CALIFORNIA
DEPARTMENT OF TRANSPORTATION

Manual Change Transmittal

TITLE	APPROVED BY	NO.
HIGHWAY DESIGN MANUAL SEVENTH EDITION – CHANGE 09/29/23	Paul Chung (signature) Paul Chung, Acting Chief	Date Issued: 09/29/23 Page 1 of 3
SUBJECT AREA Table of Contents; Chapters: 60, 80, 100, 200, 300, 400, 500, 610, 620, 630, 700, 850, and Index	ISSUING UNIT DIVISION OF DESIGN	
SUPERCEDES SEE BELOW FOR SPECIFIC PAGE NUMBERS	DISTRIBUTION **ALL HOLDERS OF THE 7TH EDITION, HIGHWAY DESIGN MANUAL**	

The Table of Contents; Chapters: 60, 80, 100, 200, 300, 400, 500, 610, 620, 630, 700, 850, and Index of the Seventh Edition, Highway Design Manual (HDM) have been revised. The changes to the HDM are summarized below with change sheets available on the Department Design website at: https://dot.ca.gov/programs/design/manual-highway-design-manual-hdm. Changes include corrections of typos, missing text, updated section numbers, updated MASH compliant bridge railing and structures terminology, deletion of reference to standard plan H9 for maintenance vehicle pullouts, place type changes, ridge pavement revision, culvert materials, and other wording changes.

These changes are effective September 29, 2023 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://lists.dot.ca.gov/mailman/listinfo/highway-design-manual-updates-announce.

A summary of the most significant revisions made throughout the manual are as follows:

Index 61.1 **Official Names, Page 60-1**
Structure Design has been replaced with Bridge Design. This change is reflected throughout the HDM.

Index 81.3 **Place Types, Pages 80-2 to 80-8**
Clarification and reorganization of Place Types definitions and descriptions.

Index 82.1 **Highway Design Manual Standards, Page 80-11**
Clarification on the use of underlined standards and boldface standards.

Index 108.2 **Transit Loading Facilities, Pages 100-19 and 20**
Removal of requirement for approval from District Director and Public Utilities Commission (PUC) involvement.

Index 208.6 **Overcrossings and Undercrossings for Pedestrians and Bicycles, Page 200-48**
Clarification of pedestrian overcrossing and undercrossing structures terminology.

Index 208.10 **Bridge Barriers and Railings, Pages 200-51 to 200-57**
Adding more MASH 2016 TL-4 & TL-2 compliant bridge rails. Deleting Concrete Barrier Type 80 and Type 80SW that were NCHRP Report 350 compliant. Adding chain link railing minimum height on structures over railroads. Adding protection of bridge columns and pier walls requirement to comply with AASHTO LRFD Bridge Design Specifications.

Index 209.3 **Structural Approach System Drainage, Page 200-63**
Added requirement to incorporate provisions for positive drainage of approach system. Added clarification regarding District and DES responsibilities for approach slab and roadway and structural related drainage.

Index 209.4 **Structure Approach Slab Rehabilitation Considerations, Pages 200-63 to 200-65**
Added information regarding structure approach slab drainage design.

Table 303.1 **Selection of Curb Type, Page 300-10**
Clarification provided in notes regarding typical uses of Type H, Type A and Type B curbs.

<u>Index 618.2</u>	**Constructability, Page 610-31** Replaced reference to K-rail with "temporary barrier system."
<u>Chapter 620</u>	**Rigid Pavement** Incorporated a new concrete pavement design catalog based on the AASHTOWare Pavement Mechanist-Empirical Design (PMED). Added language to provide recommendations when JPCP is placed as a Concrete Overlay over Asphalt (COA) in Index 621.2. Updated Tables 622.1 and 622.2 to show the property values used to develop the Rigid Pavement Design Catalog. Topics 623 and 625 have been rewritten describing engineering procedures used to develop the concrete design catalog.
<u>Index 701.2</u>	**Freeway and Expressway Access Control Fence, Page 700-4** Removed FHWA's approval of the project PS&E. Included a reference to Chapter 17 of the PDPM.
<u>Topics 852 and 855</u>	**Pipe Materials; Design Service Life, Pages 850-5 to 850-36** Updated wording in text and associated tables to reflect that bituminous coatings are no longer used as protective coatings for metal pipes.

Enclosures are included with this manual change transmittal of the total replacement pages.

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CHAPTER 60 – NOMENCLATURE

Unless indicated otherwise in this manual, wherever the following abbreviations, terms, or phrases are used, their intent and meaning shall be as identified in this Chapter.

Topic 61 – Abbreviations

Index 61.1 – Official Names

AASHTO	American Association of State Highway and Transportation Officials
BD	Bridge Design
Caltrans or Department	California Department of Transportation
CFR	Code of Federal Regulations
CTC or Commission	California Transportation Commission
DES	Division of Engineering Services
District	Department of Transportation Districts
DOT	U.S. Department of Transportation
DOD	Division of Design
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
GS	Geotechnical Services
METS	Office of Materials Engineering and Testing Services
OAP	Office of Asphalt Pavements
OCP	Office of Concrete Pavements
PP	Pavement Program
PS&E	Plans, Specifications, and Estimate
PUC	Public Utilities Commission
SHOPP	State Highway Operation and Protection Plan
STIP	State Transportation Improvement Program

Topic 62 – Definitions

62.1 Geometric Cross Section

(1) Lane.

a) Auxiliary Lane--The portion of the roadway for weaving, truck climbing, speed change, or for other purposes supplementary to through movement.

b) Lane Numbering--On a multilane roadway, the lanes available for through travel in the same direction are numbered from left to right when facing in the direction of travel.

c) Multiple Lanes--Freeways and conventional highways are sometimes defined by the number of through lanes in both directions. Thus an 8-lane freeway has 4 through lanes in each direction. Likewise, a 4-lane conventional highway has 2 through lanes in each direction. Lanes that are not equally distributed to each direction would otherwise be described as appropriate.

d) Median Lane--A speed change lane within the median to accommodate left turning vehicles.

e) Speed Change Lane--An auxiliary lane, including tapered areas, primarily for the acceleration or deceleration of vehicles when entering or leaving the through lanes.

f) Traffic Lane/Vehicle Lane--The portion of the traveled way for the movement of a single line of vehicles, both motor vehicle and bicycle.

(2) *Bikeways.*

a) Class I Bikeway (Bike Path). Provides a completely separated facility for the exclusive use of bicycles and pedestrians with crossflow by vehicles minimized.

b) Class II Bikeway (Bike Lane). Provides a striped lane for one-way bike travel on a street or highway.

c) Class III Bikeway (Bike Route). Provides for shared use with pedestrian or motor vehicle traffic.

d) Class IV Bikeway (Separated Bikeway). Provides for the exclusive use of bicycles and includes a separation (e.g., grade separation, flexible posts, inflexible physical barrier, or on-street parking) required between the separated bikeway and the through vehicular traffic.

(3) *Maintenance Vehicle Pullout (MVP).* Paved areas, or appropriate all weather surfaces, adjacent to the shoulder for field personnel to park off the traveled way and access the work site.

(4) *Median.* The portion of a divided highway separating the traveled ways in opposite directions.

(5) *Outer Separation.* The portion of an arterial highway between the traveled ways of a roadway and a frontage street or road.

(6) *Roadbed.* That portion of the roadway extending from curb line to curb line or shoulder line to shoulder line. Divided highways are considered to have two roadbeds.

(7) *Roadside.* A general term denoting the area adjoining the outer edge of the roadbed to the right of way line. Extensive areas between the roadbeds of a divided highway may also be considered roadside.

(8) *Roadway.* That portion of the highway included between the outside lines of the sidewalks, or curbs and gutters, or side ditches including also the appertaining structures, and all slopes, ditches, channels, waterways, and other features necessary for proper drainage and protection.

(9) *Shoulder.* The portion of the roadway contiguous with the traveled way for the accommodation of stopped vehicles, for emergency use, for errant vehicle recovery, and for lateral support of base and surface courses. The shoulder may accommodate on-street parking as well as bicyclists and pedestrians, see the guidance in this manual as well as DIB 82.

(10) *Sidewalk.* A surfaced pedestrian way contiguous to a roadbed used by the public where the need for which is created primarily by the local land use. See DIB 82 for further guidance.

62.3 Highway Types

(1) Freeway. A freeway, as defined by statute, is a highway in respect to which the owners of abutting lands have no right or easement of access to or from their abutting lands or in respect to which such owners have only limited or restricted right or easement of access. This statutory definition also includes expressways.

(2) The engineering definitions for use in this manual are:

a) Freeway--A divided arterial highway with full control of access and with grade separations at intersections.

b) Expressway--An arterial highway with at least partial control of access, which may or may not be divided or have grade separations at intersections.

(3) Controlled Access Highway. In situations where it has been determined advisable by the Director or the CTC, a facility may be designated a "controlled access highway" in lieu of the designation "freeway". All statutory provisions pertaining to freeways and expressways apply to controlled access highways.

(4) Conventional Highway. A highway without control of access which may or may not be divided. Grade separations at intersections or access control may be used when justified at spot locations.

(5) Highway. In general a public right of way for the purpose of travel or transportation.

(a) Alley--A road passing through a continuous row of houses, buildings, etc. that permits access from the local street network to backyards, garages, etc.

(b) Arterial Highway--A general term denoting a highway primarily for through travel usually on a continuous route.

(c) Bypass--An arterial highway that permits users to avoid part or all of a city, urban area, suburban area, or rural town.

(d) Collector-Distributor Road--A separated freeway system adjacent to a freeway, which connects two or more local road ramps or freeway connections to the freeway at a limited number of points.

(e) Collector Road--A route that serves travel of primarily intracounty rather than statewide importance in rural areas or a route that serves both land access and traffic circulation within a residential neighborhood, as well as commercial and industrial areas in urban and suburban areas.

(f) Divided Highway--A highway with separated roadbeds for traffic traveling in opposing directions.

(g) Major Street or Major Highway--An arterial highway with intersections at grade and direct access to abutting property on which geometric design and traffic control measures are used to expedite the safe movement of through traffic.

(h) Through Street or Through Highway--The highway or portion thereof at the entrance to which vehicular traffic from intersecting highways is regulated by “STOP” signs or traffic control signals or is controlled when entering on a separate right-turn roadway by a “YIELD” sign.

(6) Parkway. An arterial highway for noncommercial vehicles, with full or partial control of access, which is typically located within a park or a ribbon of park-like development.

(7) *Scenic Highway.* A State or county highway, in total or in part, that is recognized for its scenic value, protected by a locally adopted corridor protection program, and has been officially designated by the Department.

(8) *Street or Road.*

a. Cul-de-Sac Street--A local street open at one end only, with special provisions for turning around.

b. Dead End Street/No Outlet--A local street open at one end only, without special provisions for turning around.

c. Frontage Street or Road--A local street or road auxiliary to and located on the side of an arterial highway for service to abutting property and adjacent areas and for control of access.

d. Local Street or Local Road--A street or road primarily for access to residence, business or other abutting property.

e. Private Road or Private Driveway--A way or place in private ownership and used for travel by the owner and those having express or implied permission from the owner but not by other members of the public.

f. Street--A way or place that is publicly maintained and open for the use of the public to travel. Street includes highway.

g. Toll Road, Bridge or Tunnel--A highway, bridge, or tunnel open to traffic only upon payment of a toll or fee.

(9) *Throughway.* A conventional highway or a suburban arterial in developed or developing areas, that is characterized by lower density (not built out) land uses, adjacent undeveloped land or parkland, direct access to abutting property, at-grade intersections, and that may have shoulders with or without curb and gutter.

62.4 Interchanges and Intersections at Grade

(1) *Central Island.* The raised area in the center of a roundabout around which traffic circulates. The central island does not necessarily need to be circular in shape.

(2) *Circulatory Roadway.* The curved roadbed that users of a roundabout travel on in a counterclockwise direction around the central island.

(3) *Channelization.* The separation or regulation of conflicting movements into definite paths of travel by the use of pavement markings, raised islands, or other suitable means to facilitate the safe and orderly movement of vehicles, bicycles and pedestrians.

(4) *Convergence Point*. The point of convergence occurs where the right ETW of the entrance ramp is one lane width from the right ETW of the freeway.

(5) *Crosswalk.* Crosswalk is either:

(a) That portion of a roadway included within the prolongation or connection of the boundary lines of sidewalks at intersections where the intersecting roadways meet at approximately right angles, except the prolongation of such lines from an alley across a street.

(b) Any portion of a roadway distinctly indicated for pedestrian crossing by lines or other markings on the surface.

(6) *Geometric Design.* The arrangement of the visible elements of a road, such as alignment, grades, sight distances, widths, slopes, and other similar elements.

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) *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).

(49) *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.

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

(51) *Structural Section Drainage System.* See Pavement Drainage System.

(52) *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.

(53) *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.

(54) *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.

(55) *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; or AADTT for trucks.

(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 85^{th} 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 greater than 45 mph.

(e) Low Speed – A speed less than or equal to 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.

CHAPTER 80 – APPLICATION OF DESIGN STANDARDS

Topic 81 – Project Development Overview

Index 81.1 – Philosophy

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

(a) Need to provide transportation for all users (motorists, bicyclists, transit riders, and pedestrians) of the facility and transportation modes.

(b) Attainment of community goals and objectives.

(c) Needs of low mobility and disadvantaged groups.

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

(e) Planning based on realistic financial estimates.

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

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

Decisions must also emphasize the connectivity between the different transportation modes so that they work together effectively.

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

81.2 Highway Context

The context of a highway is a critical factor when developing the purpose and need statement for a project in addition to making fundamental design decisions such as its typical cross section and when selecting the design elements and aesthetic features such as street furniture and construction materials. Designing a highway that is sensitive to, and respectful of, the surrounding context is critical for project success in the minds of the Department and our stakeholders.

A “one-size-fits-all” design philosophy is not Departmental policy. Designers need to be aware of and sensitive to land use, community context and the associated user needs of the facility. In some instances, the design criteria and standards in this manual are based on the land use contexts in which the State highway is located, for instance: large population areas and downtowns in urban areas, small rural towns and communities, suburban commercial/residential areas, and rural corridors. This approach ensures the standards are flexible, and the approach allows and encourages methods to minimize impacts on scenic, historic, archaeological, environmental, and other important resources.

Beyond their intended transportation benefits, State highways can significantly impact the civic, social and economic conditions of local communities. Designing transportation facilities that integrate the local transportation and land uses while making the design responsive to the other needs of the community support the livability of the community and are usually a complementary goal to meeting the transportation needs of the users of the State highway system.

To do this successfully, the designer needs to have an understanding of the area surrounding the highway and the users of the highway, its function within the regional and State transportation systems, (which includes all transportation modes), and the level of access control needed. To gain this understanding, the designer must consult the Transportation Concept Reports and work with the planning division and the local agencies.

In this manual, the following concepts are used to discuss the context of a highway:

- Place Type - the surrounding built and natural environment;
- Type of Highway - the role the highway plays in terms of providing regional or interregional connectivity and local access; and,
- Access Control - the degree of connection or separation between the highway and the surrounding land use.

81.3 Place Types

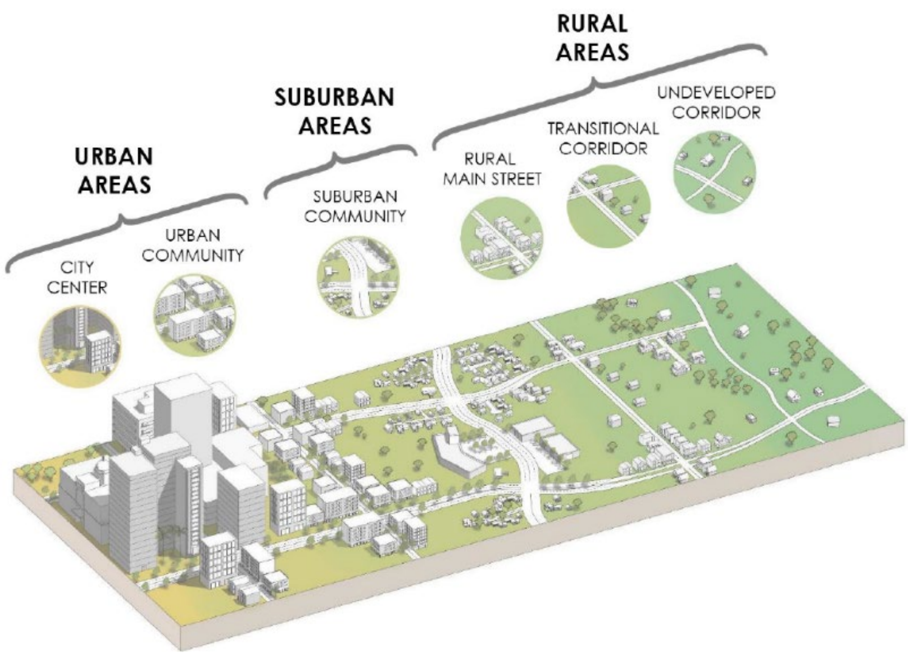
Place types describe geographic areas based on land use, development density, population, and transportation and mobility options. While state highways can influence the development of communities, the reverse can also be true. As development, land use, and population change, the transportation network must also evolve to serve both uses and users. The place types described below are intentionally broad, and there is likely to be more than one place type within the limits of a single project. Ultimately, the place types identified can be used to determine the appropriate application of design guidance. These place type definitions are independent of the Federal government definitions of urban and rural areas. See Title 23 United States Code, Section 101 for further information. Place types for the project including their segment limits may be initially determined and documented by Planning as part of the project initiation phase.

Additional Place Type guidance can also be found in the Smart Mobility Framework documents and the Main Street, California Guide. This place type guidance serves to identify common needs and priorities but cannot be substituted for community input. Ongoing community engagement throughout the project planning, approval, design, and construction phases helps to formulate context sensitive project alternatives and transportation facilities that coordinate with the local needs. It is important to note that State Highway Main Streets (State highways that are functioning as community streets) can occur in all community place types.

Figure 81.3 depicts the typical place type development patterns used in this manual.

Figure 81.3

Place Types



(1) *Urban Areas.* Urban Area communities and City Centers are the major population centers in the State, although they cover only a small percentage of the land area. Large numbers of people live in these urbanized areas where growth is expected to continue. Active transportation (which can include walking, bicycling, rolling, and transit) is important in these areas, and as the facilities for pedestrians, bicyclists, and transit vehicles expand in Urban Areas, the percentage and number of travelers using active transportation modes is also likely to increase.

Urban Areas are high-density locations with a full range of land uses, and they can be further broken down into City Centers and Urban Communities. Urban Areas as described in this design manual may vary from the boundaries defined by the FHWA for federal funding purposes. For that definition, the HEPGIS tool on the FHWA website is available to determine if the project is in an urban area. Urban areas are found on the MPO & Air Quality tab of the tool, under FHWA Adjusted Urban Area.

(a) City Center (Central City, Center City). The City Center place type applies to the downtowns of our largest metropolitan areas. There are currently only a handful of places like this in California and they include the central business districts of the state's major metropolitan areas: San Francisco, Oakland, San Jose, Sacramento, Los Angeles, and San Diego. The City Center place type is characterized by:

- High-density, compact urban form with buildings taller than four stories and minimal building setbacks; buildings front onto the street with easy pedestrian access.
- Dense street network with a walkable block pattern, often on a grid, typically with narrower lanes and parking located off-street in structures.
- Mixed-use development, typically with more office, civic, and hospitality uses than residential.
- High rates of bicycle, pedestrian, and transit mode share with lower vehicle speeds, increasing presence of micromobility, and lower rates of automobile ownership.
- Main Streets. Due to the intensity of development, nearly all streets in City Centers could be considered "Main Streets."

