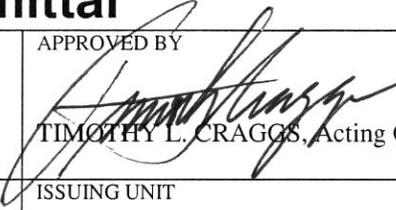


manual change transmittal

TITLE DIVISION OF DESIGN HIGHWAY DESIGN MANUAL SIXTH EDITION – CHANGE 11/02/12		APPROVED BY  TIMOTHY L. CRAGGS, Acting Chief	NO. Date Issued: 10/31/12
		Page 1 of 2	
SUBJECT AREA Table of Contents; List of Figures; Chapters: 60, 80, 300, 600-620; and, Index		ISSUING UNIT DIVISION OF DESIGN	
SUPERCEDES SEE BELOW FOR SPECIFIC PAGE NUMBERS		DISTRIBUTION ALL HOLDERS OF THE 6TH EDITION, HIGHWAY DESIGN MANUAL	

The Table of Contents; List of Figures; Chapters: 60, 80, 300, 600, 610, 620; and the Index of the Sixth Edition, Highway Design Manual (HDM) have been revised. The changes and errata to the HDM are summarized below with change sheets available on the Department Design website at: <http://www.dot.ca.gov/hq/oppd/hdm/hdmtoc.htm>. Changes include new safety edge guidance, providing a sloped edge that is placed at the edge of the paved roadbed to provide a smooth reentry for vehicles that leave the roadway. It is part of FHWA's "Every Day Counts Initiative" and the California Strategic Safety Plan to improve safety for roadways. Also included is revised joint seal guidance for concrete pavements. Recent findings from studies conducted in other states have shown that joint seals are not needed in all climatic regions. Applying these findings in California can realize cost savings. These changes and errata are effective November 2, 2012, and shall be applied to on-going projects in accordance with HDM Index 82.5 – Effective Date for Implementing Revisions to Design Standards.

HDM Holders are encouraged to use the most recent version of the HDM available on-line at the above website. Should a HDM Holder choose to maintain a paper copy, the Holder is responsible for keeping their paper copy up to date and current. Using the latest version available on-line will ensure proper reference to the latest design standards and guidance. If you would like to be notified automatically of any significant changes or updates to the HDM, go to <http://www.dot.ca.gov/hq/oppd/hdm/hdmlist.htm>.

A summary of the most significant revisions are as follows:

Index 62.7

Pavement, Page 60-11

Inserted new safety edge definition and renumbered remaining terms alphabetically.

Index 82.2

Approvals for Nonstandard Design, Page 80-7

No change in guidance, just errata rewording to clarify approval authority of mandatory standards in Chapters 600 through 670.

Index 302.3

Safety Edge, Page 300-6

New Index further describing safety edge placement as well as locations where it is not to be placed. Further details are included in the Plans Preparation Manual and the Standard Plans.

Figure 602.1

Basic Pavement Layers of the Roadway, Page 600-4

Locations where safety edge placement as required were added to the roadway cross sections for divided and undivided highways. Minor errata clarifications were added to the notes at bottom of the figure.

- Index 603.4** **Roadway Rehabilitation, Page 600-6**
Errata clarification describing where conditions warrant quieter pavements.
- Index 604.1(7)** **Division of Engineering Services (DES), Page 600-8**
Typo correction from “. . . specialized field inspectors . . .” to “. . . specialized field inspections. . .”
- Index 612.5** **Roadway Rehabilitation, Page 610-3**
The threshold of analyzing 20- vs. 40-year pavement design life for roadway rehabilitation was changed as indicated in the paragraph.
- Table 613.3B** **Lane Distribution Factors for Multilane Highways, Page 610-6**
Minor typo corrections to Note 3 at bottom of the Table.
- Index 613.5(2)** **Specific Traffic Loading Considerations, Shoulders, Page 610-9**
Changed to provide further information concerning engineering of shoulder pavement structures.
- Figure 613.5A** **Shoulder Design for TI Equal to Adjacent Lane TI, Page 610-11**
New figure added to clarify the engineering details of the Index.
- Figure 613.5B** **Shoulder Design for TI Less Than Adjacent Lane TI, Page 610-12**
New figure added to clarify the engineering details of the Index.
- Index 622.5** **Joint Seals, Page 620-5**
Joint seal guidance for concrete pavements has been revised to reflect recent findings from studies conducted in other states showing that joint seals are not needed in all climatic regions. Further guidance was added to aid the designer in selecting the appropriate sealing option for a specific project as well as added guidance to address retrofitting existing joints.
- Table 623.1B** **Rigid Pavement Catalog (North Coast, Type I Subgrade Soil), Page 620-9**
Revisions made to rigid pavement structural depth with lateral support for TIs from 11.5 to 12 and 12.5 to 13 in agreement with guidance changed within the Index.

Enclosures available on the Department Design website at: <http://www.dot.ca.gov/hq/oppd/hdm/hdmtoc.htm>.

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- (42) *Resurfacing*. A supplemental surface layer or replacement layer placed on an existing pavement to restore its riding qualities and/or to increase its structural (load carrying) strength.
- (43) *Rigid Pavement*. Pavement engineered with a rigid surface course (typically Portland cement concrete or a variety of specialty cement mixes for rapid strength concretes) which may incorporate underlying layers of stabilized or unstabilized base or subbase materials. These types of pavements rely on the substantially higher stiffness of the rigid slab to distribute the vehicle loads over a relatively wide area of underlying layers and the subgrade. Some rigid slabs have reinforcing steel to help resist cracking due to temperature changes and repetitive loading.
- (44) *Roadbed*. The roadbed is 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 surface course is placed. Where the medians are so wide as to include areas of undisturbed land, a divided highway is considered as including two separate roadbeds.
- (45) *Asphalt Rubber Binder*. A blend of asphalt binder modified with crumb rubber modifier (CRM) that may include less than 15 percent CRM by mass.
- (46) *Rubberized Hot Mix Asphalt (RHMA)*. Formerly known as rubberized asphalt concrete (RAC). RHMA is a material produced for hot mix applications by mixing either asphalt rubber or asphalt rubber binder with graded aggregate. RHMA may be gap- (RHMA-G) or open- (RHMA-O) graded.
- (47) *R-value*. See California R-Value.
- (48) *Safety Edge*. A sloped edge that is placed at the edge of the paved roadbed to provide a smooth reentry for vehicles that leave the roadway. See Standard Plans for slope of safety edge and other construction details.
- (49) *Serviceability*. The ability at time of observation of a pavement to serve vehicular traffic (automobiles and trucks) which use the facility. The primary measure of serviceability is the Present Serviceability Index (PSI), which ranges from 0 (impossible road) to 5 (perfect road).
- (50) *Settlement*. Localized vertical displacement of the pavement structure due to slippage or consolidation of the underlying foundation, often resulting in pavement deterioration, cracking and poor ride quality.
- (51) *Structural Section*. See Pavement Structure.
- (52) *Structural Section Drainage System*. See Pavement Drainage System.
- (53) *Subbase*. Unbound aggregate or granular material that is placed on the subgrade as a foundation or working platform for the base. It functions primarily as structural support, but it can also minimize the intrusion of fines from the subgrade into the pavement structure, improve drainage, and minimize frost action damage.
- (54) *Subgrade*. Also referred to as basement soil. It is the portion of the roadbed consisting of native or treated soil on which pavement surface course, base, subbase, or a layer of any other material is placed.
- (55) *Surface Course*. One or more uppermost layers of the pavement structure engineered to carry and distribute vehicle loads. The surface course typically consists of a weather-resistant flexible or rigid layer, which provides characteristics such as friction, smoothness, resistance to vehicle loads, and drainage. In addition, the surface course minimizes infiltration of surface water into the underlying base, subbase and subgrade. A surface course may be composed of a single layer with one or multiple lifts, or multiple layers of differing materials.
- (56) *Tie Bars*. Deformed reinforcing bars placed at intervals that hold rigid pavement slabs in adjoining lanes and exterior lane-to-shoulder joints together and prevent differential vertical and lateral movement.

62.8 Highway Operations

- (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 road users are impeded by some element over which the user has no control.
- (3) *Density*. The number of vehicles per mile 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 users.
- (9) *Managed Lanes*. Lanes that are proactively managed in response to changing operating conditions in efforts to achieve improved efficiency and performance. Typically employed on highways with increasing recurrent traffic congestion and limited resources.
 - (a) *High-Occupancy Vehicle (HOV) Lanes*--An exclusive lane for vehicles carrying the posted number of minimum occupants or carpools, either part time or full time.
 - (b) *High Occupancy Toll (HOT) Lanes*--An HOV lane that allows vehicles qualified as carpools to use the facility without a fee, while vehicles containing less than the required number of occupants to pay a toll. Tolls may change based on real time conditions (dynamic) or according to a schedule (static).
 - (c) *Express Toll Lanes*--Facilities in which all users are required to pay a toll, although

HOVs may be offered a discount. Tolls may be dynamic or static.

- (10) *Merging*. The converging of separate streams of traffic into a single stream.
- (11) *Running Time*. The time the vehicle is in motion.
- (12) *Spacing*. The distance between consecutive vehicles in a given lane, measured front to front.
- (13) *Speed*.
 - (a) *Design Speed*--A speed selected to establish specific minimum geometric design elements for a particular section of highway or bike path.
 - (b) *Operating Speed*--The speed at which drivers are observed operating their vehicles during free-flow conditions. The 85th percentile of the distribution of a representative sample of observed speeds is used most frequently to measure the operating speed associated with a particular location or geometric feature.
 - (c) *Posted Speed*--The speed limit determined by law and shown on the speed limit sign.
 - (d) *High Speed* – A speed equal to or greater than 45 mph.
 - (e) *Low Speed* – A speed less than 45 mph.
 - (f) *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.
- (14) *Traffic*. A general term used throughout this manual referring to the passage of people, vehicles and/or bicycles along a transportation route.
- (15) *Traffic Control Devices*.
 - (a) *Markings*--All pavement and curb markings, object markers, delineators, colored pavements, barricades, channelizing devices, and islands used to convey regulations, guidance, or warning to users.

- (b) **Sign**--Any traffic control device that is intended to communicate specific information to users through a word, symbol and/or arrow legend. Signs do not include highway traffic signals or pavement markings, delineators, or channelizing devices.
- (c) **Highway Traffic Signal**--A power-operated control device by which traffic is warned or directed to take a specific action. These devices do not include signals at toll plazas, power-operated signs, illuminated pavement markers, warning lights, or steady burning electrical lamps.
- (d) **Changeable Message Sign**--An electronic traffic sign used on roadways to give travelers information about traffic congestion, accidents, roadwork zones, speed limits or any dynamic information about current driving conditions.
- (16) **Volume**. The number of vehicles passing a given point during a specified period of time.
- (17) **Weaving**. The crossing of traffic streams moving in the same general direction accomplished by merging and diverging.
- (18) **Ramp Metering**. A vehicular traffic management strategy which utilizes a system of traffic signals on freeway entrance and connector ramps to regulate the volume of vehicles entering a freeway corridor in order to maximize the efficiency of the freeway and thereby minimizing the total delay in the transportation corridor.
- 62.9 Drainage**
- See Chapter 800 for definition of drainage terms.
- 62.10 Users**
- (1) **Bicycle**. A device propelled via chain, belt or gears, exclusively by human power.
- (2) **Bus**. Any vehicle owned or operated by a publicly owned or operated transit system, or operated under contract with a publicly owned or operated transit system, and used to provide to the general public, regularly scheduled transportation for which a fare is charged. A general public paratransit vehicle is not a transit bus.
- (3) **Bus Rapid Transit (BRT)**. A flexible rubber-tired rapid-transit mode that combines stations, vehicles, services, exclusive running ways, and Intelligent Transportation System elements into an integrated system with a strong positive identity that evokes a unique image.
- (4) **Commuter Rail**. Traditional rapid and heavy rail passenger service intended to provide travel options in suburban and urban areas. Corridor lengths are typically shorter than intercity passenger rail services. Top operating speeds are in the range of 90 to 110 miles per hour. The tracks may or may not be shared with freight trains and typically are in a separate right of way.
- (5) **Conventional Rail**. Traditional intercity passenger rail and interregional freight rail. Top operating speeds are in the range of 60 to 110 miles per hour. The tracks may or may not be shared by passenger and freight trains and typically run within their own right of way corridor.
- (6) **Design Vehicle**. The largest vehicle commonly expected on a particular roadway. Descriptions of these vehicles are found in Index 404.4.
- (7) **Equestrian**. A rider on horseback.
- (8) **High Speed Rail**. A type of intercity and interregional passenger rail service that operates significantly faster than conventional rail. Top operating speeds are typically 150 to 220 miles per hour. These trains may be powered by overhead high voltage lines or technologies such as Maglev. The tracks are grade separated within a separate controlled access right of way and may or may not be shared with freight trains.
- (9) **Light Rail**. A form of urban transit that uses rail cars on fixed rails in a right of way that may or may not be grade separated. Motorized vehicles and bicycles may share the same transportation corridor. These railcars are typically electrically driven with power supplied from an overhead line rather than an

electrified third rail. Top operating speeds are typically 60 miles per hour.

- (10) *Pedestrian*. A person who is afoot or who is using any of the following: (a) a means of conveyance propelled by human power other than a bicycle, or (b) an electric personal assistive mobility device. Includes a person who is operating a self-propelled wheelchair, motorized tricycle, or motorized quadricycle and, by reason of physical disability, is otherwise unable to move about as a pedestrian as specified in part (a) above.
- (11) *Street Car, Trams or Trolley*. A passenger rail vehicle which runs on tracks along public urban streets and also sometimes on separate rights of way. It may also run between cities and/or towns, and/or partially grade separated structures.
- (12) *Transit*. Includes light rail; commuter rail; motorbus; street car, tram, trolley bus; BRT; automated guideway; and demand responsive vehicles. The most common application is for motorbus transit. See Index 404.4 for a description of the design vehicle as related to buses.
- (13) *Vehicle*. A device to move, propel or draw a person upon a highway, except a device on rails or propelled exclusively by human power. This definition, abstracted from the CVC, is intended to refer to motor vehicles, excluding those devices necessary to provide mobility to persons with disabilities.

District Directors, Traffic Liaisons, Design Coordinators or their combination as specified in this manual. These decisions should be documented as the individual approving desires.

- (6) *Permissive Standards.* All standards other than mandatory, advisory, or decisions requiring other approvals, whether indicated by the use of “should”, “may”, or “can” are permissive.
- (7) *Other.* In addition to the design standards in this manual, see Index 82.7 for general information on the Department’s traffic engineering policy, standards, practices and study warrants.

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 most mandatory standards indicated herein require the approval of the Chief, Division of Design. This approval authority has been delegated to the Design Coordinators, except the mandatory standards in Chapters 600 through 670, which require the approval of the State Pavement Engineer, and may involve coordination with the Design Coordinator.

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

Design exception approval must be obtained pursuant to the instructions in PDPM Chapter 9.

The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) allowed significant delegation to the states by FHWA to approve and administer portions of the Federal-Aid Transportation Program. SAFETEA-LU further allowed delegation to the State DOT’s and in response to this a Joint Stewardship and Oversight Agreement (JSOA) document between FHWA and Caltrans was signed. The JSOA outlines the process to determine specific project related delegation to the Department. The JSOA requires, FHWA approval of exceptions to mandatory design standards related to the 13 controlling criteria on all Interstate projects whether FHWA has oversight responsibilities or not. FHWA approval should be sought as early in the project development process as possible. However, formal approval shall not be requested until the appropriate Design 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 Design 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" (2005). A

third AASHTO publication, the latest edition of the "Roadside Design Guide", 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 Design Coordinator or individual delegated authority 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 must 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.

82.6 Design Information Bulletins and Other Guidance

In addition to the design standards in this manual, Design Information Bulletins (DIBs) establish policies and procedures for the various design specialties of the Department that are in the Division of Design. Some DIBs may eventually become part of this manual, while others are written with the intention to remain as design guidance in the DIB format. References to DIBs are made in this manual by the "base" DIB number only and considered to be the latest version available on the Department Design website. See the Department Design website for further information concerning DIB numbering protocol and postings.

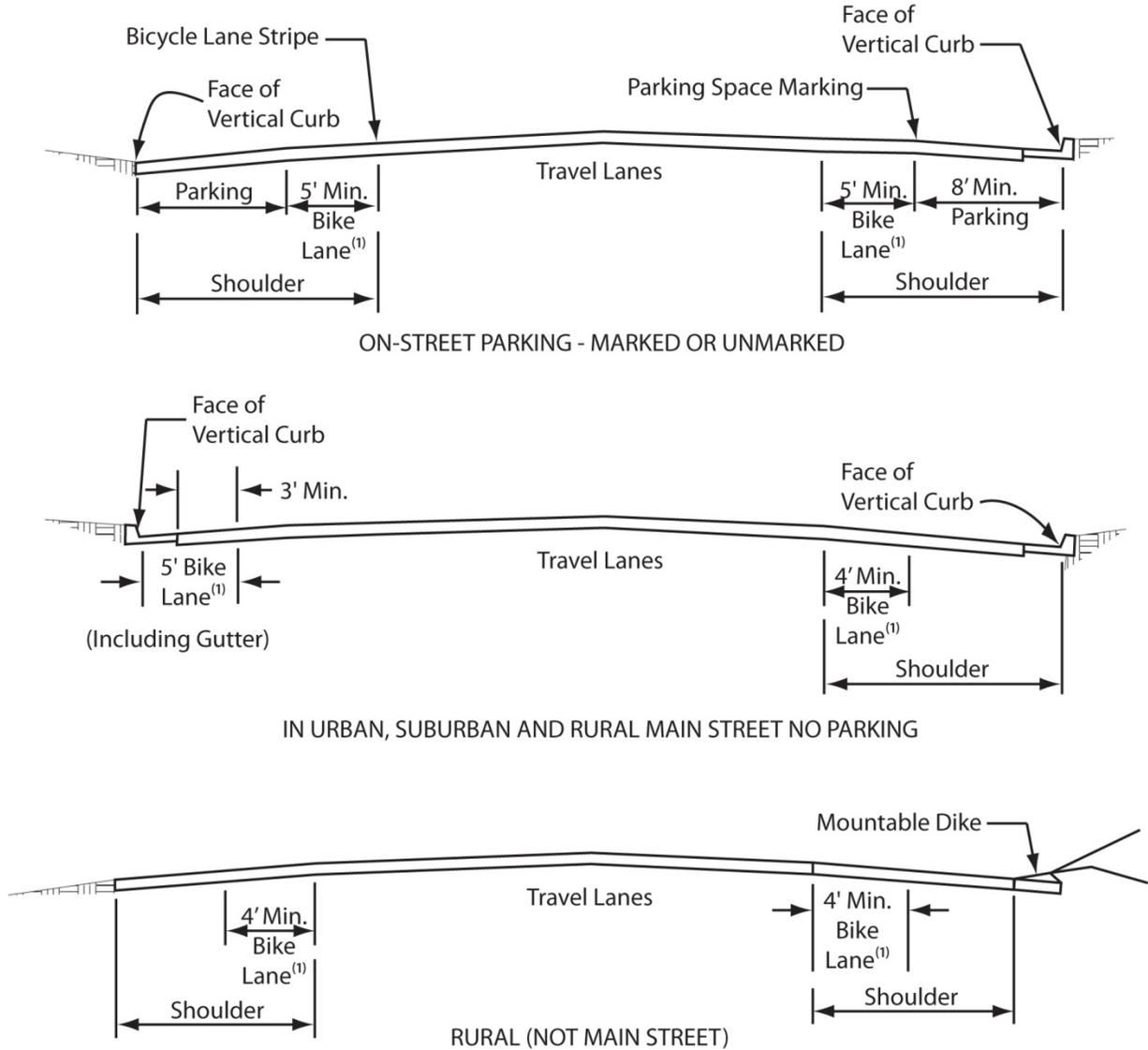
Caution must be exercised when using other Caltrans publications, which provide guidelines for the design of highway facilities, such as HOV lanes. These publications do not contain design standards; moreover, the designs suggested in these publications do not always meet Highway Design Manual Standards.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

82.7 Traffic Engineering

The Division of Traffic Operations maintains engineering policy, standards, practices and study warrants to direct and guide decision-making on a broad range of design and traffic engineering features and systems, which are provided to meet the site-specific safety and mobility needs of all highway users.

Figure 301.2A

Typical Class II Bikeway (Bike Lane) Cross Sections



NOTES:

- (1) See Index 301.2 for additional guidance.
- (2) For pavement marking guidance, see the California MUTCD, Section 9C.04.

the lanes and the shoulders with the least number of passes.

- For 2-lane roads with shoulders 4 feet or less, see Index 307.2.
- If shoulders are Portland cement concrete 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).
- Deciding to construct pedestrian facilities and elements, where none exist, is an important consideration. Shoulders are not required to be designed as accessible pedestrian routes although it is legal for a pedestrian to traverse along a highway. In urban, rural main street areas, or near schools and bus stops with pedestrians present, pedestrian facilities should be constructed. In rural areas where few or no pedestrians exist, it would not be reasonable or cost effective to construct pedestrian facilities. This determination 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 superelevated curves are discussed in Index 202.2.

See Index 307.2 for shoulder slopes on 2-lane roads with 4-foot shoulders.

302.3 Safety Edge

The safety edge is a sloped edge that is placed at the edge of the paved roadbed to provide a smooth reentry for vehicles that leave the roadway. Its design is based on research performed by the FHWA. See Standard Plans for slope of safety edge and other construction details. The safety edge is placed on all traversable pavement edges irrespective of pavement types except for:

- Next to curbs, dikes, guardrails, barriers, walls, and landscape paving.

- Where the distance from the edge of the paved roadbed to the hinge point is less than 1 foot and there is not enough room to place the safety edge.
- Within 3 feet of driveways or intersections.
- Pavement overlays that are less than 0.15 feet thick.

See the Plans Preparation Manual and the Standard Plans for further information and details on the safety edge.

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 gutters are 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 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) At curb extensions or bulbouts with posted speeds of 40 miles per hour 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.

The use of curb should be avoided on facilities with posted speeds greater than or equal to 40 miles per hour, 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.

303.2 Curb Types and Uses

Depending on their intended function, one of two general classifications of curb design is selected as appropriate. The two general classifications are

vertical and sloped. Vertical curbs are actually nearly vertical (approximate batter of 1:4) and vary in height from 6 inches to 8 inches. Sloped curbs (approximate batter of 2:3 or flatter) vary in height from 8 inches to 6 inches.

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. A curb may be placed to discourage 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.

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. B2-4 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, (for information on side gutters, see Index 834.3):

- (1) *Types A1-6, A2-6, and A3-6.* These curbs are 6 inches high. Their main function is to provide a more positive deterrent to vehicles than provided by sloped curbs. Specifically, these curbs 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 (posted speed \leq 35 miles per hour). These curbs do not constitute a barrier as they can be mounted except at low speeds and flat angles of approach.
- (2) *Types A1-8, A2-8, and A3-8.* These 8-inch high curbs may be used in lieu of 6-inch curbs when requested by local authorities, if the curb criteria stated under Index 303.1 are satisfied and posted speeds are 35 miles per hour or less. This type of curb may impede

**Table 303.1
Selection of Curb Type**

Location	Posted Speeds (mph)		
	≤ 35	40	≥ 45
Freeways and Expressways			
Collector-distributor Roads	See Index 504.3(11)		
Ramps			
Conventional Highways			
- Frontage Roads (1)	A or B-6	B-6	B-4
- Traffic Signals	A or B-6	B-6	B-4
- Raised Traffic, Median Islands & Pedestrian Refuge Islands (2)	A or B-6	B-6	B-4 or D
- Adjacent to Sidewalks	A (3)	A-6	B-6
- Bulbouts/curb extensions	B-6	NA	NA
- Bridges (4)	H, A3, or B3	H or B3	B3

NOTES:

- (1) Based on the posted speed along the frontage road.
- (2) See Design Information Bulletin Number 80, "Roundabouts" for information on curbs at roundabouts.
- (3) Type A curb includes Types A1-6, A2-6, A1-8, and A2-8.
- (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.

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 where posted speeds are 40 miles per hour or less and 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* Types B1-6, B2-6, and B3-6 are 6 inches high. Type B1-4, B2-4, and B3-4 are 4 inches high. Since all have a 1:1½ 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 3 inches high and is typically used on ramp gores as described in Index 504.3(11). It may also be appropriate where a lower curb is desirable.
- (6) *Type D Curb.* Type D curb is 4 inches or 6 inches high and is typically used for raised traffic islands, collector-distributor separation islands, or raised medians when posted speeds equal or exceed 45 miles per hour.
- (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 2 feet wide but may be 1 foot to 4 feet 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 2 feet to 3 feet 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.

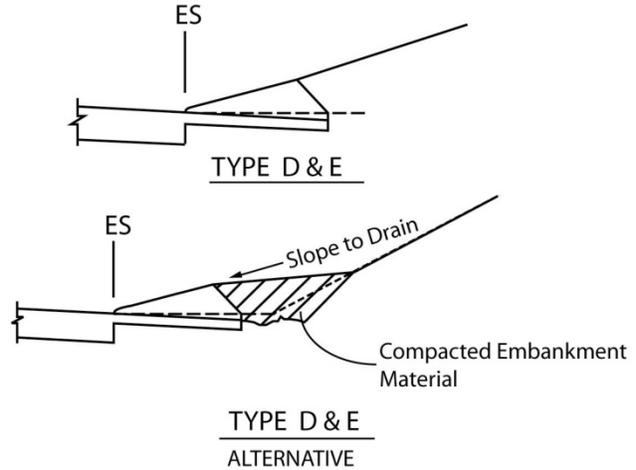
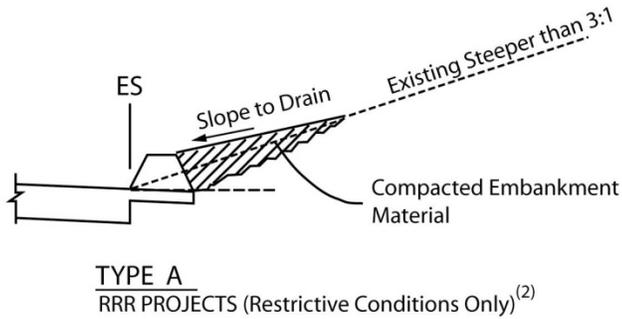
303.3 Dike Types and Uses

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.

