlement/ consolidation include soil types and depths, static and dynamic loads, ground water level, adjacent operations, and changes in any of the above. The PE must carefully follow all foundation and embankment recommendations by the OSF Branches and District Materials Unit, and any deviations from their recommendations must be approved by them.

The relative compaction of material within the embankment limits must not be less than 95%, except for the outer 1.5 m of embankment measured horizontally from the side slope. The District Materials Engineer or OSF may recommend using select material, local and/or imported borrow to assure that the compaction requirements are met and that shrink/swell problems are avoided. They may also recommend a height and duration of embankment surcharge to accelerate foundation consolidation.

(2) *Abutment Details.* The Type 14 approach slab is rigidly tied to the structure abutment and acts as an extension of the structure. Any movement of the abutment will also occur in the approach slab. A sealed joint between the approach slab and the sleeper slab, parallel to and 9 m from the abutment wall, provides for this movement.

The Type 9 approach system is used at structures having either diaphragm or seat type abutments. At a diaphragm type abutment, structure movement is accommodated at the sealed joint between the approach slab and abutment. Structure movement at a seat type abutment will occur at the structure side of the abutment. The structure/abutment joint is designed to handle the movement.

The Type 3 approach system is also used at both seat and diaphragm type abutments. Various abutment/slab tie details are available to accommodate structure movement.

(3) *Structure Approach Drainage.* Special attention must be given to providing a positive drainage system that minimizes the potential

for water damage to the structure approach embankment. The following features should be included:

(a) Abutment and Wingwall Drainage

A geocomposite drain covered with filter fabric is used behind both the abutment wall and wingwalls, as indicated in Figures 607.4, 607.5A and 607.5B.

A slotted plastic pipe drain, encapsulated with treated permeable material, is placed along the base of the inside face of the abutment wall as illustrated in Figure 607.5B. A pipe outlet system carries the collected water to a location where it will not cause erosion. Storm Water Best Practices should be incorporated. Coordination with DES is necessary for the exit location of the pipe system. The outlet type should be chosen from the standard edge drain outlet types shown in the Standard Plans. The PE must review the drainage design to insure the adequacy of the drainage ties between the abutment and wingwall drainage system and either new or existing drainage facilities.

(b) Structural Section Drainage

Figure 607.4 shows the components of the positive structural section drainage system. Filter fabric should be placed on the grading plane to minimize contamination of the TPB for all types of approach systems. For the Type 14 approach system, a transverse slotted plastic pipe is installed in the treated permeable layer under the approach slab and adjacent to the sleeper slab to intercept water that enters through this joint. The plastic pipe shall have a proper outlet to avoid erosion of the structure approach embankment. Storm Water Best Practices should be incorporated. The Districts are responsible for all drainage considerations of the roadway while DES Structures is responsible for structure related drainage.

(c) Surface Drainage

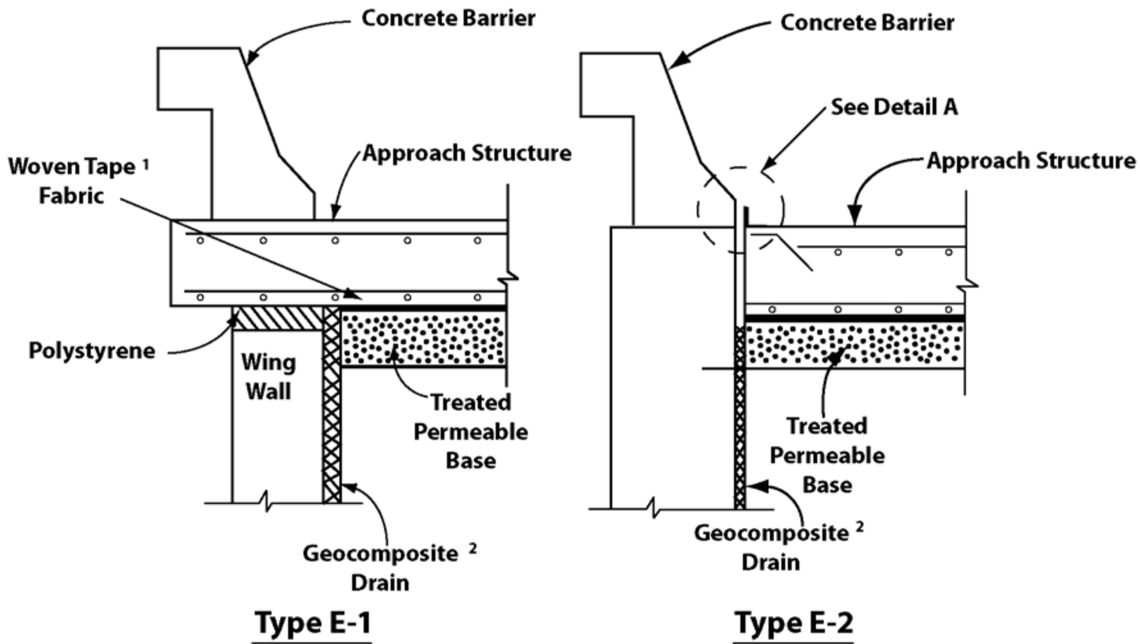
Roadway surface drainage should be intercepted before reaching the approach/ sleeper slab; likewise, structure deck drainage, when practicable, should be intercepted before reaching the abutment joint or paving notch. Cross drain interceptors are discussed in Topic 606.3(3) and shown in Figures 606.2B and 606.3. The objective is to keep water away from the structure approach embankment. The surface water, once collected, should be discharged at locations where it will not create erosion.

Containment of surface drainage requires special treatment when the approach slab edge extends only to the inside faces of the abutment wingwalls. A 76 mm x 76 mm x 6.4 mm galvanized steel angle (see Figure 607.5A), pourable seal, and hardboard spacer prevent water from entering the structural section and embankment. On wingwalls longer than 9 m, the angle is terminated at the sealed joint between the approach slab and the sleeper slab. A 155 mm x 6.4 mm steel plate will be used instead of angle for the single slope barriers such as concrete barrier Type 732 or Type 736.

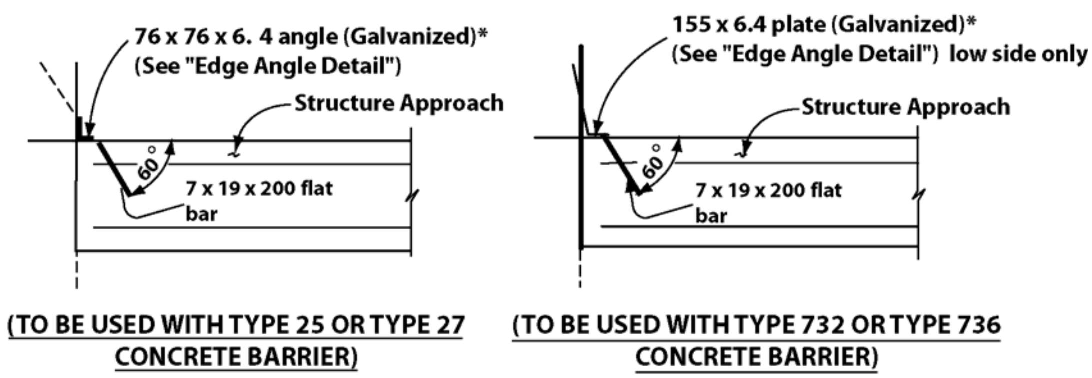
When a dike is required to protect the side slope from erosion, it should be placed on the approach and sleeper slabs and aligned to tie into the end of the structure railing. The guardrail alignment and edge of shoulder govern the positioning of the dike.