In City Centers, much of the transportation network has already been built out, but the existing right of way can be optimized to move people and goods most efficiently, while serving as a vital community space.

(b) Smart Mobility Vision for City Centers. City Centers' transportation needs can only be met through a concerted effort to maximize safety and convenience of all travel modes, along with a high degree of integration and ease of transition between the modes. City Centers include major transit hubs and transportation connections which are critical to the long-term success of the city, both to support the dense development and to support the local and regional economy. City Centers thrive when all modes of travel are accessible and well connected to Urban Communities. Urban Communities often exist adjacent to or near City Centers, such as the Mid-Wilshire district adjacent to Downtown Los Angeles, but they also include many mid-size cities with mixed-use centers, such as Santa Monica, Berkeley, or Santa Ana. This place type may occur within a larger metropolitan area or in more isolated locations in the State, such as the downtown areas of Santa Barbara or San Luis Obispo. Many Urban Communities were built prior to the widespread adoption of automobile use and their design supports walking, biking, and transit use through sidewalks, street trees, convenient destination density, and high-frequency bus and/or rail service. Urban Communities are typically characterized by:

- Centers or corridors of low-to mid-rise buildings with vertically and horizontally mixed land uses.
- Buildings are typically close to the street, although occasional strip commercial centers may exist.
- Moderately dense development, which may be primarily residential or include mixed-use centers.
- Fine-grained network of streets in a compact walkable block pattern, with good connectivity for non-motorized users.
- Parking options range from off-site nearby lots to on-site parking behind a building, or in a structure.
- Streets generally have narrow lanes, some on-street parking, variable bicycle facilities, and lower vehicle speeds.
- Main Streets. Depending on the mix of uses and density of development, many streets in Urban Communities would be considered "Main Streets."

In Urban Communities, the public right of way is often constrained and needs to balance different transportation modes. As Urban Communities intensify and expand with infill development, mobility needs and preferences for active transportation also evolve over time. Gaps in connectivity for bicycling are common, and the quality of the pedestrian environment varies significantly depending on the age of adjacent development.

Smart Mobility Vision for Urban Communities. The Smart Mobility vision for Urban Communities is similar to Center Cities: maximize safety and convenience for all travel modes. However, given the historical focus on vehicular circulation in this Place Type, the priority should shift to increasing walking, bicycling, and transit use. The greater the mode shift, the less space will be needed for parking, which frees up land for other, more valuable uses and activities.

(2) Suburban Areas. Suburban Areas are prevalent throughout California. While the original suburbs were developed as bedroom communities outside of cities or metropolitan areas, over time many independent communities in California have developed in this dispersed, low-density pattern that includes both residential and commercial zones. This place type often consists of extensive single-family neighborhoods, pockets of multi-family housing, parks, and schools, and strategically located single-story commercial centers. Relevant examples include Eastvale, Corona, Livermore, Roseville, and the master planned communities of south Orange County. Suburban Areas are characterized by:

- Low-rise residential and non-residential uses (mostly 1 to 2 stories in height), with clusters of office, civic, or other institutional buildings ranging from 2 stories or more in height.
- A hierarchy of street sizes that excludes through-traffic from certain areas and limits connectivity between different street types.
- Segregated land uses, including residential neighborhoods and town centers, that are difficult to travel between without a car.
- Large arterial roadways with wide lanes, shoulders and turn pockets, synchronized signal timing, and wide intersections designed to maximize free flow of vehicles.
- Expansive, often underused surface parking with buildings set back behind parking.
- Higher density suburban town centers, particularly those that include retail or civic uses, are often found along suburban “Main Streets.”

In Suburban Areas, the SHS typically provides a connection to nearby Urban Communities, as well as access between suburban town centers. Generally, State highways provide access to, but not through, suburban residential areas. Arterials in Suburban Areas have traditionally been designed to accommodate high volumes of vehicles, and generally include sidewalks, but not bicycle facilities. Passenger rail and transit facilities may also be present within the State highway.

Smart Mobility Vision for Suburban Communities. Decisions made by Caltrans in Suburban Communities have a direct impact on the potential evolution of the Place Type from a single use to a mixed-use environment. There is a symbiotic relationship between land use/urban form and the extent of smart mobility improvements. The Smart Mobility vision for Suburban Communities is to transform high-speed, car-dominated corridors into a multimodal environment that supports the densification and mixing of uses that is occurring over time. Potential developers along corridors are attracted by convenient and safe mobility options and an aesthetically pleasing streetscape – these features add value to the area which can then support the higher lease rates and rents needed to support new development.

(3) Rural Areas. The Rural Area Place Type applies to the low-density areas outside the built-up urban and suburban communities and can include agricultural areas, natural areas, and the small towns that support the inhabitants of these regions. Single occupancy vehicle use is high in Rural Areas, but zero- or low-vehicle ownership households may exist here as well. State highways through rural towns must consider local needs for vibrant community main streets, as well as the public's need for roadways that provide local, regional, and statewide connections. Highway design should respond to its context, thus for the purposes of applying design guidance, the Rural Area place type is broken up into Rural Main Streets (Rural Towns), Transitional Corridors, and Undeveloped Corridors. The great variability in traffic speeds, traffic volumes, roadway context, and roadway users necessitates the development of variable design solutions in each of these settings.

a) Rural Main Streets (Rural Towns). State highways in this scenario are usually a conventional highway main street through the center of town, where they may be the only main street, or one of several. A subset of Rural Towns is Gateway Communities, which are visitor-serving places situated near entries to national parks, recreational areas, and other scenic places. Examples of Gateway Communities include Three Rivers, near Sequoia National Park; Twentynine Palms, near Joshua Tree National Park; and Orick, near Redwood National Park. These communities, often situated along the highway, tend to rely heavily on the revenue provided by multimodal visitors seeking to access nearby parks and scenic resources. In many of these Gateway Communities, the State highway serves as a Rural Main Street. Rural Main Streets vary with the character of their communities, but they have many common characteristics:

- Rural Main Streets are often part of a small commercial grid around the main arterial or highway and have lower speeds. In some cases, frontage roads separate regional and local traffic.
- Land use is generally dominated by commercial and small office facilities, although this can vary with the community.
- Buildings lining Rural Main Streets, in contrast to Undeveloped or Transitional Corridors, can be up to three stories tall and very close together or abutting one another.
- Parking facilities are variable and may be located on-street or in small surface lots adjacent to or behind buildings.

Smart Mobility Vision for Rural and Rural Main Street Place Types. The vision for smart mobility in Rural Areas is to maintain walkable rural towns with streets that are operated and designed for speeds suitable for their context and safety for all users. Acknowledging that motorized vehicle travel will continuing to be the predominant mode in Rural areas outside of Rural Main Streets, efforts should be made to increase the number of vehicle trips with multiple passengers, to utilize transit as much as possible, and to improve bicycle safety on connecting roads including state highways. In Rural Main Street areas, focus on expanding use of pedestrian and bicycle modes and make them as safe and convenient to use as possible. Gateway Communities should be well connected by transit and multi-use trails to nearby scenic resources. As in other Place Types, Rural areas thrive when all modes of travel are accessible and well connected.

b) Transitional Corridors. State highways traveling through these lands tend to be increasingly clustered with industrial, commercial, and residential areas as they lead from an undeveloped rural area into a rural city or town center. The transition between high-speed rural highways and low-speed main streets and town centers occurs in these corridors and may employ traffic calming features to reinforce the lower posted speeds. In some cases, the nature of development in these areas is itself in transition as communities change over time, but in other instances this development pattern may remain stable for many years. Transitional corridors are characterized by:

- Low-rise one- to two-story buildings that are typically set back from the highway with parking areas placed in front.
- A moderately dense street network, with more frequent intersections and driveways than the outlying rural areas.

Truck traffic on these highways tends to serve the needs of industrial, commercial and retail buildings; however, there will be a component of the truck traffic that is transporting loads inter-regionally. At the same time, these corridors may be used by an increasing number of locals seeking to access the town center.

c) Undeveloped Corridors. Undeveloped Corridors feature very low building density and large tracts of agricultural or other undeveloped or natural land. This place type includes many of California's iconic landscapes, such as the National and State Forests in the Sierras, the vineyards of the coastal ranges and foothills, the Mojave Desert, the orchards and fields of the Central Valley, and the Pacific Coast, to name a few. See HDM Topic 109 for additional information on preserving the natural beauty of these corridors. Some of these Undeveloped Corridors are heavily used by recreational bicyclists and tourists, and experience high seasonal and weekend use. Undeveloped Corridors are often characterized by:

- Very low-density development with one- or two-story buildings.
- Low intersection density with a street pattern that is often non-rectilinear, reflecting underlying topography.
- Large parcels with buildings generally set far back from property lines.
- A diverse mix of land uses, where residences are often interspersed with agricultural, commercial, or other services.

State Highway projects in Undeveloped Corridors have traditionally focused on efficient movement of vehicles and freight over long distances, but often the state highway provides the only connection between destinations for non-motorized users, as well. The low user volumes, long distances, and variable terrain in these corridors may not lend themselves to a full range of complete streets features, but accommodations to support comfort and safety of non-motorized users should be incorporated wherever feasible.

(4) Special Use Areas and Protected Lands. These place types generally have a character separate from their surroundings and a specialized land use. Protected Lands are protected from development by virtue of ownership, long-term regulation, or resource constraints. Examples include national forests, state parks, nature preserves, and lands held in perpetuity by land trusts. Protected Lands are generally preservation-focused, and transportation projects should provide access while minimizing impacts. Providing access, including through extreme weather events, and maintaining goods movement are the primary focus of

infrastructure improvements. Improving bicycle/pedestrian and transit/shuttle infrastructure in this place type can help to minimize environmental impacts.

Special Use Areas are large tracts of single use lands that are outside of, or poorly integrated with, their surroundings, such as airports, industrial facilities, military installations, and some university campuses. The transportation needs of Special Use Areas are highly variable, ranging from the carefully limited access to military installations to highly accessible university campuses, and transportation projects should respond to their unique needs and users.

81.4 Type of Highway

Much of the following terminology is either already discussed in Chapter 20 or defined in Topic 62. The additional information in this portion of the manual is being provided to connect these terms with the guidance that is being provided.

(1) *Functional Classification.* One of the first steps in the highway design process is to define the function that the facility is to serve. The two major considerations in functionally classifying a highway are access and throughput. Access and mobility are inversely related; as access is increased, mobility decreases. In the AASHTO "A Policy on Geometric Design of Highways and Streets", highways are functionally classified first as either urban or rural. The hierarchy of the functional highway system within either an urban or rural area consists of the following:

- Principal arterial - main movement (high mobility, limited access) Typically 4 lanes or more;
- Minor arterial - interconnects principal arterials (moderate mobility, limited access) Typically 2 or 3 lanes with turn lanes to benefit through traffic;
- Collectors - connects local roads to arterials (moderate mobility, moderate access) with few businesses; and,
- Local roads and streets - permits access to abutting land (high access, limited mobility).

The California Road System (CRS) maps are the official functional classification maps approved by FHWA. These maps show functional classification of roads. See the link at https://caltrans.maps.arcgis.com/apps/webappviewer/index.html?id=026e830c914c495797c969a3e5668538.

(2) *Interstate Highways.* The interstate highway system was originally designed to be high-speed interregional connectors and it is a portion of the National Highway System (NHS). In urban and suburban areas, a large percentage of vehicular traffic is carried on the interstate highway system, rather than on the local arterials and streets.

(3) *State Routes.* The State highway system is described in the California Streets and Highway Code, Division 1, Chapter 2 and they are further defined in this manual in Topic 62.3, Highway Types which provides definitions for freeways, expressways, and highways.

81.5 Access Control

Index 62.3 defines a controlled access highway and a conventional highway. The level of access control plays a part in determining the design standards that are to be utilized when designing a highway. See Index 405.6 for additional access control guidance.

81.6 Design Standards and Highway Context

The design standards were initially established to increase highway mobility and development, promoting a State transportation system that operated at selected levels of service consistent with projected traffic volumes and highway classification. Design standards revolved around FHWA's controlling criteria, evolving over time to more fully consider adjacent community values, local decisions making, and area context.

The design guidance and standards in this manual have been developed with the intent of ensuring that:

- Designers have the ability to design for all modes of travel (vehicular, bicycle, pedestrian, truck and transit); and,
- Designers have the flexibility to tailor a project to the unique circumstances that relate to it and its location, while meeting driver expectation to achieve established project goals.

Designers should balance the interregional transportation needs with the needs of the communities they pass through. The design of projects should, when possible, expand the options for biking, walking, and transit use. In planning and designing projects, the project development team should work with locals that have any livable policies as revitalizing urban centers, building local economies, and preserving historic sites and scenic country roads. The "Main Street, California" document published by the Department should be consulted for additional guidance as should the FHWA publication "Flexibility in Highway Design".

Early consultation and discussion with the Project Delivery Coordinator and the District Design Liaison during the Project Initiation Document (PID) phase is also necessary to avoid issues that may arise later in the project development process. Design Information Bulletin 78 "Design Checklist for the Development of Geometric Plans" is a tool that can be used to identify and discuss design features that may deviate from standard.

For projects to accomplish complete streets facilities on the State Highway System per Director's Policy 37, Design Information Bulletin 94 "Complete Streets: Contextual Design Guidance" can be used along with this manual as applicable.

Topic 82 – Application of Standards

82.1 Highway Design Manual Standards

(1) General. The highway design criteria and policies in this manual provide a guide for the engineer to exercise sound judgment in applying standards, consistent with the above Project Development philosophy, in the design of projects. This guidance allows for flexibility in applying design standards and documenting design decisions that take the context of the project location into consideration, which enables the designer to tailor the design, as appropriate, for the specific circumstances while maintaining safety.

The design standards used for any project should equal or exceed the minimum given in the Manual to the maximum extent feasible, taking into account costs (initial and life-cycle), traffic volumes, traffic and safety benefits, project goals, travel modes, facility type, right of way, socio-economic and environmental impacts, maintenance, etc. Because design standards have evolved over many years, many existing highways do not conform fully to current standards. It is not intended that current manual standards be applied retroactively to all existing State highways; such is neither warranted nor economically feasible. However, when warranted, upgrading of existing roadway features such as guardrail, lighting, superelevation, roadbed width, etc., should be considered, either as independent projects or as part of larger projects. A record of the decision not to upgrade existing non-standard design features are to be provided through the process described in Index 82.2.

This manual does not address temporary construction features. It is recognized that the construction conditions encountered are so diverse and variable that it is not practical to set geometric criteria. Guidance for use of traffic control devices for temporary construction zones can be found in Part 6 – Temporary Traffic Control of the California Manual on Uniform Traffic Control Devices (California MUTCD). Guidance for the engineering of pavements in temporary construction zones is available in Index 612.6. In this manual, design standards and guidance are described as follows (see Index 82.4 for other procedural requirements):

(2) Absolute Requirements. Design guidance related to requirements of law, policy, or statute that do not allow exception are phrased by the use of “must,” “is required,” “without exception,” “are to be,” “is to be,” “in no event,” or a combination of these terms.

(3) Controlling Criteria. The FHWA has designated the following ten controlling criteria for projects on the National Highway System (NHS) as comprehensive design standards which cover a multitude of design characteristics, allowing flexibility in application:

- Design Speed
- Lane Width
- Shoulder Width
- Horizontal Curve Radius
- Superelevation Rate
- Stopping Sight Distance

- Maximum Grade
- Cross Slope
- Vertical Clearance
- Design Loading Structural Capacity (non-geometric)

Design loading structural capacity criteria applies to all NHS facility types. See the Technical Publications – DES Manuals for further information.

The remaining geometric criteria listed above are applicable to the NHS as follows: (1) On high-speed roadways (Interstate highways, other freeways, and roadways with design speeds of greater than or equal to 50 mph), all the geometric criteria apply. The stopping sight distance criteria applies to horizontal alignments and vertical alignments except for sag vertical curves; and (2) On low-speed roadways (non-freeways with design speeds less than 50 mph), only the design speed criteria applies.

The two speed categories stated above that FHWA designates match the high- and low-speed definitions in Index 62.8(13) when considering that design speed and posted speed are set in 5 mph increments.

The design standards related to the geometric criteria are identified in Table 82.1A among other important geometric standards in this manual regardless of the design speed of the roadway and whether or not the roadway is part of the NHS.

(4) Boldface and Underlined Standards. Boldface and underlined design standards are those considered most essential to achievement of overall design objectives. Many pertain to requirements of law or regulations such as those embodied in the FHWA's ten controlling criteria (see Index 82.1(3)). In addition to the FHWA's ten controlling criteria are "Caltrans-only" standards that have been identified by Caltrans as most essential pertaining to requirements of State law, policy or objectives. The underlined standards allow greater flexibility in application to accommodate various design constraints. The design standards are shown in this manual as either **Boldface** type with the word "shall" (listed in Table 82.1A) or <u>Underlined</u> type with the word "should" (listed in Table 82.1B).

(5) Decision Requiring Other Approvals. There are design criteria decisions that are not bold or underlined text which require specific approvals from individuals to whom such decisions have been delegated. These individuals include, but are not limited to, District Directors, Project Delivery Coordinators or their combination as specified in this manual. These decisions should be documented as the individual approving desires.

(6) Permissive Standards. All guidance other than absolute requirements, standards, or decisions requiring other approvals, whether indicated by the use of "should", "may", or "can" are permissive.

(7) Other Caltrans Publications. 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.

(8) Transportation Facilities Under the Jurisdiction of Others. Generally, if the local road or street is a Federal-aid route it should conform to AASHTO standards; see Topic 308 – Cross Sections for Roads Under Other Jurisdictions. Occasionally though, projects on the State highway system involve work on adjacent transportation facilities that are under the

jurisdiction of cities and counties. Some of these local jurisdictions may have published standards for facilities that they own and operate. The guidance in this manual may be applicable, but it was prepared for use on the State highway system. Thus, when project work impacts adjacent transportation facilities that are under the jurisdiction of cities and counties, local standards and AASHTO guidance must be used in conjunction with this manual to encourage designs that are sensitive to the local context and community values. Agreeing on which standards will be used needs to be decided early in the project delivery process and on a project by project basis.

82.2 Approvals for Nonstandard Design

(1) Boldface Standards. Design features or elements which deviate from standards indicated in boldface type require the approval of the Chief, Division of Design. This approval authority has been delegated to the District Directors for projects on conventional highways and expressways, and for certain other facilities in accordance with the current District Design Delegation Agreement. Approval authority for design standards indicated in boldface type on all other facilities has been delegated to the Project Delivery Coordinators except as noted in Table 82.1A where: (a) the standard has been delegated to the District Director, (b) the standards in Chapters 600 through 680 requires the approval of the State Pavement Engineer, and (c) specifically delegated to the District Director per the current District Design Delegation Agreements and may involve coordination with the Project Delivery Coordinator. See the HQ Division of Design website for the most current District Design Delegation Agreements.

The current procedures and documentation requirements pertaining to the approval process for deviation from design standards indicated in boldface type as well as the dispute resolution process 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 Moving Ahead for Progress in the 21st Century Act (MAP-21) of 2012 allowed significant delegation to the states by FHWA to approve and administer portions of the Federal-Aid Transportation Program. MAP-21 further allowed delegation to the State DOT's and in response to this a Stewardship and Oversight Agreement (SOA) document between FHWA and Caltrans was signed. The SOA outlines the process to determine specific project related delegation to Caltrans. In general, the SOA delegates approval of deviations from design standards related to the ten controlling criteria on all Interstate projects whether FHWA has oversight responsibilities or not to Caltrans. Exceptions to this delegation would be for projects of FHWA Division Interest, which are determined on a project by project basis. See Index 43.2 for additional information. Consultation with FHWA should be sought as early in the project development process as possible. However, formal FHWA approval, if applicable, shall not be requested until the appropriate Caltrans representative has approved the design decision document.