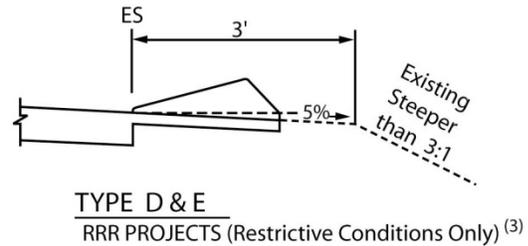
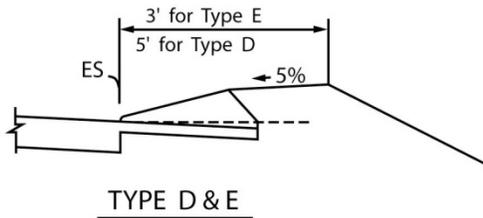
- (1) *Type A Dike.* The use of Type A dike should be avoided. For RRR projects, Type A dike may be used in cut sections with slopes steeper than 3:1 and where existing conditions do not allow for construction of the wider Type D or E dikes. Compacted embankment material should be placed behind the back of dike as shown in Figure 303.3.
- (2) *Type C Dike.* This low dike, 2 inches 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.
- (3) *Type D Dike.* This 6-inch 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

**Figure 303.3
Dike Type Selection and Placement⁽¹⁾**

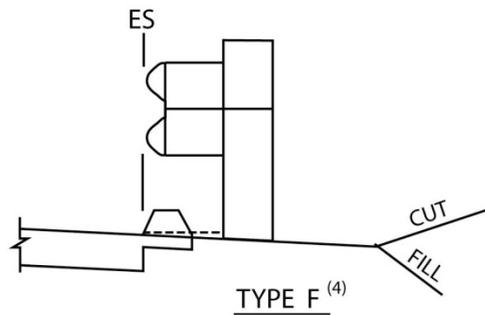
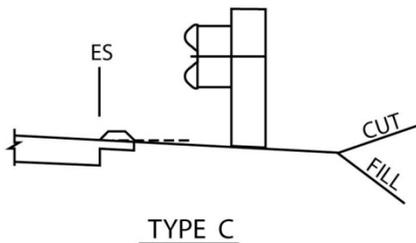
CUT SECTIONS



FILL SECTIONS



CUT/FILL SECTIONS



- 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.

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 3:1 when there is insufficient room to place the embankment material.

- (4) *Type E Dike.* This 4-inch 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 3:1 where there is insufficient room to place the embankment material.
- (5) *Type F Dike.* This 4-inch 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 Curb Extensions

- (1) *Bulbouts.* A bulbout is an extension of the sidewalk into the roadway when there is marked on-street parking. Bulbouts should conform to Figure 303.4, other design elements are not shown. Bulbouts provide queuing space and shorten crossing distances, thereby reducing pedestrian conflict time with mainline traffic. By placing the pedestrian entry point closer to traffic, bulbouts improve visibility between motorist and pedestrians. They are appropriate for an urban environment and should only be placed on routes with posted speeds 35 miles per hour or less when design vehicles are accommodated, (see Topic 404). The corner curb radii should be the minimum needed to accommodate the design vehicle.

When used, bulbouts should be placed at all corners of an intersection. Where pedestrian crossings are at mid-block locations, bulbouts should be used on both sides of the street.

The curb face of the bulbout shall be setback from the edge of traveled way such that there is a minimum of 3 feet measured from the edge of traveled way to the joint between the shoulder pavement and the gutter pan or 3 feet to curb face without gutter pan. Available width for bicyclists should not be reduced along the curb face of the bulbout.

Landscaping and appurtenant facilities located within a bulbout are to comply per Topic 405.

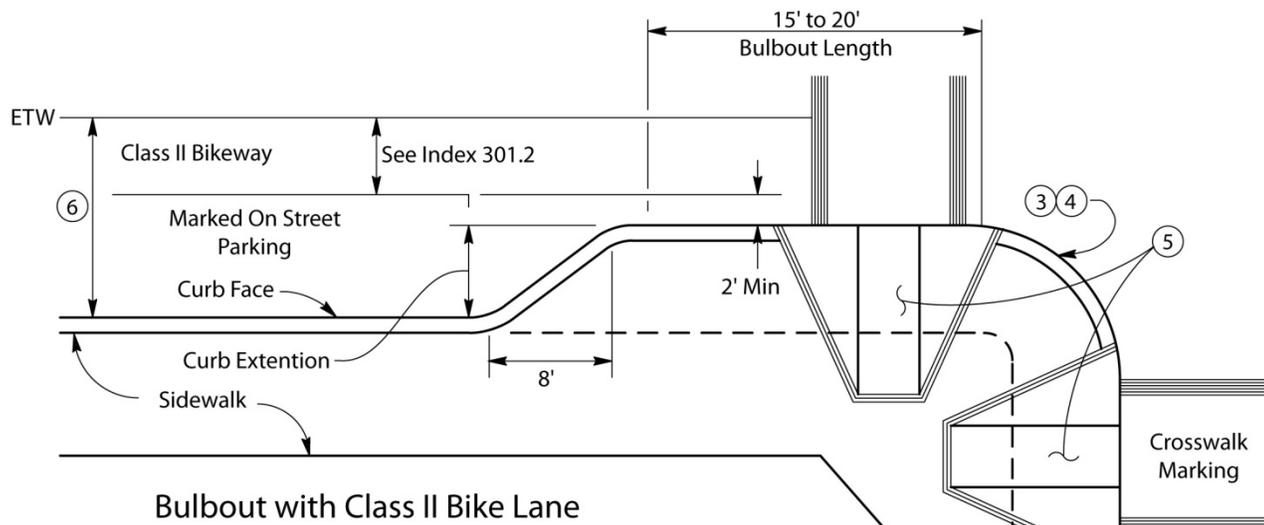
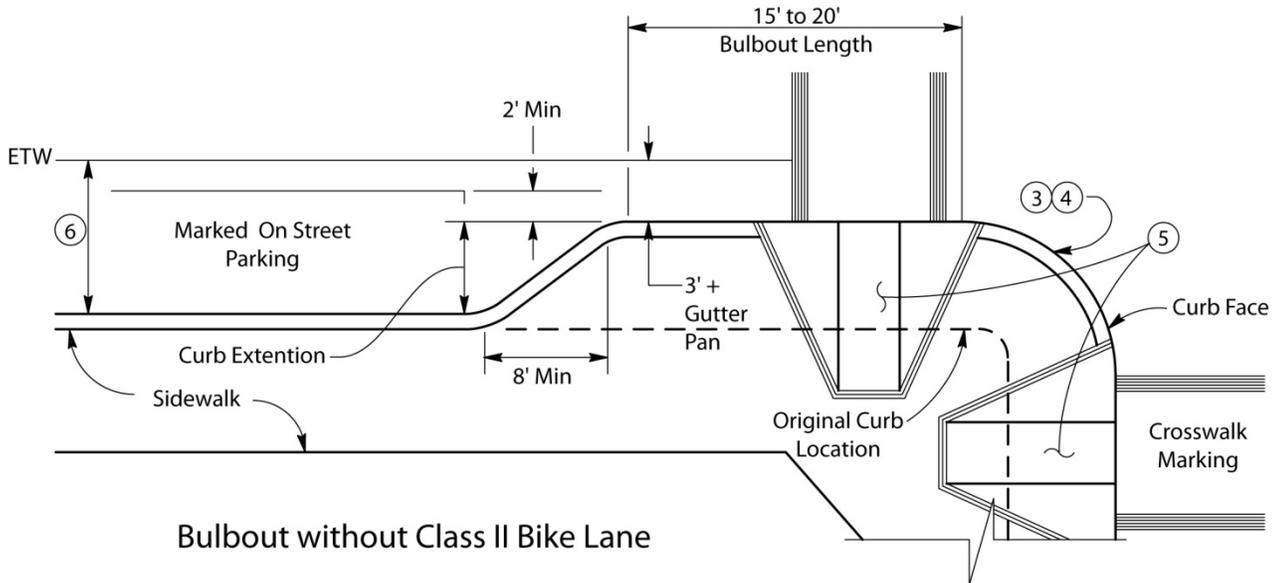
Bulbouts are considered pedestrian facilities and as such, compliance with DIB 82 is required. Avoid bulbouts on facilities where highway grade lines exceed 5 percent.

- (2) *Busbulbs.* A busbulb is a bulbout longer than 25 feet which facilitates bus loading and unloading, and provides for enhanced bus mobility. Busbulbs reduce bus dwell times and provide travel time benefits to transit passengers. Because busbulbs restrict vehicular and bicycle traffic, their use may be considered after a careful evaluation of their impact on the mobility for all users of the facility. Pursuant to the Vehicle Code, busbulbs or other transit stops which require a transit vehicle to stop in the traveled way require approval from the Department. In lieu of a busbulb, a busbay may be considered.
- (3) *Busbays.* A busbay is an indentation in the curb which allows a bus to stop completely outside of the traveled way. A busbay may be created by simply restricting parking.

303.5 Position of Curbs and Dikes

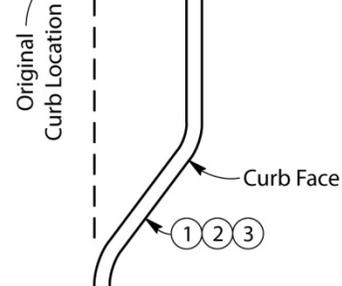
Curbs located at the edge of the traveled way may have some effect on lateral position and speed of moving vehicles, depending on the curb configuration and appearance. Curbs with low, sloped faces may encourage drivers to operate relatively close to them. Curbs with vertical faces may encourage drivers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

Figure 303.4
Bulbout with and without Class II Bike Lane



Notes:

- ① Curb transitions are to accommodate street sweeping equipment.
- ② See Topic 303 for selection of curb type.
- ③ See California MUTCD for painting of curb adjacent to bulbout.
- ④ Curb return design varies per design vehicle.
- ⑤ Provide curb ramp per Standard Plans.
- ⑥ See Table 302.1 for shoulder width standards.



All dimensions to curbs (i.e., offsets) are from the near edge of traveled way to bottom 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 2 feet 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 or equal to 35 miles per hour, no median curb offset is required if there is no gutter pan.
- (6) *Structure Approach Slabs.* When a dike is required to protect the side slope from erosion, it should be placed on the structure approach and sleeper slabs as well as 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 structure approach slab is used, concrete dikes are preferred. Hot mixed asphalt dike will inevitably crack due to expansion and contraction at the approach/sleeper slab joint. 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 the Division of Engineering Services, (DES).

- (7) *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.
- (8) *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. For new construction, widening, or where slopes are otherwise being modified, embankment (fill) slopes should be 4:1 or flatter. Factors affecting slope design are as follows:

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

Embankment slopes 4:1 or flatter are recoverable for vehicles. Drivers who encroach on recoverable slopes can generally stop or slow down enough to return to the traveled way safely.

A slope which is between 3:1 and 4:1 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 3:1 should be avoided when accessible by traffic. District Traffic, 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 user remains in contact with the ground. Likewise, the toe of slopes should be rounded to prevent users from nosing into the ground.

- (b) *Erosion Control.* Slope designs steeper than 4:1 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 erodibility 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.

A Storm Water Data Report (SWDR) documents project information and considerations pertaining to Storm Water Best Management Practices (BMPs) and Erosion Control methods. The SWDR is prepared and signed by key personnel (including the District Landscape Architect) at the completion of each phase of a project. By signing the SWDR, the District Landscape Architect approves compliance with the proposed slope designs.

- (c) *Structural Integrity.* Slopes steeper than 2:1 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, gentle, and smooth, well transitioned slopes are visually more satisfying than steep, obvious cuts and fills. In addition, flatter slopes are more easily revegetated, which helps visually integrate the transportation improvement within its surrounding environment. Contact the District Landscape Architect when preparing a contour grading plan.

In light grading where normal slopes catch in a distance less than 18 feet from the edge of the shoulder, a uniform catch point, at least 18 feet 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 18 feet 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 10 feet for all types of cross sections. When feasible, at least 15 feet should be provided.

Following are minimum clearances recommended for cuts higher than 30 feet:

- (a) Twenty feet for cuts from 30 feet to 50 feet high.
- (b) Twenty-five feet for cuts from 50 feet to 75 feet high.

- (c) One-third the cut height for cuts above 75 feet, but not to exceed a width of 50 feet.

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 user 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 20 feet wide and sloped to form a valley at least 1 foot deep with the low point a minimum of 5 feet 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 150 feet in height, with slopes steeper than 1½:1, a bench above grade may be desirable to intercept rolling rocks. The Division of Engineering Services – Geotechnical Services (DES-GS) 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 20:1 in areas of no snow; and downward on a 10:1 slope in snow areas.

304.4 Contour Grading and Slope Rounding

Contour grading, slope rounding and topsoil replacement are important factors in roadside design to help make highway improvements compatible with the surrounding environment while comply with National Pollutant Discharge Elimination System permits (NPDES). Smooth, flowing contours that tie gracefully into the existing adjacent roadside and landforms are visually appealing and conducive to safe vehicle recovery (see Index 304.1), reduce the potential for erosion and stormwater runoff, and reduce roadside maintenance activities while contributing to the long term success of revegetation planting.

Contour grading plans are to be prepared to facilitate anticipated roadside treatments and future maintenance activities. These plans should show flattened slopes where right of way permits. The tops and ends of all cut slopes should be rounded. Rock cut slopes should be irregular where possible to provide a natural appearance and the tops and ends should also be rounded. All slope designs should include consideration of an application of local or imported topsoil and duff to promote the growth of vegetation, improve stormwater pollutant filtration and control erosion. The calculation of the final grade for a project needs to take into account the reapplication of topsoil and duff.

Local topsoil and duff material within the grading limits should be identified on the plans, removed or excavated, stockpiled, and reapplied. This is to be performed on all projects that include grading or earthwork unless the materials are determined to be unsuitable.

Coordinate the development of contour grading plans including, removal, stockpiling, suitability of material and application of topsoil and duff with the District Landscape Architect.

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 1 foot to 2 feet wide. Generally, stepped slopes can be used in rippable material on slopes 2:1 or steeper. Steps may be specified for slopes as flat as 3:1. 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 percent, 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 percent variation, expressed in terms of tenths of a foot. 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 generally be considered. Widths over approximately 2 feet should be avoided because of prominence and excessive time to achieve a weathered and natural appearance. Contact the DES-GS and the District Landscape Architect for more information 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) Public Transit (rail and bus).
- (b) Traffic needs more than 20 years after completion of construction.

Median width as presented in Case (1) below applies to new construction, projects to increase mainline capacity and to reconstruction projects.

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.)

Median pedestrian refuge areas lessen the risk of pedestrian exposure to traffic. Where pedestrians are allowed to cross 4 or more lanes at a marked or unmarked crosswalk, a pedestrian refuge island should be provided. See Index 405.4 and DIB 82 for further guidance.

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

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):

(1) *Freeways and Expressways.*

- (a) Urban Areas. Where managed lanes (HOV, Express, etc) or transit facilities are planned, the minimum median width should be 62 feet. Where there is little or no likelihood of managed lanes or transit facilities planned for the future, the minimum median width should be 46 feet. However, where physical and economic limitations are such that a 46-foot median cannot be provided at reasonable cost, the minimum median width for freeways and expressways in urban areas should be 36 feet.
- (b) Rural Areas. The minimum median width for freeways and expressways in rural areas should be 62 feet.

(2) *Conventional Highways.* Appropriate median widths for non-controlled access highways vary widely with the type of facility being designed. In Urban and Rural Main Street areas, the minimum median width for

multilane conventional highways should be 18 feet. For two lane conventional highways, the minimum median width should be 12 feet. This median width will provide room for left-turn pockets at intersections, and/or the construction of two-way left-turn lanes with room for pedestrian refuge areas as appropriate.

Medians refuge areas at pedestrian crosswalks and bicycle path crossings provide a space for pedestrians and bicyclists. They allow these users to cross one direction of traffic at a time. Where medians are provided, they should allow access through them for pedestrians and bicyclists as necessary. Bicycle crossings through paved medians should line up with the bicycle path of travel and not require bicyclists to utilize the pedestrian crosswalk. See Index 405.4 for additional requirements.

Where medians are provided for proposed future two-way left-turn lanes, median widths up to 14 feet may be provided to conform to local agency standards (see Index 405.2). **In rural areas the minimum median width for multilane conventional highways shall be 12 feet.** This provides the minimum space necessary to accommodate a median barrier and 5-foot shoulders. Whenever possible, and where it is appropriate, this minimum width should be increased to 30 feet or greater.

At locations where a climbing or passing lane is added to a 2-lane conventional highway, a 4-foot 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 22 feet.**

- (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 6 feet wide or wider. Median widths in areas of multilevel interchanges or other major structures should be coordinated with the Division of Engineering Services, Structures Design (DES-SD).

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 site specific considerations of each project.

See Index 613.5(2)(b) for paved median pavement structure requirements.

305.2 Median Cross Slopes

Unsurfaced medians up to 65 feet wide should be sloped downward from the adjoining shoulders to form a shallow valley in the center. Cross slopes should be 10:1 or flatter; 20:1 being preferred. Slopes as steep as 6:1 are acceptable in exceptional cases when necessary for drainage, stage construction, etc. Cross slopes in medians greater than 65 feet should be treated as separate roadways (see 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 30 feet wide or less should be paved.
- (b) 4 Lanes--Medians 22 feet or less in width should be paved. Medians between 22 feet and 30 feet wide should be paved only if a barrier is installed. With a barrier, medians wider than 30 feet 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 minimum 0.15 foot of Portland cement 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 65 feet wide (see Index 204.7).
- (2) *Median Design.* The cross sections shown in Figure 305.6 with a 23-foot graded area left of traffic are examples of median treatment to provide maneuvering room for out-of-control users. 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 instillation, operation and maintenance

of all cross section elements needed depending upon the type of facility, including median, traffic lanes, bicycle lanes, outside shoulders, sidewalks, recovery areas, slopes, sight lines, outer separations, ramps, walls, transit facilities 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 150 feet.

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 Cross Section Selection

The cross section of a State highway is based upon the number of vehicles, including trucks, buses, bicycles, and safety, terrain, transit needs and pedestrians. Other factors such as sidewalks, bike paths and transit facilities, both existing and future should be considered. 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.

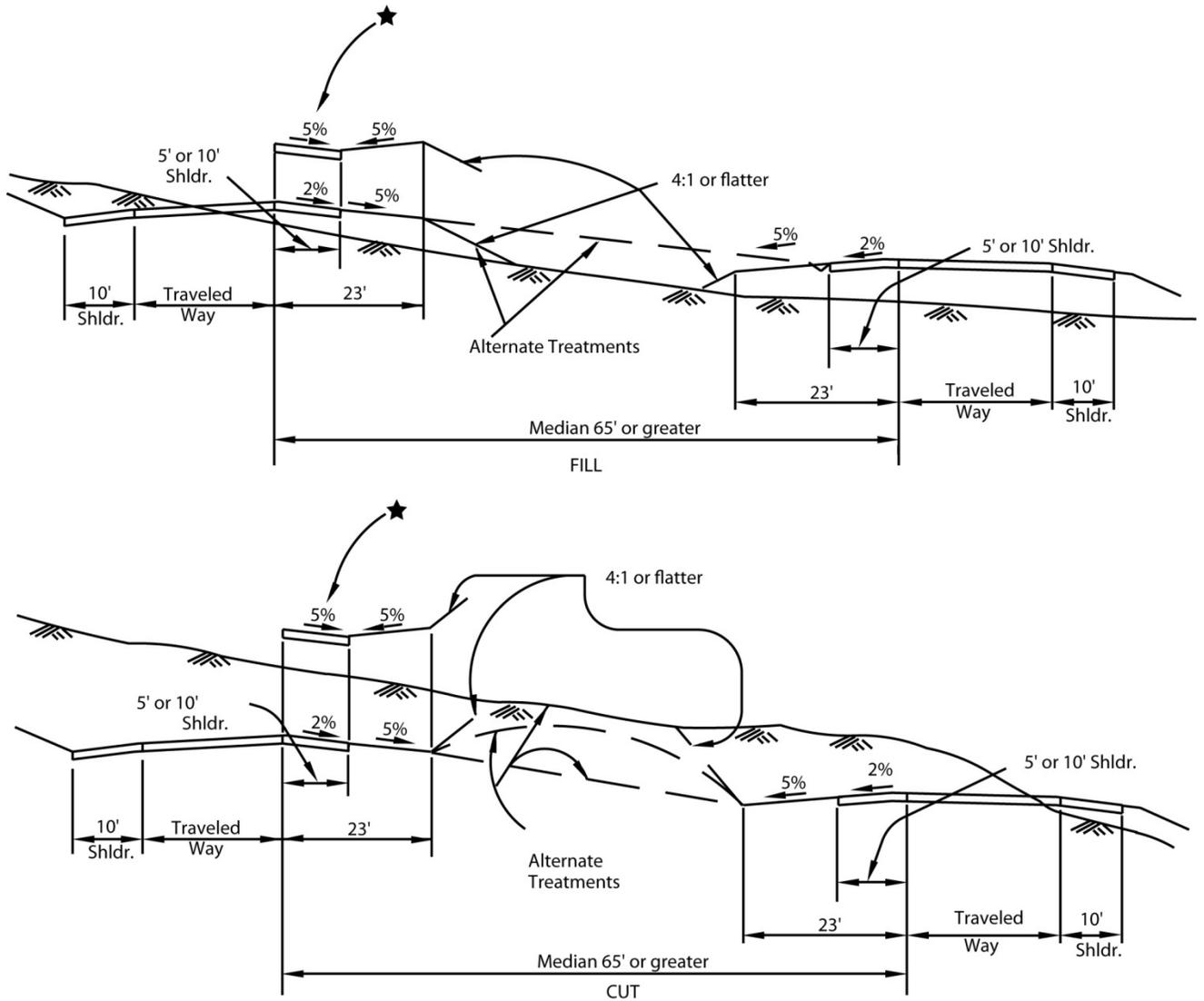
307.2 Two-lane Cross Sections for New Construction

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 24-foot wide traveled way plus paved shoulders. In order to provide structural support, the minimum paved

Figure 305.6

Optional Median Designs for Freeways with Separate Roadways



NOTES:

Left Paved Shoulder Width
 10' for 6-lane and 8-lane roadways
 5' for 4-lane roadways

Side Slopes
 See Index 304.1

★ Superelevated section

width of each shoulder should be 2 feet. Shoulders less than 4 feet are not adequate for bicycles. Where 4-foot shoulders are not possible, consideration should be given to providing turnouts for bicycles. See Index 204.5(4) for turnout information. See Topic 1003 and Index 301.2 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.

Table 307.2

Shoulder Widths for Two-lane Roadbed New Construction Projects

Two-way ADT (Design Year)	Shoulder Width ⁽¹⁾ (ft)
Less than 400	4 ⁽²⁾
Over 400	8 ⁽³⁾

NOTES:

- (1) See Index 302.1 for shoulder requirements when bike lanes are present.
- (2) Minimum bridge width is 32 feet (see Index 208.1).
- (3) See Index 405.3(2)(a) for shoulder requirements adjacent to right-turn only lanes.

On 2-lane roads with 4-foot shoulders, the shoulder slope may be increased to 7 percent for additional drainage capacity where a dike is used. With 2-foot shoulders the shoulder slope should be 2 percent without a dike, but may be increased to a maximum of 9 percent for additional drainage capacity with a dike. A design exception to Index 302.2 will be required to document the decision to increase the slope.

Bicycles are not prohibited on conventional highways: therefore, where the shoulder width is 4 feet, the gutter pan width should be reduced to 1 foot, so 3 feet is provided between the traffic lane and the longitudinal joint at the gutter pan. If an inlet grate must be located in roadway areas where bicycles are not prohibited, bicycle proof grates are

to be used. See Index 837.2(2) for further grate guidance.

307.3 Two-lane Cross Sections for 2R, 3R, and other Projects

Standards and guidelines for two-lane cross sections on resurfacing and restoration (2R) projects and resurfacing, restoration, and rehabilitation (3R) projects are found in DIB 79 and Index 603.4. DIB 79 also includes screening criteria to determining whether the project fits 2R or 3R.

3R design criteria apply to all structure and roadway 3R projects on two-lane conventional highways and three-lane conventional highways not classified as multilane conventional highways.

3R 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.

3R 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, curb ramps, pavement edge drop, dike, curb and gutter, and intersections. They may also apply to such features as bike lanes, sidewalk, and drainage.