When the Type 14 approach system is used, an AC dike will inevitably crack due to expansion and contraction at the approach/sleeper slab joint. PCC dikes may be considered for this application. A metal dike insert is used to carry the flow across the sealed joint. The insert acts as a water barrier to minimize erosion of the fill slope. Details of the metal dike insert are shown in the structure approach plans provided by DES. Index 837.3(2) should be referenced when drainage inlets are to be placed at bridge approaches and departures.

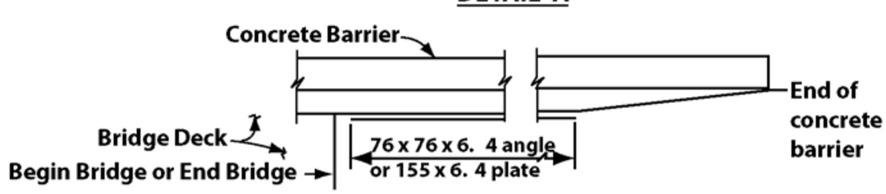
Figure 607.5A
Approach Slab Edge Details



NOTES:
1. Remove all Polystyrene

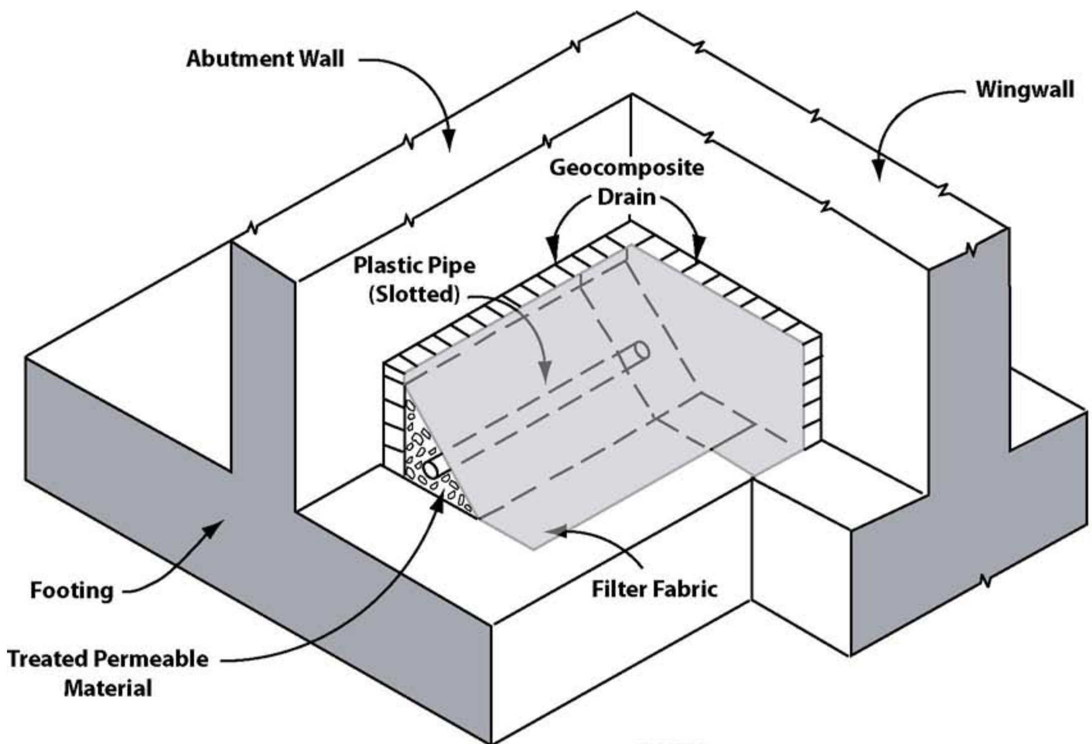


DETAIL A



EDGE ANGLE DETAIL

Figure 607.5B
Abutment Drainage Details[1]



NOTES:

1. Applicable to Type 14 Structure Approach Systems only.
2. Applicable to new construction only.

(4) *Pavement Details.* Approach/sleeper slabs extend the full width of the traveled way and shoulders. On new construction, or rehabilitation work where the structure railing will be replaced, the approach slab extends laterally to coincide with the edge of the structure superstructure. The slab extends over the wingwall, but is separated from the top of the wingwall by polystyrene fillers to preclude vertical loading of the wingwalls when settlement of the embankment occurs. The new structure railing is then attached to the approach slab.

The Type 14 approach slab system utilizes a woven tape fabric, which is used as an interlayer separator on top of the treated permeable base to reduce friction and accommodate movement of the approach slab. The sleeper slab functions as a bearing surface for the approach slab in the event that settlement/consolidation of the structure abutment foundation or embankment occurs. The sleeper slab also functions as a transition slab to the pavement structural section.

Any longitudinal construction joints (cold joints) required during construction of the structure approach or sleeper slabs should be placed on lane lines. The contact joint at the end of the sleeper slab is normal to the centerline. Transverse joints may be staggered at the lane lines at skewed structures; as illustrated in Figure 607.4. The stagger may occur 7.2 m or 10.8 m apart for skews of 20 to 45 degrees and at each lane line for skews greater than 45 degrees.

Structural adequacy must be met under the approach slabs.

(5) *Guardrail.* The extension of the approach and sleeper slabs across the full width of the outside shoulder creates a conflict between the outside edge of these slabs and the standard horizontal positioning of some guardrail posts. Spacers are attached to the posts that conflict with the approach and sleeper slabs to move the postholes outside the edge of shoulder without changing the standard alignment of the guardrail. These details are covered by DES Standard Details and by Standard Plans.

607.6 Structure Approach Slab - Rehabilitation Projects

(1) *Approach Slab Replacement.* The Type 9 approach slab is the primary rehabilitation standard for both PCC pavement and AC pavement. The Type 3 approach slab may be used on AC pavement only, if warranted by special site considerations (see Index 607.4(3)).