FHWA approval is not required for deviations from "Caltrans-only" standards. Table 82.1A identifies these "Caltrans-only" standards. Where FHWA approval of a deviation from a design standard is required, only cite the standards that are identified by the FHWA as ten controlling criteria, see Index 82.1(3).

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

(2) Underlined Standards. The authority to approve deviations from standards indicated in underlined type has been delegated to the District Directors. A list of these standards is provided in Table 82.1B. Proposals for deviations from these standards can be discussed

with the District Design Liaison during development of the approval documentation. The responsibility for the establishment of procedures for review, documentation, and long term retention of approved design decisions from these standards has also been delegated to the District Directors.

(3) *Decisions Requiring Other Approvals*. The authority to approve specific decisions identified in the text are also listed in Table 82.1C. The form of documentation or other instructions are provided as directed by the approval authority.

(4) *Permissive Standards*. A record of deviation from permissive standards and the disclosure of the engineering decisions in support of the deviation should be documented and placed in the project file. This principle of documentation also applies when following other Division of Design guidance, e.g., Design Information Bulletins and Design Memos. The form of documentation and other instructions on long term retention of these engineering decisions are to be provided as directed by the District approval authority.

(5) *Local Agencies.* Cities and counties are responsible for the design decisions they make on transportation facilities they own and operate. The responsible local entity is delegated authority to exercise their engineering judgment when utilizing the applicable design guidance and standards, including those for bicycle facilities established by Caltrans pursuant to the Streets and Highways Code Sections 890.6 and 890.8 and published in this manual. For further information on this delegation and the delegation process, see the Caltrans Local Assistance Procedures Manual, Chapter 11.

82.3 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" (2018) and "A Policy on Design Standards-Interstate System" (2016). 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 108.7, Coordination with the FHWA).

The use of publications and manuals that are developed by organizations other than the FHWA and AASHTO can also provide additional guidance not covered in this manual. The use of such guidance coupled with sound engineering judgment is to be exercised in collaboration with the guidance in this manual.

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 a design decision has been approved in accordance with Index 82.2 or otherwise noted by separate Design Memorandum.

On projects where the project development process has started, the following conditions on the effective date of the new or revised standards will be applied: For all projects where the PS&E has not been finalized, the new or revised design standards shall be incorporated unless this would impose a significant delay in the project schedule or a significant increase in the project engineering or construction costs. The Project Delivery Coordinator or individual delegated authority must 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 design standards as defined in Index 82.2.

82.6 Design Information Bulletins and Other Caltrans Publications

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.

The infrastructure within a highway or freeway corridor, segment, intersection or interchange is not "complete" for drivers, bicyclists and pedestrians unless it includes the appropriate traffic control devices; traffic safety systems; operational features or strategies; and traffic management elements and or systems. The presence or absence of these traffic elements and systems can have a profound effect on safety and operational performance. As such, they are commonly employed to remediate performance deficiencies and to optimize the overall performance of the "built" highway system. For additional information visit the Division of Traffic Operations website at http://www.dot.ca.gov/trafficops/.

Table 82.1A

Boldface Standards

CHAPTER 100	BASIC DESIGN POLICIES
Topic 101	Design Speed
Index 101.1	Technical Reductions of Design Speed
101.1	Selection of Design Speed - Local Facilities
101.1	Selection of Design Speed - Local Facilities - with Connections to State Facilities
101.2	Design Speed Standards
Topic 104	Control of Access
Index 104.4	Protection of Access Rights(1)
CHAPTER 200	GEOMETRIC DESIGN AND STRUCTURE STANDARDS
Topic 201	Sight Distance
Index 201.1	Stopping Sight Distance Standards
Topic 202	Superelevation
Index 202.2	Standards for Superelevation
202.7	Superelevation on City Streets and County Roads
Topic 203	Horizontal Alignment
Index 203.1	Horizontal Alignment - Local Facilities
203.1	Horizontal Alignment and Stopping Sight Distance
203.2	Standards for Curvature – Minimum Radius
203.2	Standards for Curvature – Lateral Clearance
Topic 204	Grade
Index 204.1	Standards for Grade - Local Facilities
204.3	Standards for Grade

Design exception approval of Boldface Standards for nonfreeway facilities, including local streets and roads at interchanges, has been delegated to the Districts. In addition, some District delegations included Boldface Standards applicable to freeways. See your District Design Delegation Agreement for specific delegation.

(1) Caltrans-only Boldface Standard.

(2) Authority to approve deviations from this Boldface Standard is delegated to the State Pavement Engineer.

Table 82.1A

Boldface Standards (Cont.)

204.8	Vertical Falsework Clearances(1)
Topic 205	Road Connections and Driveways
Index 205.1	Sight Distance Requirements for Access Openings on Expressways
Topic 208	Bridges, Grade Separation Structures, and Structure Approach Embankment
Index 208.1	Bridge Width(1)
208.4	Bridge Sidewalk (Width)(1)
208.10	Barriers on Structures with Sidewalks(1)
208.10	Bridge Approach Railings(1)
CHAPTER 300	GEOMETRIC CROSS SECTION
Topic 301	Traveled Way Standards
Index 301.1	Lane Width
301.2	Class II Bikeway Lane Width(1)
301.3	Cross Slopes – New Construction
301.3	Cross Slopes – Resurfacing or widening
301.3	Cross Slopes – Unpaved Roadway
301.3	Algebraic Differences in Cross Slopes
Topic 302	Shoulder Standards
Index 302.1	Shoulder Width
302.2	Shoulder Cross Slopes -Bridge
302.2	Shoulder Cross Slopes – Left
302.2	Shoulder Cross Slopes – Paved Median
302.2	Shoulder Cross Slopes - Right
Topic 305	Median Standards

Design exception approval of Boldface Standards for nonfreeway facilities, including local streets and roads at interchanges, has been delegated to the Districts. In addition, some District delegations included Boldface Standards applicable to freeways. See your District Design Delegation Agreement for specific delegation.

(1) Caltrans-only Boldface Standard.

(2) Authority to approve deviations from this Boldface Standard is delegated to the State Pavement Engineer.

Table 82.1A

Boldface Standards (Cont.)

Index 305.1	Median Width – Conventional Highways(1)
305.1	Median Width – Freeways and Expressways(1)
Topic 307	Cross Sections for State Highways
Index 307.2	Shoulder Standards for Two-lane Cross Sections for New Construction
Topic 308	Cross Sections for Roads Under Other Jurisdictions
Index 308.1	Cross Section Standards for City Streets and County Roads without Connection to State Facilities
308.1	Minimum Width of 2-lane Over-crossing Structures for City Streets and County Roads without Connection to State Facilities(1)
308.1	Cross Section Standards for City Streets and County Roads with Connection to State Facilities
308.1	Two-Lane Local Road Lane Width for City Streets and County Roads within Interchange
308.1	Multi-Lane Local Road Lane Width for City Streets and County Roads within Interchange
308.1	Shoulder Width Standards for City Streets and County Roads Lateral Obstructions
308.1	Shoulder Width Standards for City Streets and County Roads with Curbs and Gutter
308.1	Minimum Width for 2-lane Overcrossing at Interchanges(1)
Topic 309	Clearances
Index 309.1	Horizontal Clearances and Stopping Sight Distance
309.1	Horizontal Clearances(1)
309.1	High Speed Rail Clearances – Minimum Shoulder Width
309.2	Vertical Clearances - Minor Structures
309.2	Vertical Clearances - Rural and Single Interstate Routing System

Design exception approval of Boldface Standards for nonfreeway facilities, including local streets and roads at interchanges, has been delegated to the Districts. In addition, some District delegations included Boldface Standards applicable to freeways. See your District Design Delegation Agreement for specific delegation.

(1) Caltrans-only Boldface Standard.

(2) Authority to approve deviations from this Boldface Standard is delegated to the State Pavement Engineer.

Table 82.1A

Boldface Standards (Cont.)

309.3	Horizontal Tunnel Clearances(1)
309.3	Vertical Tunnel Clearances
309.4	Lateral Clearance for Elevated Structures(1)
309.5	Structures Across or Adjacent to Railroads - Vertical Clearance
Topic 310	Frontage Roads
Index 310.1	Frontage Road Width Cross Section
CHAPTER 400	INTERSECTIONS AT GRADE
Topic 404	Design Vehicles
Index 404.2	Design Vehicle–Traveled Way(1)
Topic 405	Intersection Design Standards
Index 405.2	Left-turn Channelization - Lane Width
405.2	Left-turn Channelization - Lane Width – Restricted Urban
405.2	Two-way Left-turn Lane Width
405.3	Right-turn Channelization – Lane and Shoulder Width
CHAPTER 500	TRAFFIC INTERCHANGES
Topic 501	General
Index 501.3	Interchange Spacing(1)
Topic 502	Interchange Types
Index 502.2	Isolated Off-Ramps and Partial Interchanges(1)
502.3	Route Continuity(1)
Topic 504	Interchange Design Standards
Index 504.2	Location of Freeway Entrances & Exits(1)
504.2	Ramp Deceleration Lane and “DL” Distance(1)
504.3	Ramp Lane Width

Design exception approval of Boldface Standards for nonfreeway facilities, including local streets and roads at interchanges, has been delegated to the Districts. In addition, some District delegations included Boldface Standards applicable to freeways. See your District Design Delegation Agreement for specific delegation.

(1) Caltrans-only Boldface Standard.

(2) Authority to approve deviations from this Boldface Standard is delegated to the State Pavement Engineer.

Table 82.1A

Boldface Standards (Cont.)

504.3	Ramp Shoulder Width
504.3	Ramp Lane Drop Taper Past the Limit Line(1)
504.3	Metered Multi-Lane Ramp Lane Drop Taper Past the Limit Line(1)
504.3	Ramp Meters on Connector Ramps(1)
504.3	Metered Connector Lane Drop(1)
504.3	Distance Between Ramp Intersection and Local Road Intersection(1)
504.4	Freeway-to-freeway Connections – Shoulder Width – 1 and 2-Lane
504.4	Freeway-to-freeway Connections – Shoulder Width – 3-Lane
504.7	Minimum Entrance Ramp-to-Exit Ramp Spacing(1)
504.8	Access Control along Ramps(1)
504.8	Access Control at Ramp Terminal(1)
504.8	Access Rights Opposite Ramp Terminals(1)
CHAPTER 610	PAVEMENT ENGINEERING CONSIDERATIONS
Topic 612	Pavement Design Life
Index 612.2	New Construction and Reconstruction(1), (2)
612.3	Widening(1), (2)
612.5	Roadway Rehabilitation(1), (2)
Topic 613	Traffic Considerations
Index 613.4	Specific Traffic Loading Considerations(1), (2)
CHAPTER 620	RIGID PAVEMENT
Topic 622	Engineering Requirements

Design exception approval of Boldface Standards for nonfreeway facilities, including local streets and roads at interchanges, has been delegated to the Districts. In addition, some District delegations included Boldface Standards applicable to freeways. See your District Design Delegation Agreement for specific delegation.

(1) Caltrans-only Boldface Standard.

(2) Authority to approve deviations from this Boldface Standard is delegated to the State Pavement Engineer.

Table 82.1A

Boldface Standards (Cont.)

Index 622.5	Transition Panels, Terminal Joints and End Anchors[(1), (2)]
Index 622.7	Dowel Bars and Tie Bars[(1) (2)]
Topic 625	Engineering Procedures for Pavement Rehabilitation
Index 625.2	Rigid Pavement Rehabilitation Strategies[(1), (2)]
Topic 626	Other Considerations
Index 626.2	Shoulder[(1), (2)]
626.2	Tied Rigid Shoulders or Widened Slab Standards[(1), (2)]
626.2	Tied Rigid Shoulders or Widened Slab at Ramps and Gore Standard[(1), (2)]
CHAPTER 630	FLEXIBLE PAVEMENT
Topic 635	Engineering Procedures for Flexible Pavement Rehabilitation
Index 635.2	Mechanistic-Empirical (ME) Design Method for Rehabilitation[(1), (2)]
CHAPTER 700	MISCELLANEOUS STANDARDS
Topic 701	Fences
Index 701.2	Fences on Freeways and Expressways[(1)]
CHAPTER 900	LANDSCAPE ARCHITECTURE
Topic 904	Planting Design
Index 904.9	Plant Establishment
Topic 905	Irrigation Design
Index 905.2	Water Supply

Design exception approval of Boldface Standards for nonfreeway facilities, including local streets and roads at interchanges, has been delegated to the Districts. In addition, some District delegations included Boldface Standards applicable to freeways. See your District Design Delegation Agreement for specific delegation.

(1) Caltrans-only Boldface Standard.

(2) Authority to approve deviations from this Boldface Standard is delegated to the State Pavement Engineer.

Table 82.1A

Boldface Standards (Cont.)

Topic 912	Roadside Site Design
Index 912.1	Freeway Ramp Design
Topic 913	Safety Roadside Rest Areas
Index 913.5	Public Pay Telephone
CHAPTER 1000	BICYCLE TRANSPORTATION DESIGN
Topic 1003	Design Criteria
Index 1003.1	Class I Bikeway Widths(1)
1003.1	Class I Bikeway Shoulder Width(1)
1003.1	Class I Bikeway Horizontal Clearance(1)
1003.1	Class I Bikeway Structure Width(1)
1003.1	Class I Bikeway Vertical Clearance(1)
1003.1	Class I Bikeway Minimum Separation From Edge of Traveled Way(1)
1003.1	Physical Barriers Adjacent to Class I Bikeways(1)
1003.1	Class I Bikeway in Freeway Medians(1)
1003.1	Class I Bikeway Design Speeds(1)
1003.1	Stopping Sight Distance
1003.1	Bikeway Shoulder Slope(1)
1003.1	Obstacle Posts or Bollards in Bicycle Paths(1)
CHAPTER 1100	HIGHWAY TRAFFIC NOISE ABATEMENT
Topic 1102	Design Criteria
Index 1102.2	Horizontal Clearance to Noise Barrier(1)
1102.2	Noise Barrier on Safety Shape Concrete Barrier(1)

Design exception approval of Boldface Standards for nonfreeway facilities, including local streets and roads at interchanges, has been delegated to the Districts. In addition, some District delegations included Boldface Standards applicable to freeways. See your District Design Delegation Agreement for specific delegation.

(1) Caltrans-only Boldface Standard.

(2) Authority to approve deviations from this Boldface Standard is delegated to the State Pavement Engineer.

Table 82.1B

Underlined Standards

CHAPTER 100	BASIC DESIGN POLICIES
Topic 101	Design Speed
Index 101.1	Selection of Design Speed – Local Facilities
101.1	Selection of Design Speed – Local Facilities – with Connections to State Facilities
101.2	Design Speed Standards
Topic 104	Control of Access
Index 104.5	Relation of Access Opening to Median Opening
Topic 105	Pedestrian Facilities
Index 105.2	Minimum Sidewalk Width – Next to a Building
105.2	Minimum Sidewalk Width – Not Next to a Building
105.5	Curb Ramp for each Crossing
Topic 107	Roadside Installations
Index 107.1	Standards for Roadway Connections
107.1	Number of Exits and Entrances Allowed at Roadway Connections
CHAPTER 200	GEOMETRIC DESIGN AND STRUCTURE STANDARDS
Topic 201	Sight Distance
Index 201.3	Stopping Sight Distance on Sustained Grades
201.7	Decision Sight Distance
Topic 202	Superelevation
Index 202.2	Superelevation on Same Plane for Rural Two-lane Roads
202.5	Superelevation Transition
202.5	Superelevation Runoff
202.5	Superelevation in Restrictive Situations
202.6	Superelevation of Compound Curves
202.7	Superelevation on City Streets and County Roads
Topic 203	Horizontal Alignment
Index 203.1	Horizontal Alignment – Local Facilities
203.3	Alignment Consistency and Design Speed

Table 82.1B

Underlined Standards (Cont.)

203.5	Compound Curves
203.5	Compound Curves on One-Way Roads
203.6	Reversing Curves – Transition Length
203.6	Reversing Curves – Transition Rate
Topic 204	Grade
Index 204.1	Standards for Grade – Local Facilities
204.3	Standards for Grade
204.3	Ramp Grades
204.4	Vertical Curves – 2 Percent and Greater
204.4	Vertical Curves – Less Than 2 Percent
204.5	Decision Sight Distance at Climbing Lane Drops
204.6	Horizontal and Vertical Curves Consistency in Mountainous or Rolling Terrain
Topic 205	Road Connections and Driveways
Index 205.1	Access Opening Spacing on Expressways
205.1	Access Opening Spacing on Expressways – Location
Topic 206	Pavement Transitions
Index 206.3	Lane Drop Transitions
206.3	Lane Width Reductions
Topic 208	Bridges, Grade Separation Structures, and Structure Approach Embankment
Index 208.3	Decking of Bridge Medians
208.6	Minimum width of Walkway of Pedestrian Overcrossings
208.6	Minimum Vertical Clearance of Pedestrian Undercrossings
208.6	Class I Bikeways Exclusive Use
208.10	Protective Screening on Overcrossings
208.10	Bicycle Railing Locations
Topic 210	Earth Retaining Systems

Table 82.1B

Underlined Standards (Cont.)

Index 210.6	Cable Railing
CHAPTER 300	GEOMETRIC CROSS SECTION
Topic 301	Traveled Way Standards
Index 301.2	Class II Bikeway Lane Width Adjacent to On-Street Parking,
301.2	Class II Bikeway with Posted Speeds Greater Than 40 Miles Per Hour
301.3	Algebraic Differences of Cross Slopes at Various Locations
Topic 303	Curbs, Dikes, and Side Gutters
303.1	Use of Curb with Posted Speeds of 40 mph and Greater
303.3	Dike Selection
303.4	Bulbout Design
Topic 304	Side Slopes
Index 304.1	Side Slopes 4:1 or Flatter
Topic 305	Median Standards
Index 305.1	Median Width Freeways and Expressways – Urban
305.1	Median Width Freeways and Expressways – Rural
305.1	Median Width Conventional Highways – Urban and Rural Main Streets
305.1	Median Width Conventional Highways – Climbing or Passing Lanes
305.2	Median Cross Slopes
Topic 309	Clearances
Index 309.1	Clear Recovery Zone – 4:1 or Flatter Apply on All Highways
309.1	Clear Recovery Zone – Necessary Highway Features
309.1	Existing Above-Ground Utilities and Existing Large Trees
309.1	Clear Recovery Zone – Discretionary Fixed Objects
309.1	Conventional Highways with Curbs Typically in Urban Areas
309.1	Areas without Curbs to Barriers at Retaining, Pier, or Abutment Walls
309.1	High Speed Rail Clearance
309.5	Structures Across or Adjacent to Railroads – Vertical Clearance

Table 82.1B

Underlined Standards (Cont.)

Topic 310	Frontage Roads
Index 310.2	Outer Separation – Urban and Mountainous Areas
310.2	Outer Separation – Rural Areas
CHAPTER 400	INTERSECTIONS AT GRADE
Topic 403	Principles of Channelization
Index 403.3	Angle of Intersection
403.6	Optional Right-Turn Lanes
403.6	Right-Turn-Only Lane and Bike Use
Topic 404	Design Vehicles and Related Definitions
Index 404.4	STAA Design Vehicles on the National Network, Terminal Access, California Legal, and Advisory routes
404.4	California Legal Design Vehicle Accommodation
404.4	45-Foot Bus and Motorhome Design Vehicle
Topic 405	Intersection Design Standards
Index 405.1	Corner Sight Distance – No Sight Obstruction in Clear Sight Triangle
405.1	Corner Sight Distance – Driver Set Back
405.1	Corner Sight Distance –Minimum Corner Sight Distance and Table
405.1	Corner Sight Distance at Signalized Public Road Intersections
405.1	Corner Sight Distance at Private Road Intersections
405.1	Decision Sight Distance at Intersections
405.3	Curve Radius for Free Right-Turn with Pedestrian Crossing
405.4	Pedestrian Refuge by Area Place Type
405.5	Emergency Openings and Sight Distance
405.5	Median Opening Locations
405.10	Entry Speeds – Single and Multilane Roundabouts
405.10	Pedestrian Crossing Width
405.10	Landscape Buffer/Strip Width
405.10	Sidewalk and Sidewalk Width
405.10	Horizontal Clearance Width

Table 82.1B

Underlined Standards (Cont.)