307.4 Multilane Divided Cross Sections

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

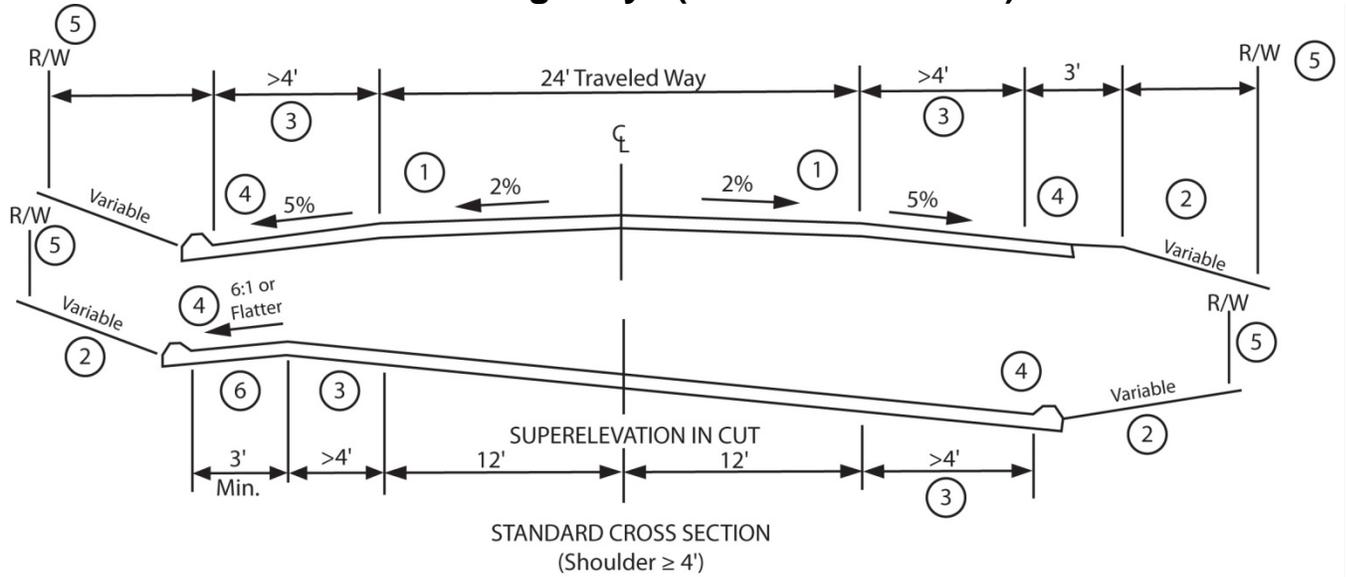
Divided highways may be designed as two separate one-way roads where appropriate to fit the terrain. Economy, pleasing appearance, and safety are factors to be considered in this determination. The

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

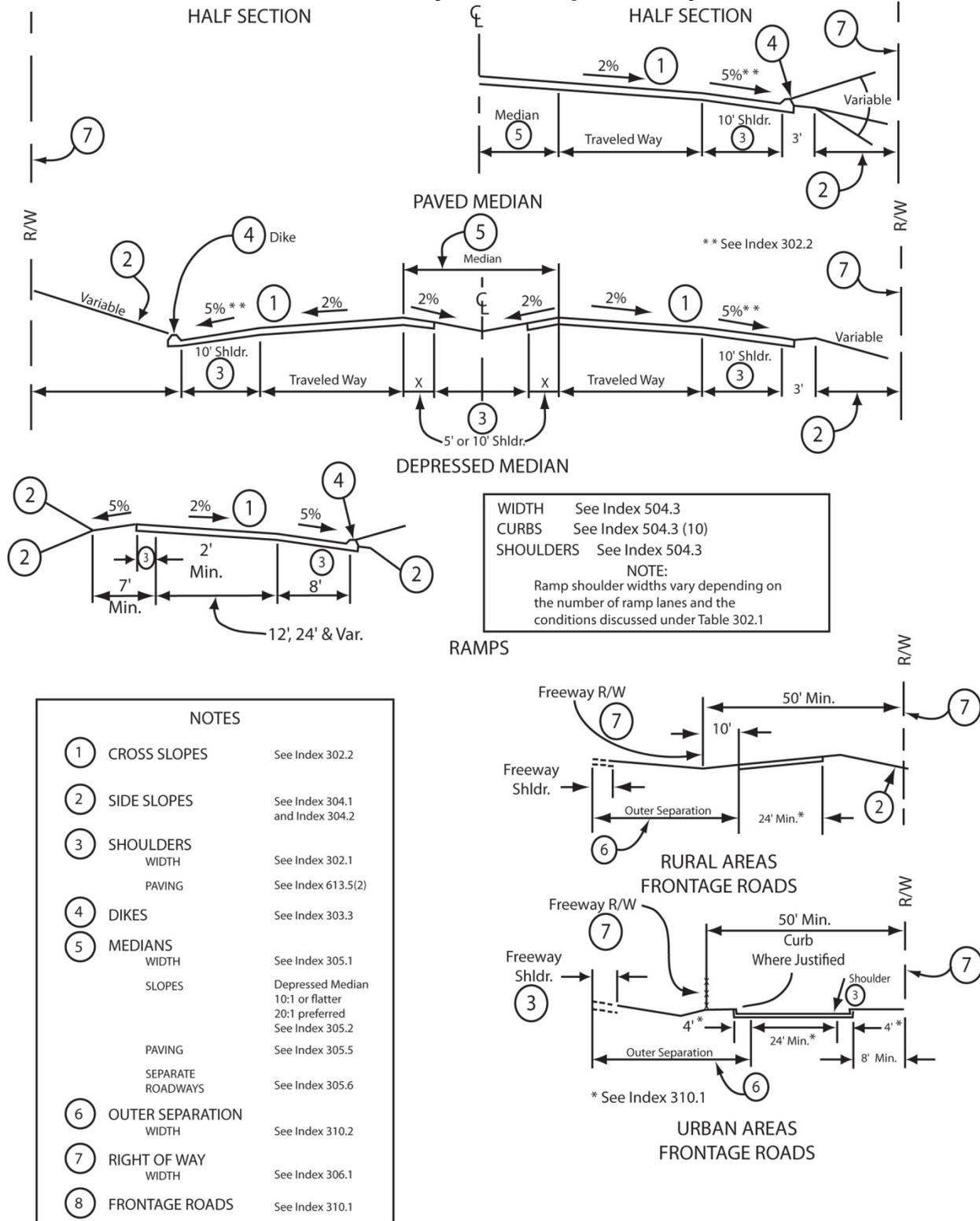
A multilane cross section with a narrow median is illustrated in Figure 307.5. This section is appropriate in special circumstances where a wider median would not be justified. It should not be considered as an alternative to sections with the

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

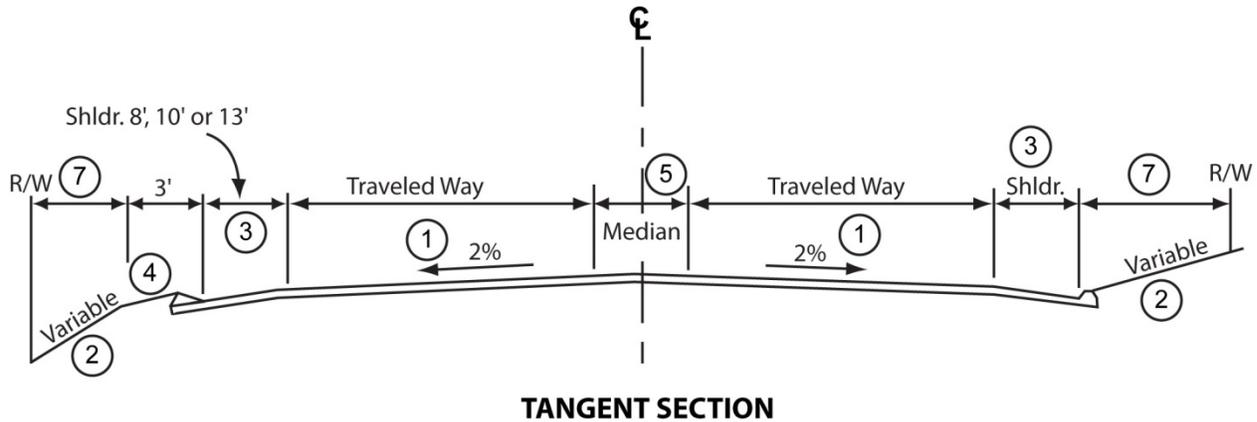


NOTES		
①	CROSS SLOPES	See Index 302.2
②	SIDE SLOPES	See Index 304.1
③	SHOULDER WIDTH	See Index 302.1
④	DIKES	See Index 303.3
⑤	RIGHT OF WAY	See Index 306.1
⑥	SIDE GUTTERS	See Index 834.3(3)

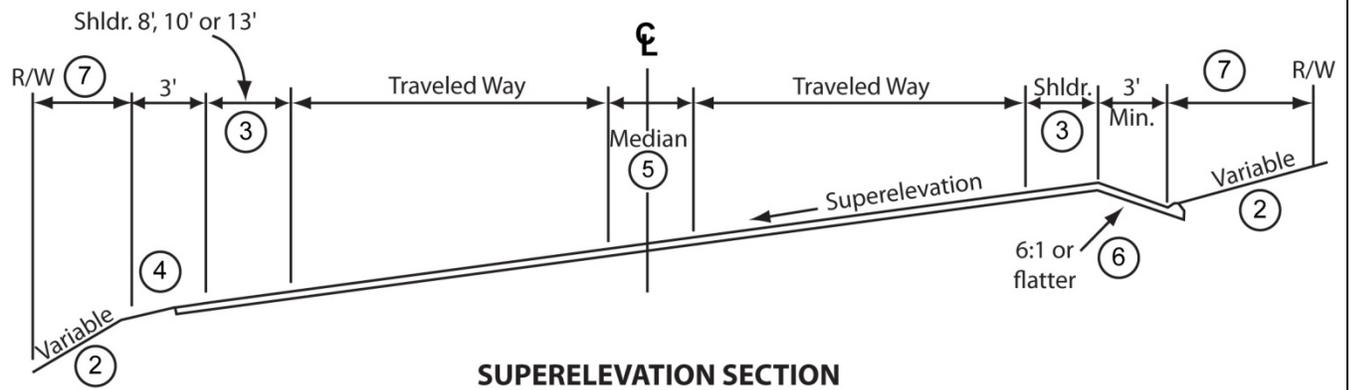
Figure 307.4
Geometric Cross Sections for
Freeways and Expressways



**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 302.1 |
| 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 |

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 8 feet wide (10 feet on freeways and expressways) as mandated in Table 302.1. Where large excavation quantities or other factors generate unreasonable costs, 4-foot 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 8-foot 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 2R and 3R Projects

3R projects on freeways, expressways, and multilane conventional highways are required to meet new construction standards.

For additional information on 2R and 3R projects, see DIB 79.

307.7 Reconstruction Projects

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

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. If the local agency has standards that exceed AASHTO standards, then the local agency standards should apply.

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

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

See Chapter 1 of AASHTO, A Policy on Geometric Design of Highways and Streets, for additional information on the AASHTO functional classifications of rural and urban arterials, collector roads, and streets.

AASHTO, A Policy on Geometric Design of Highways and Streets, 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 Transportation Research Board, Highway Capacity Manual.

The minimum width of 2-lane overcrossing structures shall not be less than 32 feet face of curb to face of curb.

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 4 feet, and as shown below.

Where the 2-lane local facility connects to a freeway within an interchange, the lane width of the local facility shall be 12 feet.

Where a multilane local facility connects to a freeway within an interchange, the outer most lane in each direction of the local facility shall be 12 feet.

Shoulder width shall not be less than 5 feet when railings or other lateral obstructions are adjacent to the right edge of shoulder.

If gutter pans are used, then the minimum shoulder width shall be 3 feet wider than the width of the gutter pan being used.

The minimum width for two-lane overcrossing structures at interchanges shall be 40 feet curb-to-curb.

Topic 309 - Clearances

309.1 Horizontal Clearances for Highways

(1) *General.* The horizontal clearance to all roadside objects should be based on engineering judgment with the objective of maximizing the distance between roadside objects and the edge of traveled way. Engineering judgment should be exercised in order to balance the achievement of horizontal clearance objectives and reduction of maintenance cost and exposure to workers, with the prudent expenditure of available funds.

Certain yielding types of fixed objects, such as sand filled barrels, metal beam guardrail, 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). Consideration should be given to the planned ultimate traveled way width of the highway facility. **Horizontal clearances greater than those cited below under subsection (3) - "Minimum Clearances" shall be provided where necessary to meet horizontal stopping sight distance requirements.** See subsection (4) for high speed rail clearance guidance. 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 (4:1 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.

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 – 30 feet
- Conventional Highways – 20 feet*

* On conventional highways with posted speeds less than or equal to 40 miles per hour and curbs, clear recovery zone widths do not apply. See minimum horizontal clearance, Index 309.1(3)(c).

Fixed objects, including bridge piers, abutments, retaining walls, and noise barriers 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:

(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 six inches 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, barrier 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 Operations.

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 are impractical, the minimum horizontal clearance cited below shall apply to the unshielded fixed object. These minimum horizontal clearances apply to yielding objects as well.

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

- (a) **The minimum horizontal clearance to all objects, such as bridge rails and safety-shaped concrete barriers, as well as sand-filled barrels, metal beam guardrail, etc., 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 4 feet shall be provided where the standard shoulder width is less than 4 feet.** 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 facilities, including auxiliary lanes, ramps and collector roads, shall not be less than 10 feet per Table 302.1.**
- (c) **On conventional 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.** For RRR projects, widths are provided in DIB 79.

On conventional highways with curbs, typically in urban conditions, a minimum horizontal clearance of 1 foot 6 inches should be provided beyond the face of curbs to any obstruction. On curbed highway sections, a minimum clearance of 3 feet 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, the face of Type 60 concrete barrier should be constructed integrally at the base of any retaining, pier, or abutment wall which faces traffic and is 15 feet 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 Railing (Type K) on bridge deck widening projects should be obtained from the HQ Transportation Permit Program.

The HQ Transportation Permit Program must 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.

- (4) *High Speed Rail Clearances.* When a high speed rail corridor is to be constructed longitudinally to a freeway, expressway or a conventional highway with posted speeds over 40 miles per hour, the nearest fixed object or feature associated with the operation of the rail facility should be located a minimum of 52 feet horizontally from the planned ultimate edge of the traveled way. See Index 62.10 for the definition of high speed rail. The terrain and the required highway features between the edge of traveled way and the rail facility to be constructed must be evaluated to determine on a case-by-case basis whether or not shielding behind guardrail, barrier or other safety device in conformance with the guidance found in Chapter 7 of the Traffic Manual is needed. For input on the need for shielding at a specific location, consult District Traffic Operations.
- (5) *Other transportation facilities* Contraflow BRT, light rail facilities, and heavy rail facilities are considered fixed objects and the clearances noted in Index 309.1 apply.

Parallel BRT facilities are preferred to have the following minimum separation between lanes:

- Freeways and Expressways** – 4 feet
- Conventional Highways (see also Index 108.5)
 - Posted Speeds over 40 miles per hour – 4 feet
 - Posted Speeds equal or greater than 25 miles per hour and up to 45 miles per hour in an urban environment – 2 feet, with curbed separation, 4 feet with 2-foot curbed separation recommended.

** See “A Guide for HOT Lane Development”, FHWA, and Caltrans High Occupancy Vehicle Guidelines for additional information.

309.2 Vertical Clearances

(1) *Major Structures.*

- (a) Freeways and Expressways, All construction except overlay projects – **16 feet 6 inches 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 – **16 feet shall be the minimum vertical clearance over the roadbed of the State facility.**
- (c) Conventional Highways, Parkways, and Local Facilities, All Projects – **15 feet shall be the minimum vertical clearance over the traveled way and 14 feet 6 inches 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 2 feet greater than the standard for major structures for the State facility in question.**

Sign structures shall have a vertical clearance of 18 feet 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. 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 16 feet over any portion of this system must be approved by FHWA in coordination with Surface Deployment and Distribution Command Transportation Engineering Agency (SDDCTEA). Documentation in the form of a Design Exception Fact Sheet must be submitted to FHWA to obtain approval for less than 16 feet

Table 309.2A
Minimum Vertical Clearances

	Traveled Way	Shoulder
Freeways and Expressways, New Construction, Lane Additions, Reconstruction and Modification	16½ ft	16½ ft
Freeways and Expressways, Overlay Projects	16 ft	16 ft
All Projects on Conventional Highways and Local Facilities	15 ft	14½ ft
Sign Structures	18 ft	18 ft
Pedestrian, Bicycle Overcrossings, and Minor Structures	Standard + 2 ft 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

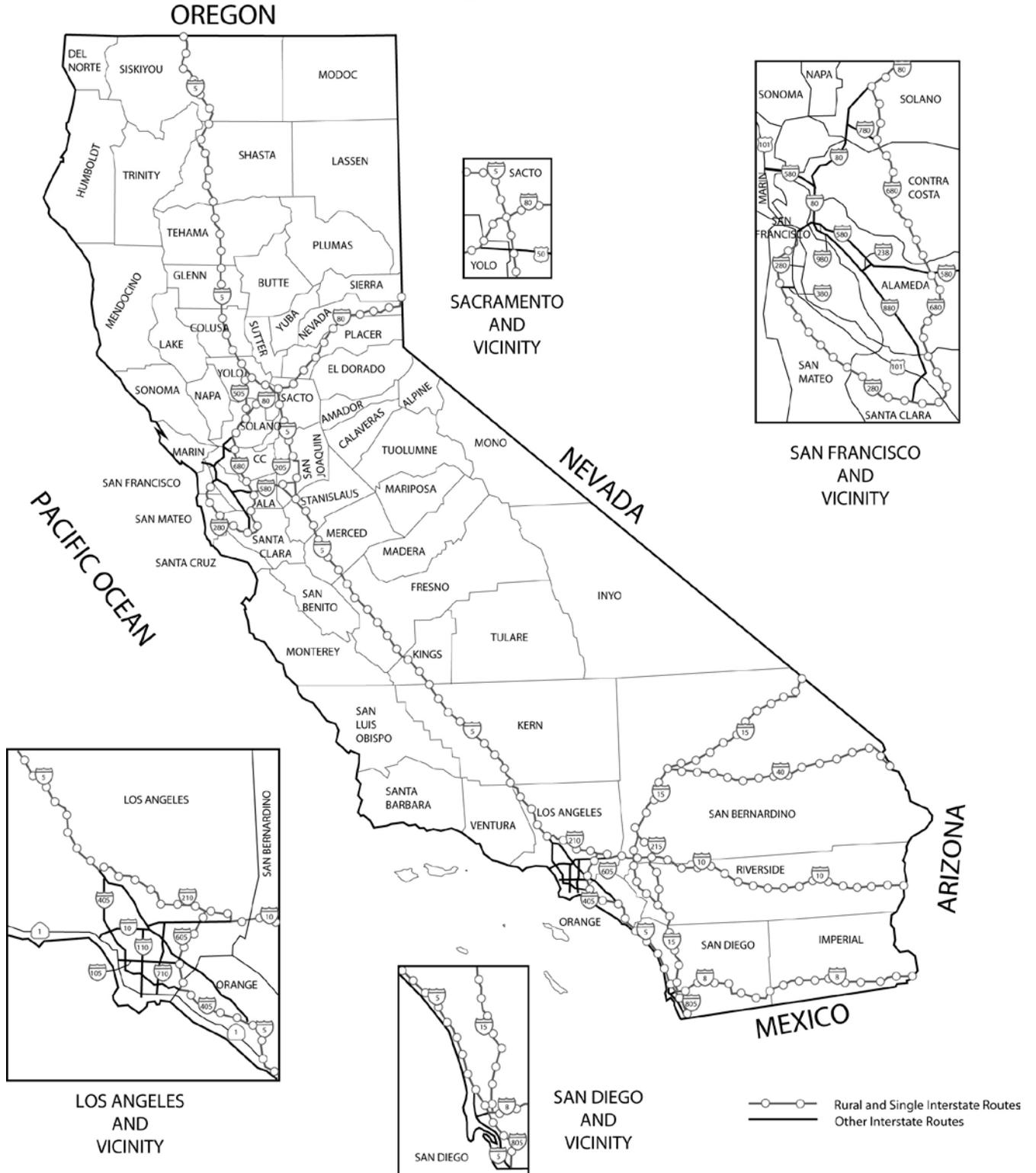


Table 309.2B
California Routes on the Rural and Single Interstate Routing System

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

of vertical clearance. Vertical clearances of less than 16 feet over any Interstate will require FHWA/SDDCTEA notification. See <http://www.fhwa.dot.gov/design/090415.cfm>

- (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.

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 15 feet over the traveled way or 14 feet 6 inches 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 16 feet 6 inches or lead to an increase in the vertical clearance should be brought to the attention of the Design 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.

- 17 feet over freeways and expressways.
- 15 feet 6 inches over other highways (15 feet over shoulders).
- For pedestrian structures, 2 feet greater than the above values.

(b) Railroad Facilities.

- 23 feet over the top of rails for non-electrified rail systems.
- 24 feet 3 inches over the top of rails for existing or proposed 25 kv electrification.
- 26 feet 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 23 feet.

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 excessive clearances should be documented in the project files. Documentation must include reasons for exception including the railroad's justification for increased vertical clearance based on an analysis of engineering, operational and/or economic conditions at a specific structure location with appropriate approval by the HQ Right of Way, Railroad Agreement Coordinator and concurrence by the FHWA.

See Index 1003.1(2) for guidance on Class I bikeway vertical clearance.

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 4 feet 6 inches on the left and 6 feet on the right. For two-way tunnels, this clearance shall be 6 feet on each side. This clearance provides space for bicycle lanes or for bicyclists who want to use the shoulder.

- (2) *Vertical Clearances.* **The minimum vertical clearance shall be 15 feet measured at any point over the traveled way and 14 feet 6 inches 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 15 feet for single-deck structures and 20 feet 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 22 feet 6 inches above tracks on which freight cars not exceeding a height of 15 feet 6 inches are transported, a minimum of 23 feet 4 inches should be used in design to allow for rebalasting and normal maintenance of track. Railroads on which freight cars are not operated, should have a minimum vertical clearance of 19 feet. See Index 309.2(5)(b) for FHWA maximums. 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)).

Horizontal clearance from piers, abutments, and barriers shall be 25 feet minimum to centerline of track. For clearance distances that are less than 25 feet, crash walls will be required. Crash wall heights shall be 6 feet for clearance distances between 13 feet and 25 feet, and 12 feet for clearances less than 13 feet. Horizontal clearances other than those stated above must be approved by the PUC and concurred by the affected railroad entity. Coordinate early in the design phase of the project with the District Railroad Coordinator when railroad agreements are required.

For future planned track expansion, a minimum horizontal clearance distance of 20 feet between existing and future track centerlines shall be provided for freight tracks and 25 feet for commuter tracks. See Figure 309.5 for typical horizontal railroad clearances from grade separated structures.

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.	23' – 0"	19' – 0"

At underpasses, General Order No. 26-D establishes a minimum vertical clearance of 14 feet above any public road, highway or street. **However, the greater clearances specified under Index 309.2 shall be used.**

For at grade crossings, all curbs, including median curbs, should be designed with 10 feet of clearance from the track centerline measured normal thereto.

- (2) *Off-track Maintenance Clearance.* The 18-foot 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 overhead is obtained at additional cost, Federal-aid funds may participate in the costs of such overhead designs that provide up to 18 feet 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.

- (3) *Walkway Clearances Adjacent to Railroads At Grade.* All plans involving construction adjacent to railroads at grade 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 requirements when the planning phase 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 40 feet wide and have been constructed as part of a State highway project. Index 308.1 gives width criteria for city streets and county roads. These widths are also applicable to frontage roads. **However, the minimum paved 2-lane cross section width including 4-foot shoulders without curb and gutter shall be:**

- 32 feet if 12-foot lanes are to be provided;
- 30 feet if 11-foot lanes are to be provided.

The minimum paved 2-lane cross section width, including 5-foot shoulders and curb and gutter shall be:

- 34 feet if 12-foot lanes are to be provided;
- 32 feet if 11-foot lanes are to be provided.

310.2 Outer Separation

In urban areas and in mountainous terrain, the width of the outer separation should be a minimum of 26 feet 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 40 feet wide from edge of traveled way to edge of traveled way.

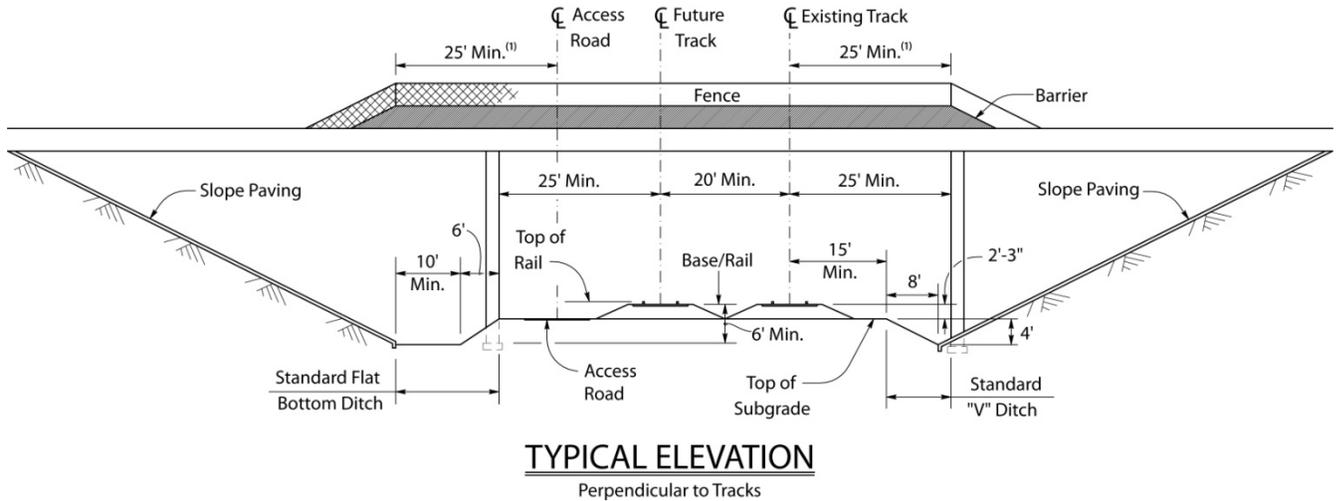
See Figure 307.4 for cross sections of outer separation and frontage road.

310.3 Headlight Glare

Care should be taken when designing new frontage roads to avoid the potential for headlight glare interfering with the vision of motorists, bicyclists, and pedestrians traveling in opposite directions on the frontage roads and in the outer freeway lanes. Consideration should also be given to bike and pedestrians paths. To prevent headlight glare interference on new construction, the preferred measures are for wider outer separations, revised alignment and raised or lowered profiles.

Figure 309.5

Typical Horizontal Railroad Clearance from Grade Separated Structures



NOTE:

The limits of the fence with barrier rail should extend to the limits of railroad right-of-way or a minimum of 25 feet beyond the centerline of the outermost existing track, future track or access roadway, whichever is greater.

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 rail-road bridge	None	8' - 0" ⁽²⁾⁽⁴⁾	9' - 0" ⁽²⁾⁽⁴⁾		
Highway overhead and other structures	18' - 0" clear to face of pier or abutment on side railroad requires for equipment road.	8' - 6" ⁽⁴⁾	9' - 6" ⁽⁴⁾	8' - 6" ⁽³⁾ (Min.)	8' - 6" + 1/2" ⁽³⁾ per degree of curve.
Curbs		10' - 0"			

NOTES:

- (1) The minimum, in general, is one foot 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).

be included in the pavement. Some of these layers include:

- (a) Interlayers can be used between pavement layers or within pavement layers to reinforce pavement and/or improve resistance to reflective cracking of the pavement structure.
- (b) Bond Breakers are used to prevent bonding between two pavement layers such as rigid pavement surface course to a stabilized base.
- (c) Tack Coats are used to bond a layer of asphalt binder mix to underlying existing pavement layers or between layers of asphalt binder mixes where multiple lifts are required.
- (d) Prime Coats can be used on aggregate base prior to paving for better bonding and to act as water proofing of the aggregate base.
- (e) Leveling Courses are used to fill and level surface irregularities and ruts before placing overlays.

Topic 603 – Types of Pavement Projects

603.1 New Construction

New construction is the building of a new facility. This includes new roadways, interchanges or grade separation crossings, and new parking lots or safety roadside rest areas.

603.2 Widening

Widening projects involve the construction of additional width to improve traffic flow and increase capacity on an existing highway facility. Widening may involve adding lanes (including transit or bicycle lanes), shoulders, pullouts for maintenance/transit traffic; or widening existing lane, shoulder or pullouts.

It is often not cost-effective or desirable to widen a highway without correcting for bad ride and major structural problems in adjacent pavements when that work is needed. Therefore, on widening

projects such as lane/shoulders additions, auxiliary lanes, climbing or passing lanes, etc., the existing adjacent pavement condition should be investigated to determine if rehabilitation or pavement preservation is warranted. If warranted, combining rehabilitation or pavement preservation work with widening is strongly encouraged. Combining widening with work on existing pavement can minimize traffic delay and long-term costs. For example, grinding the adjoining rigid pavement lane next to the proposed widening can improve constructability and provide a smoother pavement surface for the widening. For flexible pavement projects, a minimum of 0.15 foot overlay over the widening and existing pavement should be used to eliminate pavement joints which are susceptible to water intrusion and early fatigue failure.