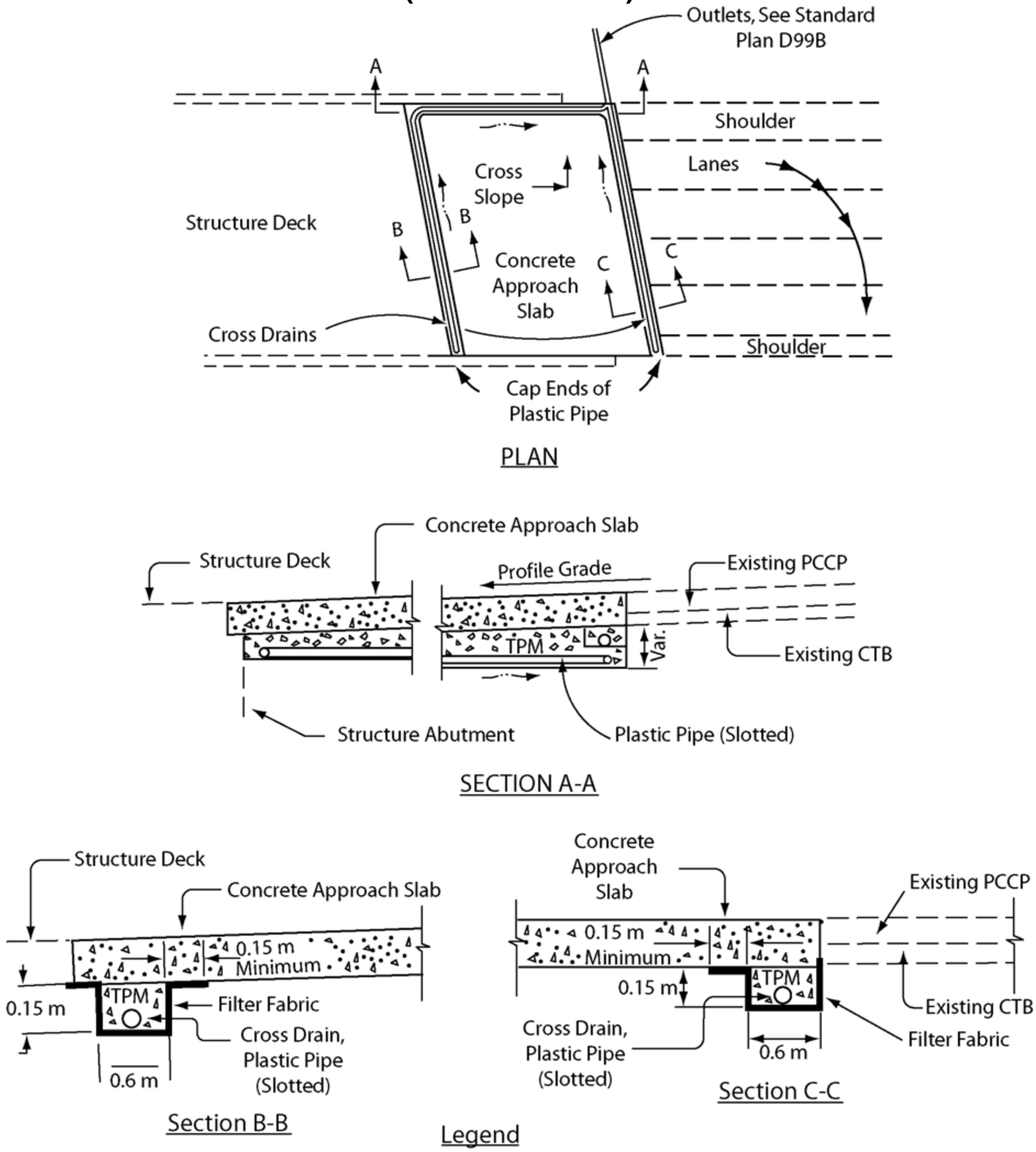
Replacement of a PCC approach slab consists of removing the existing pavement, approach slab, cement treated base and subsealing material (if applicable) and then replacing with an appropriate type of structure approach system. Depending on the thickness of the existing pavement and base materials to be removed, the minimum 300 mm approach slab thickness (Type 9 approach system) may have to be increased.

(2) *Structure Approach Structure Section Drainage.* Typical details for positive drainage of a full-width structure approach system are shown in Figure 607.6A. Cross drains are placed at the abutment backwall and at the transverse joint between the existing pavement and the concrete approach slab. A collector/outlet system is placed adjacent to the wingwall at the low side of pavement. The collected water is carried away from the structure approach embankment to a location where it will not cause erosion. Storm Water Best Practices should be implemented.

The approach slab edge details to prevent entry of water at the barrier rail face (see Figure 607.5A- Type E2) apply when the wingwalls and/or bridge barrier railing are not being reconstructed.

(3) *Pavement Details.* Special pavement details are necessary when PCC approach slabs will be replaced in conjunction with the crack, seat, and AC overlay pavement rehabilitation strategy for PCC pavement. Figure 607.6B, which is applicable to full-width slab replacement, illustrates a method of transitioning from the typical 105 mm AC overlay thickness to the minimum 45 mm final AC lift thickness. Care should be taken in

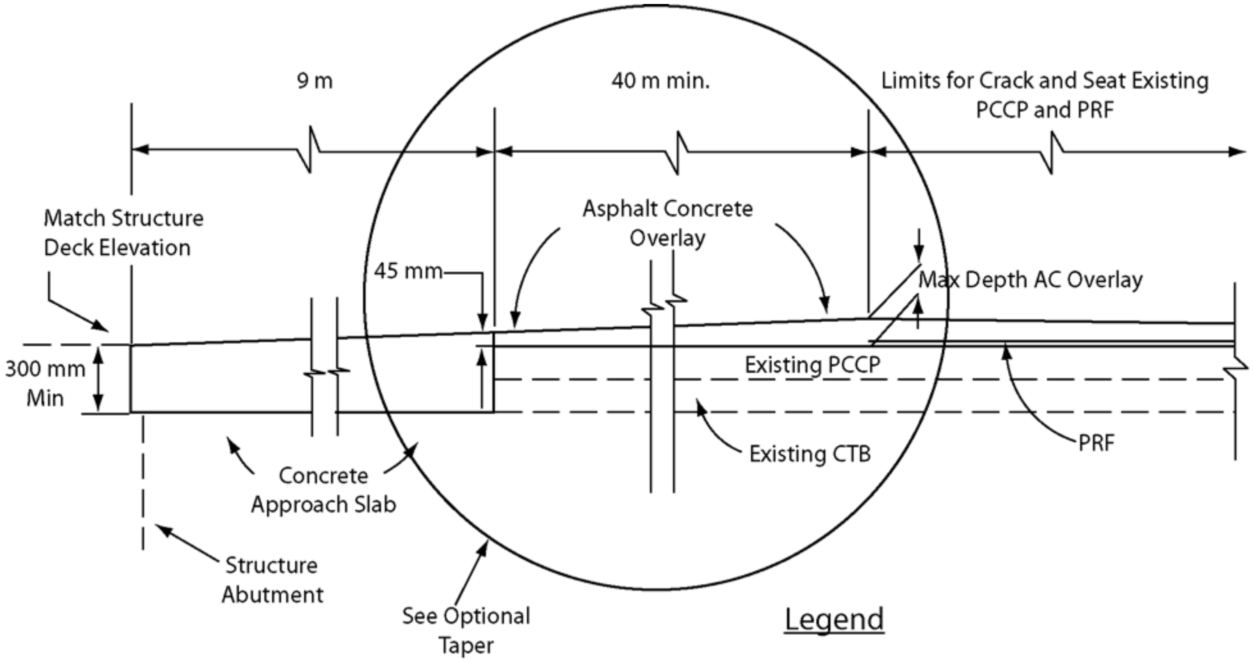
Figure 607.6A
Structure Approach Drainage Details (Rehabilitation)



Legend

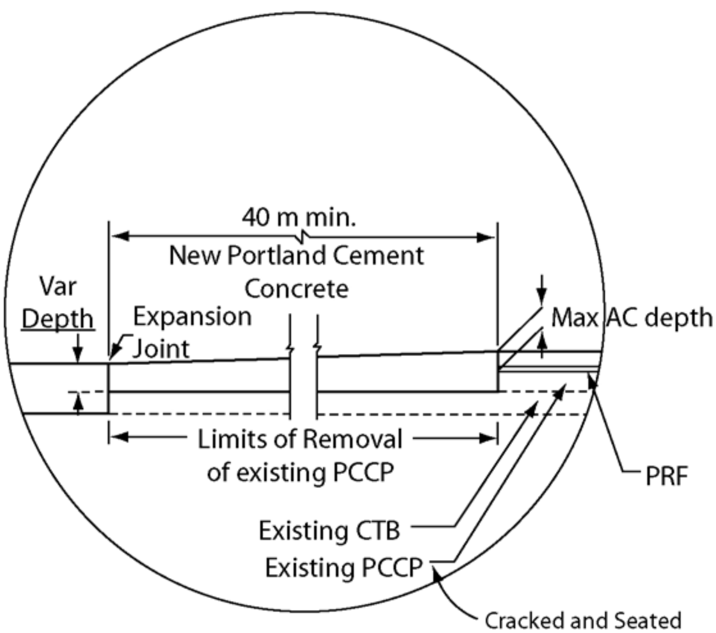
—··→	Direction of Flow
CTB	Cement Treated Base
PCCP	Portland Cement Concrete Pavement
TPM	Treated Permeable Material

Figure 607.6B
Structure Approach Pavement Transition Details (Rehabilitation)



Legend

CTB	Cement Treated Base
PRF	Pavement Reinforcing Fabric
PCCP	Portland Cement Concrete Pavement



Optional Taper

areas with flat grades to avoid creating a ponding condition at the structure abutment.