CHAPTER 500	TRAFFIC INTERCHANGES
Topic 504	Interchange Design Standards
Index 504.2	Ramp Entrance and Exit Standards
504.2	Collector-Distributor Deceleration Lane and “DL” Distance
504.2	Paved Width at Gore
504.2	Contrasting Surface Treatment
504.2	Auxiliary Lanes
504.2	Freeway Exit Nose Design Speed
504.2	Decision Sight Distance at Exits and Branch Connections
504.2	Design Speed and Alignment Consistency at Inlet Nose
504.2	Freeway Ramp Profile Grades
504.2	Differences in Pavement Cross Slopes at Freeway Entrances and Exits
504.2	Vertical Curves Beyond Freeway Exit Nose
504.2	Crest Vertical Curves at Freeway Exit Terminal
504.2	Sag Vertical Curves at Freeway Exit Terminal
504.2	Ascending Entrance Ramps with Sustained Upgrades
504.3	Ramp Terminus Design Speed
504.3	Ramp Lane Drop Taper At 6-foot Separation Point
504.3	Ramp Lane Drop Location
504.3	Metered Entrance Ramps (1 GP + 1 HOV Preferential Lane) Auxiliary Lane
504.3	Metered Entrance Ramps (1 GP + 1 HOV Preferential Lane) Auxiliary Lane on Sustained Grades and Certain Truck Volumes
504.3	HOV Preferential Lane Restrictive Condition Auxiliary Lane
504.3	Metered Multi-Lane Entrance Ramps Lane Drop
504.3	Metered Multi-Lane Entrance Ramps Auxiliary Lane
504.3	Metered Multi-Lane Entrance Ramps Auxiliary Lane on Sustained Grades and Certain Truck Volumes

Table 82.1B

Underlined Standards (Cont.)

504.3	Metered Freeway-to-Freeway Connector Lane Drops
504.3	Ramp Terminals and Grade
504.3	Ramp Terminals and Sight Distance
504.3	Distance between Ramp Intersection and Local Road Intersection
504.3	Entrance Ramp Lane Drop
504.3	Single-Lane Ramp Widening for Passing
504.3	Two-lane Exit Ramps
504.3	Two-lane Exit Ramps and Auxiliary Lanes
504.3	Distance Between Successive On-ramps
504.3	Distance Between Successive Exits
504.4	Freeway-to-freeway Connections Design Speed
504.4	Profile Grades on Freeway-to-freeway Connectors
504.4	Single-lane Freeway-to-freeway Connector Design
504.4	Single-lane Connector Widening for Passing
504.4	Volumes Requiring Branch Connectors
504.4	Merging Branch Connector Design
504.4	Diverging Branch Connector Design
504.4	Merging Branch Connector Auxiliary Lanes
504.4	Diverging Branch Connector Auxiliary Lanes
504.4	Freeway-to-freeway Connector Lane Drop Taper
504.6	Mainline Lane Reduction at Interchanges
504.8	Access Control at Ramp Terminal
CHAPTER 610	PAVEMENT ENGINEERING CONSIDERATIONS
Topic 612	Pavement Design Life
Index 612.6	Temporary Pavements and Detours

Table 82.1B

Underlined Standards (Cont.)

CHAPTER 620	RIGID PAVEMENT
Topic 625	Engineering Procedures for Pavement Rehabilitation
Index 625.2	Rigid Pavement Rehabilitation Strategies
CHAPTER 640	COMPOSITE PAVEMENTS
Topic 645	Engineering Procedures for Pavement Rehabilitation
Index 645.1	General Considerations
CHAPTER 700	MISCELLANEOUS STANDARDS
Topic 701	Fences
Index 701.2	Fences on Freeways and Expressways
CHAPTER 900	LANDSCAPE ARCHITECTURE
Topic 904	Locating Plants
Index 904.4	Median Planting on freeways
904.5	Minimum Tree Setback
904.5	Large trees on freeway and expressway medians
Table 904.5	Large Tree Setback Requirements on Conventional Highways
904.9	Plant Establishment Period
Topic 905	Irrigation Design
Index 905.4	Irrigation Controller
CHAPTER 1000	BICYCLE TRANSPORTATION DESIGN
Topic 1003	Bikeway Design Criteria
Index 1003.1	Class I Bikeway Horizontal Clearance
1003.1	Class I Bikeway in State Highway or Local Road Medians

Table 82.1C

Decision Requiring Other Approvals

CHAPTER 100	BASIC DESIGN POLICIES
Topic 103	Design Designation
Index 103.2	Design Period
Topic 108	Coordination With Other Agencies
Index 108.2	Transit Loading Facilities – Location
108.2	Transit Loading Facilities - ADA
108.3	Rail Crossings*
108.3	Parallel Rail Facilities*
108.5	Bus Rapid Transit – Location and ADA
108.7	Coordination With the FHWA - Approvals
Topic 110	Special Considerations
Index 110.1	Overload Category
110.8	Safety Review Items and Employee Exposure
110.10	Proprietary Items
110.10	Proprietary Items – On Structure
110.10	Proprietary Items – National Highway System
Topic 111	Material Sites and Disposal Sites
Index 111.1	Mandatory Material Sites on Federal-aid Projects
111.6	Mandatory Material Sites and Disposal Sites on Federal-aid Projects
Topic 116	Bicyclists and Pedestrians on Freeway
Index 116	Bicycles and Pedestrians on Freeways
CHAPTER 200	GEOMETRIC DESIGN AND STRUCTURE STANDARDS
Topic 204	Grade

* Authority to approve deviations from this “Decision Requirement” is delegated to the District Director.

Table 82.1C

Decision Requiring Other Approvals (Cont.)

Index 204.8	Grade Line of Structures – Temporary Vertical Clearances
Topic 205	Road Connections and Driveways
Index 205.1	Conversion of a Private Opening
Topic 208	Bridges, Grade Separation Structures, and Structure Approach Embankment
Index 208.11	Deviations from Foundation and Embankment Recommendations
210.4	Cost Reduction Incentive Proposals
CHAPTER 300	GEOMETRIC CROSS SECTION
Topic 303	Curbs, Dikes, and Side Gutters
Index 303.4	Busbulbs
Topic 304	Side Slopes
Index 304.1	Side Slopes – Erosion Control
304.1	Side Slopes – Structural Integrity
309.2	Vertical Clearance on National Highway System
309.2	Vertical Clearance Above Railroad Facilities
309.5	Horizontal and Vertical Clearances at Railroad Structures
CHAPTER 500	TRAFFIC INTERCHANGES
Topic 502	Interchange Types
Index 502.2	Other Types of Interchanges
Topic 503	Interchange Procedure
Index 503.2	Interchange Geometrics

*Authority to approve deviations from this “Decision Requirement” is delegated to the District Director.

Table 82.1C

Decision Requiring Other Approvals (Cont.)

Topic 504	Interchange Design Standards
Index 504.3	HOV Preferential Lane
504.3	Modification to Existing HOV Preferential Lanes
504.3	Enforcement Areas and Maintenance Pullouts – Required Enforcement Area
504.3	Enforcement Areas and Maintenance Pullouts – Removal
504.3	Enforcement Areas and Maintenance Pullouts - Length
504.6	Mainline Lane Reduction
CHAPTER 600	PAVEMENT ENGINEERING
Topic 604	Roles, Resources, and Proprietary Items
Index 604.3	Pavement Recommendations
604.4	Other Resources
Topic 606	Research and Special Designs
Index 606.1	Research and Experimentation
CHAPTER 610	PAVEMENT ENGINEERING CONSIDERATIONS
Topic 614	Soil Characteristics
Index 614.6	Other Considerations
CHAPTER 620	RIGID PAVEMENT
Topic 626	Other Considerations
Index 626.2	Shoulder – Widened Slab
CHAPTER 700	MISCELLANEOUS STANDARDS
Topic 701	Fences
Index 701.2	Locked Gates - Maintenance Force Use*
701.2	Locked Gates – Utility Companies, Non-Utility Entities, or Public Agencies*

*Authority to approve deviations from this “Decision Requirement” is delegated to the District Director

Table 82.1C

Decision Requiring Other Approvals (Cont.)

Topic 706	Roadside Management and Vegetation Control
Index 706.2	Vegetation Control
CHAPTER 800	HIGHWAY DRAINAGE DESIGN
Topic 805	Preliminary Plans
Index 805.1	Requires FHWA Approval
805.2	Bridge Preliminary Report
805.4	Unusual Hydraulic Structures
805.5	Levees and Dams Formed by Highway Fills
805.6	Geotechnical
Topic 808	Selected Computer Programs
Index 808.1	Table 808.1
CHAPTER 820	CROSS DRAINAGE
Topic 829	Other Considerations
Index 829.9	Dams
CHAPTER 830	TRANSPORTATION FACILITY DRAINAGE
Topic 837	Inlet Design
Index 837.2	Inlet Types
CHAPTER 850	PHYSICAL STANDARDS
Topic 853	Pipe Liners and Linings for Culvert Rehabilitation
Index 853.4	Alternative Pipe Liner Materials
CHAPTER 870	CHANNEL AND SHORE PROTECTION – EROSION CONTROL
Topic 872	Planning and Location Studies
Index 872.3	Site Consideration
Topic 873	Design Concepts
Index 873.1	Introduction
873.3	Armor Protection

*Authority to approve deviations from this “Decision Requirement” is delegated to the District Director.

Table 82.1C

Decision Requiring Other Approvals (Cont.)

CHAPTER 900	LANDSCAPE ARCHITECTURE - ROADSIDES
Topic 904	Planting Design
Index 904.1	Planting Design General
Index 904.3	Plant Selection
Topic 905	Irrigation Design
Index 905.1	Irrigation Design General
Index 905.4	Irrigation System Equipment
CHAPTER 910	LANDSCAPE ARCHITECTURE – ROADSIDE SITES
Topic 912	Roadside Sites Design
Index 912.1	Roadside Sites Layout
Index 912.3	Site Furnishings
Topic 913	Safety Roadside Rest Areas
Index 913.4	Safety Roadside Rest Area Buildings and Structures
Index 913.5	Safety Roadside Rest Area Utilities and Facilities
Topic 914	Vista Points
Index 914.3	Vista Point Amenities
Topic 915	Park & Ride Facilities
Index 915.1	Park & Ride Facilities General
CHAPTER 1000	BICYCLE TRANSPORTATION DESIGN
Topic 1003	Miscellaneous Criteria
Index 1003.5	Bicycle Path at Railroad Crossings
CHAPTER 1100	HIGHWAY TRAFFIC NOISE ABATEMENT
Topic 1101	General Requirements
Index 1101.2	Objective – Extraordinary Abatement

*Authority to approve deviations from this “Decision Requirement” is delegated to the District Director.

101.2 Highway Design Speed Standards

Table 101.2 shows appropriate ranges of design speeds that shall be used for the various types of facilities, place types, and conditions listed. For additional guidance, see Index 101.1(2).

Table 101.2

Vehicular Design Speed

Facility Type	Design Speed (mph)
LIMITED ACCESS HIGHWAYS	
Freeways and expressways in mountainous terrain	50-80
Freeways in urban areas	55-80
Freeways and expressways in rural areas	70-80
Expressways in urban areas	50-70
CONVENTIONAL HIGHWAYS (2)	
Rural	
Flat terrain	55-70
Rolling terrain	50-60
Mountainous terrain	40-50
Main Streets – Cities, Towns, and Community Centers	30-40
Urban	
Arterials – Throughways	40-60
Arterials - Main Streets/Rural and Suburban Main Streets	30-40
Downtowns and City Centers	30
LOCAL FACILITIES (Within State right of way)	
Facilities crossing a freeway or expressway, connecting to a conventional highway or traversing a State facility	AASHTO (1)
Facilities connecting to a freeway or expressway	35[B]/45[U]
	B=Boldface Standard U=Underlined Standard

(1) If outside of State right of way and no specific local standards apply, the minimum design speed shall be 30 miles per hour.
(2) For conventional highways eligible or designated as State scenic highways, see Index 109.2.

Topic 102 – Design Capacity & Level of Service

102.1 Design Capacity (Automobiles)

Design capacity (automobiles) is the maximum volume of vehicle traffic for which a projected highway can provide a selected level of service. Design capacity varies with a number of factors, including:

(a) Level of service selected.

(b) Width of lanes.

(c) Number of lanes.

(d) Presence or absence of shoulders.

(e) Grades.

(f) Horizontal alignment.

(g) Operating speed.

(h) Lateral clearance.

(i) Side friction generated by parking, drive ways, intersections, and interchanges.

(j) Volumes of trucks, transit, recreational vehicles, bicycles and pedestrians.

(k) Spacing and timing of traffic signals, and the required timing to accommodate pedestrian crossing

Level of Service (LOS) is largely related to speed and density among many variables. Freeways should be designed to accommodate the design year peak hour traffic volumes and to operate at a LOS determined by District Planning and/or Traffic Operations. For a rough approximation of the number of lanes required on a multilane freeway, use the following design year peak hour traffic volumes per lane at the specified LOS:

	Level of Service	Design Year Peak Hour Vehicle Traffic Volume (Average Automobiles Per Lane Per Hour)
Urban	C-E	1400-2400
Rural	C-D	1000-1850

For conventional highways and expressways, District Planning and Traffic Operations should be consulted.

Automobile traffic volumes can be adjusted for the effect of grades and the mix of automobiles, trucks, and recreational vehicles if a more refined calculation is desired. In those cases, consult the "Highway Capacity Manual", published by the Transportation Research Board.

105.2 Sidewalks and Walkways

The design of sidewalks and walkways varies depending on the setting, standards, and requirements of local agencies. Sidewalks are desirable on conventional highways and on other areas of State highway right of way to serve pedestrians when warranted by sufficient population, density and development. Coordination with the local agency that the State highway passes through is needed to determine the appropriate time to provide sidewalks.

Most local agencies in California have adopted varying design standards for urban and rural areas, as well as more specific requirements that are applicable to residential settings, downtowns, special districts, and other place types. These standards are typically tied to zoning requirements for land use established by local agencies. These land use decisions should take into account the ultimate need for public right of way, including the transportation needs of bicyclists and pedestrians. The minimum width of a sidewalk should be 8 feet between a curb and a building when in urban and rural main street place types. For all other locations the minimum width of sidewalk should be 6 feet when contiguous to a curb or 5 feet when separated by a planting strip. Sidewalk width does not include curbs. See Index 208.4 for bridge sidewalks. Using the minimum width may not be enough to satisfy the actual need if additional width is necessary to maintain an acceptable Level of Service (LOS) for pedestrians. Note that street furniture, buildings, utility poles, light fixtures and platoon generators, such as window displays and bus stops, can reduce the effective width of sidewalks and likewise the LOS of the walkway. Also, adequate width for curb ramps and driveways are other important accessibility considerations.

See Index 205.3(6) and the Standard Plans for sidewalk requirements at driveways.

See Index 208.6 for information on pedestrian overcrossings and undercrossings and Index 208.4 for sidewalks on bridges.

"A Policy on Geometric Design of Highways and Streets", issued by AASHTO, and the "Highway Capacity Manual", published by the Transportation Research Board contain pedestrian LOS criteria. These are means of measuring the ability of the existing pedestrian facilities to provide pedestrian mobility and to determine the need for improvements or expansions. If adequate capacity is not provided, pedestrian mobility may be seriously impeded.

Traffic volume-pedestrian warrants for sidewalks or other types of walkways along highways have not been established. In general, whenever the roadside and land development conditions are such that pedestrians regularly move along a highway, those pedestrians should be furnished with a sidewalk or other walkway, as is suitable to the conditions. Sidewalks are typically within public right of way of the local agency or the State. When within the State highway right of way, the need for sidewalks becomes a shared interest, since the zoning, planned development, and growth are under the local agency's purview. The State may assume financial responsibility for the construction of sidewalks and walkways under the conditions described below. See the Project Development Procedures Manual for further discussion of the State's responsibility in providing pedestrian facilities.

(1) *Replacement in Kind.* Where existing sidewalks are to be disturbed by highway construction, the replacement applies only to the frontages involved and no other sidewalk construction is authorized except:

(a) As part of a right of way agreement.

(b) Where the safety or capacity of the highway will be improved.

(2) *Conventional Highways.* The roadway cross section usually provides areas for pedestrians. If the safety or capacity of the highway will be improved, the State may contribute towards the cost of building a pedestrian facility with a local agency project or fund it entirely with a State highway project. The city, county, or property owner whose adjacent development generated the pedestrian traffic may build sidewalks on State right of way under a permit in accordance with the route concept report.

(3) *Freeway and other Controlled Access Facilities.* Sidewalks should be built across the freeway right of way on overcrossings and through undercrossings where necessary to connect with existing or planned sidewalks. Construction of planned sidewalks should be imminent. Within the foregoing criteria, sidewalks can be part of the original project or added later when the surrounding area develops.

(4) *Overcrossing and Undercrossing Approaches.* Where sidewalks are planned on overcrossing structures or under a structure, an area should be provided to accommodate future sidewalks.

(5) *School Pedestrian Walkways.* School pedestrian walkways may be identified along a route used by school pedestrians that is not limited to crossing locations, but includes where physical conditions require students to walk in or along rural or suburban roadways.

(6) *Frontage Roads.* Sidewalks may be built along frontage roads connecting local streets that would otherwise dead end at the freeways. Such sidewalks can be new or replacements of existing facilities. Sidewalks may not be needed on the freeway side of frontage roads except where connections must be made to pedestrian separations or other connections where appropriate.

(7) *Separated Cross Streets.* Sidewalks may be built on separated cross streets where reconstruction of the cross street is made necessary by the freeway project and where the criteria of paragraph (3) above apply.

(8) *Transit Stops.* Sidewalks should be built to connect transit stops to local streets.

(9) *Vehicular Tunnels*. Sidewalks and pedestrian facilities may be built as part of vehicular tunnels which do not require ventilation as part of the tunnel structure. Contact DES-BD, regarding allowable conditions.

(10) *Maintenance.* The State is responsible for maintaining and replacing damaged sidewalks within the right of way except:

(a) Where the sidewalk was placed by a private party under encroachment permit that requires the permittee to maintain the sidewalk, but only if the original permittee still owns the abutting property.

(b) Where the city or county has placed nonstandard sidewalks with colored or textured surfaces, or meandering alignment. See Maintenance Manual for additional discussion on State's maintenance responsibilities regarding sidewalks.

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

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

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

Section 93 also makes the Department responsible for restoration of the local road or street to its former condition at the conclusion of its use as a detour. The Department is responsible for all reasonable additional maintenance costs incurred by local agencies attributable to the detour. If a betterment is requested by the local agency as a part of restoration it should be done at no cost to the Department.

Topic 107 – Roadside Installations

107.1 Roadway Connections

All connections to vista points, truck weighing or brake inspection stations, safety rest areas, park and ride lots, transit stations or any other connections used by the traveling public, should be constructed to standards commensurate with the standards established for the roadway to which they are connected. On freeways this should include standard acceleration and deceleration lanes and all other design features required by normal ramp connections (Index 504.2). On conventional highways and expressways, the standard public road connection should be the minimum connection (Index 405.7).

Only one means of exit and one means of entry to these installations should be allowed.