Additional guidance and requirements on widening existing facilities, including possible options as well as certain circumstances that may justify adding rehabilitation or pavement preservation work to widening, or deferring it, are discussed in Index 612.3.

603.3 Pavement Preservation

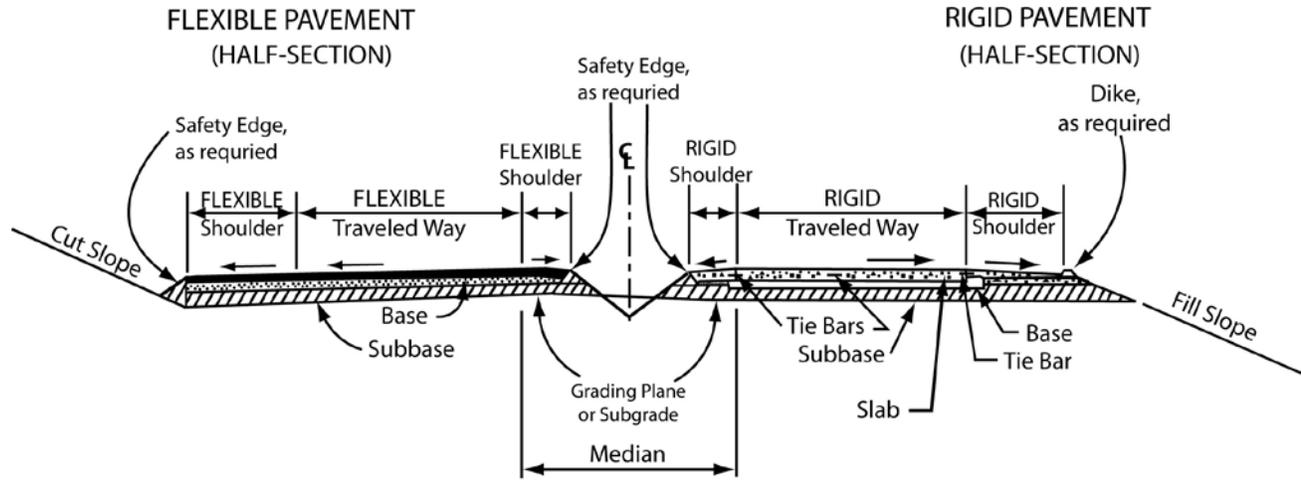
Pavement Preservation has two main categories or programs:

(1) *Preventive Maintenance.* Preventive maintenance projects are used to provide preventive treatments to preserve pavements in good condition. These projects are typically done by Department Maintenance forces or through the Major Maintenance Program. The District Maintenance Engineer typically determines which preventive treatment to apply and when. Examples of preventive maintenance projects include:

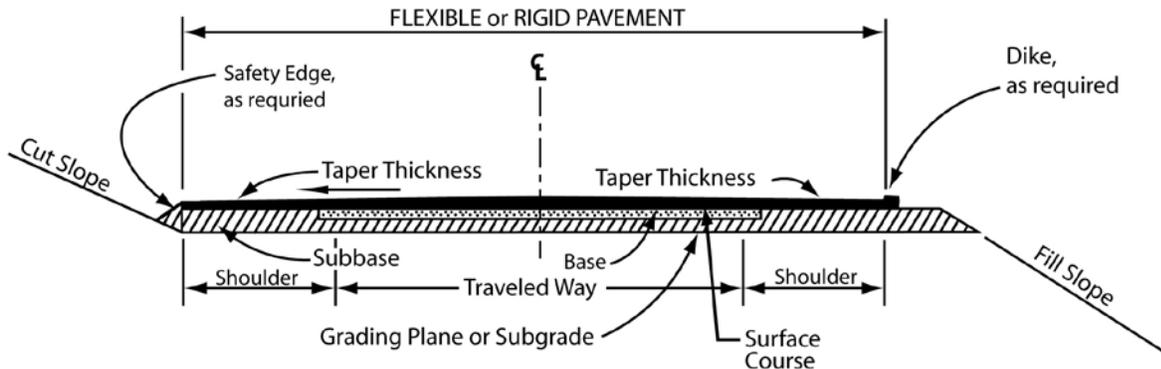
- Removal and replacement of a non-structural wearing course (for example, open graded friction courses);
- Thin non-structural overlays less than or equal to 0.08 foot (or 0.10 foot when needed to enhance compaction in colder temperatures);

Figure 602.1

Basic Pavement Layers of the Roadway



DIVIDED HIGHWAYS



UNDIVIDED HIGHWAYS

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. Pavement drainage design, both on divided and undivided highways, are illustrated and discussed under Chapter 650.
3. Only flexible and rigid pavements shown. Composite pavements are the same as rigid pavements with a flexible layer overlay.
4. See Index 626.2 for criteria for when and how to use flexible or rigid shoulders.

- Replacing joint seals; crack sealing; grinding or grooving rigid pavement surface to improve friction;
- Grinding rigid pavement to eliminate rutting from chain wear;
- Seal coats; slurry seals; and microsurfacing.

Traffic safety and other operational improvements, geometric upgrades, or widening are normally not included in preventative maintenance projects. Strategies and guidelines on preventive maintenance treatments currently used by the Department are available in the Maintenance Policy Directive. Note that such strategies are periodically updated.

- (2) *Capital Preventive Maintenance (CAPM).* Capital Preventive Maintenance (CAPM) is a program of short-term (5 to less than 20 years) repair projects agreed to between the Department and FHWA in 1994. Detailed information regarding the CAPM program can be found in Design Information Bulletin 81. CAPM Guidelines available on the Department Pavement website and in Chapters 620, 630 and 640 of this manual.

The primary purpose of the CAPM program is to repair pavement exhibiting minor surface distress and/or triggered ride (International Roughness Index (IRI) greater than 170 inches per mile) as determined by the Pavement Condition Survey (PCS) and the Pavement Management System (PMS). Ride improvement and preservation of serviceability are key elements of this program. Timely application of CAPM treatments will postpone the need for major roadway rehabilitation and is generally more cost effective than having to rehabilitate pavements exhibiting major distress. CAPM gives the districts the flexibility to make the most effective use of all funds available in the biennial State Highway Operation and Protection Plan (SHOPP).

Since the CAPM program is part of pavement preservation, CAPM projects are more closely related to preventive maintenance (Major

Maintenance) projects than to roadway rehabilitation projects. CAPM projects involve non-structural overlays and repairs, which do not require Traffic Index calculations or deflection studies. CAPM projects include all appropriate items or work necessary to construct and address impacts from the pavement. See DIB 82 for required work regarding accessibility for persons with disabilities. Limited drainage and traffic operational work can also be included when appropriate, but they do not include major facility upgrades like widening, geometric upgrades, or roadside upgrades. Further information on CAPM strategies, including appropriate drainage/operational work and other guidance for CAPM projects, can be found in the CAPM Guidelines.

Examples of CAPM projects include:

- Surface course overlays less than or equal to 0.20 foot (0.25 foot if International Roughness Index >170 in/mile).
- Removal and replacement of surface course (not to exceed the depth of the surface course overlay).
- Surface in-place recycling projects. (Overlay to not exceed 0.20 foot for Hot Mix Asphalt and 0.15 foot for Rubberized Hot Mix Asphalt.)
- Individual rigid pavement slab replacements or punchout repairs.
- Diamond grinding of rigid pavements to eliminate faulting or restore ride quality to an acceptable level.
- Dowel bar retrofit.

Items that are not considered CAPM include:

- Crack, seat, and overlay of rigid pavements.
- Surface course overlays greater than 0.25 foot.
- Removal and replacement of more than 0.25 foot of the surface course (unless the work is incidental to maintaining an existing vertical clearance or to conform to existing bridges or pavements).

- Lane/shoulder replacements (including pulverization and other base restoration/recycling projects).

Projects that require these types of treatments are roadway rehabilitation projects and should meet those standards, see Index 603.4.

603.4 Roadway Rehabilitation

The primary purpose of roadway rehabilitation projects is to return roadways that exhibit major structural distress, to good condition. Many of these structural distresses indicate failure of the surface course and underlying base layers. Roadway rehabilitation work is generally regarded as major, non-routine maintenance work engineered to preserve and extend the service life as well as provide upgrades to enhance safety where needed. As described in Design Information Bulletin 79, Section 1.2, rehabilitation criteria also apply to minor projects and certain other projects in addition to roadway rehabilitation projects. Roadway rehabilitation is different from pavement preservation that simply preserves or repairs the facility to a good condition.

Roadway rehabilitation projects are divided into 2R (Resurfacing and Restoration) and 3R (Resurfacing, Restoration and Rehabilitation). Roadway rehabilitation projects should address other highway appurtenances such as pedestrian and bicyclist facilities, drainage facilities lighting, signal controllers, and fencing that are failing, worn out or functionally obsolete. Also, unlike pavement preservation projects, geometric enhancements and operational improvements may be added to roadway rehabilitation work if such work is critical or required by FHWA standards. Where conditions warrant, quieter pavement strategies could be used to reduce tire/pavement noise. In certain cases, where traditional noise abatement is infeasible, quieter pavement strategies may be considered as an alternative. See Chapter 1100 for additional information on highway traffic noise abatement.

Examples of roadway rehabilitation projects include:

- Overlay.
- Removal and replacement of the surface course.

- Crack, seat, and overlay of rigid pavements regardless of overlay thickness.
- Lane/shoulder replacements.

Roadway rehabilitation strategies for rigid, flexible and composite pavements are discussed in Chapters 620, 630 and 640. Additional information and guidance on roadway rehabilitation, including determining whether the project fits 2R or 3R screening criteria, and other rehabilitation projects may also be found in the Design Information Bulletin, Number 79 - "Design Guidance and Standards for Roadway Rehabilitation Projects" and in the PDPM Chapter 9, Article 5.

603.5 Reconstruction

Pavement reconstruction is the replacement of the entire existing pavement structure by the placement of the equivalent or increased pavement structure. Reconstruction usually requires the complete removal and replacement of the existing pavement structure utilizing either new or recycled materials. Reconstruction is required when a pavement has either failed or has become structurally or functionally outdated.

Reconstruction features typically include the addition of lanes, as well as significant change to the horizontal or vertical alignment of the highway. Although reconstruction is often done for other reasons than pavement repair (realignment, vertical curve correction, improve vertical clearance, etc.), it can be done as an option to rehabilitation when the existing pavement meets any of the following conditions:

- Is in a substantially distressed condition and rehabilitation strategies will not restore the pavement to a good condition; or
- Grade restrictions prevent overlaying the pavement to meet the pavement design life requirements for a rehabilitation project; or
- Life cycle costs for rehabilitation are greater than those for reconstruction.

Reconstruction differs from lane/shoulder replacement roadway rehabilitation options in that lane/shoulder replacements typically involve replacing isolated portions of the roadway width whereas reconstruction is the removal and

replacement of the entire roadway width. Incidental rebuilding of existing pavements for rehabilitation in order to conform to bridges, existing pavement, or meet vertical clearance standards are also considered a rehabilitation and not reconstruction. Storm or earthquake damage repair (i.e., catastrophic) also are not considered reconstruction projects.

Pavement reconstruction projects are to follow the same standards as new construction found in this manual unless noted otherwise.

603.6 Temporary Pavements and Detours

Temporary pavements and detours are constructed to temporarily carry traffic anticipated during construction. These types of pavements should be engineered using the standards and procedures for new construction except where noted otherwise.

Topic 604 - Roles and Responsibilities

604.1 Roles and Responsibilities for Pavement Engineering

The roles and responsibilities listed below apply only to pavement engineering.

- (1) *Pavement Engineer*. The pavement engineer is the engineer who performs pavement calculations, develops pavement structure recommendations, details, or plans. The pavement engineer can be the Project Engineer, District Materials Engineer, District Maintenance Engineer, consultant, or other staff engineer responsible for this task.
- (2) *Project Engineer (PE)*. The PE is the registered civil engineer in responsible charge of appropriate project development documents (i.e., Project Study Report, Project Report, and PS&E) and coordinates all aspects of project development. The PE is responsible for project technical decisions, engineering quality (quality control), and estimates. This includes collaborating with the District Materials Engineer, District Pavement Advisor and other subject matter experts regarding pavement details and selecting pavement strategy for new and rehabilitation projects. The PE clearly conveys pavement related decisions and information on the project plans

and specifications for a Contractor to bid and build the project.

The PE coordinates with the Structures District Liaison Engineer and Division of Engineering Services (DES) staff for the proper selection and engineering of any structure approach system including 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 timely review and project scheduling.

- (3) *District Materials Engineer (DME)*. The DME is responsible for materials information for pavement projects in the district. The District Materials Unit is responsible for conducting or reviewing the findings of a preliminary soils and other materials investigation to evaluate the quality of the materials available for constructing the project. The DME prepares or reviews the Materials Report for each project; provides recommendations to and in continuous consultation with the Project Engineer throughout planning and design, and with the PE and Resident Engineer during construction; and coordinates Materials information with the Department functional units, Material Engineering and Testing Services (METS), Headquarters functional units, local agencies, industry, and consultants.
- (4) *District Pavement Advisor (DPA)*. The DPA manages and coordinates overall pavement strategies for the District. They are primarily involved in pavement management such as identifying future pavement preservation, rehabilitation, and reconstruction needs, and prioritizing pavement projects to meet those needs. The DPA establishes pavement projects and reviews planning documents prepared by the PE for consistency with overall District and statewide goals for pavements. The District Pavement Advisor is typically either the District Maintenance Engineer or another individual within District Maintenance.

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- (5) *Pavement Program (PP)*. The PP, within the Division of Maintenance (DOM) is responsible for statewide standards and guidelines for the pavement engineering process. The DOM Assistant Division Chief for Pavement Program serves as the State Pavement Engineer for the Department.

The PP Office of Concrete Pavement and Pavement Foundations (OCPPF) and Asphalt Pavement (OAP) are responsible for maintaining pavement engineering standards, specifications, standard plans, design methodologies, design software, and practices that are used state wide. OCPPF and OAP also provide technical expertise on material properties and products for pavements. OCPPF and OAP work closely with the District Materials Engineers, Maintenance Engineers, and Resident Engineers to investigate ongoing field and materials issues.

- (6) *State Pavement Engineer*. The State Pavement Engineer provides leadership and commitment to ensure safe, effective, and environmentally sensitive highway pavements that improve mobility across California. The State Pavement Engineer is responsible for conveying clear direction and priorities on pavement initiatives, policies, and standards that reflect departmental goals; and for the implementation of pavement policies, standards, and specifications.
- (7) *Division of Engineering Services (DES)*. The following units within DES provide services that relate to pavements:

- *Materials and Geotechnical Services*: The Materials and Geotechnical Services subdivision consists of the Materials unit (formerly Materials Engineering and Testing Services (METS)) and the Geotechnical Services (GS) unit. The Materials unit is responsible for conducting laboratory testing, field testing, specialized field inspections, and maintaining the test method procedures for the Department. The GS unit provides the Districts, Structures, and Headquarters with expertise and guidance in soil related investigations and groundwater issues, GS prepares or reviews Geotechnical Design

Reports based upon studies and information supplied by the District.

- *Structure Design (SD)*: Structure Design is responsible for selecting the type of structure approach system to be used when the construction or rehabilitation of a structure approach slab is necessary.

604.2 Other Resources

The following resources provide additional standards and guidance related to pavement engineering. Much of this information can be found on the Department Pavement website, see category (5) below.

- (1) *Standard Plans*. These are collections of commonly used engineering details intended to provide consistency for contractors, resident engineers and maintenance engineers in defining the scope of work for projects, assist in the biddability of the project contract plans, and assist maintenance in maintaining the facility. The standard plans were developed based on research and field experience and in consultation with industry. Standard plans for pavement should not be altered or modified without the prior written approval of the Chief, Office of Concrete Pavement and Pavement Foundations. Standard plans for pavements can be found on the Department Pavement website.
- (2) *Standard Specifications and Standard Special Provisions*. The Standard Specifications provide material descriptions, properties and work quality requirements, contract administration requirements, and measurement and payment clauses for items used in the project. The Standard Special Provisions are additional specification standards used to modify the Standard Specifications including descriptions, quality requirements, and measurement and payment for the project work and materials. When no Standard Specification or Standard Special Provision exists for new or proprietary items, the Pavement Program must review and concur with a special provision. For further information, see the Specifications section on the Department Pavement website.

- (3) *Pavement Technical Guidance.* Pavement Technical Guidance is a collection of supplemental guidance and manuals regarding pavement engineering which is intended to assist project engineers, pavement engineers, materials engineers, consultants, construction oversight personnel, and maintenance workers in making informed decisions on pavement structural engineering, constructability and maintainability issues. Information includes, but is not limited to, resources for assistance in decision making, rigid, flexible and composite pavement rehabilitation strategies, pavement preservation strategies, and guidelines for the use of various products and materials. Technical assistance is also available from the Pavement Program to assist with pavements that utilize new materials, methods, and products. These Technical Guidance documents may be accessed on the Department Pavement website.
- (4) *Supplemental District Standards and Guidance.* Some Districts have developed additional pavement standards and guidance to address local issues. Such guidance adds to or supplements the standards found in this manual, the Standard Plans, the Standard Specifications, and Standard Special Provisions. District guidance does not replace minimum statewide standards unless the State Pavement Engineer has approved an exception. Supplemental District Guidance can be obtained by contacting the District Materials Engineer.
- (5) *Department Pavement website.* The Department Pavement website provides a one-stop resource for those seeking to find standards, guidance, reports, approved software, and other resource tools related to pavements. The Department Pavement website can be accessed at <http://www.dot.ca.gov/hq/esc/Translab/OPD/DivisionofDesign-Pavement-Program.htm>.
- (6) *Pavement Interactive Guide.* The Pavement Interactive Guide is a reference tool developed by the Department in partnership with other states. It includes discussion and definitions to terms and practices used in pavement engineering that are intended to aid design engineers in obtaining a better understanding

of pavements. This document is not a standards manual or guideline, rather, it supplements the standards, definitions, and guidance in this manual. Because of copyright issues, the Pavement Interactive Guide is only available to Department employees on the Pavement intranet, or internal, website.

- (7) *The AASHTO "Guide for Design of Pavement Structures.* Although not adopted by the Department, the AASHTO "Guide for Design of Pavement Structures" is a comprehensive reference guide that provides background that is helpful to those involved in engineering of pavement structures. This reference is on file in the Pavement Program and a copy should be available in each District. Engineering procedures included in the AASHTO Guide are used by FHWA to check the adequacy of the specific pavement structures adopted for the Department projects, as well as the procedures and standards included in Chapters 600 - 670 of this manual.

Topic 605 – Record Keeping

605.1 Documentation

One complete copy of the documentation for the type of pavement selected should be retained in permanent District Project History files as well as subsequent updates of construction changes to the pavement structure. The documentation must contain the following:

- Pavement design life (including both the construction year and design year),
- The California R-values and unified soil classification of the subgrade soil,
- The California R-value(s) or strength properties for the materials selected for the subbase and/or base layers,
- The Traffic Index (TI) for each pavement structure, and
- Life cycle cost analysis (including the data required for the life-cycle cost analysis) and other factors mentioned in Topic 619.

605.2 Subsequent Revisions

Any subsequent changes in pavement structures must be documented and processed in accordance with the appropriate instructions stated above and with proper reference to the original design.

Topic 606 - Research and Special Designs

606.1 Research and Experimentation

Research and experimentation are undertaken on an ongoing basis to provide improved methods and standards, which take advantage of new technology, materials, and practices. They may involve investigations of new materials, construction methods, and/or new engineering procedures. Submittal of new ideas by Headquarters and District staff, especially those involved in the engineering, construction, maintenance, paving materials, and performance of the pavement, is encouraged. Research proposals should be sent to the Division of Research and Innovation in Headquarters for review and consideration. Suggestions for research studies and changes in pavement standards may also be submitted to the State Pavement Engineer. The Pavement Program must approve pilot projects and experimental construction features before undertaking such projects. District Maintenance should also be engaged in the discussion involving pilot projects and experimental construction features. Experimental sections must be clearly marked so that District Maintenance can easily locate and maintain such sites.

606.2 Special Designs

Special designs must be fully justified and submitted to the Headquarters Pavement Program, Office of Concrete Pavement and Pavement Foundations (OCPPF) for approval. "Special" designs defined as those designs that meet either or both of the following criteria:

- Involve products, methods, or strategies which either reduce the structural thickness to less than what is determined by the standards and procedures of this manual and accompanying technical guidance, or

- Utilize experimental products or procedures (such as mechanistic-empirical engineering method) not covered in the engineering tables or methods found in this manual or accompanying technical guidance.

Special designs must be submitted to the Headquarters Pavement Program, Office of Concrete Pavement and Pavement Foundations (OCPPF) either electronically or as hard copies. Hard copy submittals must be in duplicate. All submittals must include the proposed pavement structure(s) and a location strip map (project title sheet is acceptable). The letter of transmittal should include the following:

- Pavement design life, including both the construction year and design year (See Topic 612).
- The California R-value(s) and unified soil classification of the subgrade soil(s) (See Indexes 614.2 and 614.3).
- The California R-value(s) or strength properties for the materials selected for the subbase and/or base layers (See Tables 663.1A and 663.1B).
- The Traffic Index (TI) for each pavement structure (See Indexes 613.3 & 613.4).
- Justification for the "special" design(s).

OCPPF will act as the Headquarters focal point to obtain concurrence of Pavement Program and other Headquarters functional units as needed prior to OCPPF granting approval of the "special" designs.

606.3 Mechanistic-Empirical Design

Mechanistic-Empirical (ME) Design is currently under development by the Department, FHWA, AASHTO and other States. On March 10, 2005, the Department committed to develop ME Design as an alternative and possible replacement of current methods. The Department is currently working on the procedures and criteria for performing this analysis. Until the criteria are established and the methodology verified, ME Design will be considered experimental and cannot, at this time, be used to engineer pavements on the State highway system or other roads maintained by the State.

606.4 Proprietary Items

The use of proprietary materials and methods on State highway projects is discussed in Topic 110.10.

life of the adjacent roadway (but not less than the project design period as defined in Index 103.2), or the pavement design life values in Table 612.2 depending on which has the lowest life-cycle costs. Life-cycle cost analysis is discussed further in Topic 619.

When widening a roadway, the existing pavement should be rehabilitated and brought up to the same life expectancy as the new widened portion of the roadway.

612.4 Pavement Preservation

- (1) *Preventive Maintenance:* Because preventive maintenance projects involve non-structural overlays, seals, grinds, or repairs, they are not engineered to meet a minimum structural design life like other types of pavement projects. Their intended goal is to extend the service life of an existing pavement structure while it is in good condition. Typically, for preventive maintenance, the added service life can vary from a couple of years to over 7 years depending on the strategy being used and the condition of the existing pavement.
- (2) *Capital Preventive Maintenance:* The strategies used for CAPM projects have been engineered to extend the service life of a pavement that exhibits minor distress and/or triggered ride (International Roughness Index (IRI) greater than 170 inches per mile) by a minimum of 5 years. Some strategies such as rigid pavement diamond grinding, slab replacement, punchout repairs, and dowel bar retrofit can last at least 10 years.

612.5 Roadway Rehabilitation

The minimum pavement design life for roadway rehabilitation projects shall be 20 years except for roadways with existing rigid pavements or with a current Annual Average Daily Traffic (AADT) of at least 15,000 vehicles, where the minimum pavement design life shall be 20 or 40 years depending on which design life has the lowest life-cycle costs. At the discretion of the District, a 40-year pavement design life may be considered and evaluated for all projects with an AADT less than 15,000 using the Department's

life cycle cost analysis procedures. Life-cycle cost analysis is discussed further in Topic 619.

612.6 Temporary Pavements and Detours

Temporary pavements and detours should be engineered to accommodate the anticipated traffic loading that the pavement will experience during the construction period. The minimum design life for temporary pavements and detours should be no less than the construction period for the project. This period may range from a few months to several years depending on the type, size and complexity of the project.

612.7 Non-Structural Wearing Courses

As described in Index 602.1(5), a non-structural wearing course is used on some pavements to ensure that the underlying layers will be protected from wear and tear from tire/pavement interaction, the weather, and other environmental factors for the intended design life of the pavement. Because non-structural wearing courses are not considered to contribute to pavement structural capacity, they are not expected to meet the same design life criteria as the structural layers. However, when selecting materials, mix designs and thickness of these courses, appropriate evaluation and sound engineering judgment should be used to optimize performance and minimize the need for maintenance of the wearing course and the underlying structural layers. Based on experience, a properly engineered non-structural wearing course placed on new pavement should perform adequately for 10 or more years, and 5 or more years when placed on existing pavement as a part of rehabilitation or preventive maintenance.

Topic 613 - Traffic Considerations

613.1 Overview

Pavements are engineered to carry the truck traffic loads expected during the pavement design life. Truck traffic, which includes transit vehicles trucks and truck-trailers, is the primary factor affecting pavement design life and its serviceability. Passenger cars and pickups are

considered to have negligible effect when determining traffic loads.

Truck traffic information that is currently required for pavement engineering includes projected volume for each of four categories of truck and transit vehicle types by axle classification (2-, 3-, 4-, and 5-axles or more). When the Department adopts the Mechanistic – Empirical (ME) design method, additional information such as axle configurations (single, tandem, tridem, and quad), axle loads, and number of load repetitions would also be required. This information is used to estimate anticipated traffic loading and performance of the pavement structure. The Department currently estimates traffic loading by using established constants for a 10-, 20-, 30-, or 40-year pavement design life to convert truck traffic data into 18-kip equivalent single axle loads (ESALs). The total projected ESALs during the pavement design life are in turn converted into a Traffic Index (TI) that is used to determine minimum pavement thickness. Another method for estimating pavement loading known as Axle Load Spectra is currently under development by the Department for future use with the Mechanistic-Empirical (ME) design procedure.

613.2 Traffic Volume Projections

(1) *Traffic Volume and Loading Data.* In order to determine expected traffic loads on a pavement it is first necessary to determine projected traffic volumes during the design life for the facility.

Traffic volume or loading on State highways can come from vehicle counts and classification, weigh-in-motion (WIM) stations, or the Truck Traffic (Annual Average Daily Truck Traffic) on California State Highways published annually by Headquarters Division of Traffic Operations. Current and projected traffic volume by vehicle classification must be obtained for each project in accordance with the procedures found in this Topic.

Districts typically have established a unit within Traffic Operations or Planning specifically responsible for providing travel forecast information. These units are

responsible for developing traffic projections (including truck volumes, equivalent single axle loads, and TIs) used for planning and engineering of State highways in the District. The Project Engineer should coordinate with the forecasting unit in their District early in the project development process to obtain the required traffic projections.