Cracking and seating of the existing PCC pavement as well as the pavement reinforcement fabric (PRF) should be terminated at the start of the transition from the maximum AC overlay depth.

AC overlays should not be placed on structure decks without the concurrence of Structures Maintenance Investigations (SMI). The need for overlays on structure decks is the responsibility of the SMI. SMI is responsible for maintaining the structural adequacy of all State bridges. Some reasons for overlays include ride quality and/or deck protection. If an overlay is needed, SMI will provide the recommended strategy. If the recommended strategy is AC or slurry seal, the District will typically provide the details. If another strategy, such as polyester concrete, the details will be provided by either SMI or Office of Structure Design.

(4) *Composite Pavements.* Flexible surfacing over rigid pavement is considered to be a rigid pavement for structure approach rehabilitation. The guidelines for rigid pavement apply to all composite pavement rehabilitation projects, which include structure approach slab replacements.

(5) *Traffic Handling.* Traffic handling considerations generally preclude full-width construction procedures. Structure approach rehabilitation is therefore usually done under traffic control conditions, which require partial-width construction.

District Division of Traffic Operations should be consulted for guidance on lane closures and traffic handling.

Pavement joint should not be located underneath the wheel paths.

Topic 834 - Roadside Drainage

834.1 General

Median drainage, ditches and gutters, and overside drains are some of the major roadside drainage facilities.

834.2 Median Drainage

(1) *Drainage Across the Median.* When it is necessary for sheet flow to cross flush medians, it should be intercepted by the use of slotted drains or other suitable alternative facilities. See Standard Plan D98-B for slotted drain details.

(2) *Grade and Cross Slope.* The longitudinal slope or grade for median drainage is governed by the highway grade line as discussed under Index 831.2. Refer to Index 204.3 for minimum grade and Indexes 305.2 and 405.5(4) for standards governing allowable cross slope of medians.

Existing conditions control median grades and attainable cross slope on rehabilitation projects. The flattest desirable grade for earth medians is 0.25 percent and 0.12 percent for paved gutters in the median.

(3) *Erosion.* When velocities are excessive for soil conditions, provisions for erosion control should be provided. See Table 862.2 for recommended permissible velocities for unlined channels.

Economics and aesthetics are to be taken into consideration in the selection of median erosion control measures. Under the less severe conditions, ground covers of natural or synthetic materials which render the soil surface stable against accelerated erosion are adequate. Under the more severe conditions, asphalt or concrete ditch paving may be required.

Whenever median ditch paving is necessary, consideration should be given to the use of cement or lime treatment of the soil. The width treated will depend on the capacity needed to handle the drainage. A depth of 150 mm is generally satisfactory. The amount of cement or lime to be used should be based on laboratory tests of the in-place material to be tested, and normally varies from 6 percent to 10 percent. If a clear or translucent curing compound is used, the completed area is unobtrusive and aesthetically pleasing.

Asphalt concrete ditch paving and soil cement treatments cured with an application of liquid asphalt are highly visible and tend to become unsightly from streaks of eroded material. Cobbles, though effective for erosion control, are not satisfactory in a recovery area for out of control vehicles. See Topic 872 for further discussion on erosion protection and additional types of ditch linings. Erosion control references are given under Index 871.3.

(4) *Economy in Design.* Economy in median drainage can be achieved by locating inlets to utilize available nearby culverts or the collector system of a roadway drainage installation. The inlet capacity can be increased by placing it in a local depression. Use of slotted pipe at sag points where a local depression might be necessary may be an alternative solution to a grate catch basin.

834.3 Ditches and Gutters

(1) *Grade.* The flattest grade recommended for design is 0.25 percent for earth ditches and 0.12 percent for paved ditches.

(2) *Slope Ditches.* Slope ditches, sometimes called surface, brow, interception, or slope protection ditches, should be provided at the tops of cuts where it is necessary to intercept drainage from natural slopes inclined toward the highway.

When the grade of a slope ditch is steep enough that erosion would occur, the ditch should be paved. Refer to Table 862.2 for permissible velocities for unlined channels in various types of soil. When the ditch grade exceeds a 1:4 slope, a downdrain is advisable. Slope ditches may not be necessary where side slopes in favorable soils are flatter than 1:2 or where positive erosion control measures are to be instituted during construction.

(3) *Side Gutters.* These are triangular gutters adjoining the shoulder as shown in Figures 307.2 and 307.5. The main purpose of the one meter wide side gutter is to prevent runoff from the cut slopes on the high side of superelevation from flowing across the roadbeds. The use of side gutters in tangent alignment should be avoided where possible. Local drainage conditions, such as in snow areas, may require their use on either tangent or curved alignment in cut sections. In snow areas it may be necessary to increase the width of side gutters from 1 m to 2 m. The slope from the edge of the shoulder to the bottom of the gutter should be no steeper than 1:6. The structural section for paved side gutters should be adequate to support maintenance equipment loads.

(4) *Dikes.* Dikes placed adjoining the shoulder, as shown in Figures 307.2, 307.4, and 307.5, provide a paved triangular gutter within the shoulder area. For conditions governing their use, see Index 303.3.

(5) *Chart Solutions.* Charts for solutions to triangular channel flow problems are contained in FHWA Hydraulic Engineering Circular No. 22, "Urban Drainage Design Manual".

834.4 Overside Drains

The purpose of overside drains, sometimes called slope drains, is to protect slopes against erosion. They convey down the slope drainage which is collected from the roadbed, the tops of cuts, or from benches in cut or fill slopes. They may be pipes, flumes or paved spillways.

(1) *Spacing and Location.* The spacing and location of overside drains depend on the configuration of the ground, the highway profile, the quantity of flow and the limitations on flooding stated in Table 831.3. When possible, overside drains should be positioned at the lower end of cut sections. Diversion from one watershed to another should be avoided. If diversion becomes necessary, care should be used in the manner in which this diverted water is disposed.

Overside drains which would be conspicuous or placed in landscaped areas should be concealed by burial or other means.

(2) *Type and Requirement.* Following are details of various types of overside drains and requirements for their use:

(a) Pipe Downdrains. Metal and plastic pipes are adaptable to any slope. They should be used where side slopes are 1:4 or steeper. Long pipe downdrains should be anchored.

The minimum pipe diameter is 200 mm but large flows, debris, or long pipe installations may dictate a larger diameter.

Watertight joints are necessary to prevent leakage which causes slope erosion. Economy in long, high capacity downdrains is achieved by using a pipe taper in the initial reach. Pipe tapers should insure improved flow characteristics and permit use of a smaller diameter pipe below the taper. See Standard Plan D87-A for details.