107.2 Maintenance and Police Facilities on Freeways

Roadside maintenance yards and police facilities other than truck weighing installations and enforcement areas are not to be provided with direct access to freeways. They should be located on or near a cross road having an interchange which provides for all turning movements. This policy applies to all freeways including Interstate Highways.

Maintenance Vehicle Pullouts (MVPs) provide parking for maintenance workers and other field personnel beyond the edge of shoulder. This improves safety for field personnel by separating them from traffic. It also frees up the shoulder for its intended use. The need and location of MVPs should be determined by the PDT during the Project

Initiation Document phase. MVPs should only be provided if it has been determined that maintenance access from outside the state right of way through an access gate or a maintenance trail within the state right of way is not feasible. Where frequent activity of field personnel can be anticipated, such as at a signal control box (See Index 504.3 (2)(j)) or at an irrigation controller, the MVP should be placed upstream of the work site, so that maintenance vehicles can help shield field personnel on foot. If the controller or roadside feature is located within the clear recovery zone, relocating it outside the clear recovery zone should be considered (See Index 309.1). The shoulder adjacent to MVPs should be wide enough for a maintenance vehicle to use for acceleration before merging onto the traveled way. If adequate shoulder width is unattainable, sufficient sight distance from the MVP to upstream traffic should be provided to prevent maintenance vehicles from disrupting traffic flow. When considering drainage alongside an MVP, it is preferable to provide a flow line around the MVP rather than along the edge of shoulder to collect the drainage before the MVP. This will prevent ponding between the MVP and edge of shoulder.

107.3 Location of Border Inspection Stations

Other agencies require vehicles entering California to stop at buildings maintained by these agencies for inspection of vehicles and cargoes. No such building, parking area, or roadway adjacent to the parking area at these facilities should be closer than 30 feet from the nearest edge of the ultimate traveled way of the highway.

Topic 108 – Coordination With Other Agencies

108.1 Divided Nonfreeway Facilities

Per Section 144.5 of the Streets and Highways Code, advance notice is required when a conventional highway, which is not a declared freeway, is to be divided or separated into separate roadways, if such division or separation will result in preventing traffic on existing county roads or city streets from making a direct crossing of the State highway at the intersection. In this case, 30 day notice must be given to the City Council or Board of Supervisors having jurisdiction over said roads or streets.

The provisions of Section 144.5 of the Streets and Highways Code are considered as not applying to freeway construction, or to temporary barriers for the purpose of controlling traffic during a limited period of time, as when the highway is undergoing repairs, or is flooded. As to freeway construction, it is considered that the local agency receives ample notice, by virtue of the freeway agreement, of the manner in which all local roads will be affected by the freeway, and that the special notice would therefore be superfluous.

When the notice is required, a letter should be prepared and submitted to the appropriate authorities at least 60 days before road revision will occur. Prior to the submittal of the letter and before plans are completed, the appropriate authorities should be contacted and advised of contemplated plans. The timing of this notice should provide ample opportunity for consideration of any suggestions or objection made. In general, it is intended that the formal notice of intent which is required by law will confirm the final plans which have been developed after discussions with the affected authorities.

The PS&E package should document the date notice was given and the date of reply by the affected local agencies.

The Division of Design must be notified by letter as soon as possible in all cases where controversy develops over the closures to crossing traffic.

108.2 Transit Loading Facilities

(1) *Freeway Application.* These instructions are applicable to projects involving transit loading facilities on freeways as authorized in Section 148 of the Streets and Highways Code. Instructions pertaining to the provisions for mass public transportation facilities in freeway corridors, authorized in Section 150 of the Streets and Highways Code, are covered in other Departmental written directives.

(a) During the early phases of the design process, the District must send to the governing bodies of local jurisdictions and common carriers or transit authorities operating in the vicinity, a map showing the proposed location and type of interchanges, with a request for their comments regarding transit loading facilities. The transmittal letter should state that transit loading facilities will be constructed only where they are in the public interest and where the cost is commensurate with the public benefits to be derived from their construction. It should also state that if the agency desires to have transit loading facilities included in the design of the freeway that their reply should include locations for transit stops and any supporting data, such as estimates of the number of transit passengers per day, which would help to justify their request.

(b) Public Meeting and Hearings. No public meeting or hearing is to be held when all of the contacted agencies respond that transit loading facilities are not required on the proposed freeway. The freeway should be designed without transit loading facilities in these cases.

Where any one of the agencies request transit loading facilities on the proposed freeway, the District should hold a public meeting and invite representatives of each agency.

Prior to the public meeting, the District should prepare geometric designs of the transit loading facilities for the purpose of making cost estimates and determining the feasibility of providing the facilities.

(c) Justification. General warrants for the provision of transit loading facilities in terms of cost or number of passengers have not been established. Each case should be considered individually because the number of passengers justifying a transit loading facility may vary greatly between remote rural locations and high volume urban freeways. Consultation with the Project Delivery Coordinator should occur as to the location and design concept.

Transit stops adjacent to freeways introduce security and operational concerns that may necessitate relocating the stop at an off-freeway location. These concerns go beyond having a facility located next to high speed traffic, but also entail the pedestrian route to the facility through a low density area removed from the general public.

It may be preferable for patrons to board and leave the bus or transit facility at an off-freeway location rather than use stairways or ramps to freeway transit stops. Where existing highways with transit service are incorporated into the freeway right of way, it may be necessary to make provisions for bus service for those passengers who were served along the existing highway. This may be accomplished either by providing freeway bus and/or transit loading facilities or by the bus leaving and re-entering the freeway at interchanges. See "A Policy on Geometric Design of Highways and Streets", AASHTO, and "Guide for Geometric Design of Transit Facilities on Highways and Streets", AASHTO for a discussion of transit design and bus stop guidelines.

(d) Reports. On projects where all the agencies contacted have expressed the view that transit stops are not needed, a report to the Division of Design is not required. However, a statement to the effect that the bus companies and local governmental agencies have been contacted regarding transit stops and have made no request for their provisions should be included in the final environmental document or the PS&E submittal, whichever is appropriate.

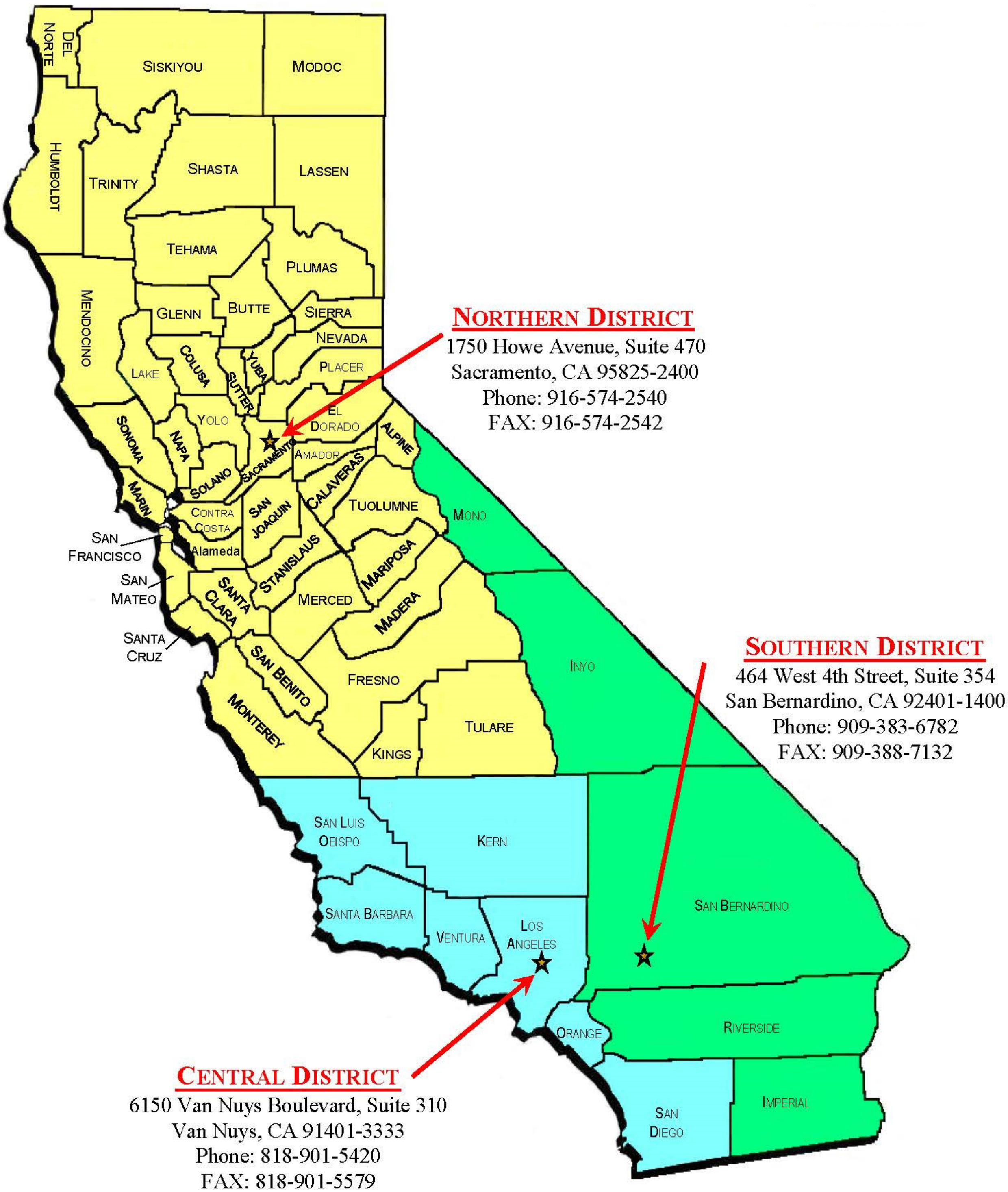
For projects where one or more of the agencies involved have requested transit loading facilities either formally or informally during public meeting(s), a complete report should be incorporated in the final environmental document. It should include:

- A map showing the section of freeway involved and the locations at which transit loading facilities are being considered.
- A complete discussion of all public meetings held.
- Data on type of transit service provided, both at present and after completion of the freeway.
- Estimate of cost of each facility, including any additional cost such as right of way or lengthening of structures required to accommodate the facility.
- Number of transit trips or buses per day and the number of on and off passengers per day served by the transit stops and the number estimated to use the proposed facilities.
- District's recommendation as to the provision of transit loading facilities. If the recommendation is in favor of providing transit loading facilities, drawings showing location and tentative geometric designs should be included.

(e) The DES-BD has primary responsibility for the structural design of transit loading facilities involving structures. See Index 210.7. See also DIB 82 for instructions on submitting rail and transit station plans to the Department of General Services – Division of the State Architect (DSA) for review and approval of pedestrian facilities with regard to accessibility features. Accessible paths of travel must be provided to all pedestrian facilities, including shelters, tables, benches, drinking fountains, telephones, vending machines, and information kiosks. The path of travel from designated accessible parking, if applicable, to accessible facilities should be as short and direct as practical, must have an even surface, and must include curb ramps, marked aisles and crosswalks, and other features as required to facilitate use of the facility by individuals using wheelchairs, walkers or other mobility aids. See the Department of General Services, Division of the State Architect, as well as the California Department of Transportation enforce the California Building Code (Title 24) for the various on-site improvements.

Figure 110.12

California Mining and Tunneling Districts



(4) Proximity and identity of existing utilities and abandoned underground tanks.

(5) Recommendation from owner, agency, lessee, or their agent relative to the possibility of encountering flammable gas or vapors;

(6) The Division may require additional drill hole or other geologic data prior to making gas classifications.

(b) The Division shall classify all tunnels or portions of tunnels into one of the following classifications:

(1) Nongassy, which classification shall be applied to tunnels where there is little likelihood of encountering gas during the construction of the tunnel.

(2) Potentially gassy, which classification shall be applied to tunnels where there is a possibility flammable gas or hydrocarbons will be encountered.

(3) Gassy, which classification shall be applied to tunnels where it is likely gas will be encountered or if a concentration greater than 5 percent of the LEL of:

(A) flammable gas has been detected not less than 12 inches from any surface in any open workings with normal ventilation.

(B) flammable petroleum vapors that have been detected not less than 3 inches from any surface in any open workings with normal ventilation.

(4) Extra hazardous, which classification shall be applied to tunnels when the Division finds that there is a serious danger to the safety of employees and:

Flammable gas or petroleum vapor emanating from the strata has been ignited in the tunnel; or

(A) A concentration of 20 percent of the LEL of flammable gas has been detected not less than 12 inches from any surface in any open working with normal ventilation; or

(B) A concentration of 20 percent of LEL petroleum vapors has been detected not less than three inches from any surface in any open workings with normal ventilation.

(c) A notice of the classification and any special orders, rules, special conditions, or regulations to be used shall be prominently posted at the tunnel job site, and all personnel shall be informed of the classification.

(d) The Division shall classify or reclassify any tunnel as gassy or extra hazardous if the preliminary investigation or past experience indicates that any gas or petroleum vapors in hazardous concentrations is likely to be encountered in such tunnel or if the tunnel is connected to a gassy or extra hazardous excavation and may expose employees to a reasonable likelihood of danger.

(e) For the purpose of reclassification and to ensure a proper application of classification, the Division shall be notified immediately if a gas or petroleum vapor exceeds any one of the individual classification limits described in subsection (b) above. No underground works shall advance until reclassification has been made.

(1) A request for declassification may be submitted in writing to the Division by the employer and/or owner's designated agent whenever either of the following conditions occur:

(A) The underground excavation has been completed and/or isolated from the ventilation system and/or other excavations underway, or

(c) *Width*. Paved widths of at least 15 feet in fill sections and 12 feet in cut sections are recommended. Width is measured from the edge of traveled way. On the outside of curves along steep fill slopes or dropoffs, greater width or the installation of guardrail should be considered.

(d) *Location*. Turnouts should be located where there is stopping sight distance for approaching drivers to see vehicles leaving and re-entering the through lanes.

204.6 Coordination of Horizontal and Vertical Alignment

A proper balance between curvature and grades should be sought. When possible, vertical curves should be superimposed on horizontal curves. This reduces the number of sight restrictions on the project, makes changes in profile less apparent, particularly in rolling country, and results in a pleasing appearance. Where the change in horizontal alignment at a grade summit is moderate, a pleasing appearance may be attained by making the vertical curve overlap the horizontal curve.

When horizontal and vertical curves are superimposed, the combination of superelevation and profile grades may cause distortion in the outer pavement edges which could create drainage concerns or confuse drivers at night. In such situations edge of pavement profiles should be plotted and smooth curves introduced to eliminate any irregularities or distortion.

On highways in mountainous or rolling terrain where horizontal and vertical curves are superimposed at a grade summit or sag, the design speed of the horizontal curve should be at least equal to that of the crest or sag, and not more than 10 miles per hour less than the measured or estimated running (85^{th} percentile) speed of vehicles on the approach roadway.

On long open curves, a uniform grade line should be used because a rolling profile makes for a poor appearance.

Horizontal and vertical curvature at intersections should be as flat as physical conditions permit.

See “Combination of Horizontal and Vertical Alignment” in Chapter III of AASHTO, A Policy on Geometric Design of Highways and Streets, for further guidance on an alignment consistency.

204.7 Separate Grade Lines

Separate or independent grade lines are appropriate in some cases for freeways and expressways.

They are not normally considered appropriate where medians are less than 65 feet wide (see Index 305.6). Exceptions to this may be minor differences between opposing grade lines in special situations. In addition, for either interim or ultimate expressways, any appreciable grade differential between roadbeds should be avoided in the vicinity of at-grade intersections. For traffic entering from the crossroad, confusion and wrong-way movements could result if the pavement of the far roadway is obscured because of excessive grade differential.

204.8 Grade Line of Structures

(1) *Structure Depth.* The depth to span ratio for each structure is dependent on many factors. Some of these are: span, type of construction, aesthetics, cost, falsework limitations, and vertical clearance limitations. For purposes of preliminary planning and design, the depth to span ratios listed below may be used in setting grade lines at grade separations.

(a) Railroad Underpass Structures.

- Single track, through girder type structures: use 5-foot depth from top of rail to structure soffit (bottom of girder).
- Deck-type structures: for simple spans use d/s (depth to span ratio)= 0.08; for continuous multiple span structures use d/s= 0.07. These ratios do not include the additional 2 feet required above the deck for ballast and rail height.

(b) Highway Structures.

- Structures with single spans of 100 feet or less, use d/s= 0.06.
- Structures with single spans between 100 feet and 180 feet use d/s= 0.045.
- Continuous structures with multiple spans of 100 feet or less, use d/s= 0.055.
- Continuous structures with multiple spans of more than 100 feet, use d/s= 0.04.
- Geometric plans should be submitted to the DES–BD prior to preparation of the project report so that preliminary studies can be prepared.

  Preliminary bridge type selection should be a joint effort between the DES–BD and the District.

(2) *Steel or Precast Concrete Structures.* Steel and precast concrete girders in lieu of cast-in-place concrete eliminate falsework, and may permit lower grade lines and reduced approach fill heights. Potential cost savings from elimination of falsework, lowered grade lines, and the ability to accommodate settlement beneath the abutments should be considered in structure type selection along with unit price, aesthetics, uniformity, and any other relevant factors. Note that grade lines at grade separations frequently need to be adjusted after final structure depths are determined (see Index 309.2(3)). Details of traffic handling and stage construction should be provided when the bridge site plan is submitted to the DES–BD if the design or construction of the structure is affected (see Drafting and Plans Manual, Section 3-3.2).

(3) *Depressed Grade Line Under Structures.* Bridge and drainage design will frequently be simplified if the low point in the grade line is set a sufficient distance from the intersection of the centerlines of the structure and the highway so that drainage structures clear the structure footings.

(4) *Grade Line on Bridge Decks.* Vertical curves on bridge decks should provide a minimum fall of 0.05-foot per station. This fall should not extend over a length greater than 100 feet. The flattest allowable tangent grade should be 0.3 percent.

(5) *Falsework.* In many cases, it is economically justified to have falsework over traffic during construction in order to have a support-free open area beneath the permanent structure. The elimination of permanent obstructions usually outweighs objections to the temporary inconvenience of falsework during construction.

Because the width of traffic openings through falsework can, and oftentimes does, significantly affect costs, special care should be given to determining opening widths. The following should be considered: staging and traffic handling requirements, accommodation of pedestrians and bicyclists, the width of approach roadbed that will exist at the time the bridge is constructed, traffic volumes, needs of the local agencies, controls in the form of existing facilities, and the practical challenges of falsework construction.

The normal width of traffic openings and required falsework spans are shown in Table 204.8.

The normal spans shown in Table 204.8 are for anchored temporary barrier. When temporary barrier is not anchored, add 8 feet minimum to normal span to include barrier deflection.

The minimum vertical falsework clearance over freeways and nonfreeways shall be 15 feet. The following items should be considered:

- Mix, volume, and speed of traffic.
- Effect of increased vertical clearance on the grade of adjacent sections.
- Closing local streets to all traffic or trucks only during construction.
- Detours.
- Carrying local traffic through construction on subgrade.
- Temporary or permanent lowering of the existing facility.
- Cost of higher clearance versus cost of traffic control.
- Desires of local agency.

Worker safety should be considered when determining vertical falsework clearance. Requests for approval of temporary vertical clearances less than 15 feet should discuss the impact on worker safety.

Temporary horizontal clearances less than shown in Table 204.8 or temporary vertical clearances less than 15 feet should be noted in the PS&E Transmittal Report.

To establish the grade of a structure to be constructed with a falsework opening, allowance must be made for the depth of the falsework. The minimum depths required for various widths of traffic opening are shown in Table 204.8.

Where vertical clearances, either temporary or permanent are critical, the District and the DES–BD should work closely during the early design stage when the preliminary grades, structure depths, and falsework depths can be adjusted without incurring major design changes.