(2) *Design Year Annual Average Daily Truck Traffic (AADTT):* An expansion factor obtained from the traffic forecasting unit is used to project current AADTT to the design year AADTT for each axle classification (see Table 613.3A). In its simplest form, the expansion factor is a straight-line projection of the current one-way AADTT data. When using the straight-line projection, the truck traffic data is projected to find the AADTT at the midway of the design life. This represents the average one-way AADTT for each axle classification during the pavement design life.

When other than a straight-line projection of current truck traffic data is used for engineering purposes, the procedure to be followed in developing design year traffic projections will depend on travel forecast information for the region. In such cases, the projections require a coordinated effort from the District's Division of Transportation Planning and Traffic Operations, working closely with the Regional Agencies to establish realistic values for truck traffic growth rates based on travel patterns, land use changes, and other socioeconomic factors.

Due to various changes in travel patterns, land use changes, and other socioeconomic factors that may significantly affect design year traffic projections, the TI for facilities with longer service life, such as a 30- or 40-year design life require more effort to determine than for a 10- or 20-year design life. For this reason, the Project Engineer should involve District Transportation Planning and/or Traffic Operations in determining a realistic and appropriate TI for each project early in the project development process. In the absence of 30- or 40-year traffic projection data, 20-year projection data may be extrapolated to

30- and 40-year values by applying the expansion factors.

613.3 Traffic Index Calculation

The Traffic Index (TI) is determined using the following procedures:

(1) *Determine the Projected Equivalent Single Axle Loads (ESALs)*. The information obtained from traffic projections and Truck Weight Studies is used to develop 18-kip Equivalent Single Axle Load (ESAL) constants that represent the estimated total accumulated traffic loading for each heavy vehicle (trucks and buses and each of the four truck types during the pavement design life. Typically, buses are assumed to be included in the truck counts due to their relatively low number in comparison to trucks. However, for facilities with high percentage of buses such as high-occupancy vehicle (HOV) lanes and exclusive bus-only lanes, projected bus volumes need to be included in the projection used to determine ESALs. The ESAL constants are used as multipliers of the projected AADTT for each truck type to determine the total cumulative ESALs and in turn the Traffic Index (TI) during the design life for the pavement (see Index 613.3(3)). The ESALs and the resulting TI are the same magnitude for both flexible, rigid, and composite pavement alternatives. The current 10-, 20-, 30-, and 40-year ESAL constants are shown in Table 613.3A.

(2) *Lane Distribution Factors*. Truck/bus traffic on multilane highways normally varies by lane with the lightest volumes generally in the median lanes and heaviest volumes in the outside lanes. Buses are also typically found in HOV lanes. For this reason, the distribution of truck/bus traffic by lanes must be considered in the engineering for all multilane facilities to ensure that traffic loads are appropriately distributed. Because of the uncertainties and the variability of lane distribution of trucks on multilane freeways and expressways, statewide lane distribution factors have been established for pavement engineering of highway facilities in California.

These lane distribution factors are shown in Table 613.3B.

(3) *Traffic Index (TI)*. The Traffic Index (TI) is a measure of the number of ESALs expected in the traffic lane over the pavement design life of the facility. The TI does not vary linearly with the ESALs but rather according to the following exponential formula and the values presented in Table 613.3C. The TI is determined to the nearest 0.5.

$$TI = 9.0 \times \left(\frac{(ESAL \times LDF)}{10^6} \right)^{0.119}$$

Where:

TI = Traffic Index

ESAL = Total number of cumulative 18-kip Equivalent Single Axle Loads

LDF = Lane Distribution Factor (see Table 613.3B)

Index 613.4 contains additional requirements and considerations for determining projected traffic loads.

613.4 Axle Load Spectra

(1) *Development of Axle Load Spectra*. Axle load spectra is an alternative method of measuring heavy vehicle loads that is currently under development for the future mechanistic-empirical design method. Axle load spectra is a representation of normalized axle load distribution developed from weigh-in-motion (WIM) data for each axle type (single, tandem, tridem, and quad) and truck class (FHWA vehicle classes 4 through 13). Axle load spectra do not involve conversion of projected traffic loads into equivalent single axle loads (ESALs), instead traffic load applications for each truck class and axle type are directly characterized by the number of axles within each axle load range.

In order to accurately predict traffic load related damage on a pavement structure, it is important to develop both spatial and temporal axle load spectra for different truck loadings and pavements. The following data is needed to develop axle load spectra:

Table 613.3A
ESAL Constants

Vehicle Type (By Axle Classification)	10-Year Constants	20-Year Constants	30-Year Constants	40-Year Constants
2-axle trucks or buses	690	1,380	2,070	2,760
3-axle trucks or buses	1,840	3,680	5,520	7,360
4-axle trucks	2,940	5,880	8,820	11,760
5 or more-axle trucks	6,890	13,780	20,670	27,560

Table 613.3B
Lane Distribution Factors for Multilane Highways

Number of Mixed Flow Lanes in One Direction	Factors to be Applied to Projected Annual Average Daily Truck Traffic (AADTT)			
	Mixed Flow Lanes (see Notes 1-6)			
	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:

- Lane 1 is next to the centerline or median.
- For more than four lanes in one direction, use a factor of 0.8 for the outer two lanes plus any auxiliary/collector lanes, use a factor of 0.2 for other mixed flow through lanes.
- For HOV lanes and other inside lanes (non truck lanes), use a factor of 0.2. However, as noted in Index 613.5(1)(b), the TI should not be less than 10 for a 20-year pavement design life, or than 11 for a 40-year pavement design life. Additionally, for freeways and expressways, the maximum TI must not exceed 11 or 12 for a 20-year and 40-year design life, respectively.
- If trucks are permitted to use HOV or other inside lanes, HOV and/or other inside lanes shall be designed to the same standards as found in this table for the outside lanes.
- For lanes devoted exclusively to buses and/or trucks, use a factor of 1.0 based on projected AADTT of mixed-flow lanes for auxiliary and truck lanes, and a separate AADTT based on expected bus traffic for exclusive bus-only lanes.
- The lane distribution factors in this table represent minimum factors and, based on knowledge of local traffic conditions and sound engineering judgment, higher values should be used for specific locations when warranted.

Table 613.3C
Conversion of ESAL to Traffic Index

ESAL ⁽¹⁾	TI ⁽²⁾	ESAL ⁽¹⁾	TI ⁽²⁾
4,710		6,600,000	
	5.0		11.5
10,900		9,490,000	
	5.5		12.0
23,500		13,500,000	
	6.0		12.5
47,300		18,900,000	
	6.5		13.0
89,800		26,100,000	
	7.0		13.5
164,000		35,600,000	
	7.5		14.0
288,000		48,100,000	
	8.0		14.5
487,000		64,300,000	
	8.5		15.0
798,000		84,700,000	
	9.0		15.5
1,270,000		112,000,000	
	9.5		16.0
1,980,000		144,000,000	
	10.0		16.5
3,020,000		186,000,000	
	10.5		17.0
4,500,000		238,000,000	
	11.0		17.5 ⁽³⁾
6,600,000		303,000,000	

Notes:

- (1) For ESALs less than 5,000 or greater than 300,000,000, use the TI equation to calculate design TI, see Index 613.3(3).
- (2) The determination of the TI closer than 0.5 is not justified. No interpolations should be made.
- (3) For TI's greater than 17.5, use the TI equation, see Index 613.3(3).

- Truck class (FHWA Class 4 for buses through Class 13 for 7+ axle multi-trailer combinations)
- Axle type (single, tandem, tridem, and quad)
- Axle load range for each axle type and truck class (3 to 102 kips)
- The number of axle load applications within each axle load range by axle type and truck class
- The percentage of the total number of axle applications within each axle load range with respect to each axle type, truck class, and year of data. These are the normalized values of axle load applications for each axle type and truck class

The aforementioned data are obtained from traffic volume counts and WIM data for vehicle classification, and axle type and weight. Traffic counts and WIM stations should be deployed widely to ensure that projected volume estimates for each vehicle class and axle type are in line with the actual volumes and growth rates.

- (2) *Use of Axle Load Spectra in Pavement Engineering:* Pavement engineering calculations using axle load spectra are generally more complex than those using ESALs or Traffic Index (TI) because loading cannot be reduced to one equivalent number. However, the load spectra approach of quantifying traffic loads offers a more practical and realistic representation of traffic loading than using TI or ESALs. Due to its better performance modeling, axle load spectra will be used in the Mechanistic-Empirical (M-E) design method currently under development to evaluate traffic loading over the design life for new and rehabilitated pavements. This information will be used to validate original pavement design loading assumptions, and to continuously monitor pavement performance given the loading spectrum. Axle load spectral data will also be used to facilitate effective and pro-active deployment of maintenance efforts and in the development of appropriate strategies to

mitigate sudden and unexpected pavement deterioration due to increased volumes or loading patterns.

In this edition of the Highway Design Manual, axle load spectra are not used to engineer pavements.

613.5 Specific Traffic Loading Considerations

(1) *Traveled Way.*

- (a) **Mainline Lanes.** Because each lane for a multilane highway with 3 or more lanes in each direction may have a different load distribution factor (see Table 613.3B), multiple TIs may be generated for the mainline lanes which can result in different pavement thickness for each lane. Such a design with different thickness for each lane would create complications for constructing the pavement. Therefore, the decision to use a single or multiple TI's for the pavement engineering of mainline lanes for a multilane highway with 3 or more lanes in each direction should be based on a thorough consideration of constructibility issues discussed in Index 618.2 together with sound engineering judgment. If one TI is used, it should be the one that produces the most conservative pavement structure.

- (b) **Freeway Lanes.** TI for new freeway lanes, including widening, auxiliary lanes, and high-occupancy vehicle (HOV) lanes, should be the greater of either the calculated value, 10.0 for a 20-year pavement design life, or 11.0 for a 40-year pavement design life. For roadway rehabilitation projects, use the calculated TI.

(c) **Ramps and Connectors:**

1. **Connectors.** AADTT and TI's for freeway-to-freeway connectors should be determined the same way as for mainline traffic.

2. Ramps to Weigh Stations. Pavement structure for ramps to weigh stations should be engineered using the mainline ESALs and the load distribution factor of 1.0 for exclusive truck lanes as noted in Table 613.3B.
3. Other Ramps. Estimating future truck traffic on ramps is more difficult than on through traffic lanes. It is typically more difficult to accurately forecast ramp AADTT because of a much greater impact of commercial and industrial development on ramp truck traffic than it is on mainline truck traffic.

If reliable truck traffic forecasts are not available, ramps should be engineered using the 10-, 20-, and 40-year TI values given in Table 613.5A for light, medium, and heavy truck traffic ramp classifications. Design life TI should be the greater of the calculated TI or the TI values in Table 613.5A.

The three ramp classifications are defined as follows:

- Light Traffic Ramps - Ramps serving undeveloped or residential areas with light to no truck traffic predicted during the pavement design life.
- Medium Traffic Ramps - Ramps in metropolitan areas, business districts, or where increased truck traffic is likely to develop because of anticipated commercial development within the pavement design life
- Heavy Traffic Ramps - Ramps that will or currently serve industrial areas, truck terminals, truck stops, and/or maritime shipping facilities.

The final decision on ramp truck traffic classification rests with the District.

**Table 613.5A
Traffic Index (TI) Values for
Ramps and Connectors**

Ramp Truck Traffic Classification	Minimum Traffic Index (TI)	
	20-Yr Design Life	40-Yr Design Life ⁽¹⁾
Light	8.0	9.0
Medium	10.0	11.0
Heavy	12.0	14.0

NOTE:

- (1) Based on straight line extrapolation of 20-year ESALs.
- (2) *Shoulders.*

(a) Purpose and Objectives.

Shoulder pavement structures must be designed and constructed to assure that the following performance objectives are met:

- Be safely and economically maintained.
- Enhance the performance of adjacent travel lanes.
- Be structurally adequate to handle maintenance and emergency vehicles and to serve as emergency parking.
- Accommodate pedestrians and bicyclists as necessary.
- Provide versatility in using the shoulders as temporary detours for construction or maintenance activities in the future.
- Make it easier and more cost-effective to convert into a traffic lane as part of a future widening.
- Simplify the Contractor's operation which leads to reduced working days and lower unit prices.

Shoulders do not need to be designed to traffic lane standards to meet these objectives. To achieve these performance

objectives, the following design standards apply for shoulders on the State highway.

- (b) New Construction and Reconstruction. **New or reconstructed shoulders shall be engineered to match the TI of the adjacent traffic lane when any of the following conditions apply:**

- **the shoulder width is less than 5 feet.**
- **the median width is 14 feet or less.** See Index 305.5 for further paved median guidance.
- **on roads with less than two lanes in the direction of travel and there is a sustained (greater than 1 mile in length) grade of over 4 percent without a truck climbing lane.**
- **the shoulders are adjacent to exclusive truck or bus only lanes, or weigh station ramps.** This standard does not apply to mixed use (automobile plus bus) lanes, including high-occupancy vehicle (HOV) and toll (HOT) lanes.

The shoulder may also be engineered to match the TI of the adjacent traffic lane provided that:

- There is an identified plan (such as Regional Transportation Plan, Metropolitan Transportation Plan, Interregional Improvement Plan) to convert a shoulder into a traffic lane within the next 20 years.
- The shoulder is designed following the lane width and cross slope guidance in Topic 301.
- Agreement is obtained by the Program Fund Manager or Agency funding the project.

When the above conditions apply and the shoulder and lane will both be constructed as part of the same project, the shoulder pavement structure should match the adjacent traffic lane for ease of construction. For asphalt pavements, the thickness of the shoulder surface course

may be tapered from the lane surface course thickness to the shoulder pavement edge thickness of no less the 0.35 foot to address different cross slope conditions (see Figure 613.5A).

For all other cases, the minimum TI for the shoulder shall match the TI of the adjacent traffic lane for the first 2 feet of the outside shoulder width and 1 foot of the inside shoulder measured from the edge of traveled way. See Figure 613.5B.

For the remaining width of the shoulder, the TI shall:

- **be no less than 2 percent of the projected ESALs of the adjacent traffic lane or a TI of 5, whichever is greater.**
- **not exceed 9.**

Treated permeable bases needed to perpetuate an existing treated permeable base under the adjacent lane may be included underneath the pavement. Non-permeable treated bases, such as lean concrete base, are not to be included underneath the pavement.

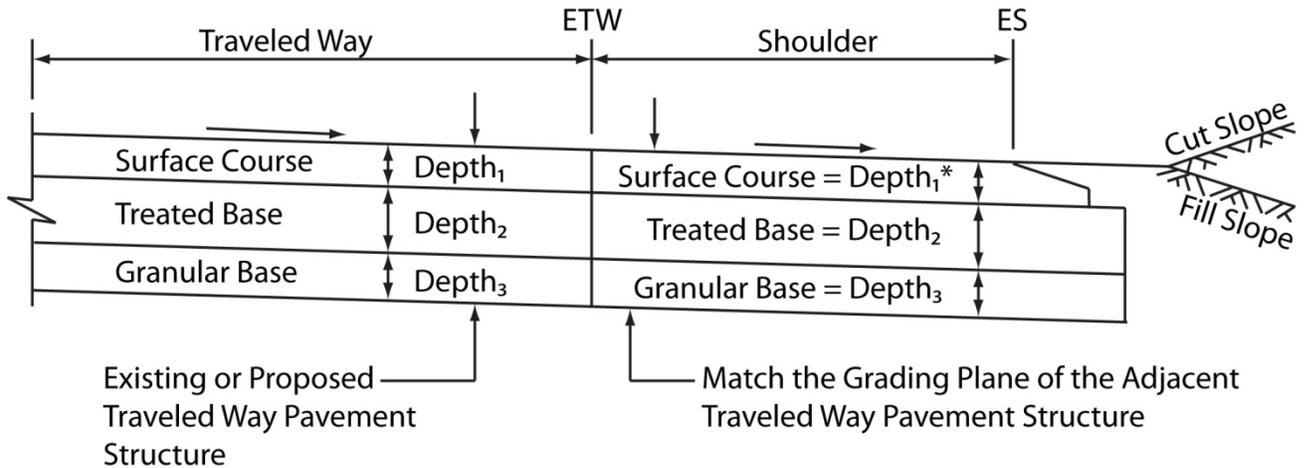
The total depth of the shoulder pavement structure (depth from the surface to the subgrade) shall match the pavement structure grading plane of the adjacent traffic lane.

Matching the grading plane of the shoulder pavement structure to that of the adjacent traffic lane can be accomplished by increasing the depth of the aggregate base and/or subbase as needed (see Figure 613.5B). This will provide a path for water in the pavement structure to drain away from the lane and into the shoulder. It can also provide a more cost effective means to upgrade the shoulder to a traffic lane in the future. Although using a thinner overall shoulder pavement structure than the traveled way requires less material and may appear to reduce construction costs, the added costs of time and labor to the Contractor to build the step between the

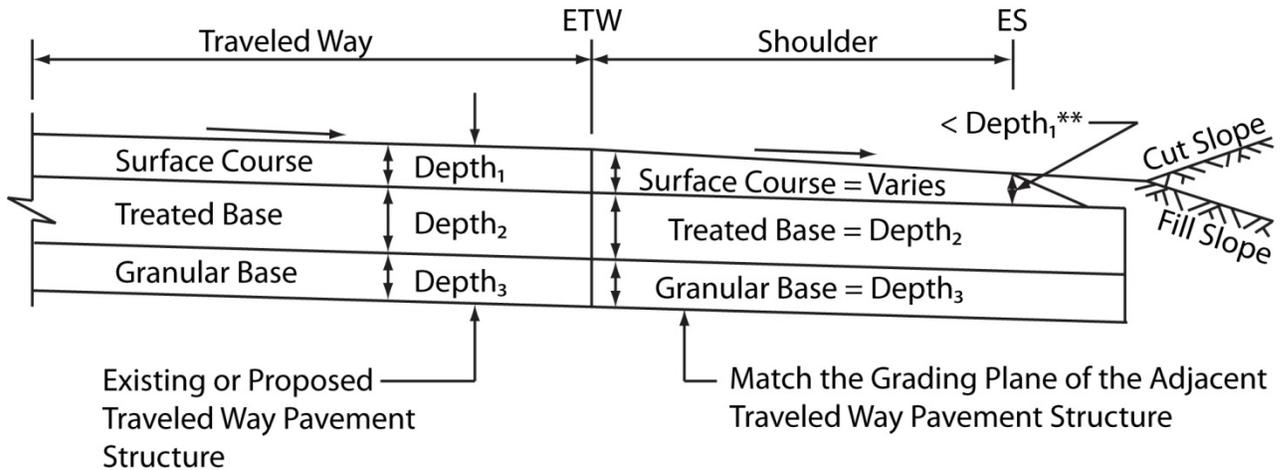
Figure 613.5A

Shoulder Design for TI Equal to Adjacent Lane TI

Shoulder Pavement Structure is the Same as Traveled Way Structure



Variable Shoulder Thickness Option for Asphalt Pavement

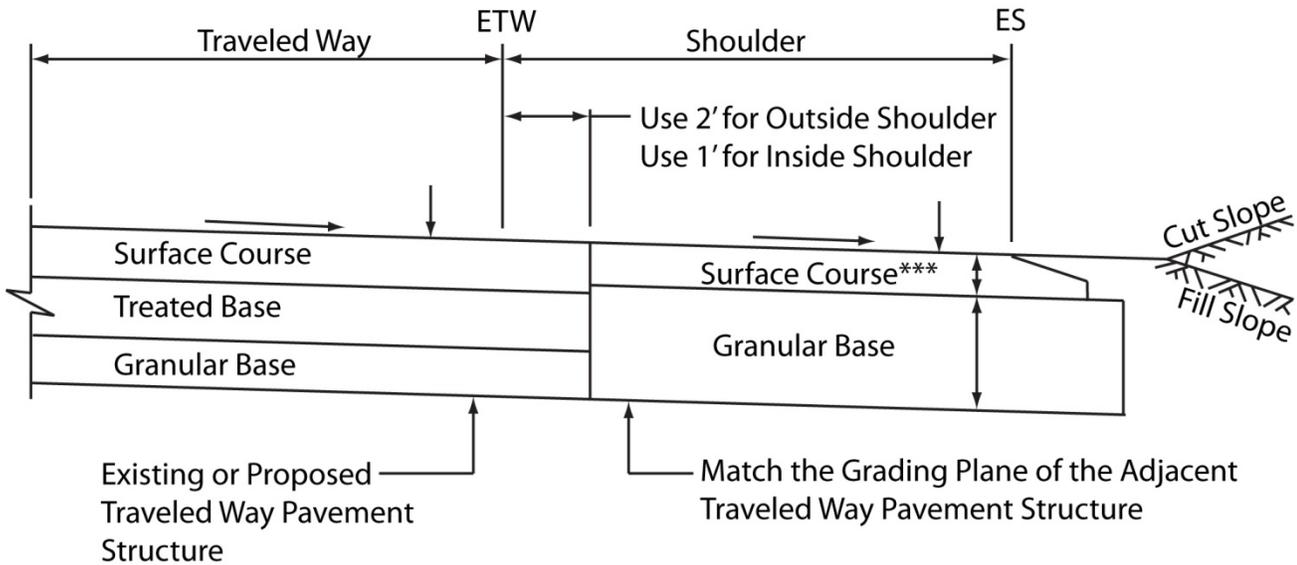


NOTES:

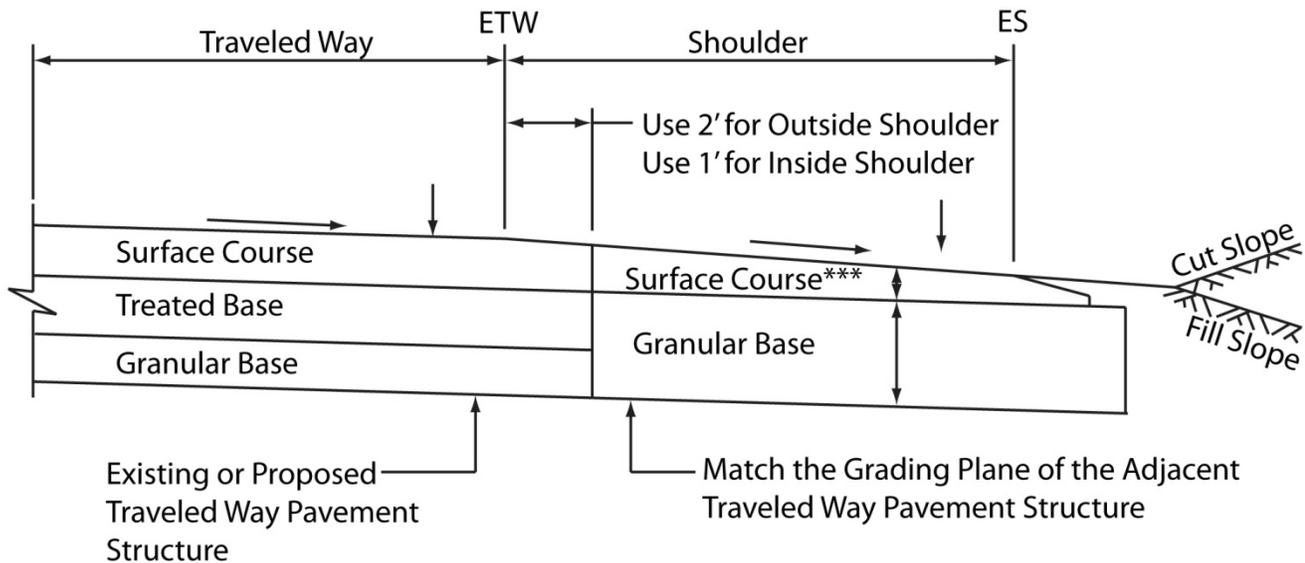
- * Applies to concrete and asphalt pavements.
- ** For asphalt pavement, minimum thickness of surface course $\geq 0.35'$.

Figure 613.5B
Shoulder Design for TI Less Than Adjacent Lane TI

Variable Surface Course Option



Uniform Surface Course Option



NOTES:

*** For rigid pavement, minimum thickness of surface course is $\geq 0.60'$ ($0.75'$ for High Mountain or High Desert Climate Region)

For flexible pavement, minimum thickness of surface course is $\geq 0.35'$

traveled way and shoulder can offset any perceived savings from reduced materials.

For asphalt shoulders, the thickness of the asphalt layer (not including nonstructural wearing surface) should not be less than 0.35 foot or the thickness of the asphalt layer of the adjacent traffic lane, whichever is less.

For concrete shoulders, a pavement structure of 0.70 foot undoweled jointed plain concrete pavement (0.85 foot in High Mountain and High Desert climate regions) over aggregate base is sufficient to meet the requirement of the TI not exceeding 9.0 and provide adequate structure for maintenance equipment and temporary traffic detours.

An alternate shoulder design is to taper the surface course from the surface course thickness of the adjacent traffic lane to no less than 0.60 foot (0.75 foot in High Mountain and High Desert climate regions) for concrete and 0.35 foot for asphalt at the edge of shoulder (see Figure 613.5B).

Bases and subbases for new or reconstructed shoulders should extend at least 1 foot beyond the edge of shoulder as shown in Figures 613.5A and 613.5B.

(c) Widening.

Existing shoulders do not need to be replaced or upgraded to new construction or reconstruction standards as part of a shoulder widening project unless the following conditions exist:

- Adding or widening lanes will require removal of all or a portion of the existing shoulder.
- The existing shoulder of 5 feet or less in width is being widened and the existing shoulder does not meet the current standards for new construction or reconstruction. For shoulders wider than 5 feet, the District and Program Fund Manager/Agency determines whether to reconstruct the entire shoulder to new construction or reconstruction standards, or match the

pavement structure of the existing shoulder.

- There is an identified plan that the widened shoulder will be converted or replaced with a traffic lane within 20 years.
- The widened shoulder will be used as a temporary detour as discussed in Index 613.5(2)(f).

For all other cases, widening of the existing shoulder should match the pavement structure of the existing shoulder. For shoulders left in place, repair any existing distresses prior to overlaying.

(d) Pavement Preservation.

Shoulder preservation should be done in conjunction with work on the adjacent traffic lanes to assure that the shoulder pavement structure will meet the performance requirements stated in Index 613.5(2)(a). Shoulders can be preserved by:

- Sealing cracks greater than ¼ inch in width,
- Grinding out rolled up sections next to concrete pavement,
- Fog or slurry sealing asphalt surfaces,
- Limiting digouts of failed locations.

For CAPM projects, the following additional strategies can be considered if warranted:

- Milling and replacing 0.15 foot of oxidized and cracked surfaces can be considered either prior to an overlay or as a stand-alone action.
- Grinding of concrete shoulders if the adjacent traffic lane is being ground.