(b) Flume Downdrains. These are rectangular corrugated metal flumes with a tapered entrance. See the Standard Plan D87-D for details. They are best adapted to slopes that are 1:2 or flatter but if used on 1:1.5 slopes, lengths over 20 m are not recommended. Abrupt changes in alignment or grade should be avoided. Flume downdrains should be depressed so that the top of the flume is flush with the fill slope.

(c) Paved Spillways. Permanent paved spillways should only be used when the side slopes are flatter than 1:4. On steeper slopes a more positive type of overside drain such as a pipe downdrain should be used.

Temporary paved spillways are effective in preserving raw fill slopes that are 1:6 or flatter in friable soils during the period when protective growth is being established. Paved spillways should be spaced so that a dike 50 mm high placed at the outer edge of the paved shoulder will effectively confine drainage between spillways. When it is necessary to place a spillway on curved alignment, attention must be given to possible overtopping at the bends. See Index 866.2(3) for discussion of superelevation of the water surface.

(3) *Entrance Standards.* Entrance tapers for pipes and flume downdrains are detailed on the Standard Plans. Pipe entrance tapers should be depressed at least 150 mm.

The local depressions called "paved gutter flares" on the Standard Plans are to be used at all entrance tapers. See Standard Plans D87-A and D87-D for details and Index 837.5 for further discussion on local depressions.

In areas where local depressions would decrease safety the use of flush grate inlets or short sections of slotted drain for entrance structures may be necessary.

(4) *Outlet Treatment.* Where excessive erosion at an overside drain outlet is anticipated, a simple energy dissipator should be employed. Preference should be given to inexpensive expedients such as an apron of broken concrete or rock, a short section of pipe placed with its axis vertical with the lowermost 150 mm filled with coarse gravel or rock, or a horizontal tee section which is usually adequate for downdrain discharges.

(5) *Anchorage*. For slopes flatter than 1:3 overside drains do not need to be anchored. For slopes 1:3 or steeper overside drains should be anchored with 1.8 m pipe stakes as shown on the Standard Plans to prevent undue strain on the entrance taper or pipe ends. For drains over 50 m long, and where the slope is steeper than 1:2, cable anchorage should be considered as shown on the Standard Plans. Where the cable would be buried and in contact with soil, a solid galvanized rod should be used the buried portion and a cable, attached to the rod, used for the exposed portion. Beyond the buried portion, a slip joint must be provided when the installation exceeds 20 m in length. Regardless of pipe length or steepness of slope, where there is a potential for hillside movement cable anchorage should be considered.

When cable anchorage is used as shown on the Standard Plans, the maximum allowable downdrain lengths shall be 60 m for a slope of 1:1.5 and 80 m for a slope of 1:2. For pipe diameters greater than 600 mm, or downdrains to be placed on slopes steeper than 1:1.5, special designs are required. Where there is an abrupt change in direction of flow, such as at the elbow or a tee section downstream of the end of the cable anchorage system, specially designed thrust blocks should be considered.

(6) *Drainage on Benches.* Drainage from benches in cut and fill slopes should be removed at intervals ranging from 100 to 150 m.

(7) *Selection of Types.* Pipe and flume downdrains may consist of either corrugated steel, corrugated aluminum, or any other approved material that meets the minimum design service life required under Chapter 850. Refer to Index 854.4 for additional discussion on limitations of abrasive resistance of aluminum pipe culverts.

Topic 835 - Dikes and Berms

835.1 General

Dikes and berms are to be used only as necessary to confine drainage and protect side slopes susceptible to erosion.

835.2 Earth Berms

(Text Later)

835.3 Dikes

Details of dikes are shown on Standard Plan A87. See Topic 303 for a detailed discussion on the types and placement considerations for dikes.

Topic 836 - Curbs and Gutters

836.1 General

The primary reason for constructing curbs and gutters may be for delineation or pedestrian traffic rather than for drainage considerations. Refer to Topic 303 for further discussion and Standard Plan A87 for details on concrete curbs and gutters.

Whatever the justification for constructing curbs and gutters, they will usually have an effect on surface water runoff and result in becoming a roadway drainage design consideration.

836.2 Gutter Design

(1) *Capacity.* Gutters and drainage facilities are to be designed to keep flooding within the limits given in Table 831.3. Easy solutions to gutter flow problems can be obtained by using the charts contained in FHWA Hydraulic Engineering Circular No. 22, "Urban Drainage Design Manual" which applies to triangular channels and other shapes illustrated in the charts. Parked cars reduce gutter capacity and also can cause water to shoot over the curb. The downstream ends of driveway ramps can also cause water to flow over the curb. As a rule of thumb, gutter capacity should be determined on a depth equal to 0.5 the curb height for grades up to 10 percent and 0.4 the curb height for grades over 10 percent in locations where parking is allowed or where driveways are constructed.

(2) *Grade and Cross Slope.* The longitudinal grade of curbs and gutters is controlled by the highway grade line as discussed under Index 831.2.

The cross slope of standard gutters is typically 8.33 percent toward the curb. Pavement slopes on superelevated roadways extend the full width of the gutter, except that gutter slopes on the low side should be not less than 8.33 percent. Because they cut down gutter capacity and severely reduce inlet efficiency, cross slopes flatter than 8.33 percent should be avoided, except where gutters are adjacent to curb ramps where ADA requirements limit the slope to a maximum of 5 percent.

(3) *Curbed Intersections.* If pedestrian traffic is a ruling factor, intersection drainage presents the following alternatives to be weighed as to effectiveness and economy.

(a) Intercept the whole flow upstream of the crosswalk.

(b) Intercept a part of the water and allow the overflow to cross the intersection. The width of flow should be controlled so that pedestrian traffic is not unduly hampered.

(c) If flow is small, pass the entire flow across the intersecting street in a valley gutter.

(4) *Valley Gutters.* Valley gutters across the traveled way of the highway should not be used. Valley gutters may be used across intersecting streets and driveways, however, at intersections with high traffic volumes on all approaches, it is desirable to intercept all gutter flow upstream of the intersection and avoid the use of valley gutters. Valley gutters are also undesirable along streets where speeds are relatively high. In locations of frequent intermittent low flows, the use of valley gutters with slotted drains should be considered. In general, the total width of gutters should not exceed 2 m and cross slopes should not exceed 3 percent. Two percent is suggested where more than nominal speeds are involved.

Topic 837 - Inlet Design

837.1 General

The basic features of standard storm drain inlets are shown in Figure 837.1. Full details appear on Standard Plan D72 through D75, D98-A and D98-B. The variety of standard designs available is considered sufficient to any drainage situation; hence, the use of nonstandard inlets should be rare.

837.2 Inlet Types

From an operating standpoint, there are five main groups of inlets; these are:

(1) *Curb-Opening.* Curb opening inlets have an opening parallel to the direction of flow in the gutter. This inlet group is adapted to curb and gutter installations. The curb opening is most effective with flows carrying floating trash. As the gutter grade steepens, their interception capacity decreases. Hence, they are commonly used on grades flatter than 3 percent.

When curb opening inlets are used on urban highways other than fenced freeways, a 20 mm plain round protection bar is placed horizontally across any curb or wall opening whose height is 180 mm or more. The unsupported length of bar should not exceed 2.1 m. Use of the protection bar on streets or roads under other jurisdiction is to be governed by the desires of the responsible authorities.

The Type OS and OL inlets are only used with Type A or B curbs. A checkered steel plate cover is provided for maintenance access.

The Type OS inlet has a curb opening 1.07 m long. Since a fast flow tends to overshoot such a short opening, it should be used with caution on grades above 3 percent.