Where the vertical falsework clearance is less than 15 feet, advance warning devices are to be specified or shown on the plans. Such devices may consist of flashing lights, overhead signs, over-height detectors, or a combination of these or other devices.

Warning signs on the cross road or in advance of the previous off-ramp may be required for overheight permit loads. Check with the Regional Permit Manager.

After establishing the opening requirements, a field review of the bridge site should be made by the District designer to ensure that existing facilities (drainage, other bridges, or roadways) will not conflict with the falsework.

The placement and removal of falsework requires special consideration. During these operations, traffic should either be stopped for short intervals or diverted away from the

Table 204.8

Falsework Span and Depth Requirements

Facility to be Spanned	Minimum Normal Width of Traffic Opening (2)(3)(4)	Resulting Falsework	Depth of Superstructure(5) Up to 6 feet	Up to 8 feet	Up to 10 feet	Up to 12 feet
		Normal Span(1)	Minimum Falsework Depth			
Freeway & Non Freeway	20'	31'	1'-10"	2'-0"	2'-0"	2'-4"
	25'	36'	1'-11"	2'-4"	2'-4"	2'-10"
	32'	43'	2'-5"	2'-11"	2'-11"	3'-2"
	37'	48'	3'-0"	3'-1"	3'-3"	3'-3"
	40'	51'	3'-1"	3'-2"	3'-3"	3'-3"
	49'	60'	3'-3"	3'-3"	3'-3"	3'-4"
	52'	63'	3'-4"	3'-3"	3'-3"	3'-5"
	61'	72'	3'-5"	3'-8"	3'-8"	3'-9"
	64'	75'	3'-5"	3'-8"	3'-8"	3'-9"
	73'	84'	3'-8"	3'-9"	3'-9"	3'-10"

NOTES:

(1) Includes 11' for two temporary barriers and 3.5' to center line of falsework post (12 inch post assumed). This is a minimum clearance for barriers with the maximum number of required anchors. Additional span distance may be required depending on temporary barrier system used and its configuration. See RSS 12-3.20 for additional information.

(2) Approach roadway width measured normal to lanes. Use next highest width if the approach roadway width is not shown in the table.

(3) Dependent upon the width of approach roadbed available at the time of bridge construction.

(4) Clear vehicular opening between temporary railings.

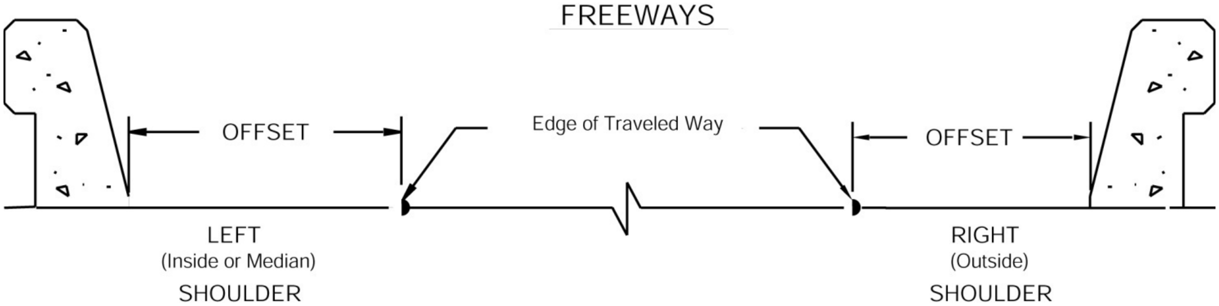
(5) See Index 204.8 for preliminary depth to span ratios. For more detailed information, contact the DES–BD and refer to the Bridge Design Aids.

(6) Distances rounded to nearest inch.

Figure 208.1

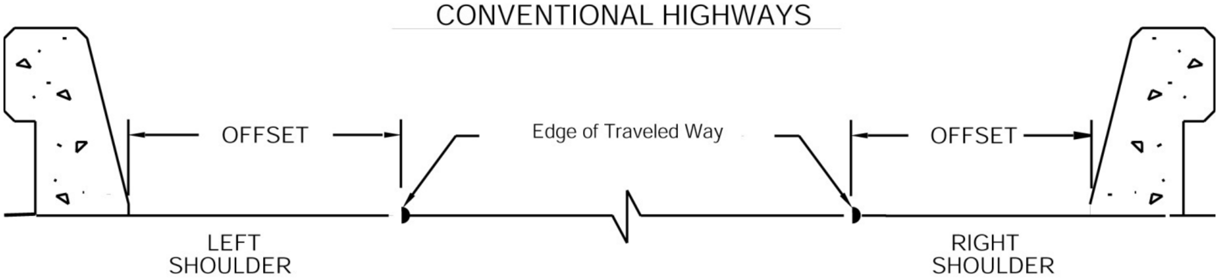
Offsets to Safety-Shape Barriers

FREEWAYS



Approach Shoulder Width	Left Shoulder	Right Shoulder
* 2' & 4' (Ramps)	4'	4'
5'	5'	5'
8'	8'	8'
10'	10'	10'

CONVENTIONAL HIGHWAYS



Approach Shoulder Width	Left Shoulder	Right Shoulder
* 2' & 4'	4'	4'
8'	8'	8'

* See Index 208.1(1)(b)

208.2 Cross Slope

The crown is normally centered on the bridge except for one-way bridges where a straight cross slope in one direction should be used. The cross slope should be the same as for the approach pavement (see Index 301.3 and Index 203.9).

208.3 Median

On multilane divided highways a bridge median that is 36 feet wide or less should be decked. Exceptions require individual analysis. See Traffic Safety Systems Guidance for median barrier warrants.

208.4 Bridge Sidewalks

Sidewalks on bridges should be provided wherever there are sidewalks or other pedestrian facilities that follow the highway. **The minimum width of a bridge sidewalk shall be 6 feet**. The recommended width should be 8 feet for pedestrian comfort. Bridge sidewalks in place types (see Index 81.3) with high levels of pedestrian activity may need to be greater than 8 feet (see Figure 208.10B).

208.5 Open End Structures

Embankment end slopes at open end structures should be no steeper than 1½:1 for all highways.

208.6 Overcrossings and Undercrossings for Pedestrians and Bicycles

A pedestrian overcrossing (POC) or undercrossing (PUC) is a grade separation structure for pedestrians and/or bicycles. See Index 105.3. For the purposes of design guidance, the structure span should conform to guidance for Class I bikeways, or in certain situations the guidance for Class IV bikeways. See Index 1003.1 for Class I bikeway guidance or DIB 89 for Class IV bikeways (separated bikeways) guidance.

The minimum width of walkway for pedestrian overcrossing should be 8 feet. The minimum vertical clearance of a pedestrian undercrossing should be 10 feet. Skewed crossings should be avoided.

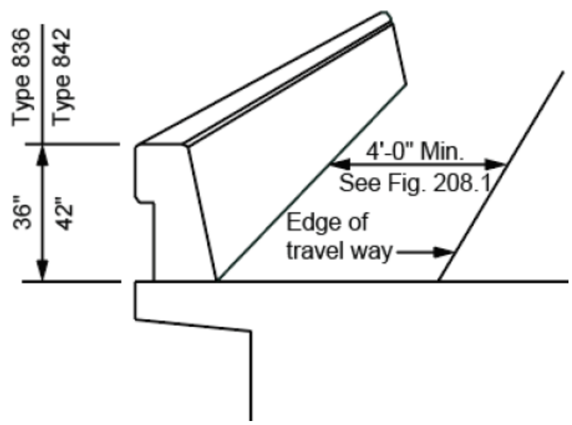
Class I bikeways are designed for the exclusive use of bicyclists and pedestrians; equestrian access is prohibited. See Chapter 1000 for Class I bikeway design guidance and Index 208.7 for equestrian undercrossing guidance. For additional information about the need to separate bicyclists from equestrian trails, see Index 1003.4.

The pedestrian features of POC's and PUC's must be designed to comply with DIB 82.

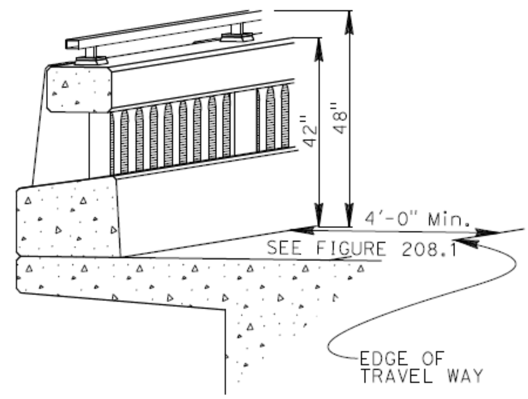
See Topic 309 for vertical clearances.

Figure 208.10A

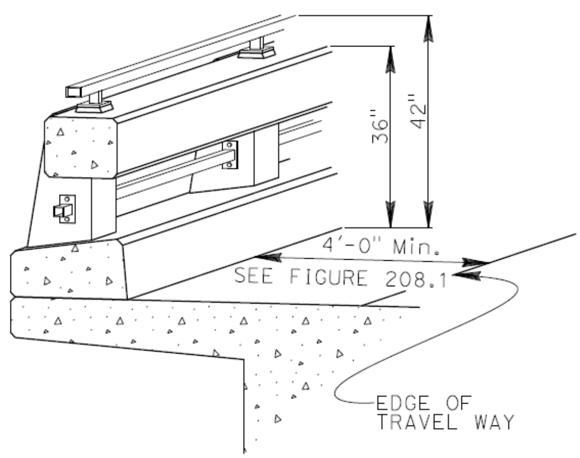
Vehicular and Combination Barriers and Railings



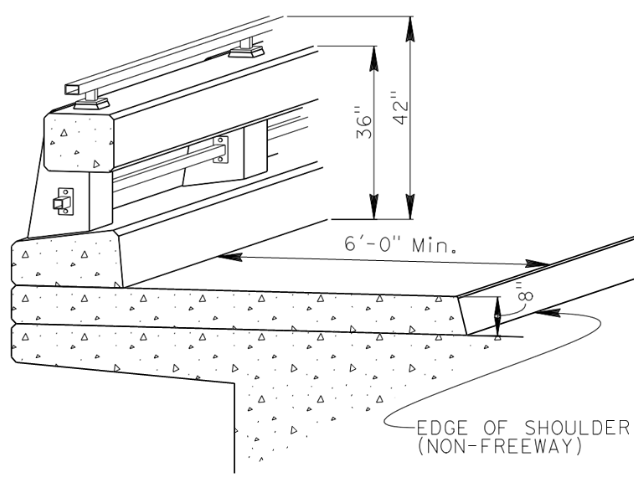
Concrete Barrier Type 836 and Type 842 (MASH 2016 Compliant)



Concrete Barrier Type 86H (MASH 2016 Compliant)



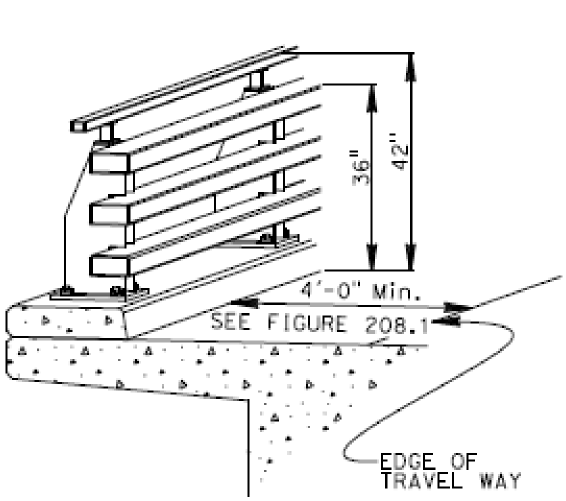
Concrete Barrier Type 85 (MASH 2016 Compliant)



Concrete Barrier Type 85SW (MASH 2016 Compliant)

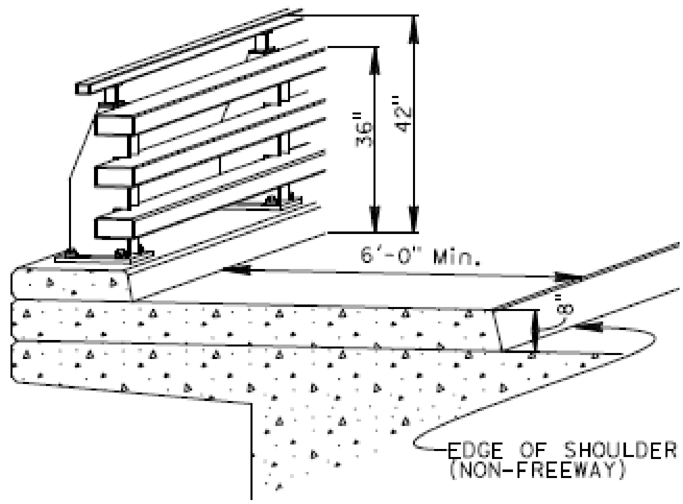
Figure 208.10A (Cont.)

Vehicular and Combination Barriers and Railings



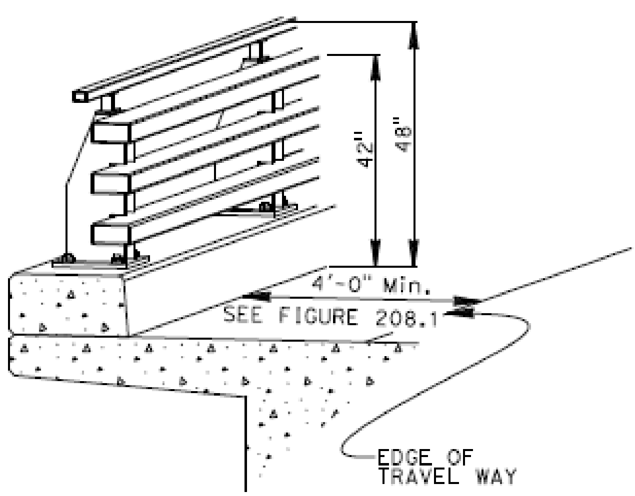
California ST-75 Bridge Rail

(MASH 2016 Compliant)



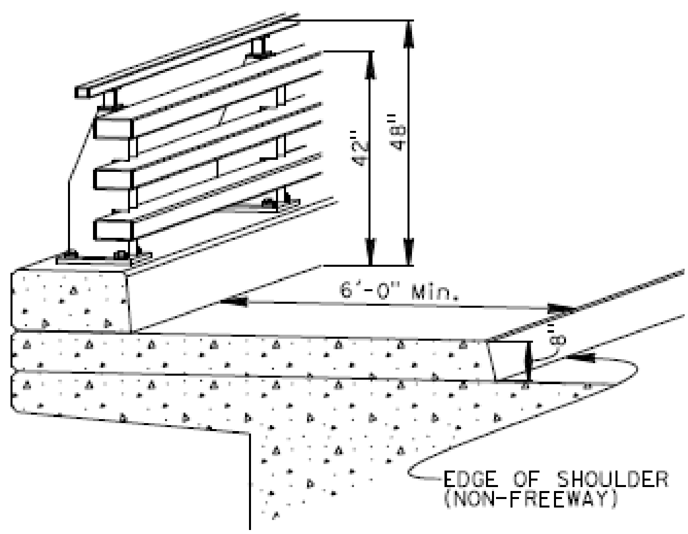
California ST-75SW Bridge Rail

(MASH 2016 Compliant)



California ST-76 Bridge Rail

(MASH 2016 Compliant)

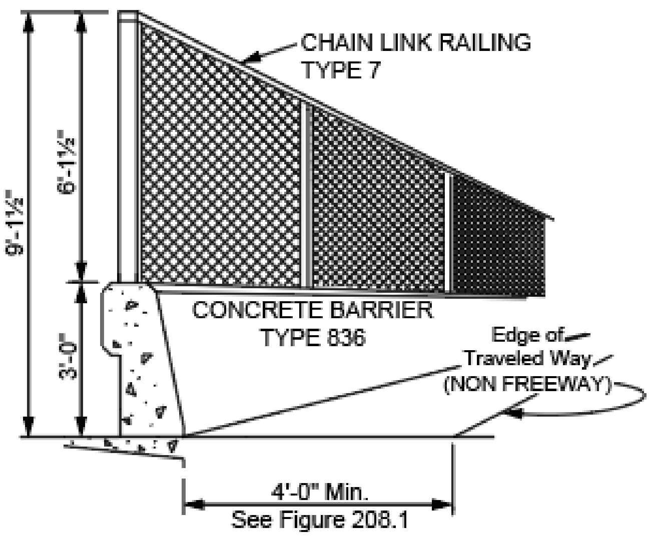


California ST-76SW Bridge Rail

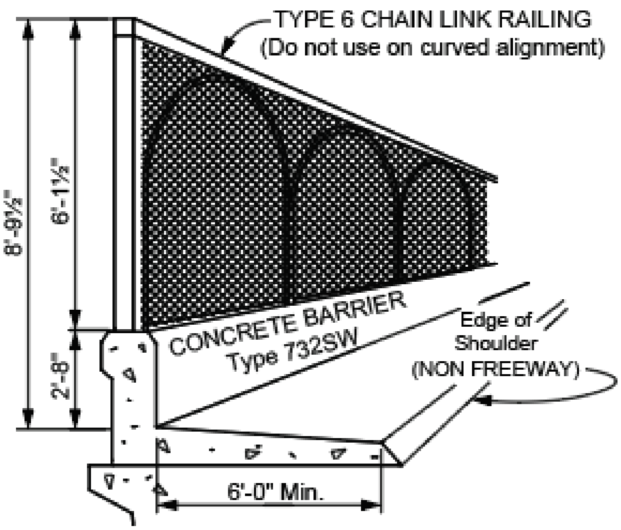
(MASH 2016 Compliant)

Figure 208.10A (Cont.)