Shoulder preservation strategies should be identified and discussed with District Maintenance and the Headquarters Pavement Reviewer during the scoping phase of the project or whenever a change in strategy is proposed.

(e) Roadway Rehabilitation.

The goal in roadway rehabilitation projects is to maintain existing shoulders wherever possible. The TI is not a consideration in choosing the shoulder rehabilitation strategy unless it has been determined that the shoulder needs to be replaced for one of the following reasons:

- The shoulder will be used to temporarily detour traffic during construction and the existing shoulder does not provide adequate structure to handle the expected loads.
- The adjacent lane is being replaced as part of the project. In this situation, if the shoulder is wider than 5 feet, replace only two feet of the outside shoulder (1 foot of inside shoulder) adjacent to the traffic lane. For shoulders 5 feet wide or less, replace the entire shoulder.
- The existing shoulder exhibits extensive distress and/or settlement and it is agreed to by the Headquarters Pavement Reviewer that replacement is the only viable option.

For replacements other than temporary traffic detours, use the standards for new construction and reconstruction in Index 613.5(2)(b). For temporary traffic detours, see Index 613.5(2)(f) for further discussion.

Regardless of whether or not the TI is considered, shoulder rehabilitation repairs of the existing shoulder are often necessary and should be done in conjunction with work on the adjacent traffic lanes to assure that the shoulder pavement will meet the performance requirements stated in Index 613.5(2)(a).

Existing asphalt shoulders can typically be maintained as part of a rehabilitation project by milling and replacing 0.15 feet of asphalt surface plus digouts of failed areas to remove oxidized layers. This can be done either prior to an overlay or to

maintain the existing surface. Where the existing shoulders have little to no cracking and are older than 3 years from the last treatment, a fog seal or slurry seal with digouts is all that is needed.

Existing concrete shoulders typically only require sealing any unsealed cracks ½ inch or wider or replacing the joint seals. Shoulders should be sealed if the adjacent traffic lanes are sealed. If shoulders are spalled, the spalls should be repaired and any shattered slabs replaced. Grinding should not be done, even if the shoulder is faulted or curled unless the adjacent traffic lane is also being ground.

Shoulder rehabilitation strategies should be identified and discussed with District Maintenance and the Headquarters Pavement Reviewer during the scoping phase of the project or whenever a change in strategy is proposed.

(f) Temporary Detours.

When existing shoulders will be used to stage traffic during construction, the existing shoulder pavement structure should be checked for structural adequacy. If the existing shoulder is not structurally adequate or if it is a new shoulder, calculate the TI based on the actual truck traffic expected to be encountered during construction. Design the shoulder based on the requirements for new or reconstructed shoulders in Index 613.5(2)(b) except the TI may exceed 9. Do not use treated bases for temporary detours. For existing shoulders, remove the surface course layer and replace with a new surface course sufficiently thick enough to support temporary traffic loads.

(g) Conversion to Lane.

If a decision has been made to convert an existing shoulder to a portion of a traffic lane, a deflection study must be performed to determine the structural adequacy of the in place asphalt shoulder. The condition of the existing shoulder must also be evaluated for undulating grade, rolled-up

hot mix asphalt at the rigid pavement joint, surface cracking, raveling, brittleness, oxidation, etc.

The converted facility must provide a roadway that is structurally adequate for the proposed pavement design life. This is necessary to eliminate or minimize the likelihood of excessive maintenance or rehabilitation being required in a relatively short time because of inadequate structural strength and deterioration of the existing pavement structure.

If the existing shoulder is determined to be structurally inadequate for the proposed pavement design life, then the shoulder should be upgraded or replaced in accordance with the standards for new construction and reconstruction discussed in Index 613.5(2)(b).

(h) Other.

- Tracking and Sweep Width Lines.

For projects where the tracking width and sweep width lines are shown to encroach onto the paved shoulders, the shoulder pavement structure must be engineered to sustain the weight of the design vehicle. If curb and gutter are present and any portion of the gutter pan is likewise encroached, the gutter pan must be engineered to match the adjacent shoulder pavement structure. See Topic 404 for design vehicle guidance.

- Minimizing Worker Exposure.

Consult with District Maintenance and the Headquarters Program Advisor during the scoping phase on options for minimizing maintenance worker exposure to maintain shoulders.

- Concrete shoulders and asphalt pavement structure.

Do not place concrete shoulders adjacent to asphalt pavement structure.

(3) *Intersections.* Future AADTT and TI's for intersections should be determined for each approach the same way as for mainline traffic.

At some intersections, the level of truck/transit traffic from all approaches may add more loads on the pavement than what the mainline pavement was designed for. Separate ESAL/TI or load spectra calculations should be performed at intersections when any of the following criteria apply:

- Two or more State highways intersect (including ramps to/from State highways)
- Truck traffic on the local road exceeds 25 percent of the truck traffic on the State highway.
- Ramp connecting a State highway to a local road is classified as Medium or Heavy as described in Index 613.5(1)(c).

In these cases, combine the traffic counts/ESALs of the approaches to calculate the TI or load spectra for all approaches combined. If the resulting TI or load spectra are higher than what is calculated for the mainline, then the intersections will need to be engineered using the combined TI or load spectra.

For all roundabout designs, look at the traffic projections for each turning movement of each leg of the roundabout, then, sum up the truck/transit traffic volumes using each quadrant of the roundabout. From the total truck traffic volume, generate an ESAL/TI or load spectra for each quadrant. Choose the quadrant with the highest TI or load spectra to design the entire roundabout.

Special attention should be given to truck and transit traffic behavior (turning and stopping) to determine the loading patterns and to select the most appropriate materials.

The limits for engineering pavement at an intersection should include intersection approaches and departures, to the greater of the following distances:

- For signalized intersections, the limits of the approach should extend past the furthest set of signal loop detectors where trucks do the majority of their braking; or
- For "STOP" controlled intersections the limits for the approach should be long

enough to cover the distance trucks will be braking and stopping either at the stop bar or behind other trucks and vehicles; or

- 100 feet.

The limits for the intersection departures should match the limits of the approach in the opposing lane to address rutting caused by truck acceleration.

For further assistance on this subject, contact either your District Materials Engineer, or Headquarters Pavement Program – Office of Concrete Pavement and Pavement Foundations.

- (4) *Roadside Facilities.* The pavement for safety roadside rest areas, including parking lots, should meet or exceed the TI requirements found in Table 613.5B for a 20-year pavement design life for new/reconstructed or rehabilitated pavements.

Table 613.5B
Minimum TI's for Safety Roadside Rest Areas

Facility Usage	Minimum TI (20-Year)
Truck Ramps & Roads	8.0 ⁽¹⁾
Truck Parking Areas	6.0 ⁽¹⁾
Auto Roads	5.5
Auto Parking Areas	5.0

NOTE:

- (1) For safety roadside rest areas next to all Interstates and those State Routes with AADTT greater than 15,000 use Table 613.5A medium truck traffic for truck ramps, truck roads, and a minimum TI of 9.0 for truck parking areas.

Topic 614 - Soil Characteristics

614.1 Engineering Considerations

California is a geologically active state with a wide variety of soil types throughout. Thorough understanding of the native soils in a project area is essential to properly engineer or update a highway facility.

Subgrade is the natural soil or rock material underlying the pavement structure. Unlike concrete and steel whose characteristics are fairly uniform, the engineering properties of subgrade soils may vary widely over the length of a project.

Pavements are engineered to distribute stresses imposed by traffic to the subgrade. For this reason, subgrade condition is a principal factor in selecting the pavement structure. Before a pavement is engineered, the structural quality of the subgrade soils must be evaluated to ensure that it has adequate strength to carry the predicted traffic loads during the design life of the pavement. The pavement must also be engineered to limit the expansion and loss of density of the subgrade soil.

614.2 Unified Soil Classification System (USCS)

The USCS classifies soils according to their grain size distribution and plasticity. Therefore, only a sieve analysis and Atterberg limits (liquid limit, plastic limit, and plasticity index) are necessary to classify a soil in this system. Based on grain size distribution, soils are classified as either (1) coarse grained (more than 50 percent retained on the No. 200 sieve), or (2) fine grained (50 percent or more passes the No. 200 sieve). Coarse grained soils are further classified as gravels (50 percent or more of coarse fraction retained on the No. 4 sieve) or sands (50 percent or more of coarse fraction passes the No. 4 sieve); while fine grained soils are classified as inorganic or organic silts and clays and by their liquid limit (equal to or less than 50 percent, or greater than 50 percent). The USCS also includes peat and other highly organic soils, which are compressible and not recommended for roadway construction. Peat and other highly organic soils should be removed wherever possible prior to placing the pavement structure.

The USCS based on ASTM D 2487 is summarized in Table 614.2.

614.3 California R-Value

The California R-value is the measure of resistance to deformation of the soils under wheel loading and saturated soil conditions. It is used to determine the bearing value of the subgrade. Determination of R-value for subgrade is provided under California Test (CT) 301. Typical R-values used by the

**Table 614.2
Unified Soil Classification System (from ASTM D 2487)**

Major Classification Group	Sub-Groups		Classification Symbol	Description
Coarse Grained Soils More than 50% retained on the No. 200 sieve	Gravels 50% or more of coarse fraction retained on the No. 4 sieve	Clean Gravels	GW	Well-graded gravels and gravel-sand mixtures, little or no fines
			GP	Poorly graded gravels and gravel-sand mixtures, little or no fines
		Gravels with Fines	GM	Silty gravels, gravel-sand-silt mixtures
			GC	Clayey gravels, gravel-sand-clay mixtures
	Sands 50% or more of coarse fraction passes the No. 4 sieve	Clean Sands	SW	Well-graded sands and gravelly sands, little or no fines
			SP	Poorly graded sands and gravelly sands, little or no fines
		Sands with Fines	SM	Silty sands, sand-silt mixtures
			SC	Clayey sands, sand-clay mixtures
Fine Grained Soils More than 50% passes the No. 200 sieve	Silts and Clays Liquid Limit 50% or less	ML	Inorganic silts, very fine sands, rock four, silty or clayey fine sands	
		CL	Inorganic clays of low to medium plasticity, gravelly/sandy/silty/lean clays	
		OL	Organic silts and organic silty clays of low plasticity	
	Silts and Clays Liquid Limit greater than 50%	MH	Inorganic silts, micaceous or diatomaceous fine sands or silts, elastic silts	
		CH	Inorganic clays of high plasticity, fat clays	
		OH	Organic clays of medium to high plasticity	
Highly Organic Soils			PT	Peat, muck, and other highly organic soils

Prefix: G = Gravel, S = Sand, M = Silt, C = Clay, O = Organic

Suffix: W = Well Graded, P = Poorly Graded, M = Silty, L = Clay, LL < 50%, H = Clay, LL > 50%

Department range from five for very soft material to 80 for treated base material.

The California R-value is determined based on the following separate measurements under CT 301:

- The exudation pressure test determines the thickness of cover or pavement structure required to prevent plastic deformation of the soil under imposed wheel loads.
- The expansion pressure test determines the pavement thickness or weight of cover required to withstand the expansion pressure of the soil.

Because some soils, such as coarse grained gravels and sands, may exhibit a higher California R-value test result than would normally be required for pavement design, the California R-value for subgrade soils used for pavement design should be limited to no more than 50 unless agreed to otherwise by the District Materials Engineer. Local experience with these soils should govern in assigning R-value on subgrade. The California R-value of subgrade within a project may vary substantially but cost and constructability should be considered in specifying one or several California R-value(s) for the project. Engineering judgment should be exercised in selecting appropriate California R-values for the project to assure a reasonably "balanced design" which will avoid excessive costs resulting from over conservatism. The following should be considered when selecting California R-values for a project:

- If the measured California R-values are in a narrow range with some scattered higher values, the lowest California R-value should be selected for the pavement design.
- If there are a few exceptionally low California R-values and they represent a relatively small volume of subgrade or they are concentrated in a small area, it may be more cost effective to remove or treat these 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 pavement structure to accommodate major differences in R-values that extend over a considerable length. Care should be exercised to avoid many variations in the pavement structure that may result in increased

construction costs that exceed potential materials cost savings.

614.4 Expansive soils

With an expansive subgrade (Plasticity Index greater than 12), special engineering or construction considerations will be required. Engineering alternatives, which have been used to compensate for expansive soils, are:

- (a) Treating expansive soil with lime or other additives to reduce expansion in the presence of moisture. Lime is often used with highly plastic, fine-grained soils. When mixed and compacted, the plasticity and swelling potential of clay soils are reduced and workability increased, as lime combines with the clay particles. It also increases the California R-value of the subgrade. Soil treated with lime is considered to be lime treated subbase. Lime treated subbase is discussed further in Chapter 660.
- (b) Replacing the expansive material with a non-expansive material to a depth where the seasonal moisture content will remain nearly constant.
- (c) Providing a pavement structure of sufficient thickness to counteract the expansion pressure.
- (d) Utilizing two-stage construction by placing a base or subbase to permit the underlying material to expand and stabilize before placing leveling and surface courses.
- (e) Stabilizing the moisture content by minimizing the access of water through surface and subsurface drainage and the use of a waterproof membrane (i.e., geomembrane, asphalt saturated fabric, or rubberized asphalt membrane).
- (f) Relocating the project alignment to a more suitable soil condition.

Treatment (e) is considered to be the most effective approach if relocation is not feasible such as in the San Joaquin Delta. The District Materials Engineer determines which treatment(s) is/are practical.

The California R-value of the subgrade can be raised above 10 by treatment to a minimum depth of 0.65 foot with an approved stabilizing agent such as lime, cement, asphalt, or fly ash. Native

soil samples should be taken, treated, and tested to determine the California R-value for the treated subgrade. For pavement structure design, the maximum California R-value that can be specified for treated subgrade regardless of test results is 40. Treating the subgrade does not eliminate or reduce the required aggregate subbase for rigid or composite pavements in the rigid pavement catalog (see Topic 623). With HMA, treated subgrade can be substituted for all or part of the required aggregate subbase layer. Since aggregate subbase has a gravel factor (G_f) of 1.0, the actual thickness and the gravel equivalent (GE) are equal. When the treated subgrade is substituted for aggregate subbase for flexible pavements, the actual thickness of the treated subgrade layer is obtained by dividing the GE by the appropriate G_f . The G_f is determined based on unconfined compressive strength (UCS) of the treated material as follows:

$$G_f = 0.9 + \frac{UCS(psi)}{1000}$$

This equation is only valid for UCS of 300 psi or more. The gravel factor G_f should be a minimum of 1.2. The maximum G_f allowed using this equation is 1.7. Because the treatment of subgrade soil may be less expensive than the base material, the calculated base thickness can be reduced and the treated subgrade thickness increased because of cost considerations. The base thickness is reduced by the corresponding gravel equivalency provided by the lime treated subgrade soil or subbase. The maximum thickness of lime treated subgrade is limited to 2 feet.

Rigid or composite pavement should not be specified in areas with expansive soils unless the pavement has been adequately treated to address soil expansion. Flexible pavement may be specified in areas where expansive soils are present with the understanding that periodic maintenance would be required.

The District Materials Engineer should be contacted to assist with the selection of the most appropriate method to treat expansive soils for individual projects. Final decision as to which treatment to use rests with the District.

614.5 Subgrade Enhancement Geotextile (SEG)

The placement of subgrade enhancement geotextile (SEG), formerly called subgrade enhancement fabric (SEF), below the pavement will provide subgrade enhancement by bridging soft areas and providing a separation between soft subgrade fines susceptible to pumping and high quality subbase or base materials. On weak subgrades, the use of SEG can provide for stabilization (the coincident function of separation and reinforcement). As the soft soil undergoes deformation, properly placed geotextile when stretched will develop tensile stress. Locations that may require placement of SEG include areas with the following soil characteristics:

- Poor (low strength) soils which are classified in the unified soil classification system (USCS) as sandy clay (SC), silty clay (CL), high plastic clay (CH), silt (ML), high plasticity or micaceous silt (MH), organic silt (OL), organic clay (OH), and peat & mulch (PT).
- Low undrained shear strength (equivalent to California R-value <20).
- High water table, and high soil sensitivity.

Subgrade soils with R-value <20 are considered poor or weak soils and require SEG to provide reinforcement as the primary function and separation as the secondary function. However, pavements constructed over subgrade soils with R-value up to 40 can especially benefit from separation if the soil contains an appreciable amount of fines, depending on type and treatment of the base layer. The SEG when placed with aggregate subbase provides a working platform for access of construction equipment, mainly on subgrades with R-values of 5 to 10.

The use of SEG on weak subgrades (with R-value <20) can raise the effective R-value of such soils to 20. Therefore, the benefit of using SEG on such weak soils can be realized though using thinner aggregate bases or subbases in flexible pavement design. Likewise, SEG can also affect the design of rigid pavements by providing a stronger subgrade system.

The method of determining the functions realized from the use of SEG and the selection of the

appropriate properties of the SEG based on project specifics are explained in the “Subgrade Enhancement Geotextile Guide” on the Department Pavement website.

614.6 Other Considerations

(1) *Fill.* Because the quality of excavated material may vary substantially along the project length, the pavement design over a fill section should be based on the minimum California R-value or unified soil classification of the material that is to be excavated as part of the project. If there is any excavated material that should not be used, it should be identified in the Materials Report and noted as appropriate in the PS&E.

(2) *Imported Borrow.* Imported borrow is used in the construction of embankments when sufficient quantity of quality material is not available. The pavement design should be based on the minimum California R-value of imported borrow or excavated fill material on the project. When imported borrow of desired quality is not economically available or when all of the earthwork consists of borrow, the California R-value specified for the borrow becomes the design R-value. Since no minimum California R-value is required by the Standard Specifications for imported borrow, a minimum R-value for the imported borrow material placed within 4 feet of the grading plane must be specified in the Materials Report and in the project plans.

(3) *Compaction.* Compaction is densification of the soil by mechanical means. The Standard Specifications require no less than 95 percent relative compaction be obtained for a minimum depth of 2.5 feet below finished grade for the width of the traveled way and auxiliary lanes plus 3 feet on each side. The 2.5 feet depth of compaction should not be waived for the traveled way, auxiliary lanes, and ramps on State highways.

These specifications sometimes can be waived by special provision with approval from the District Materials Engineer, when any of the following conditions apply:

- A portion of a local road is being replaced with a stronger pavement structure.

- Partial-depth reconstruction is specified.
- Existing buried utilities would have to be moved.
- Interim widening projects are required on low-volume roads, intersection channelization, or frontage roads.

Locations where the 2.5 feet of compaction depth is waived must be shown on the typical cross sections of the project plan. If soft material below this depth is encountered, it must be removed and replaced with suitable excavated material, imported borrow or subgrade enhancement fabric. Location(s) where the Special Provisions apply should be shown on the typical cross section(s).

Topic 615 - Climate

The effects that climate will have on pavement must be considered as part of pavement engineering. Temperatures will cause pavements to expand and contract creating pressures that can cause pavements to buckle or crack. Binders in flexible pavements will also become softer at higher temperatures and more brittle at colder temperatures. Precipitation can increase the potential for water to infiltrate the base and subbase layers, thereby resulting in increased susceptibility to erosion and weakening of the pavement structural strength. In freeze/thaw environments, the expansion and contraction of water as it goes through freeze and thaw cycles, plus the use of salts, sands, chains, and snow plows, create additional stresses on pavements. Solar radiation can also cause some pavements to oxidize. To help account for the effects of various climatic conditions on pavement performance, the State has been divided into the following nine climate regions.

- North Coast
- Central Coast
- South Coast
- Low Mountain
- High Mountain
- South Mountain
- Inland Valley

- Desert
- High Desert

Figure 615.1 provides a representation of where these regions are. A more detailed map along with a detailed list of where State routes fall within each climate region can be found on the Department Pavement website.

In conjunction with this map, designs, standards, plans, and specifications have been and are being developed to tailor pavement standards and practices to meet each of these climatic conditions. The standards and practices found in this manual, the Standard Plans, Standard Specifications, and Special Provisions should be considered as the minimum requirements to meet the needs of each climate region. Districts may also have additional requirements based on their local conditions. Final decision for the need for any requirements that exceed the requirements found in this manual, the Standard Plans, Standard Specifications, and Standard Special Provisions rests with the District.

Topic 616 - Existing Pavement Type and Condition

The type and condition of pavement on existing adjacent lanes or facilities should be considered when selecting new pavement structures or rehabilitation/preservation strategies. The selection process and choice made by the engineer is influenced by their experience and knowledge of existing facilities in the immediate area that have given adequate service. Providing continuity of existing pavement type will also ensure consistency in maintenance operations.

In reviewing existing pavement type and condition, the following factors should be considered:

- Type of pavement on existing adjacent lanes or facilities
- Performance of similar pavements in the project area
- Corridor continuity
- Maintaining or changing grade profile
- Existing pavement widening with a similar material

- Existing appurtenant features (median barriers, drainage facilities, curbs and dikes, lateral and overhead clearances, and structures which may limit the new or rehabilitated pavement structure.)

Topic 617 - Materials

617.1 Availability of Materials

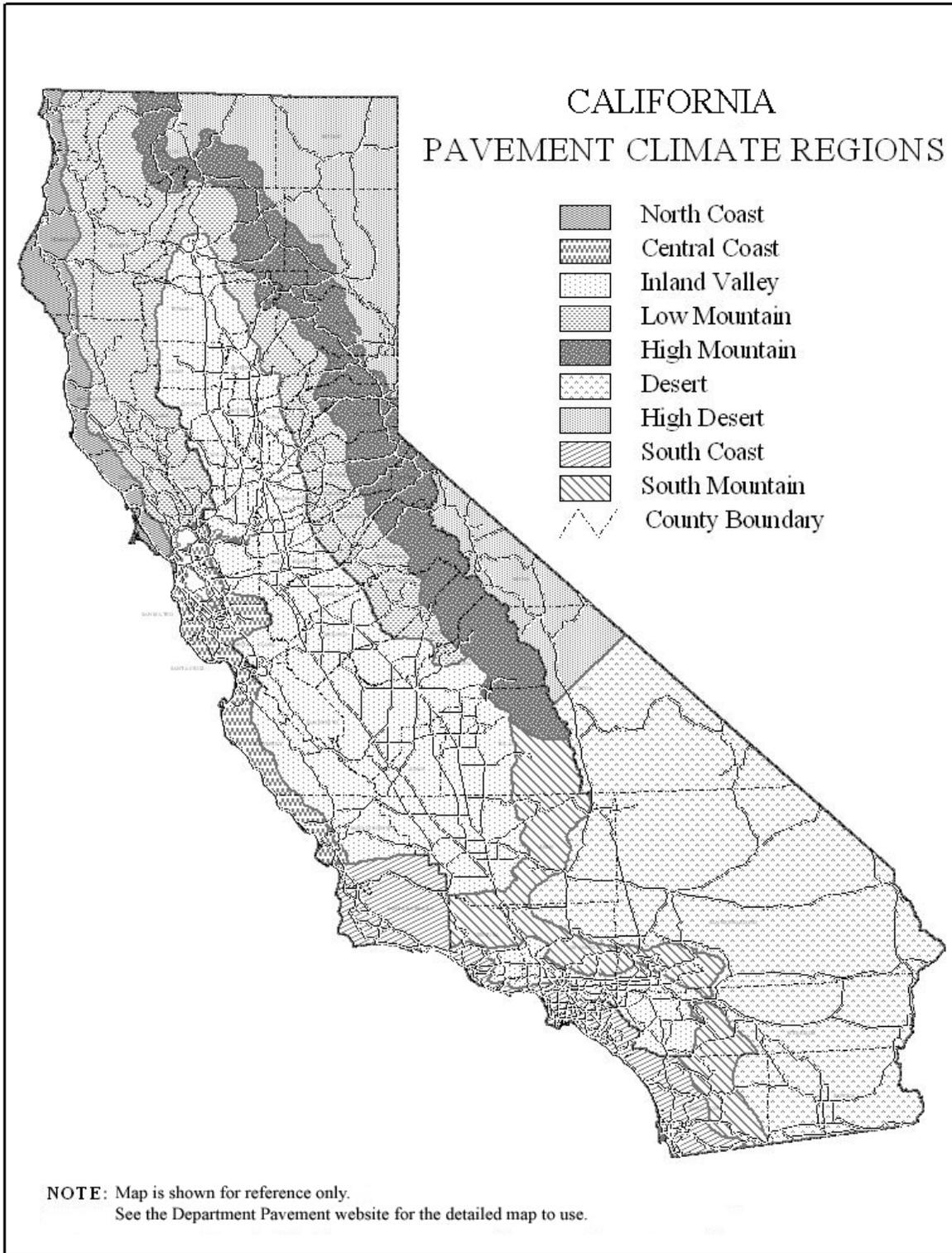
The availability of suitable materials such as subbase and base materials, aggregates, binders, and cements for pavements should be considered in the selection of pavement type. The availability of commercially produced mixes and the equipment capabilities of area contractors may also influence the selection of pavement type, particularly on small widening, reconstruction or rehabilitation projects. Materials which are locally available or require less energy to produce and transport to the project site should be used whenever possible.

617.2 Recycling

The Department encourages and seeks opportunities to utilize recycled materials in construction projects whenever such materials meet the minimum engineering standards and are economically viable. Accordingly, consideration should be given on every project to use materials recycled from existing pavements as well as other recycled materials such as scrap tires. Existing pavements can be recycled for use as subbase and base materials, or as a partial substitute for aggregate in flexible surface course for rehabilitation or reconstruction projects. The decision to use recycled materials however should be made on a case-by-case basis based on a thorough evaluation of material properties, performance experience in prior projects, benefit/cost analysis, and engineering judgment. Additional information on use of recycled pavements is available in Index 110.11 and on the Department Pavement website.

Candidates for recycling flexible pavement surface courses are those with uniform asphalt content. The existence of heavy crack-sealant, numerous patches, open-graded friction course, and heavy seal coats make the new recycled hot mix asphalt design inconsistent thereby resulting in mix properties that are more difficult to control. To avoid this problem when it occurs and still use the

**Figure 615.1
Pavement Climate Regions**



recycle option, for flexible pavement, a minimum of 0.08 foot should be milled off prior to the recycling operation. Light crack sealing (less than 5 percent of the pavement) or a uniform single seal coat will not influence the pavement engineering sufficiently to require milling.

The Department has established a minimum mill depth of 0.15 foot for recycling flexible pavement surface courses. Since existing surface course thickness will have slight variations, the recycling strategy should leave at least the bottom 0.15 foot of the existing flexible surface course in place. This is to insure the milling machine does not loosen base material and possibly contaminate the recycled material. As mentioned in Index 110.11(2), recycling of existing hot mix asphalt must be considered, in all cases, as an alternative to placing 100 percent new hot mix asphalt.