The Type OL inlet is a high capacity unit in which the length of curb opening ranges from 2.1 m to 6.4 m.

(2) *Grate.* Grate inlets provide a grate opening in the gutter or waterway. As a class, grate inlets perform satisfactorily over a wide range of gutter grades. Their main disadvantage is that they are easily clogged by floating trash and should not be used without a curb opening where total interception of flow is required. They merit preference over the curb opening type on grades of 3 percent or more. Gutter depressions, discussed under Index 837.5, increase the capacity of grate inlets. Grate inlets may also be used at locations where a gutter depression is not desirable.

Locating grate inlets within pedestrian paths of travel or areas subject to bicycle traffic should be avoided when practicable. If grate inlets must be located in roadway areas where cyclists may be expected to travel, bicycle proof grates are to be specified. Bicycle proof grates are shown on Standard Plan D77B. The table of final pay masses indicates the acceptable grate types to be used with each inlet type. If grate inlets must be placed within a pedestrian path of travel, the grate must be made compliant with Americans with Disabilities Act (ADA) regulations which limit the maximum opening in the direction of pedestrian travel to no more than 13 mm. Presently, the only standard grating which meets such restrictive spacing criterion is the slotted corrugated steel pipe with heel guard, as shown on Standard Plan D98B. Because such small openings have an increased potential for clogging, a minimum clogging factor of 50% should be assumed, and that factor should be increased in areas prone to significant debris. Other options which may be considered are grated line drains with specialty grates (See Standard Plan D98C for grated line drain details, and refer to manufacturers catalogs for special application grates) or specially designed grates for standard inlets. The use of specially designed grates is a nonstandard design that must be approved by the Office of State Highway Drainage Design prior to submittal of PS&E.

(3) *Combination.* Combination inlets provide both a curb opening and a grate. These are high capacity inlets which make use of the advantages offered by both kinds of openings.

(a) Type GO and GDO. These types of inlets have a curb opening directly opposite the grate. The GDO inlet has two grates placed side by side and is designed for intercepting a wide flow. A typical use of these inlets would be in a sag location either in a curb and gutter installation or within a shoulder fringed by a dike. When used as the surface inlet for a pumping installation, the trash rack shown on the Standard Plan D74B is provided.

(b) Type GOL. This is called a sweeper inlet because the curb opening precedes the grate. It is particularly useful as a trash interceptor during the initial phases of a storm. When used in a grade sag, the sweeper inlet can be modified by providing a curb opening on both sides of the grate.

(4) Pipe. Pipe drop inlets are made of a commercial pipe section of concrete or corrugated metal. As a class, they develop a high capacity and are generally the most economical type. This type of inlet is intended for uses outside the roadbed at locations that will not be subjected to normal highway wheel loads.

Two kinds of inlets are provided; a wall opening and a grate top. The wall opening inlet should only be used at protected locations where it is unlikely to be hit by an out of control vehicle.

(a) Wall Opening Intake. This opening is placed normal to the direction of surface flow. It develops a high capacity unaffected by the grade of the approach waterway. The inlet capacity is increased by depressing the opening; also by providing additional openings oriented to intercept flows from different directions. When used as the surface intake to a pumping installation, a trash rack across the opening is required. See Standard Plan Numbers D75A, D75B and D75C. Because this type of inlet projects above grade, its use should be avoided in areas subject to traffic leaving the roadway.

(b) Grate Intake. The grate intake intercepts water from any direction. For maximum efficiency, however, the grate bars must be in the direction of greatest surface flow. Being round, it is most effective for flows that are deepest at the center, as in a valley median.

(5) Slotted Drains. This type of inlet is made of corrugated metal pipe with a continuous slot on top. The slot is formed by a pair of angle irons or grating which serves as a paving bulkhead. See Standard Plans D98-A and D98-B. This type of inlet can be used in flush, all paved medians with superelevated sections to prevent sheet flow from crossing the centerline of the highway. Short sections of slotted drain may be used as an alternate solution to a grate catch basin in the median or edge of shoulder.

Drop inlets or other type of cleanout should be provided at intervals of about 30 m.

(6) Grated Line Drains. This type of inlet is made of monolithic polymer concrete with a ductile iron frame and grate on top. See Standard Plan D98-C. This type of inlet can be used as an alternative at the locations described under slotted drains, preferably in shoulder areas away from traffic loading. However, additional locations may include localized flat areas of pavement at private and public intersections, superelevation transitions, along shoulders where widening causes a decrease to allowable water spread, tollbooth approaches, ramp termini, parking lots and on the high side of superelevation in snow and ice country to minimize black ice and sheet flow from snow melt. Removable grates should not be placed where subject to traffic.

Short sections of grated line drain may be used in conjunction with an existing drainage inlet as a supplement in sag locations. However, based on the depth of the water, the flow condition will be either weir or orifice. The transition between weir and orifice occurs at approximately 180 mm depth of flow. The HEC-22 method of design for slotted pipe is recommended as the basis for grated line drain design. It should be noted that this is inlet

CHAPTER 840
SUBSURFACE DRAINAGE

Topic 841 - General

Index 841.1 - Introduction

Saturation of the structural section or underlying foundation materials is a major cause of premature pavement failures. In addition, saturation can lead to undesireable infiltration into storm drain systems and, where certain soil types are below groundwater, liquefaction can occur due to seismic forces. Subsurface drainage systems designed to rapidly remove and prevent water from reaching or affecting the roadbed are discussed in this chapter.

The solution for subsurface drainage problems often calls for a knowledge of geology and the application of soil mechanics. The Project Engineer should request assistance from the Roadway Geotechnical Unit in the Engineering Service Center for projects involving cuts, sections depressed below the original ground surface, or whenever the presence of groundwater is likely. The Roadway Geotechnical Unit can also provide assistance related to the design of features to relieve hydrostatic pressure at bridge abutments. The designer should consider the potential for large fluctuations in groundwater levels. Wet periods after several years of drought, or changes to recharge practices can lead to considerable rises in groundwater levels.

For tunnel, structure abutments, or other structure projects which might require relief of hydrostatic pressures, contact the Structure Foundations Branch of the Engineering Service Center.

The basis for design will generally be the Geotechnical Design Report. This report will include findings on subsurface conditions and recommendations for design. Refer to Topic 113 for more information on Geotechnical Design Reports.

There are many variables and uncertainties as to the actual subsurface conditions. In general, the more obvious subsurface drainage problems can be anticipated in design; the less obvious are frequently uncovered during construction. Extensive exploration and literature review may be required to obtain the design variables with reasonable accuracy.

841.2 Subsurface (Groundwater) Discharge

Groundwater, as distinguished from capillary water, is free water occurring in a zone of saturation below the ground surface. Subsurface discharge, the rate at which groundwater and infiltration water can be removed depends on the effective hydraulic head and on the permeability, depth, slope, thickness and extent of the water-bearing formation (the aquifer). The discharge can be obtained by analytical methods. Such methods, however, are usually cumbersome and unsatisfactory; field explorations will yield better results.

841.3 Preliminary Investigations

Field investigations may include:

- Soils, geological, and geophysical studies.
- Borings, pits, or trenches to find the elevation, depth, and extent of the aquifer.
- Inspection of cut slopes in the immediate vicinity.
- Measurement of groundwater discharge.

Preliminary investigations should be as thorough as possible, recognizing that further information is sometimes uncovered during construction. Where an existing road is part of new construction, the presence and origin of groundwater is often known or easily detected. Personnel responsible for maintenance of the existing road are an excellent source of such information and should be consulted. Explorations, therefore, are likely to be lesser in scope and cost than explorations for a project on new alignment. In slope stability questions, and other problems of equal importance, an extensive knowledge of subsurface conditions is required. The District should ask for the assistance of the Office of Structural Foundations in the Engineering Service Center in such cases.