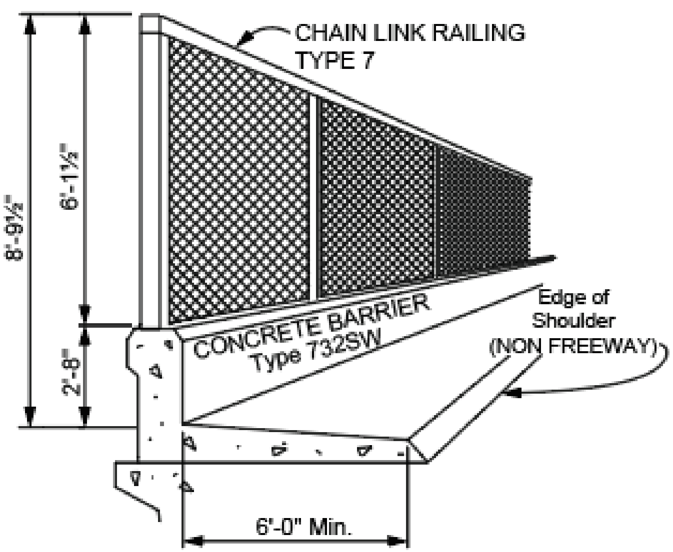
Vehicular and Combination Barriers and Railings



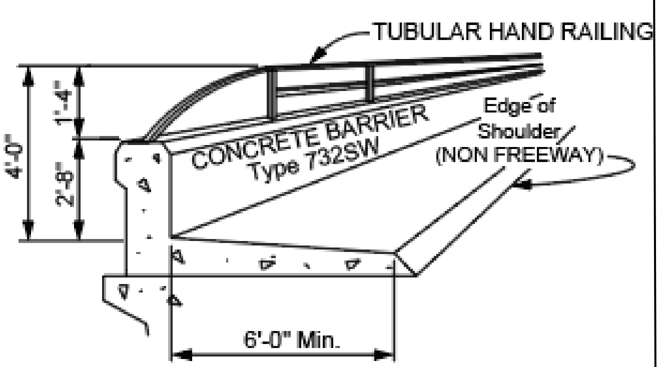
TYPE 836 WITH TYPE 7



TYPE 732SW WITH TYPE 6



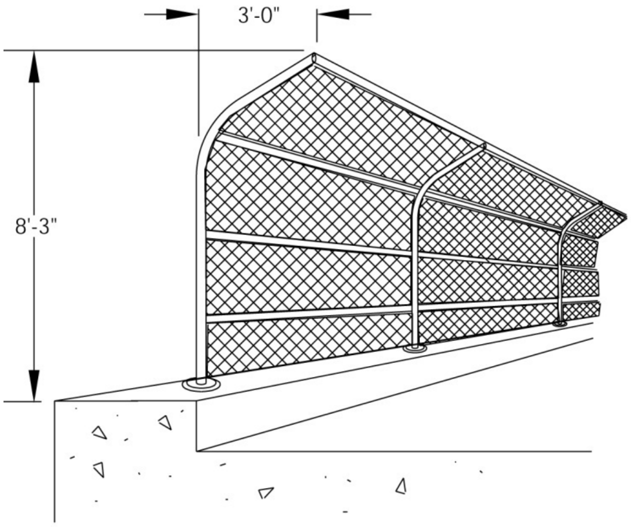
TYPE 732SW WITH TYPE 7



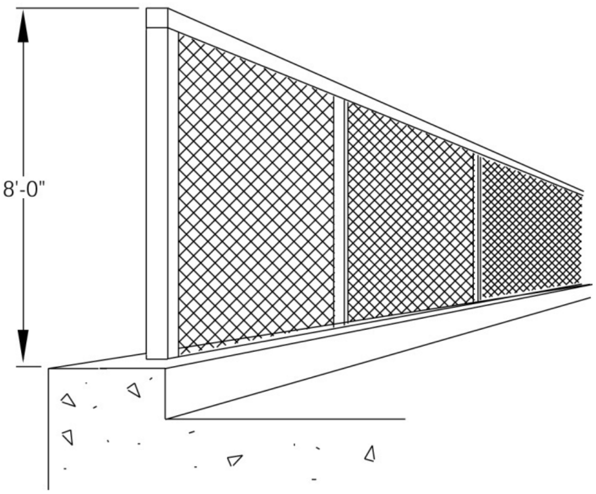
TYPE 732SW WITH TUBULAR HAND RAILING

Figure 208.10B

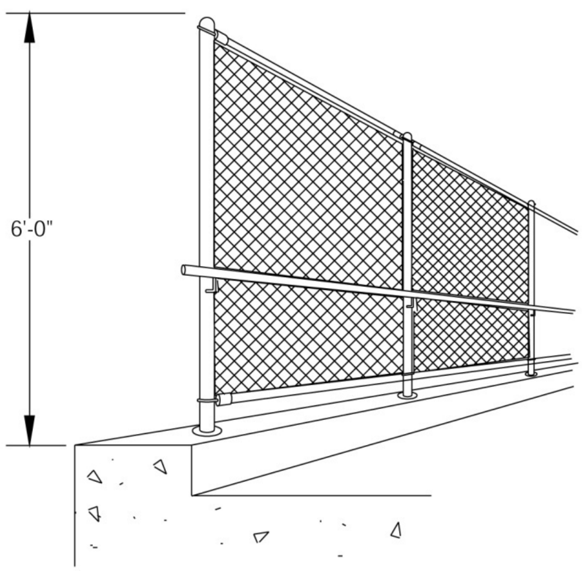
Pedestrian/Bicycle Chain Link Railings



CHAIN LINK RAILING TYPE 3



CHAIN LINK RAILING TYPE 7 (MODIFIED)



CHAIN LINK RAILING

CHAIN LINK RAILING

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

Barriers and railings are denoted by crash testing criteria and crash test level (TL). For more information on the crash test level, see the Traffic Safety Systems Guidance, Table 1, issued by the Division of Traffic Operations.

(3) *Vehicular and Combination Barriers and Railings.* See Figure 208.10A.

(a) Concrete Barrier Type 836 and Concrete Barrier Type 842 – The Type 836 is a TL-4 solid concrete barrier with 36-inch vehicular rail height, and satisfies the Manual for Assessing Safety Hardware (MASH 2016). The Type 842 is a TL-4 solid concrete barrier with 42-inch vehicular rail height and 42-inch bicycle railing height, and satisfies MASH 2016. These vehicular barriers are for general use adjacent to traffic. Figure 208.1 illustrates the position of the barrier relative to the edge of traveled way.

(b) California ST-70SM Side Mounted Bridge Rail – This TL-4 steel post-and-beam barrier is 42-inch vehicular rail height and 42-inch bicycle railing height. This vehicular barrier is for general use adjacent to traffic on slab deck bridges only. This barrier is especially useful when there are right-of-way issues or space limitations. This barrier satisfies MASH 2016.

(c) California ST-75 Bridge Rail – This TL-4 steel post-and-beam barrier is 36-inch vehicular railing height and 42-inch bicycle railing height. This combination vehicular barrier is for general use adjacent to traffic. This barrier satisfies MASH 2016.

(d) California ST-76 Bridge Rail – Similar to California ST-75 Bridge Rail but has a 12-inch concrete curb instead of 6-inch concrete curb. This TL-4 steel post-and-beam barrier is 42-inch vehicular railing height and can have 42-inch or 48-inch bicycle railing height. This combination vehicular barrier is for general use adjacent to traffic. This barrier satisfies MASH 2016.

(e) Concrete Barrier Type 86H – This TL-4 concrete post-and-beam with concrete balusters barrier is 42 inches in vehicular railing height and can have 42-inch or 48-inch bicycle railing height. This combination vehicular barrier is for general use adjacent to traffic and provides the aesthetic solution to replace historic bridge rail. This barrier satisfies MASH 2016.

(f) Concrete Barrier Type 85 – This TL-4 concrete post-and-beam barrier is 36-inch vehicular railing height and 42-inch bicycle railing height. This combination vehicular barrier is for general use adjacent to traffic. This barrier satisfies MASH 2016

(g) Concrete Barrier Type 732SW – This TL-2 solid concrete bridge railing is 32-inch vehicular railing height above top of integral raised sidewalk and can have 42-inch or 48-inch tubular handrailing or taller chain link railing (tubular handrailing and chain link railing are pedestrian railings). This combination vehicular barrier is for general use when sidewalks are provided on a bridge. It must be accompanied with either a tubular handrailing or a fence-type chain link railing. See Index 208.4 for minimum width, however, this width may be increased as circumstances require. This barrier satisfies MASH 2016.

(h) Concrete Barrier Type 85SW – Similar to the Concrete Barrier Type 85, modified with a raised integral sidewalk and tubular handrailing. This TL-2 combination vehicular barrier is intended for use in lower speed scenic or context sensitive areas where more see-through area is desired than is provided by a solid concrete parapet. See Index 208.4 for minimum width, however, this width may be increased as circumstances require. This barrier satisfies MASH 2016..

(i) California ST-75SW Bridge Rail – Similar to ST-75, modified with a raised integral sidewalk and tubular handrailing. This TL-2 combination vehicular barrier is intended for use in lower speed scenic or context sensitive areas where more see-through area is desired than is provided by a solid concrete parapet. See Index 208.4 for minimum width, however, this width may be varied as circumstances require. This barrier satisfies MASH 2016.

(j) California ST-76SW Bridge Rail – Similar to California ST-76 Bridge Rail, modified with a raised integral sidewalk and tubular handrailing. This TL-2 combination vehicular barrier is intended for use in lower speed scenic or context sensitive areas where more see-through area is desired than is provided by a solid concrete parapet. See Index 208.4 for minimum width, however, this width may be increased as circumstances require. This barrier satisfies MASH 2016.

(k) Chain Link Railing Type 7 on bridge rail – This is the fence-type railing for general use with Type 732SW with integral raised sidewalk or with Type 836 or Type 842 to reduce the risk of objects being dropped off, knocked off or thrown off the edge of a structure. When a bridge rail with integral raised sidewalk is provided on one side of a bridge and a solid concrete bridge rail without integral raised sidewalk on the other side, Chain Link Railing Type 7 may be placed on top of the Type 836 or 842 as additional protection from dropped objects. Consideration should be given to the effect of the Chain Link Railing Type 7 on sight distance and view over the side of the bridge. Lighting fixtures may be provided with Chain Link Railing Type 7.

(l) Chain Link Railing Type 6 – This railing may be used in lieu of Type 7 when special architectural treatment is required. It should not be used on curved alignment because of fabrication difficulties.

(m) Chain link railing minimum height on structures over Railroads must be 10 ft from top of bridge deck. See also Figure 309.5A for the limits of the chain link railing/fencing on barrier rail on a bridge over railroad tracks/future tracks/railroad access roads.

(n) Tubular Handrailing – This railing is used with Type 732SW, Type 85SW, ST-75SW, and ST-76SW to increase the combined rail height for the safety of pedestrians. It should be used in lieu of chain link railing on Type 732SW where object dropping/ knocking/ throwing will not be a problem or at the ends of bridges to increase sight distance if fence-type railing would restrict sight distance.

(4) Pedestrian/Bicycle Chain Link Railings. See Figure 208.10B

(a) Chain Link Railing Type 3 – This railing is used on pedestrian structures to reduce the risk of objects being dropped on the roadway below.

(b) Chain Link Railing Type 7 (Modified) – This railing is similar to Type 7 except that it is mounted on the structure at the sidewalk level.

(c) Chain Link Railing – This railing is not as high as Types 3 or 7 and therefore, its use is restricted to those locations where object dropping or throwing will not be a problem.

(d) Chain Link Railing (Modification) – Existing railing may be modified for screening under the protective screening policy. The DES-BD should be contacted for details.

(5) Bicycle Railing. The height of bicycle rail shall not be less than 42.0 inches, measured from the top of the riding surface. If bicycle railing was not attached to a particular bridge rail as part of the crash testing, then the bicycle railing shall be offset 15.0 inches behind the top of the traffic face of the vehicular rail (this applies to Type 836 and Type 842). If stand-alone bicycle railing (not attached to vehicular rail) is at the outside edge of bridge deck, then bicycle railing must be a minimum of 48” height per Section 13 of the California

Amendments to Section 13 of the AASHTO LRFD Bridge Design Specifications (BDS) 8th Edition. Contact DES, Office of Design and Technical Services for more information. Pedestrian railings and combination railings consisting of a concrete barrier surmounted by a fence or tubular railing are satisfactory for bicycles, if a minimum 42-inch height is met. Per Section 13 of AASHTO LRFD BDS 8th Edition with CA Amendments, bicycle railings must be taller than 42 inches minimum in some cases. Bicycles are not considered to operate on a sidewalk, except in special cases where signs specifically direct cyclists to use a bike path or the sidewalk.

As a general policy, bicycle railings should be installed at the following locations:

(a) On a Class I bikeway, except that a lower rail may be used if a curbed sidewalk, not signed for bicycle use, separates the bikeway from the rail or a shoulder at least 8 feet wide exists on the other side of the rail.

(b) On the outside of a Class II or III bikeway, unless a curbed sidewalk, not signed for bicycle use, separates the bikeway from the rail.

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

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

Refer to Traffic Safety Systems Guidance (TSSG) for placement and design criteria of guardrail.

(7) Barrier protection of bridge columns and pier walls must comply with AASHTO LRFD Bridge Design Specifications, Section 3.6.5. The level of protection is required to be TL-5 instead of TL-3 when determined by applying Section 3.6.5.1.

(8) Aesthetic Low Maintenance Guardrail System – This TL-3 system is a combination railing (without integral sidewalk) of an aesthetic see-through bridge railing on a trench footing as an aesthetic low maintenance alternative to guardrail. Examples of these are the Type 85B, Type 86HB, ST-75B, and the ST-76B for which details can be found on the Standard Plan sheets or Bridge Standard Detail sheets for each of these respective bridge rails. These barriers satisfy MASH 2016.

208.11 Structure Approach Embankment

(1) General. Structure approach embankment is that portion of the fill material within approximately 150 feet longitudinally of the structure. Refer to Figure 208.11A for limits, the Standard Specifications, and Standard Special Provisions for more information.

Quality requirements for embankment material are normally specified only in the case of imported borrow. When select material or local borrow for use in structure abutment embankments is shown on the plans, the Resident Engineer (RE) is responsible for assuring the adequacy of the quantity and quality of the specified material. The Project Engineer should include adequate information and guidance in the RE File to assist the RE in fulfilling this responsibility.

(2) Foundations and Embankment Design. Overall performance of the highway approach to the bridge depends, to a significant degree, upon the long-term settlement/consolidation of the approach foundation and structure abutment embankment. A design that minimizes this post construction settlement/consolidation is essential. Factors that influence settlement/consolidation include soil types and depths, static and dynamic loads, ground water level, adjacent operations, and changes in any of the above. The PE must follow the foundation and embankment recommendations by the Division of Engineering Services, Geotechnical Services (DES-GS) and District Materials Engineer

(DME). The DME and/or DES-GS must approve any deviations from their recommendations including Construction Change Orders (CCO's).

The relative compaction of material within the embankment limits must be at least 95 percent, except for the outer 5 feet of embankment measured horizontally from the side slope (see Figure 208.11A). The DME and/or OSF may recommend using select material, local and/or imported borrow to assure that the compaction requirements are met and that shrink/swell problems are avoided. They may also recommend a height and duration of embankment surcharge to accelerate foundation consolidation.

Poor quality material, such as expansive soils, must be precluded from structure abutment embankments unless treated. If sufficient quality roadway excavation material is unavailable for constructing of structure abutment embankments, the designer may specify select material, local borrow, or imported borrow to satisfy the design requirements.

(3) *Abutment Drainage.* Special attention must be given to providing a positive drainage system that minimizes the potential for water damage to the structure approach embankment, see Chapter 870 for further details. The DES-BD is responsible for the design of the structure approach drainage system, which includes:

- A geocomposite drain covered with filter fabric placed behind both the abutment wall and wingwalls, as indicated in Figure 208.11B.
- A slotted plastic pipe drain, encapsulated with treated permeable material, placed along the base of the inside face of the abutment wall as illustrated in Figure 208.11B.

(4) *Slope Treatment.* See Topic 707, Slope Treatment Under Structures, for guidance regarding the treatment of bridge approach end slopes.

The District Hydraulic Engineer or Project Engineer must design a pipe outlet that ties into the structure approach drainage system as it exits the structure. A pipe outlet system should carry the collected water to a location where it will not cause erosion. Storm Water Best Management Practices should be incorporated. For further information on Storm Water Management, visit the Division of Design Storm Water website.

Coordination with DES is necessary for the exit location of the pipe system. The outlet type should be chosen from the standard edge drain outlet types shown in the Standard Plans or tied into an underground drainage system. The PE must review the drainage design to ensure the adequacy of the drainage ties between the structure approach drainage system and either new or existing drainage facilities. For alternative details, see Bridge Design Aids.

Figure 208.11A

Limits of Structure Approach Embankment Material

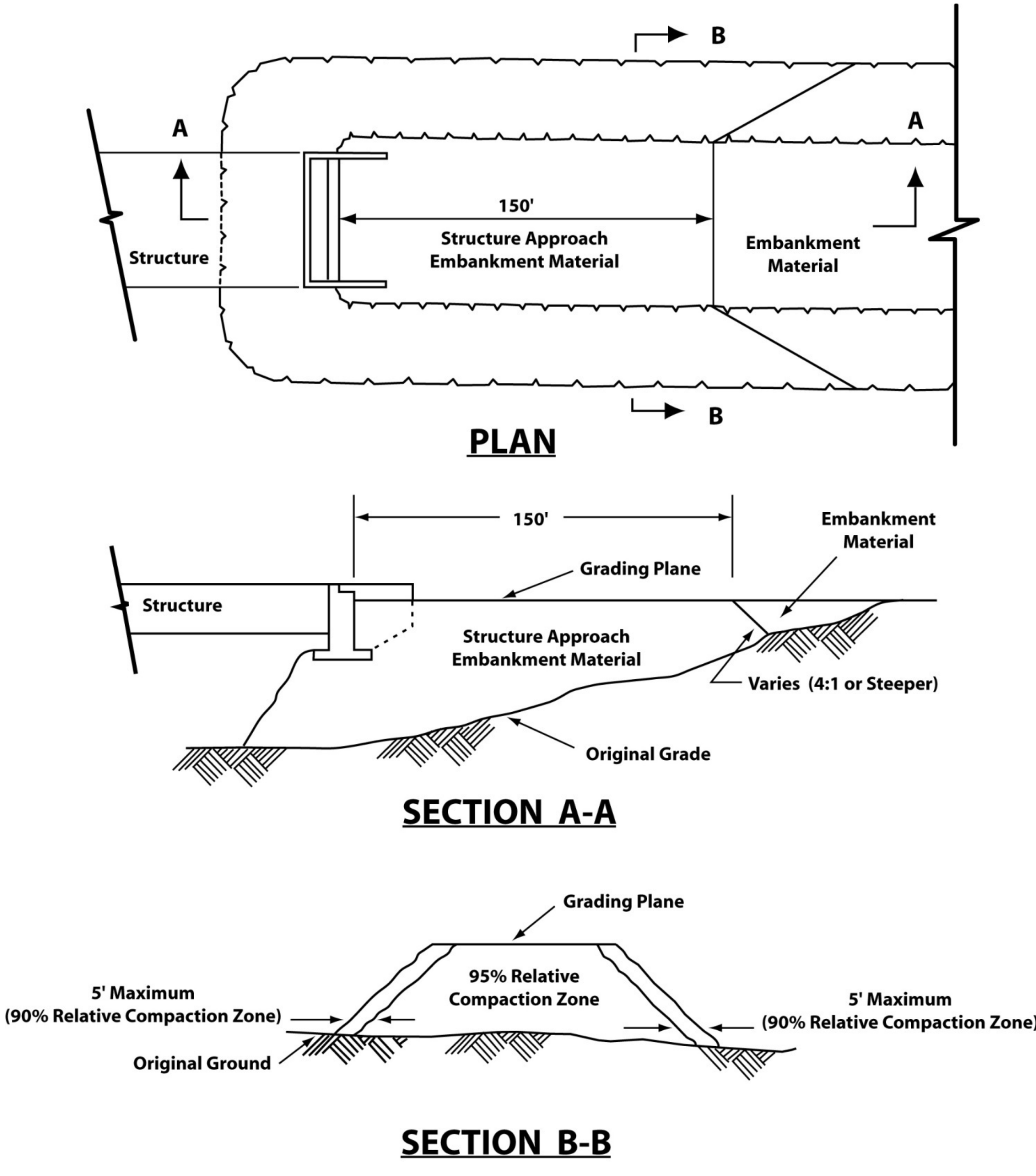
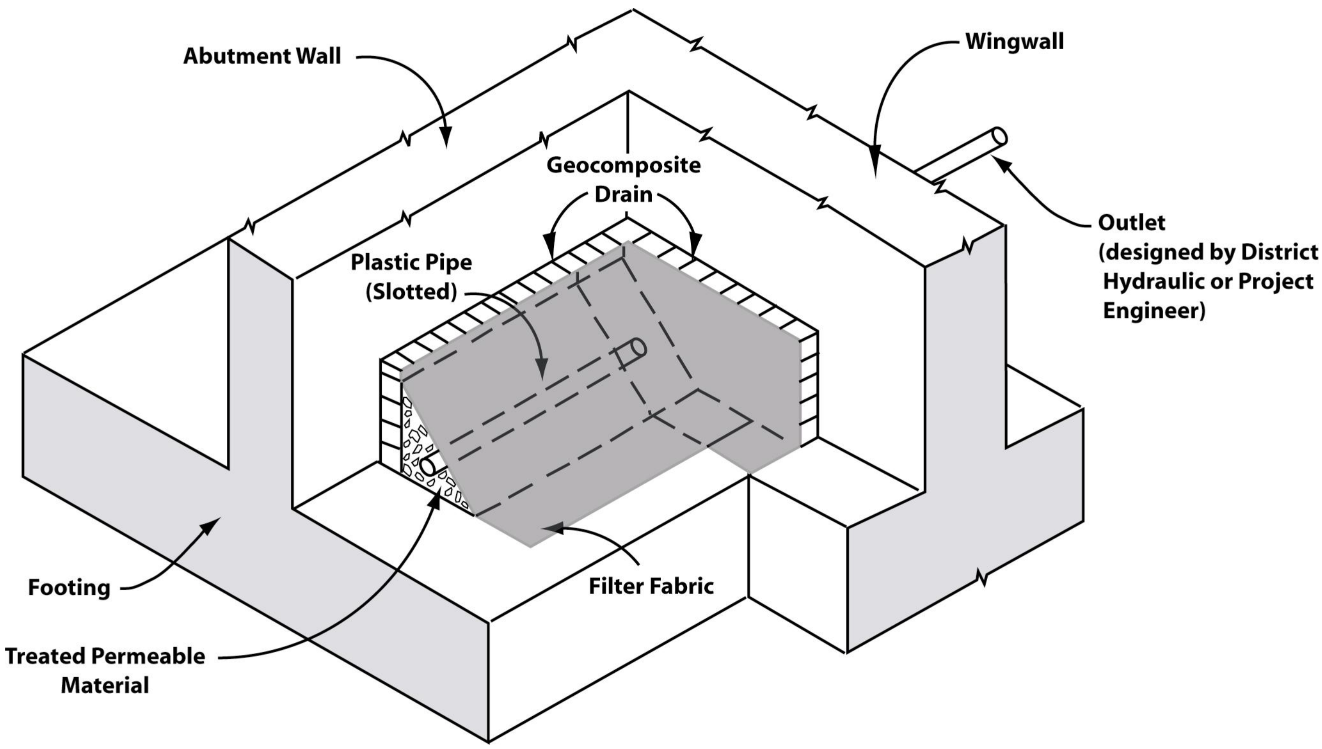


Figure 208.11B

Abutment Drainage Details



NOTES:

1. Applicable to new construction only.
2. Reference Standard Plan B9-6.
3. All details shown are designed by the DES except where noted otherwise.
4. Outlet may be in wingwall of abutment wall.