Topic 618 - Maintainability and Constructibility

618.1 Maintainability

Maintainability is the ability of a highway facility to be restored in a timely and cost-effective way with minimal traffic exposure to the workers and minimal traffic delays to the traveling public. It is an important factor in the selection of pavement type and pertinent appurtenances. Maintainability issues should be considered throughout the project development process to ensure that maintenance needs are adequately addressed in the engineering and construction of the pavement structure. For example, while a project may be constructible and built in a timely and cost-effective manner, it may create conditions requiring increased worker exposure and increased maintenance effort that is more expensive and labor intensive to maintain. Another example is the pavement drainage systems that need frequent replacement and often do not provide access for cleanout.

Besides the minimum considerations for the safety of the public and construction workers found in this manual, the Standard Specifications, and other Department manuals and guidance, greater emphasis should also be placed on the safety of maintenance personnel and long-term maintenance costs over the service life for the proposed project rather than on constructibility or initial costs.

Minimizing exposure to traffic through appropriate pavement type selection and sound engineering practices should always be a high priority. The District Maintenance Engineer and Maintenance Supervisor responsible for maintaining the project after it is built should be consulted for recommendations on addressing maintainability.

618.2 Constructibility

Construction issues that influence pavement type selection include: size and complexity of the project, stage construction, lane closure requirements, traffic control and safety during construction, construction windows when the project must be completed, and other constructibility issues that have the potential of generating contract change orders.

The Project Engineer must be cognizant of the issues involved in constructing a pavement, and provide plans and specifications that both meets performance standards and requirements. The Construction Engineer for the area where the pavement will be built should be consulted regarding constructibility during the project development process. The recommendations given by Construction should be weighed against other recommendations and requirements for the pavement. Constructibility recommendations should be accommodated where practical, provide minimum performance requirements, safety, and maintainability. Some constructibility items that should be addressed in the project include:

- Clearance width of paving machines to barriers and hinge points.
- Access for delivery trucks and construction equipment.
- Public safety and convenience.
- Time and cost of placing multiple thin lifts of different materials as opposed to thicker lifts of a single material. (For example, sometimes it is more efficient and less costly to place one thick lift of aggregate base rather than two thin lifts of aggregate base and subbase).
- The impact of combined lifts of different materials on long-term performance or maintenance of the pavement. (For example, it may seem to be a good idea to combine layers of portland cement concrete and lean concrete

base into a single layer to make it easier to construct, but combining these layers has a negative impact on the pavement performance and will lead to untimely failure).

- Time and cost of using multiple types of hot mix asphalt on a project in an area away from commercial hot mix asphalt sources.

Topic 619 - Life-Cycle Cost Analysis

619.1 Life-Cycle Cost Analysis

Life-cycle cost analysis (LCCA) is a useful tool for comparing the value of alternative pavement structures and strategies. LCCA is an economic analysis that compares initial cost, future cost, and user delay cost of different pavement alternatives. LCCA is an integral part of the decision making process for selecting pavement type and design strategy. It can be used to compare life-cycle cost for:

- Different pavement types (rigid, flexible, composite).
- Different rehabilitation strategies.
- Different pavement design lives (20 vs. 40, etc).

LCCA comparisons must be made between properly engineered, viable pavement structures that would be approved for construction if selected. The alternatives being evaluated should also have identical improvements. For example, comparing 20-year rehabilitation vs. 40-year rehabilitation or flexible pavement new construction vs. rigid pavement new construction, provide an identical improvement. Conversely, comparing pavement rehabilitation to new construction, or pavement overlay to pavement widening are not identical improvements.

LCCA can also be useful to determine the value of combining several projects into a single project. For example, combining a pavement rehabilitation project with a pavement widening project may reduce overall user delay and construction cost. In such case, LCCA can help determine if combining projects can reduce overall user delay and construction cost for more efficient and cost-effective projects. LCCA could also be used to

identify and measure the impacts of splitting a project into two or more projects.

LCCA must conform to the procedures and data in the Life-Cycle Cost Analysis Procedures Manual. LCCA must be completed for any project with a pavement cost component except for the following:

- Major maintenance projects.
- Minor A and Minor B projects.
- Projects using Permit Engineering Evaluation Reports (PEER).
- Maintenance pullouts.
- Landscape.

For the above exempted projects, the Project Manager and the Project Development Team (PDT) will determine on a case-by-case basis if and how a life-cycle cost analysis should be performed and documented. Information on how to document life-cycle costs can be found in the Department's Project Development Procedures Manual, Chapter 8.

Table 622.2
Rigid Pavement Performance Factors

Factor	Value
General	
Design Life	Determined per Topic 612
Terminal IRI ⁽¹⁾ at end of design life	160 in/mile max
JPCP only	
Transverse cracking at end of design life	10% of slabs max
Longitudinal cracking at end of design life	10% of slabs max
Corner cracking at end of design life	10% of slabs max
Average joint faulting at end of design life	0.10 inch max
CRCP only	
Punchouts at end of design life	10 per mile max

NOTE:

- (1) The International Roughness Index (IRI) is a nationally recognized method for measuring the smoothness of pavements.
- Rigid pavement should not be tied to adjacent rigid pavement when the spacing of transverse joints of adjacent slabs is not the same.
 - No more than 50 feet width of rigid pavement should be tied together to preclude random longitudinal cracks from occurring due to the pavement acting as one large rigid slab. In order to maintain some load transfer across the longitudinal joint, Standard Plan P18 includes details for placing dowel bars in the longitudinal joint for this situation.

For individual slab replacements, the placement of dowel bars is determined on a project-by-project basis based on proposed design life, construction work windows, existence of dowel bars in adjacent slabs, condition of adjacent slabs, and other pertinent factors. For further information on slab replacements, see Standard Plan P8, the “Slab Replacement Guide” and supplementary “Design Tools for Slab and Lane Replacements” on the Department Pavement website.

622.5 Joint Seals

- (1) *General.* Joint and crack seals are used to protect wide joints (joints 3/8 inch or wider) from infiltration of surface moisture and intrusion of incompressible materials. Infiltration of surface moisture and intrusion of incompressible materials into joints is minimized when a narrow joint is used.
- (2) *New Construction, Widening, and Reconstruction.* Joints are not sealed for new construction, widening, or for reconstruction except for the following conditions:
 - isolation joints,
 - expansion joints,
 - longitudinal construction joints in all desert and mountain climate regions, and
 - transverse joints in JPCP in all desert and mountain climate regions.
- (3) *Preservation and Rehabilitation.* To be effective, existing joint seals should be replaced every 10 to 15 years depending on the type used. As part of preservation or rehabilitation strategies, existing joint seals should be replaced when the pavement is ground, replaced or dowel bar retrofitted. Previously unsealed joints should be reviewed to determine if joint sealing is warranted in accordance with the criteria in the Maintenance Technical Advisory Guide. The condition of the existing joints and joint seals should be reviewed with the District Maintenance Engineer to determine if joint seal replacement is warranted.
- (4) *Selection of Joint Seal Material.* Various products are available for sealing joints with each one differing in cost and service life.

The type of joint sealant is selected based on the following criteria:

- Project environment.

In mountain and high desert climate regions where chains are used during winter storms, joint sealants that use backer rods are not recommended. Severe climate conditions (such as in the mountains or deserts) will require more durable sealants and/or more frequent replacement.

- Type of roadway.

Interstate or State highway, and corresponding traffic characteristics including traffic volumes and percentage of truck traffic.

- Condition of existing reservoir.

If the sides of in-place joint faces are variable in condition, do not use preformed compression seal.

- Expected performance.

If suitable for intended use and site conditions, the sealant with the longest service life is preferred.

The joint sealant selected should match the type of existing joint sealant being left in place.

- Cost effectiveness.

Life cycle cost analysis (LCCA) is used to select the appropriate sealant type.

Joint sealants should not last longer than the pavement being sealed.

For additional information on various joint seal products and selection guidance, consult the Maintenance Technical Advisory Guide on the Department Pavement website.

622.6 Bond Breaker

When placing rigid pavement 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 rigid pavement, which will lead to premature cracking. Several methods are available for preventing

bonding including a liberal application of wax curing compound, or slurry seals. Application rates may be found in the Standard Specifications. For specific recommendations on how to prevent bonding between rigid pavement and lean concrete base, consult the District Materials Engineer.

622.7 Texturing

Longitudinal tining is the typical texturing for new pavements. Grooving is typically done to rehabilitate existing pavement texture or to improve surface friction. Grinding is typically done to restore a smooth riding surface on existing pavements or for individual slab replacements. Grooving or grinding are options on new pavement in lieu of longitudinal tining where there is a desire to minimize noise levels on rigid pavement.

622.8 Transitions and Anchors

Transitions and anchors are used at transverse joints to minimize deterioration or faulting of the joint where rigid pavement abuts to flexible pavement, a different rigid pavement type, or in some cases, a bridge. For JPCP, a pavement end anchor or transition should be used at transitions to flexible pavement. **For CRCP, a terminal anchor or terminal joint shall be used at all transitions to or from structure approach slabs, JPCP, PPCP, or flexible pavement.** Standard Plans include a variety of details for these transitions.

Topic 623 - Engineering Procedure for New and Reconstruction Projects

623.1 Catalog

Tables 623.1B through M contain the minimum thickness for rigid pavement surface layers, base, and subbase for all types of projects. All JPCP structures shown are doweled. The tables are categorized by subgrade soil type and climate regions. Figure 623.1 is used to determine which table to use to select the pavement structure.

The steps for selecting the appropriate rigid pavement structure are as follows:

- (1) *Determine the Soil Type for the Existing Subgrade.* Soil types for existing subgrade are

categorized into Types I, II, and III as shown in Table 623.1A. Soils are classified by the Unified Soil Classification System (USCS). If a soil can be classified in more than one type in Table 623.1A, then the engineer should choose the more conservative design based on the less stable soil. Subgrade is discussed in Topic 614.

- (2) *Determine Climate Region.* Find the location of the project on the Pavement Climate Map. The Pavement Climate Map is discussed in Topic 615.
- (3) *Select the Appropriate Table (Tables 623.1B through M).* Select the table that applies to the project based on subgrade, soil type, and climate region. Use Figure 623.1 to determine which table applies to the project.
- (4) *Determine Whether Pavement Has Lateral Support Along Both Longitudinal Joints.* The pavement is considered laterally supported if it is tied to an adjacent lane, has tied rigid shoulders, or has a widened slab. If lateral support is provided along only one longitudinal joint, then the pavement is considered to have no lateral support. As shown in Tables 623.1B through M, pavement thicknesses are reduced slightly for slabs engineered with lateral support along both longitudinal joints.
- (5) *Select Pavement Structure.* Using the Traffic Index provided or calculated from the traffic projections, select the desired pavement structure from the list of alternatives provided.

Note that although the pavement structures listed for each Traffic Index are considered to be acceptable for the climate, soil conditions, and design life desired, they should not be considered as equal designs. Some designs will perform better than others, have lower maintenance/repair costs, and/or lower construction life-cycle costs. Sound engineering judgment should be used in selecting the option that is most effective for the location. For these reasons, the rigid pavement structures in these tables cannot be used as substitutes for the pavement structures recommended in approved Materials Reports or shown in approved contract plans.

Table 623.1A**Relationship Between Subgrade Type⁽¹⁾**

Subgrade Type ⁽²⁾	California R-value (R)	Unified Soil Classification System (USCS)
I	$R > 40$	SC, SP, SM, SW, GC, GP, GM, GW
II	$10 \leq R \leq 40$	CH (PI ≤ 12), CL, MH, ML
III	$R < 10$	CH (PI > 12)

NOTES:

- (1) See Topic 614 for further discussion on subgrade and USCS.
- (2) Choose more conservative soil type (i.e., use soil with a lower R-value or USCS) if native soil can be classified by more than one type.

Legend

PI = Plasticity Index

623.2 Mechanistic-Empirical Method

For information on Mechanistic-Empirical Design application and requirements, see Index 606.3.

Figure 623.1
Rigid Pavement Catalog Decision Tree

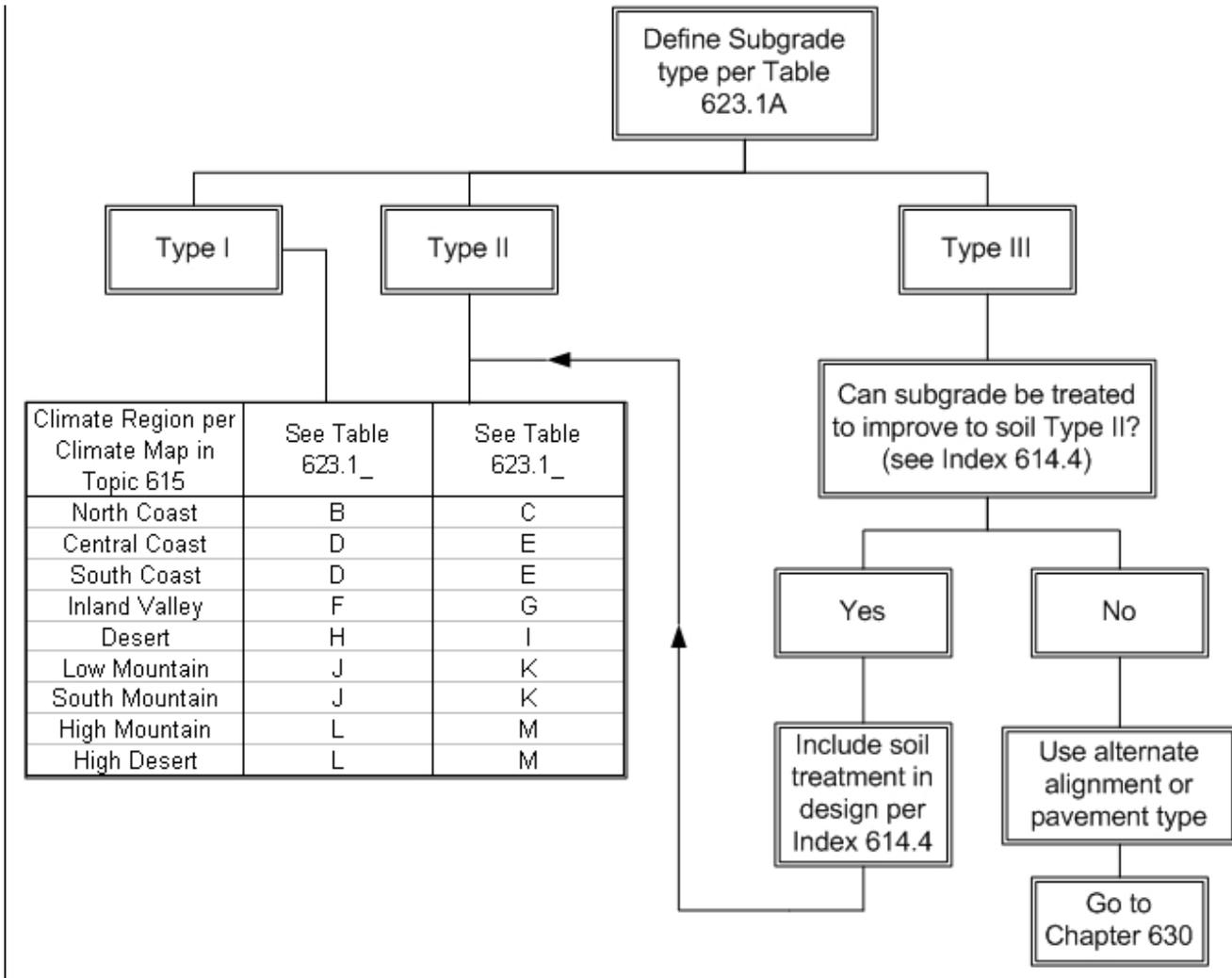


Table 623.1B
Rigid Pavement Catalog (North Coast, Type I Subgrade Soil)^{(1), (2), (3), (4),(5)}

TI	Rigid Pavement Structural Depth							
	With Lateral Support (ft)				Without Lateral Support (ft)			
< 9	0.70 JPCP	0.70 JPCP	0.70 JPCP	0.70 JPCP	0.70 JPCP	0.70 JPCP	0.70 JPCP	0.70 JPCP
	0.35 LCB	0.25 HMA-A	0.50 AB	0.35 ATPB	0.35 LCB	0.25 HMA-A	0.50 AB	0.35 ATPB
9.5 to 10	0.70 JPCP	0.70 JPCP	0.75 JPCP	0.75 JPCP	0.70 JPCP	0.70 JPCP	0.75 JPCP	0.75 JPCP
	0.35 LCB	0.25 HMA-A	0.60 AB	0.35 ATPB	0.35 LCB	0.25HMA-A	0.60 AB	0.35 ATPB
10.5 to 11	0.70 JPCP	0.70 JPCP	0.70 JPCP		0.75 JPCP	0.75 JPCP	0.75 JPCP	
	0.35 LCB	0.25 HMA-A	0.70 AB		0.35 LCB	0.25 HMA-A	0.70 AB	
11.5 to 12	0.75 JPCP	0.75 JPCP	0.75 CRCP		0.80 JPCP	0.80 JPCP	0.80 CRCP	
	0.35 LCB	0.25 HMA-A	0.35 HMA-A		0.35 LCB	0.25HMA-A	0.40 HMA-A	
12.5 to 13	0.80 JPCP	0.80 JPCP	0.75 CRCP		0.85 JPCP	0.85 JPCP	0.80 CRCP	
	0.35 LCB	0.25 HMA-A	0.25 HMA-A		0.50 LCB	0.50 HMA-A	0.50 HMA-A	
13.5 to 14	0.80 JPCP	0.80 JPCP	0.75 CRCP		0.90 JPCP	0.85 JPCP	0.80 CRCP	
	0.35 LCB	0.25 HMA-A	0.25 HMA-A		0.35 LCB	0.25 HMA-A	0.25 HMA-A	
14.5 to 15	0.85 JPCP	0.85 JPCP	0.80 CRCP		0.95 JPCP	0.95 JPCP	0.85 CRCP	
	0.35 LCB	0.25 HMA-A	0.25 HMA-A		0.35 LCB	0.25 HMA-A	0.25 HMA-A	
15.5 to 16	0.90 JPCP	0.90 JPCP	0.85 CRCP		1.00 JPCP	1.00 JPCP	0.90 CRCP	
	0.35 LCB	0.25 HMA-A	0.25 HMA-A		0.35 LCB	0.25 HMA-A	0.25 HMA-A	
16.5 to 17	0.95 JPCP	0.95 JPCP	0.85 CRCP		1.05 JPCP	1.05 JPCP	0.95 CRCP	
	0.35 LCB	0.25 HMA-A	0.25 HMA-A		0.35 LCB	0.25 HMA-A	0.25 HMA-A	
> 17	1.00 JPCP	1.00 JPCP	0.90 CRCP		1.10 JPCP	1.10 JPCP	1.00 CRCP	
	0.35 LCB	0.25 HMA-A	0.25 HMA-A		0.35LCB	0.25 HMA-A	0.25 HMA-A	
< 9	0.70 JPCP	0.70 JPCP	0.70 JPCP	0.70 JPCP	0.70 JPCP	0.70 JPCP	0.70 JPCP	0.70 JPCP

NOTES:

- (1) Thicknesses shown for JPCP are for doweled pavement only. The thickness shown in these tables are not valid for nondoweled JPCP.
- (2) Includes 0.03 ft sacrificial wearing course for future grinding of JPCP/CRCP.
- (3) Portland cement concrete may be substituted for LCB when justified for constructibility or traffic handling. If Portland cement concrete is used in lieu of LCB, it must be placed in a separate lift than JPCP and must not be bonded to the JPCP.
- (4) If ATPB is needed for TIs > 10.0 to perpetuate an existing treated permeable layer, place the ATPB between the surface layer (JPCP or CRCP) and the base layer. No deduction is made to the thickness of the base and subbase layers on account of the ATPB.
- (5) Place a Bond Breaker between JPCP and LCB in all cases

Legend:

JPCP = Jointed Plain Concrete Pavement
 CRCP = Continuously Reinforced Concrete Pavement
 LCB = Lean Concrete Base
 HMA-A = Hot Mix Asphalt (Type A)

ATPB = Asphalt Treated Permeable Base
 AB = Class 2 Aggregate Base
 TI = Traffic Index

Table 623.1C
Rigid Pavement Catalog (North Coast, Type II Subgrade Soil) ^{(1), (2), (3), (4), (5)}

TI	Rigid Pavement Structural Depth							
	With Lateral Support (ft)				Without Lateral Support (ft)			
≤ 9	0.70 JPCP	0.70 JPCP	0.70 JPCP	0.70 JPCP	0.70 JPCP	0.70 JPCP	0.70 JPCP	0.70 JPCP
	0.35 LCB	0.25 HMA-A	1.00 AB	0.35 ATPB	0.35 LCB	0.25 HMA-A	1.00 AB	0.35 ATPB
	0.50 AS	0.50 AS		0.80 AB	0.50 AS	0.50 AS		0.80 AB
9.5 to 10	0.70 JPCP	0.70 JPCP	0.75 JPCP	0.75 JPCP	0.70 JPCP	0.70 JPCP	0.75 JPCP	0.75 JPCP
	0.35 LCB	0.25 HMA-A	1.00 AB	0.35 ATPB	0.35 LCB	0.25 HMA-A	1.00 AB	0.35 ATPB
	0.50 AS	0.50 AS		0.80 AB	0.50 AS	0.50 AS		0.80 AB
10.5 to 11	0.70 JPCP	0.70 JPCP	0.70 JPCP		0.75 JPCP	0.75 JPCP	0.75 JPCP	
	0.35 LCB	0.25 HMA-A	1.30 AB		0.35 LCB	0.25 HMA-A	1.30 AB	
	0.60 AS	0.60 AS			0.60 AS	0.60 AS		
11.5 to 12	0.75 JPCP	0.75 JPCP	0.75 CRCP		0.80 JPCP	0.80 JPCP	0.80 CRCP	
	0.35 LCB	0.25 HMA-A	0.25 HMA-A		0.35 LCB	0.25 HMA-A	0.25 HMA-A	
	0.60 AS	0.60 AS	0.60 AS		0.60 AS	0.60 AS	0.60 AS	
12.5 to 13	0.80 JPCP	0.80 JPCP	0.75 CRCP		0.85 JPCP	0.85 JPCP	0.80 CRCP	
	0.35 LCB	0.25 HMA-A	0.25 HMA-A		0.35 LCB	0.25 HMA-A	0.25 HMA-A	
	0.70 AS	0.70 AS	0.70 AS		0.70 AS	0.70 AS	0.70 AS	
13.5 to 14	0.80 JPCP	0.80 JPCP	0.75 CRCP		0.90 JPCP	0.85 JPCP	0.80 CRCP	
	0.35 LCB	0.25 HMA-A	0.25 HMA-A		0.35 LCB	0.25 HMA-A	0.25 HMA-A	
	0.70 AS	0.70 AS	0.70 AS		0.70 AS	0.70 AS	0.70 AS	
14.5 to 15	0.85 JPCP	0.85 JPCP	0.80 CRCP		0.95 JPCP	0.95 JPCP	0.85 CRCP	
	0.35 LCB	0.25 HMA-A	0.25 HMA-A		0.35 LCB	0.25 HMA-A	0.25 HMA-A	
	0.70 AS	0.70 AS	0.70 AS		0.70 AS	0.70 AS	0.70 AS	
15.5 to 16	0.90 JPCP	0.90 JPCP	0.85 CRCP		1.00 JPCP	1.00 JPCP	0.90 CRCP	
	0.35 LCB	0.25 HMA-A	0.25 HMA-A		0.35 LCB	0.25 HMA-A	0.25 HMA-A	
	0.70 AS	0.70 AS	0.70 AS		0.70 AS	0.70 AS	0.70 AS	
16.5 to 17	0.95 JPCP	0.95 JPCP	0.85 CRCP		1.05 JPCP	1.05 JPCP	0.95 CRCP	
	0.35 LCB	0.25 HMA-A	0.25 HMA-A		0.35 LCB	0.25 HMA-A	0.25 HMA-A	
	0.70 AS	0.70 AS	0.70 AS		0.70 AS	0.70 AS	0.70 AS	
> 17	1.00 JPCP	1.00 JPCP	0.90 CRCP		1.10 JPCP	1.10 JPCP	1.00 CRCP	
	0.35 LCB	0.25 HMA-A	0.25 HMA-A		0.35 LCB	0.25 HMA-A	0.25 HMA-A	
	0.70 AS	0.70 AS	0.70 AS		0.70 AS	0.70 AS	0.70 AS	

NOTES:

- (1) Thicknesses shown for JPCP are for doweled pavement only. The thickness shown in these tables are not valid for nondoweled JPCP.
- (2) Includes 0.03 ft sacrificial wearing course for future grinding of JPCP/CRCP.
- (3) Portland cement concrete may be substituted for LCB when justified for constructibility or traffic handling. If Portland cement concrete is used in lieu of LCB, it must be placed in a separate lift than JPCP and must not be bonded to the JPCP.
- (4) If ATPB is needed for TIs > 10.0 to perpetuate an existing treated permeable layer, place the ATPB between the surface layer (JPCP or CRCP) and the base layer. No deduction is made to the thickness of the base and subbase layers on account of the ATPB.
- (5) Place a Bond Breaker between JPCP and LCB in all cases

Legend:

JPCP = Jointed Plain Concrete Pavement

CRCP = Continuously Reinforced Concrete Pavement

LCB = Lean Concrete Base

HMA-A = Hot Mix Asphalt (Type A)

ATPB = Asphalt Treated Permeable Base

AB = Class 2 Aggregate Base

AS = Class 2 Aggregate Subbase

TI = Traffic Index

Topic 624 – Engineering Procedures for Pavement Preservation

624.1 Preventive Maintenance

Examples of rigid pavement preventive maintenance strategies include the following or combinations of the following:

- Seal random cracks.
- Joint seal, repair/replace existing joint seals.
- Spall repair.
- Grooving.
- Grinding to restore surface texture.
- Special surface treatments (such as methacrylate, polyester concrete, and others). These strategies are normally used on bridge decks but can be applied, in limited situations, to rigid pavements for repair of problem areas.

Rigid pavement preventive maintenance strategies are discussed further in the Maintenance Manual, Chapter B.

624.2 Capital Preventive Maintenance (CAPM)

CAPM strategies include the following or combinations of the following:

- (a) Slab replacement. 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. Slab replacements may include replacing existing cement treated base or lean concrete base with rapid strength concrete. For further information (including information on rapid strength concrete) see the “Slab Replacement Guidelines” on the Department Pavement website.
- (b) Grinding to correct faulting.
- (c) Dowel bar retrofit. Guidelines for selecting and engineering dowel bar retrofit projects can be found on the Department Pavement website.