841.4 Exploration Notes

In general, explorations should be made during the rainy season or after the melting of snow in regions where snow cover is common. An exception would be where seepage occurs from irrigation sources.

Groundwater difficulties frequently stem from water perched on an impermeable layer some distance above the actual water table. Perched water problems can often be solved with horizontal drains. See Index 841.5.

Pumped water supply wells often give unreliable indications of the water table and such data should be used with caution.

841.5 Category of System

Depending upon the scope and complexity of the problem, an appropriate solution may require the installation of one or a combination of different types of subsurface drainage systems. The type of subsurface drainage system initially considered is usually an underdrain.

The standard underdrain is the pipe underdrain. A pipe underdrain consists of a perforated pipe near the bottom of a narrow trench lined with filter fabric and backfilled with permeable material.

Pipe underdrains are discussed in more detail under Topic 842.

"French Drains" have proven to be unreliable underdrains. A "French drain" consists of a trench backfilled with rock. They are not to be used where a permanent solution is needed. Exceptions may be made for special cases such as where depth of the underdrain and soil conditions would conflict with industrial safety regulations. Under such circumstances a design that includes a filter fabric liner and permeable material backfill, without the perforated pipe may be used.

In addition to pipe underdrains, the following special purpose categories of subsurface drains are used to intercept, collect, and discharge groundwater.

- *Structural Section and Edge Drains.* Subsurface drainage systems that are primarily designed for the rapid removal of surface water infiltration from treated or untreated pavement structural section materials are called structural section drains or more typically edge drains. An 80 mm slotted plastic pipe with 3 rows of slots is the standard for structural section drains. Structural section drainage is discussed under Topic 606.

- *Horizontal Drains.* Horizontal drains are 40 mm perforated or slotted pipes placed in drilled holes bored into the aquifer or water bearing formations. They are installed in cut slopes and under fills more to guard against slides by relieving hydrostatic pressure than to prevent saturation of the roadbed. They may be used in varying lengths up to 300 m on grades that range from 0 to 25 percent. A collection system to remove the intercepted water from the area is generally also required.

  An example of a horizontal drain system is illustrated in Chapter C5 of the Maintenance Manual.

- *Prefabricated Geocomposite Drains.* Available in sheets or rolls, geocomposite drains provide a cost effective solution to subsurface drainage behind bridge abutments, wingwalls and retaining walls. Prefabricated subsurface drainage systems consist of a plastic drain core covered on one or both sides with a filter fabric.

- *Stabilization Trenches.* This category of subsurface drainage system is constructed in swales, ravines, and under sidehill fills to stabilize water logged fill foundations. The Geotechnical Design Report should contain depth and width of trench recommendations. Stabilization trenches may be only a few feet in width requiring a backhoe or similar type of excavation equipment, or they may be large enough for earth moving equipment such as dozers

(6) *Spiral Rib Steel.* Galvanized steel spiral rib pipe is fabricated using sheet steel and lock seam fabrication as used for helical corrugated metal pipe. The thickness of metal and zinc coating is identical to that for corrugated pipe. Spiral rib pipe has a lower roughness coefficient (Manning's "n") than corrugated metal pipe.

Aluminized steel spiral rib pipe, type 2 (ASSRP) is available in the same sizes as galvanized steel spiral rib and will support the same fill heights (the aluminizing is simply a replacement coating for zinc galvanizing that allows thinner steel to be placed in certain corrosive environments - See Figure 854.3B for the acceptable pH and resistivity ranges for placement of aluminized steel pipes). Tables 854.3F, G & H give the maximum height of overfill for steel spiral rib pipe constructed under the acceptable methods contained in the Standard Specifications and essentials discussed in Index 829.2.

854.4 Corrugated Aluminum Pipe, Aluminum Spiral Rib Pipe and Pipe Arches

(1) *Hydraulics.* Corrugated aluminum pipe comes in various corrugated profiles. Annular and helical corrugated aluminum pipe configurations are applicable in the situations where velocity reduction is important or if a culvert is being designed with an inlet control condition. Spiral rib pipe, on the other hand, may be more appropriate for use in stormdrain situations or if a culvert is being designed with an outlet control condition.

(2) *Durability.* Aluminum culverts or stormdrains may be specified as an alternate culvert material. When a 50-year maintenance free service life of aluminum pipe is required the pH and minimum resistivity, as determined by California Test Method 643, must be known and the following conditions met:

(a) The pH of the soil, backfill, and effluent is within the range of 5.5 and 8.5, inclusive. Bituminous coatings are not recommended for corrosion protection or abrasion resistance.

(b) The minimum resistivity of the soil, backfill, and effluent is 1500 ohm-centimeters or greater.

(c) Under similar conditions, aluminum culverts will abrade approximately three times faster than steel culverts. Therefore, aluminum culverts are not recommended where abrasive materials are present, and where flow velocities would encourage abrasion to occur. Culvert flow velocities that frequently exceed 1.5 m/s should be carefully evaluated prior to selecting aluminum as an allowable alternate.

(d) Aluminum culverts should not be installed in an environment where other aluminum culverts have exhibited significant distress, such as extensive perforation or loss of invert, for whatever reason, apparent or not.

(e) Aluminum may be considered for side drains in environments having the following parameters:

- When pH is between 5.5 and 8.5 and the minimum resistivity is between 500 and 1500 ohm-cm.
- When pH is between 5.0 and 5.5 or between 8.5 and 9.0 and the minimum resistivity is greater than 1500 ohm-cm.

For these conditions, the METS should be contacted to confirm the advisability of using aluminum on specific projects.

(f) Aluminum must not be used as a section or extension of a culvert containing steel sections.

Figure 854.3B should be used to determine the limitations on the use of corrugated aluminum pipe for various levels of pH and minimum resistivity. The minimum thickness (1.5 mm) of aluminum pipe obtained from the chart only satisfies corrosion requirements. Overfill requirements for minimum metal thickness must also be satisfied. The metal thickness of corrugated aluminum pipe should satisfy both requirements.

(3) *Strength Requirements.* The strength requirements for corrugated aluminum pipe and pipe arches fabricated under the acceptable methods contained in the Standard Specifications, are given in Tables 854.4A, B & C. For aluminum spiral rib pipe, see Tables 854.4D & E.

(a) Design Standards.

- Corrugation Profiles - Corrugated aluminum pipe and pipe arches are available in 68 mm x 13 mm and 75 mm x 25 mm profiles with helical or annular corrugations. Aluminum spiral rib pipe is available in a 19 mm x 19 mm x 190 mm or a 19 mm x 25 mm x 292 mm helical corrugation profile.
- Metal thickness - Corrugated aluminum pipe and pipe arches are available in the thickness as indicated on Tables 854.4A, B & C. Where a maximum overfill is not listed on these tables, the pipe or pipe arch is not normally available in that thickness. Aluminum spiral rib pipe are available in the thickness as indicated on Tables 854.4D & E.
- Height of Fill - The allowable overfill heights for corrugated aluminum pipe and pipe arches for various diameters and metal thickness are shown on Tables 854.4A, B & C. For aluminum spiral rib pipe, overfill heights are shown on Tables 854.4D, & E.

To properly use the above mentioned tables, the designer should be aware of the basic premises on which the tables are based as well as their limitations. (See Index 854.3(2)).