The roadway rehabilitation requirements for overlays (see Index 625.1(2)) and preparation of existing pavement surface (Index 625.1(3)) apply to CAPM projects. Additional details and information regarding CAPM policies and strategies can be found in Design Information Bulletin 81 “Capital Preventive Maintenance Guidelines” as well as the “Rigid Pavement CAPM and Rehabilitation Guidelines for Designers.” Both can be found on the Department Pavement website.

Topic 625 - Engineering Procedures for Pavement and Roadway Rehabilitation

625.1 Rigid Pavement Rehabilitation Strategies

(1) *Strategies.* An overview of rigid pavement strategies for roadway rehabilitation is discussed in the “Rigid Pavement CAPM and Rehabilitation Guidelines for Designers,” which can be found on the Department Pavement website. Some rehabilitation strategies discussed in the guide include the following or combinations of the following:

- (a) Lane replacement. Lane replacements are engineered using the catalogs found in Index 623.1. Attention should be given to maintaining existing drainage patterns underneath the surface layer, (see Chapter 650 for further guidance). For further information see “Design Tools for Slab and Lane Replacements,” on the Department Pavement website.
- (b) Unbonded rigid overlay with flexible interlayer. To determine the thickness of the rigid layer, use the rigid layer thicknesses for new pavement found in Index 623.1. Include a 0.10 foot minimum flexible interlayer between the existing pavement and rigid overlay. The interlayer may need to be thicker if it is used temporarily for traffic handling.
- (c) Crack, seat, and flexible overlay. The minimum standard thicknesses for a 20-year design life using this strategy are found in Table 625.1.

Table 625.1 is for a 20-year pavement design life. There are currently no standard crack, seat, and flexible overlay designs for pavement design lives greater than 20 years. For projects with longer than 20-year pavement design life, consider lane replacement, unbonded overlays, or consult Headquarters Office of Concrete Pavement and Pavement Foundations for possible experimental designs.

For crack, seat, and asphalt overlay projects, a nonstructural wearing course (such as an open graded friction course) may be placed in addition to (but not as a substitute for) the thickness found in Table 625.1. Once a rigid pavement has been cracked, seated, and overlaid with asphalt pavement it is considered to be a composite pavement and subsequent preservation and rehabilitation strategies are determined in accordance with the guidelines found in Chapter 640.

- (d) Flexible overlay (without crack and seat). If the existing rigid pavement (JPCP) will not be cracked and seated, for a 20-year design life, add an additional 0.10 foot HMA to the minimum standard thicknesses of HMA surface course layer given in Table 625.1. Since the maximum thickness for RHMA-G is 0.20 foot (see Index 631.3), no additional thickness is needed if RHMA-G is used for the overlay.
- (2) **Overlay Limits. On overlay projects, the entire traveled way and paved shoulder shall be overlaid.** Not only does this help provide a smoother finished surface, it also benefits bicyclists and pedestrians when they need to use the shoulder.
- (3) **Preparation of Existing Pavement. Existing pavement distresses should be repaired before overlaying the pavement.** Cracks wider than ¼ inch should be sealed; loose pavement removed and patched; spalls repaired; and broken slabs or punchouts replaced. Existing thermoplastic traffic striping and above grade pavement markers should be removed. This applies to both lanes and adjacent shoulders

(flexible and rigid). The Materials Report should include a reminder of these preparations. Crack sealants should be placed ¼ inch below grade to allow for expansion (i.e., recess fill) and to alleviate a potential bump if an overlay is placed. For information and criteria for slab replacements, see Chapter 2 of the Slab Replacement Guidelines on the Department Pavement website.

- (4) **Selection.** The selection of the appropriate strategy should be based upon life-cycle costs, load transfer efficiency of the joints, materials testing, ride quality, safety, maintainability, constructibility, visual inspection of pavement distress, and other factors listed in Chapter 610. The Materials Report should discuss any historical problems observed in the performance of rigid pavement constructed with aggregates found near the proposed project and subjected to similar physical and environmental conditions.

625.2 Mechanistic-Empirical Method

For information on Mechanistic-Empirical Design application and requirements, see Index 606.3.

Topic 626 - Other Considerations

626.1 Traveled Way

- (1) **Mainline.** No additional considerations.
- (2) **Ramps and Connectors.** If tied rigid shoulders or widened slabs are used on the mainline, then the ramp or connector gore area (including ramp traveled way adjacent to the gore area) should also be constructed with rigid pavement (see Figure 626.1). This will minimize deterioration of the joint between flexible and rigid pavement. When the ramp or connector traveled way is rigid pavement, utilize the same base and thickness for the gore area as that to be used under the ramp traveled way, especially when concrete shoulders are utilized on the mainline. Note that in order to optimize constructability, any concrete pavement structure used for mainline concrete shoulders should still be perpetuated through the gore area. If the base is Treated Permeable Base (TPB) under the ramp's

Table 625.1**Minimum Standard Thicknesses for Crack, Seat, and Flexible Overlay⁽¹⁾**

TI <12.0	0.35' HMA GPI or SAMI-R 0.10' HMA (LC)	0.35' HMA SAMI-F or SAMI-R 0.10' HMA (LC)	0.20' RHMA-G SAMI-R 0.10' HMA (LC)
TI ≥12.0	0.40' HMA GPI or SAMI-R 0.15' HMA (LC)	0.20' RHMA-G SAMI-R 0.15' HMA (LC)	0.20' RHMA-G 0.15' HMA SAMI-F or SAMI-R 0.10' HMA (LC)

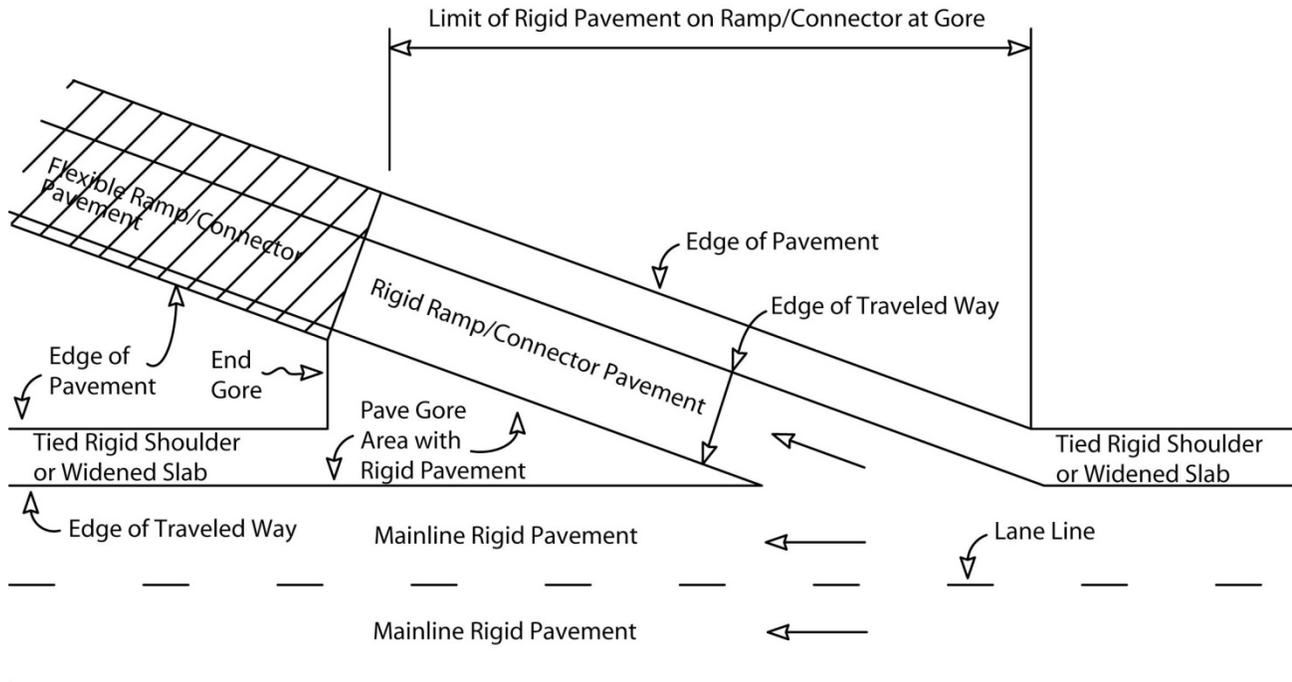
NOTE:

(1) If the existing rigid pavement is not cracked and seated, add minimum of 0.10 foot HMA above the SAMI layer.

Legend:

HMA = Hot Mix Asphalt
HMA (LC) = Hot Mix Asphalt Leveling Course
RHMA-G = Rubberized Hot Mix Asphalt (Gap Graded)
GPI = Geosynthetic Pavement Interlayer
SAMI-R = Stress Absorbing Membrane Interlayer (Rubberized)

Figure 626.1
Rigid Pavement at Ramp or Connector Gore Area



- Notes: 1) Not all details shown
2) Off ramp shown. Same conditons apply for on ramps.

traveled way and shoulder, TPB should still be utilized in the ramp gore areas as well.

- (3) *Ramp Termini.* Rigid pavement is sometimes placed at ramp termini instead of flexible pavement where there is projected heavy truck traffic (as defined in Index 613.5(1)(c)) to preclude pavement failure such as rutting or shoving from vehicular braking, turning movements, and oil dripping from vehicles. Once a design TI is selected for the ramp in accordance with Index 613.5, follow the requirements in Index 623.1 to engineer the rigid pavement structure for the ramp termini. The length of rigid 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 rigid pavement should extend to the first set of signal loops on signalized intersections. A length of 150 feet 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. End anchors or transitions should be used at flexible/rigid pavement joints. The Department Pavement website has additional information and training for engineering pavement for intersections and rigid ramp termini.

626.2 Shoulder

The types of shoulders that are used for rigid pavements are shown in Figure 626.2A and can be categorized into the following three types:

- (1) *Tied Rigid Shoulders.* These are shoulders that are built with rigid pavement that are tied to the adjacent lane with tie bars. These shoulders provide lateral support to the adjacent lane, which improves the long-term performance of the adjacent lane, reducing the need for maintenance or repair of the lane. To obtain the maximum benefit, these shoulders should be built monolithically with the adjacent lane (i.e., no contact joints). This will create aggregate interlock between the lane and shoulder, which provides increased lateral support. In order to build the lane and shoulder integrally, the shoulder cross slope

needs to match the lane cross slope which may require a design exception (see Index 302.2 for further discussion).

The pavement structure for the tied rigid shoulder should match the pavement structure of the adjacent traffic 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.

Tied rigid shoulders are the most adaptable to future widening and conversion to a lane. They should be the preferred shoulder type when future widening is planned within the design life of the pavement or where the shoulder will be used temporarily as a truck or bus lane. Where the shoulder is expected to be converted into a traffic lane in the future, the shoulder should be built to the same geometric and pavement standards as the lane. Additionally, the shoulder width should match the width of the future lane.

- (2) *Widened Slab.* Widened slabs involve constructing the concrete panel for the lane adjacent to the shoulder 14 feet wide in lieu of the prescribed lane width. The additional width becomes part of the shoulder width and provides lateral support to the adjacent lane. Widened slabs provide as good or better lateral support than tied rigid shoulders at a lower initial cost provided that trucks and buses are kept at least 2 feet from the edge of the slab. A rumble strip or a raised pavement marking next to the pavement edge line of widened concrete slabs helps discourage trucks and buses from driving on the outside 2 feet of the slab. The use of rumble strips or raised markings requires approval from District Traffic Operations.

Widened slabs are most useful in areas where lateral support is desired but future widening is not anticipated or where there is a need to have a different cross slope on the shoulder than that of the adjacent lane.

- (3) *Untied Shoulders.* Untied shoulders are flexible shoulders that are not built with a

widened slab or rigid shoulders that are not tied to the adjacent lane and not built adjacent to a widened slab. These shoulders do not provide lateral support to the adjacent lane. Although non-supported shoulders may have lower initial costs, they do not perform as well as tied rigid shoulders or widened slabs, which can lead to higher maintenance costs, user delays, and life cycle costs.

(4) *Selection Criteria.* It is preferred that shoulders be constructed of the same material as the traveled way pavement (in order to facilitate construction, improve pavement performance, and reduce maintenance cost). However, shoulders adjacent to rigid pavement traffic lanes can be either rigid or flexible with the following conditions:

(a) **Tied rigid shoulders shall be used for:**

- **Rigid pavements constructed in the High Mountain and High Desert climate regions (see climate map in Topic 615).**
- **Paved buffers between rigid High-Occupancy Vehicle (HOV) lanes and rigid mixed flow lanes. Same for High-Occupancy Toll (HOT) lanes.**
- **Rigid ramps to and from truck inspection stations.**

(b) **Either tied rigid shoulders or widened slabs shall be used for:**

- **Continuously reinforced concrete pavement.**
- **Horizontal radii 300 feet or less.**
- **Truck and bus only lanes.**

Where tied rigid shoulders or widened slabs are used, they shall continue through ramp and gore areas (see Figure 626.2B).

Because heavy trucks cause deterioration by repeated heavy loading on the outside edge of pavement, at the corners, and the midpoint of the slab, widened slabs or tied rigid shoulders should be used for heavy truck routes with a TI greater than or equal to 14.0.

In those instances where flexible shoulders are used with rigid pavement, the minimum flexible shoulder thickness should be determined in accordance with Topic 633.

These conditions apply to all rigid pavement projects including new construction, reconstruction, widening, adjacent lane replacements, and shoulder replacements. Typically existing flexible shoulders next to rigid pavement are not replaced for rehabilitation projects that involve only grinding, dowel bar retrofits, and individual slab replacements. Consideration should be given to replacing flexible shoulders with tied rigid shoulders or widened slabs when the adjacent lane is being replaced or overlaid with a rigid pavement. The District determines when an existing flexible shoulder is replaced with a rigid shoulder or widened slab.

The shoulder pavement structure selected must meet or exceed the pavement design life standards in Topic 612. In selecting whether to construct rigid or flexible shoulders the following factors should be considered:

- Life-cycle cost of the shoulder.
- 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 engineering a shoulder that requires the least amount of maintenance, even if it is more expensive to construct.
- Future plans to widen the facility or convert the shoulder to a traffic lane.
- Width of shoulder. When shoulder widths are less than 5 feet, tied rigid shoulders are preferable to a widened rigid slab and narrow flexible shoulder, less than 3 feet, for both constructibility and maintainability.
- For projects where the tracking width lines are shown to encroach onto paved shoulders or any portion of the gutter pan, tied rigid shoulders and the gutter pan

structure must be engineered to sustain the weight of the design vehicle. See Topic 404 for design vehicle guidance.

See Index 1003.5(1)) for surface quality guidance for highways open to bicyclists.

626.3 Intersections

Standard joint spacing patterns found in the Standard Plans do not apply to intersections. Special paving details for intersections need to be included in the project plans. Special consideration needs to be given to the following features when engineering a rigid pavement intersection:

- Intersection limits.
- Joint types and joint spacing.
- Joint patterns.
- Slab dimensions.
- Pavement joints at utilities.
- Dowel bar and tie bar placement.

Additional information and training is available on the Department Pavement website.

626.4 Roadside Facilities

(1) *Safety Roadside Rest Areas and Vista Points.* If rigid pavement is selected for some site-specific reason(s), the pavement structures used should be sufficient to handle projected loads at most roadside facilities. To select the pavement structure, determine the Traffic Index either from traffic studies and projections developed for the project or the values found in Table 613.5B, whichever is greater. Then select the appropriate pavement structure from the catalog in Index 623.1.

Joint spacing patterns found in the Standard Plans do not apply to parking areas. Joint patterns should be engineered as square as possible. Relative slab dimensions should be approximately 1:1 to 1:1.25, transverse-to-longitudinal. Transverse and longitudinal joints should be perpendicular to each other. Joints are doweled in one direction and tied in the other in accordance with Index 622.4. Special attention should be given to joint patterns around utility covers and manholes.

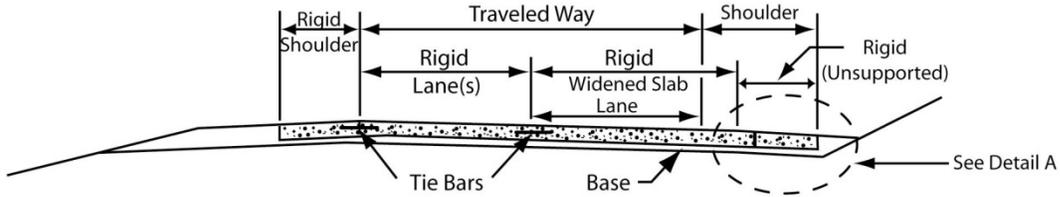
Use guidelines for intersections in Index 626.3 for further information.

- (2) *Park and Ride Facilities.* Flexible pavement should be used for park and ride facilities. If transit buses access the park and ride facility, use the procedures for bus pads in this Index for engineering bus access.
- (3) *Bus Pads.* Bus pads are subjected to similar stresses as intersections; however, it is not practical to engineer rigid bus pads according to the Traffic Index, or according to bus counts. The minimum pavement structure for bus pads should be 0.85 foot JPCP with dowel bars at transverse joints on top of 0.5 foot lean concrete base or Type A hot mix asphalt (0.75 foot CRCP may be substituted for 0.85 foot JPCP). For Type II soil as described in Table 623.1A, include 0.5 foot of aggregate subbase. Type III soil should be treated in accordance with Index 614.4. Where local standards are more conservative than the pavement structures mentioned above, local standards should govern.

Relative slab dimensions for bus pads should be approximately 1:1 to 1:1.25, transverse-to-longitudinal. The width of the bus pad should be no less than the width of the bus plus 4 feet. If the bus pad extends into the traveled way, the rigid bus pad should extend for the full width of the lane occupied by buses. The minimum length of the bus pad should be 1.5 times the length of the bus(es) that will use the pad at any given time. This will provide some leeway for variations in where the bus stops. Additional length of rigid pavement should be considered for approaches and departures from the bus pad since these locations may be subjected to the same stresses from buses as the pad. A 115-foot length of bus pad (which is approximately 250 percent to 300 percent times the length of typical 40-foot buses) should provide sufficient length for bus approach and departure. The decision whether to use rigid pavement for bus approach and departure to/from bus pads is the responsibility of the District.

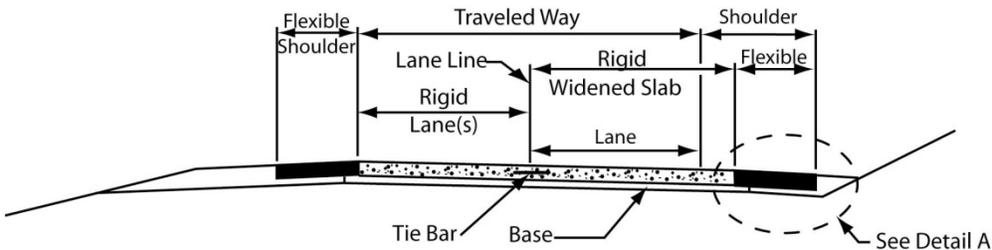
An end anchor may improve long-term performance at the flexible-to-rigid pavement transition. Doweled transverse joints should

Figure 626.2A
Rigid Pavement and Shoulder Details



RIGID SHOULDERS

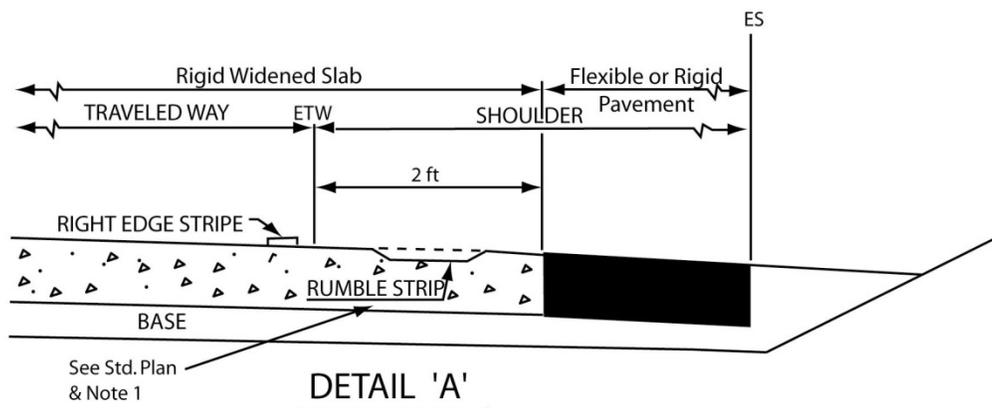
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FLEXIBLE SHOULDERS

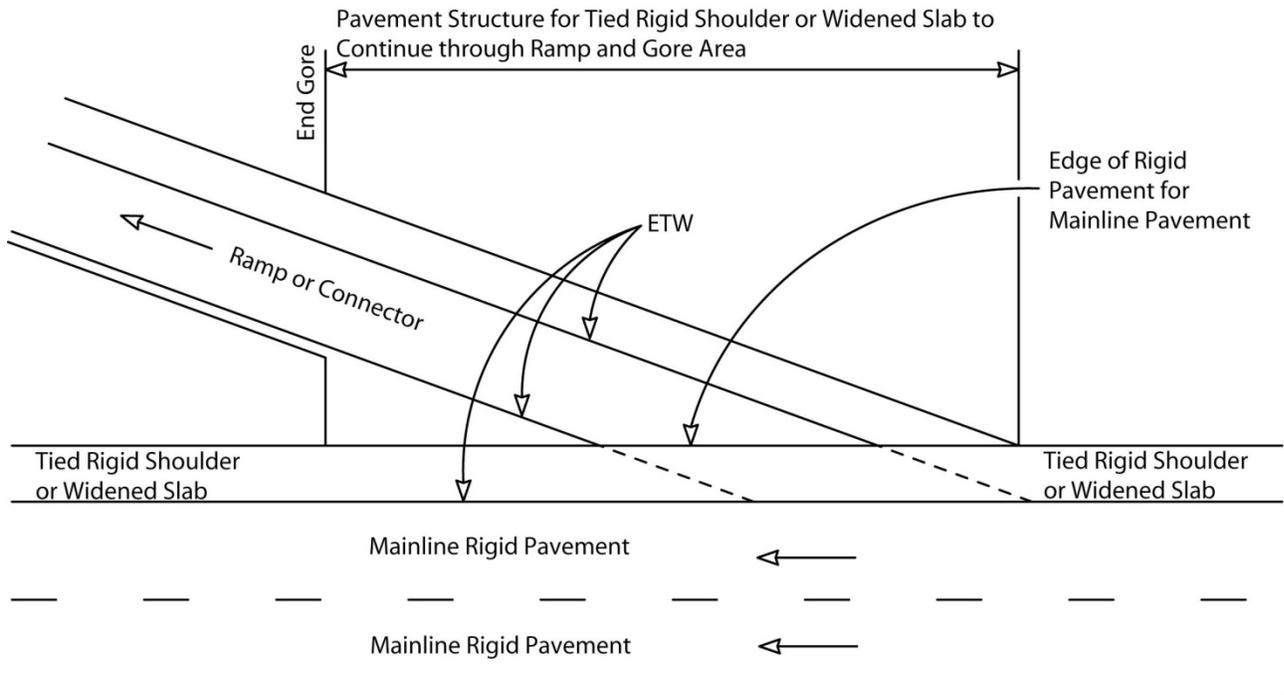
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NOTE: These illustrations are only to show nomenclature and are not to be used for geometric cross section details.



- NOTES: 1. Use of Rumble Strips is determined in consultation with District Traffic Operations.
 2. Right side widened slab is shown. Left side widened slab is similar.

Figure 626.2B
Rigid Shoulders Through Ramp and Gore Areas

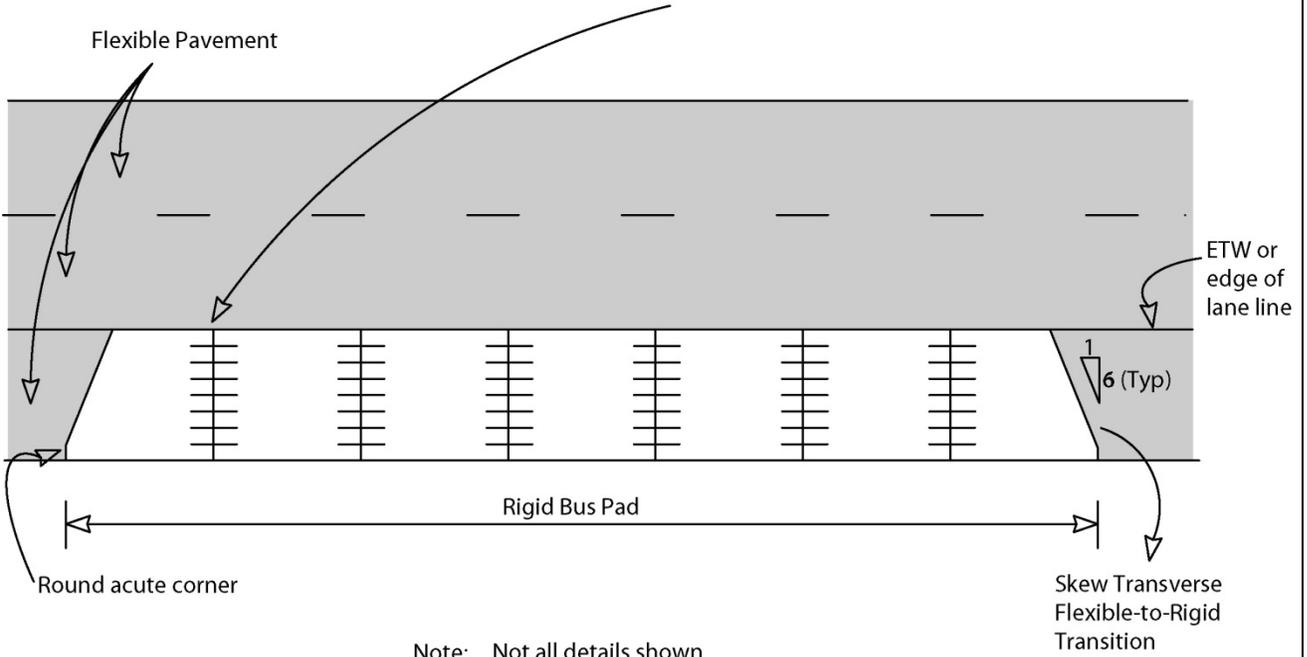


- Notes: 1) Not all details shown
2) Off ramp shown. Same conditions apply for on ramps.

be perpendicular to the longitudinal joint at maximum 15 feet spacing, but consider skewing (at 1:6 typical) entrance/exit transverse flexible-to-rigid transitions, note that since acute corners can fail prematurely, acute corners should be rounded (see Figure 626.4). 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.

Figure 626.4
Rigid Bus Pad

Doweled Transverse Weakened Plane
Joint Perpendicular to the Longitudinal
Joint (15 ft max spacing), typical



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O

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