(4) *Shapes.* Corrugated aluminum pipe, aluminum spiral rib pipe and pipe arches are available in the diameters and arch shapes as indicated on the maximum height of cover tables. Helical corrugated pipe must be specified if anticipated heights of cover exceed the tabulated values for annular corrugated pipe.

For larger diameters, arch spans or special shapes, see Index 854.6. Non-standard pipe diameters and arch sizes are also available.

(5) *Invert Protection.* Invert protection of corrugated aluminum is not recommended.

(6) *Spiral Rib Aluminum.* Aluminum spiral rib pipe is similar to spiral rib steel. Figure 854.3B should be used to determine the limitations on the use of spiral rib aluminum pipe for the various levels of pH and minimum resistivity. Tables 854.4D & E give the maximum overfill for aluminum spiral rib pipe constructed under the acceptable methods contained in the Standard Specifications and the essentials discussed in Index 829.2.

854.5 Special Purpose Types

(1) *Smooth Steel.* Smooth steel (welded) pipe can be utilized for drainage facilities under conditions where corrugated metal or concrete pipe will not meet the structural or design service life requirements.

(2) *Composite Steel Spiral Rib Pipe.* Composite steel spiral rib pipe is a smooth interior pipe with efficient hydraulic characteristics. See Table 851.2.

Composite steel spiral rib pipe with its interior polyethylene liner exhibits good abrasion resistance and also resists corrosion from chemicals found in a typical stormdrain or sanitary sewer environment. The exterior of the pipe is protected with a polyethylene film which offers resistance to corrosive backfills. The pipe will meet a 50 year maintenance free service life under most conditions.

(3) *Proprietary Pipe.* See Indexes 110.10 and 601.5(3) for further discussion and guidelines on the use of proprietary items.

854.6 Structural Metal Plate

(1) *Pipe and Arches.* Structural plate pipes and arches are available in steel and aluminum for the diameters and thickness as shown on Tables 854.6A, B, C & D.

DHV--The design hourly volume of vehicles in the design year.

Long Vehicles--The percent of trucks and other vehicles which require long parking spaces.

Turnover--The average length of time a vehicle stays in the rest area (20 minutes) divided into 60 minutes. Round upward to highest whole number.

Persons/Vehicle--The national average number of persons in the vehicle is 2.2.

When feasible, the design should allow the parking area to be expanded by 25% beyond the 20-year design period. The master plans should indicate this future expansion.

Rest areas designed for freeways shall have standard freeway exit and entrance ramps (see Chapter 500). Projects to rehabilitate existing ramps and/or parking lots must address upgrading of ramps and geometrics to the current design standards. Rest areas on expressways and conventional highways should be designed with standard public road connections and median left turn lanes (see Topic 405).

Rest areas must not only be designed to accommodate the demand for parking spaces, but must have adequate water supply and a sewage system.

(2) *Grading*. This is an important feature in making a rest area accessible, safe, functional, aesthetically pleasing, and economical. Certain concepts are necessary to ensure that the grading is properly designed to accomplish this. Generally, grading operations should be held to a minimum so as to disturb as little of a site as possible. Grading should be designed so that the slopes and grades developed follow the natural direction of slope of the area.

Cuts and fills close to existing trees to be saved should be avoided. When necessary, special treatment for the trees should be incorporated. The District Landscape Architect will recommend such treatment as necessary in these cases. Cuts and fills should be shaped and rounded to conform to existing ground shapes. Grading should be done to ensure water flows away from walkways or is taken care of by drainage boxes.

Areas around buildings, shelters, and table slabs should be sloped away from the structure at an approximate 2% grade, but not less than 1% nor more than 3% on paved areas. Parking area slopes parallel to direction of parking should not exceed 2% in the truck area, nor 3% in the car area. For accessibility guidelines on grade and cross slopes, see Topic 105.3. Cross slopes in either case should not exceed 4%. When entrance ramps exceed a 6% grade, up or down, a transition area between the end of the ramp and the parking or other facility should be incorporated.

General area grading should be shown on plans by existing and proposed contour lines of not more than 0.5-meter vertical intervals. Pavement should be shown either by spot grades (existing and proposed) or by a combination of spot grades and contour lines. Profiles and sections should be shown when grading intent is not clear by plan indications only. Building finish floor grades and all pads for architectural elements should be individually defined by spot grades. Changes in grade should be done smoothly and gradually without abrupt edges or slopes.

(3) *Roads and Parking*. Vehicular circulation must be simple, direct and obvious to the motorist. See Topic 403 for principles of channelization. The minimum distance between successive noses should be 180 m on exit ramps into rest areas. Vehicles leaving the rest area should be oriented toward the exit and not confused into using the wrong ramp. Safety roadside rest areas not on freeways must be designed with a public road connection. If the road will ultimately be a freeway, the design should take the ultimate location of structures and roads into consideration.

Parking areas must be well defined by means of striping and curbs in order to encourage orderly and proper parking, for safety and efficiency. The curb angle points should be rounded. Large, paved areas should be relieved by incorporating planting islands, which also help define the circulation pattern. A curvilinear parking area is more pleasing than a long, straight parking lot, and is easier to use. Design plans should show pavement profiles, cross sections and spot grades, indicating both existing and proposed elevations.

All roads and parking areas should be designed to control vehicle traffic by the use of curbs or other barriers. The following comments relate to barriers:

(a) Service vehicles must be allowed access into the pedestrian area through rolled curb or a removable barrier.

(b) It is most desirable to have only one type of barrier throughout a development.

(c) Individuals with disabilities must be afforded easy access into the rest area without need to negotiate wheelchair or crutches over a curb. Rest areas shall be barrier free and accessible to all travelers. Accessibility means reasonable access to all rest area facilities such as parking, picnic tables, walkways, comfort stations, and historical or informational displays.

(d) Indiscriminate parking should be discouraged through the strategic placement of curbs and barriers.

The basic lengths and widths for parking spaces are as follows. For disabled accessible parking requirements, see Standard Plan A90.

	Length (m)	Width (m)
Auto	6	3
Trucks	21	4.5

Road widths at entrances and exits from parking spaces depend upon the parking angle and vehicle. Reference is made to the booklet, "Guide for Development of Rest Areas on Major Arterials and Freeways," Third Edition, 2001, published by AASHTO. Truck turns should be used to verify road widths at entrances and exits from parking spaces. The minimum width for two-way roads is 9.6 m. See Index 604.6 for the design of roadside rest structural sections.

(4) *Comfort Facilities*. The architect in the OSD will consult with the District Landscape Architect in regard to the design concept type and size of comfort station, and will perform the architectural design work. Buildings are to be well lighted, both interior and exterior. Comfort stations will be provided with flush-type toilet fixtures and a sewage disposal system.

The size of comfort stations will be determined by providing fixtures for each sex based upon parking capacity. For men, at least one-half of the total fixtures should be urinals. Lavatories should be provided on the basis of one per each two toilet fixtures. The DES-SD will determine the exact facilities to be provided. A minimum of 4 toilet fixtures including one that is accessible for persons with disabilities for each sex must be provided. Diaper changing tables should be provided in each comfort station.

Maintenance forces must be provided a storage and utility area sufficient in size for equipment and supplies needed to maintain the rest area. A crew room with personal lockers and a Manager's office should also be provided.

A dedicated lockable office and water closet should be provided for use by the California Highway Patrol (CHP). A designated CHP parking space with sign should be provided.

Drinking fountains with chilled water should be provided in conjunction with the comfort station. Drinking fountains without chilled

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