Topic 209 – Structure Approach Slabs

209.1 Purpose and Application

(1) *Purpose.* The approaches to any structure, new or existing, often present unique geometric, drainage, pavement, and traffic situations that require special considerations.

Structure approach slabs provide a smooth transition between a pavement that is generally supported on a yielding medium (soil that is subject to consolidation and settlement) and a structure, which is supported on a relatively unyielding foundation (bridge).

These guidelines should be followed in the engineering of all structure approach slab projects involving new construction, reconstruction, widening, preservation, or rehabilitation of structure approaches. They are not, however, a substitute for engineering knowledge, experience, or sound judgment.

(2) *Application.* There are several alternatives that may be considered in the design of a structure approach slab system. These alternatives are designated as Types 30, and 10 structure approach slab systems. Standard details and special provisions for each type of approach slab system can be found on the Bridge Design website. Figure 209.1 shows a generic structure approach slab system layout.

Structure approach slabs extend the full width of the traveled way and shoulders. The DES will select the appropriate structure approach slab and provide applicable details, specifications, and an estimate of cost for inclusion in the PS&E package. The Project Engineer (PE) must coordinate with structure engineer to assure that the proper structure approach slab is included in the PS&E package.

On new construction projects, overcrossing structures constructed in conjunction with the State highway facility should receive the same considerations as the highway mainline.

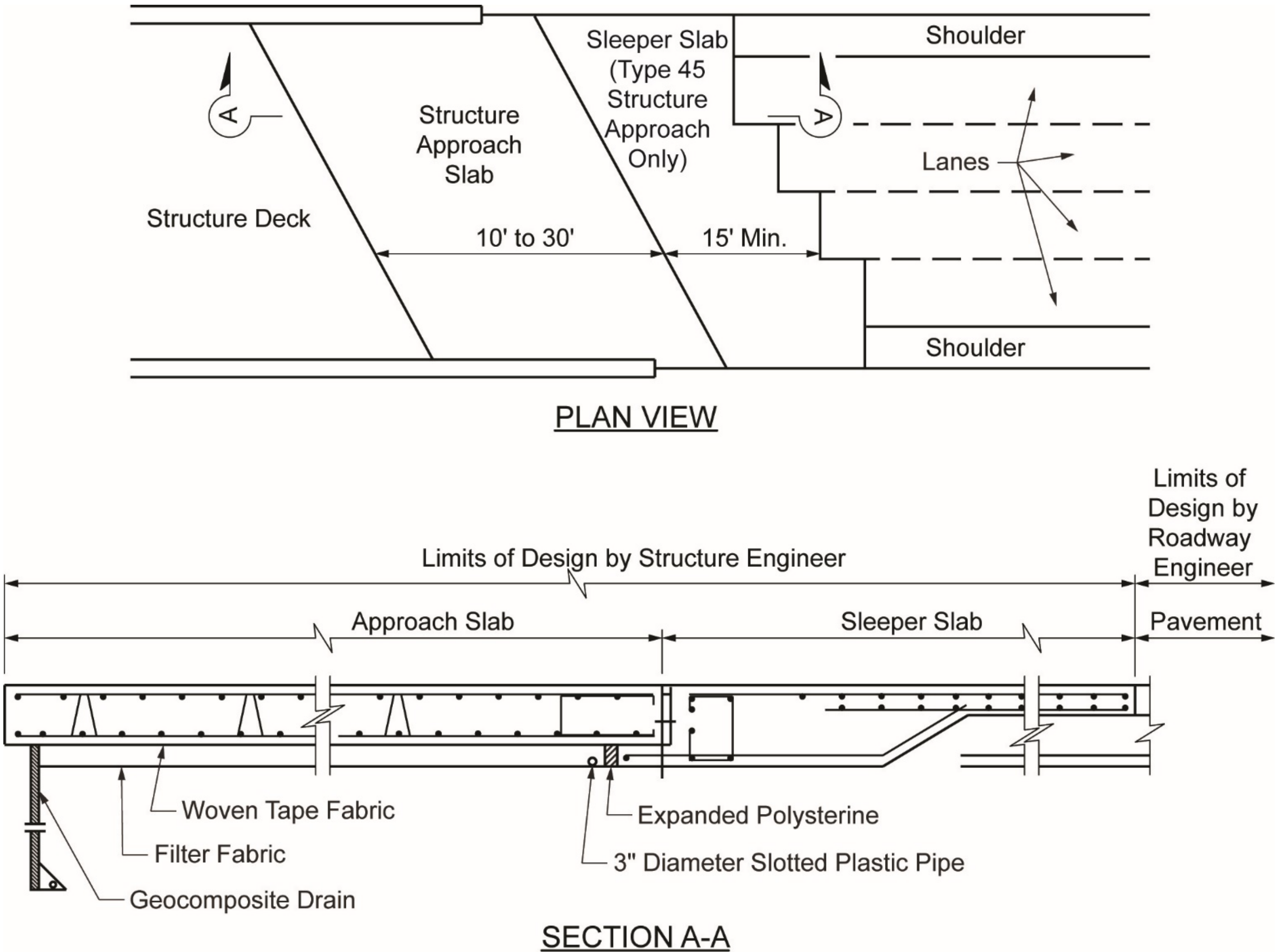
209.2 General Considerations

(1) *Field Investigations.* Adequate information must be available early in the project development process if all factors affecting the selection and engineering of a structure approach slab system are to be adequately addressed. A field review will often reveal existing conditions, which must be taken into consideration during the design.

(2) *Load Transfer at Approach Slab/Concrete Pavement Joint*. No matter what structure approach slab alternative is being considered, it is recommended that dowel bars be placed at the transverse joint between the structure approach slab and new rigid pavement to ensure load transfer at the joint. If the structure approach slab is being replaced but the adjacent rigid pavement is not, a dowel bar retrofit is not necessary. The thinner of either the pavement or the structure approach slab will govern placement of the dowel bar at half the thickness of the thinner slab. The Standard Plans provide other details for transitions from the structure approach slabs to flexible pavement.

Figure 209.1

Structure Approach Slab Layout



(3) *Barriers*. On new construction, the structure approach slab extends laterally to coincide with the edge of structure. Any concrete barriers next to the structure approach slab will therefore need to be placed on top of the structure approach slab; this design is part of the responsibilities of the structures engineer. The PE should coordinate with structure engineers to coordinate the limits and responsibility for barriers.

(4) *Guardrails*. The extension of the structure approach slab across the full width of the outside shoulder creates a conflict between the outside edge of these slabs and the standard horizontal positioning of some guardrail posts. Consult with district traffic branch if a conflict is encountered. See DES Standard Details and the Standard Plans.

209.3 Structural Approach System Drainage

(1) *Subsurface Drainage*. Figure 209.1 shows the components of the positive structural drainage system. Filter fabric should be placed on the grading plane to minimize contamination of the treated permeable base (TPB) for all types of structure approach systems. The plastic pipe shall have a proper outlet to avoid erosion of the structure approach embankment. On all new construction projects, regardless of the type of structure approach slab, provisions for positive drainage of the approach system should be incorporated into the design. See Bridge Design Standard Details for requirements. The Districts are responsible for all drainage considerations for the roadway while DES Structures is responsible for structure related drainage. The structure engineer is responsible for engineering of both the approach slab and the drainage system, which normally drain through the wingwall. The highway engineer is responsible for engineering the collection and disposal system, which begins on the outside face of the wingwall.

(2) Surface Drainage. Roadway surface drainage should be intercepted before reaching the approach/sleeper slab. The objective is to keep water away from the structure approach embankment. The surface water, once collected, should be discharged at locations where it will not create erosion. Refer to Chapter 831 for more information.

209.4 Structure Approach Slab Rehabilitation Considerations

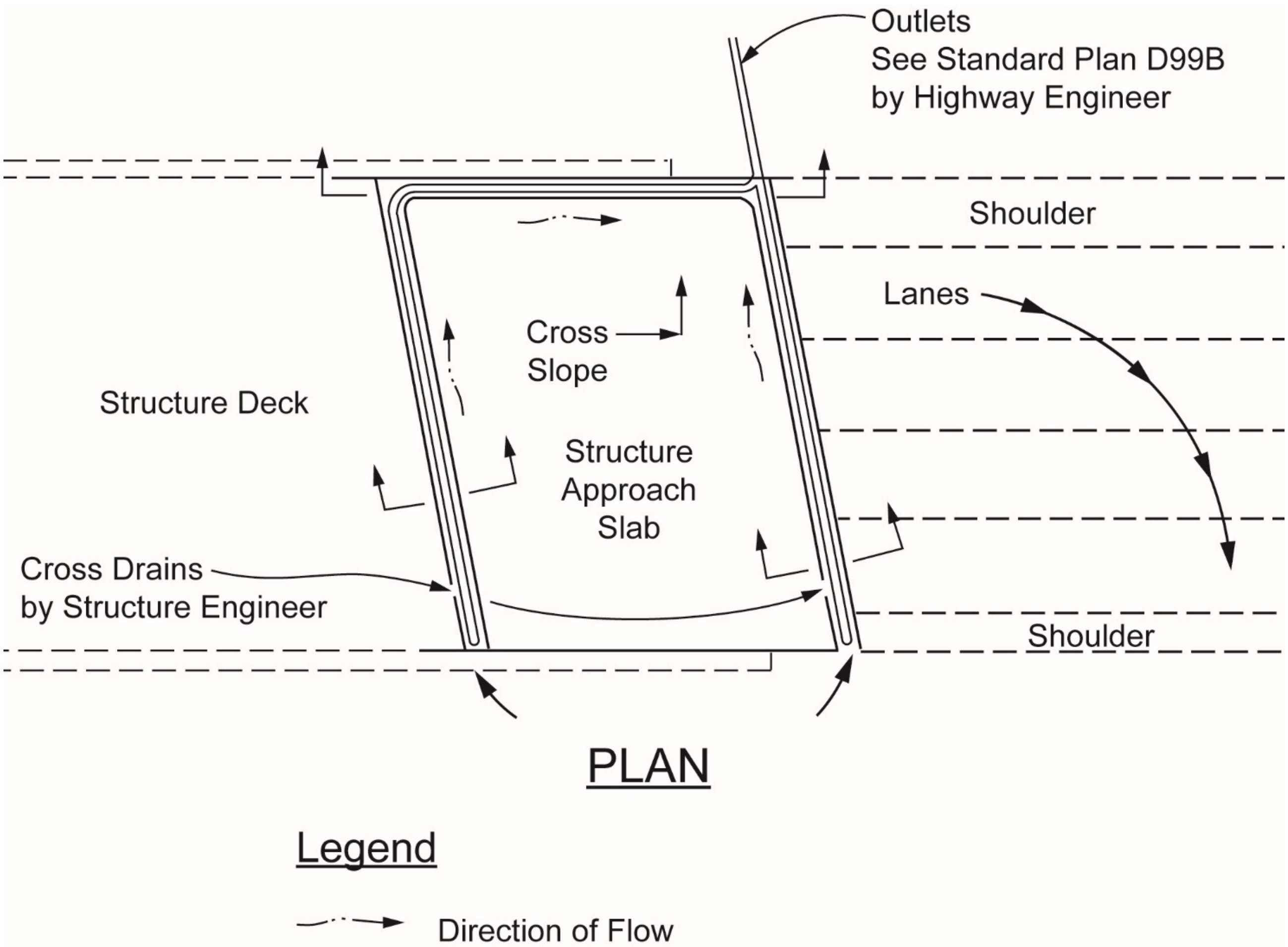
(1) *Approach Slab Replacement.* Approach slabs are replaced only when they exhibit sufficient cracking or patching that they are no longer maintainable as is. Structure Maintenance and Investigations (SMI) typically determines when an approach slab warrants replacement. Approach slabs that otherwise experience only rough ride, subsidence, or minor damage are ground, overlaid, or patched as recommended by SMI. Approach slab repairs are typically funded from one of the bridge repair programs in the SHOPP, but can also be funded from another fund program with the agreement of the Headquarters Program Manager for that program when no other bridge work is involved.

Replacement of a structural approach slab consists of removing the existing pavement, approach slab, underlying base and subsealing material (if applicable) and then replacing with an appropriate type of structure approach system. Depending on the thickness of the existing surface and base layers to be removed, the minimum 1-foot approach slab thickness may have to be increased. The PE needs to make sure the structure engineer addresses this in their reports, plans, and specifications.

(2) *Approach Slab Overlays.* Asphalt pavement overlays should not be placed on structure decks and approach slabs without the concurrence of Structure Maintenance and Investigations (SMI). If an overlay is needed, SMI will provide the recommended strategy.

Figure 209.4A

Structure Approach Drainage Details (Rehabilitation)



If another strategy such as polyester concrete is used, either SMI or the Office of Bridge Design (OBD) will provide the design details.

(3) Structure Approach Slab Drainage. Typical details for providing positive drainage of a full-width structure approach system are shown in Figure 209.4A. Cross drains are placed at the abutment backwall and at the transverse joint between the existing pavement and the structure approach slab by the structure engineer. A collector/outlet system is placed adjacent to the wingwall at the low side of pavement. The collected water is carried away from the structure approach slab at a location where it will not cause erosion. The PE is responsible for the engineering of the outlet for the structure approach slab drainage. Storm Water Best Management Practices should be considered.

Storm water guidelines are available on the Division of Design, Storm Water website.

The structure approach slab edge details to prevent entry of water at the barrier rail face apply when the wingwalls and/or bridge barrier railing are not being reconstructed.

(4) Transition Details with Pavement Overlays. Modification to structure approach slab thicknesses are advantageous when structure approach slabs will be replaced in conjunction with a pavement overlay strategy to promote a smooth transition between structure and pavement. Figure 209.4B, which is applicable to full-width slab replacement, illustrates a method of transitioning from an asphalt overlay thickness to a structure approach slab by tapering the thickness of the structure approach slab. Care should be taken in areas with flat grades to avoid creating a ponding condition at the structure abutment.

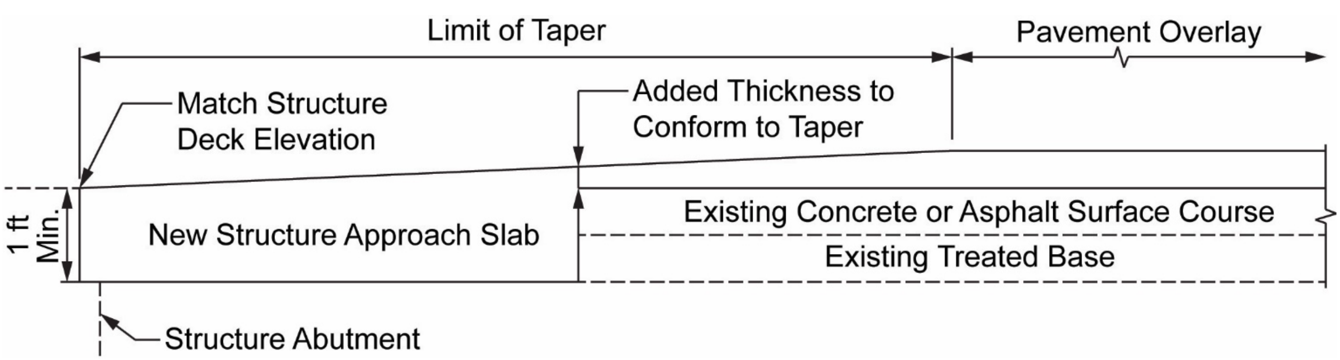
(5) Traffic Handling. Traffic handling considerations typically preclude full-width construction procedures. Structure approach rehabilitation is therefore usually done under traffic control conditions, which require partial-width construction.

District Division of Traffic Operations should be consulted for guidance on lane closures and traffic handling.

When developing traffic handling plans for structure approach slabs, where replacing markings is necessary, and where there is a need to maintain traffic during construction, the engineer should be aware that pavement joints should not be located underneath any of the wheel paths.

Figure 209.4B

New Structure Approach Pavement Transition Details



Topic 210 – Reinforced Earth Slopes and Earth Retaining Systems

210.1 Introduction

Constructing roadways on new alignments, widening roadways on an existing alignment, or repairing earth slopes damaged by landslides are situations that may require the use of reinforced earth slopes or earth retaining systems. Using cut and embankment slopes that are configured at slope ratios that are stable without using reinforcement is usually preferred; however, topography, environmental concerns, and right of way (R/W) limitations may require the need for reinforced earth slopes or an earth retaining system.

The need for reinforced earth slopes or an earth retaining system should be identified as early in the project development process as possible, preferably during the Project Initiation Document (PID) phase.

210.2 Construction Methods and Types

(1) Construction Methods

Both reinforced earth slopes and earth retaining systems can be classified by the method in which they are constructed, either top-down or bottom-up.

- "Top-down" construction – This method of construction begins at the top of the reinforced slope or earth retaining system and proceeds in lifts to the bottom of the reinforced slope or earth retaining system.

  If required, reinforcement is inserted into the in situ material during excavation.

- "Bottom-up" construction – This method of construction begins at the bottom of the reinforced slope or earth retaining system, where a footing/leveling pad is constructed, construction then proceeds towards the top of the reinforced slope or earth retaining system. If required, reinforcement is placed behind the face of the reinforced slope or earth retaining system. It should be noted that if a "Retaining Wall" earth retaining system is to be used in a cut situation, a temporary back cut or shoring system is required behind the wall.

The District Project Engineer (PE) should conduct an initial site visit and assessment to determine all potential construction limitations. The preferred construction method is top-down due to the reduced shoring, excavation and backfilling. However, this method is not always available or appropriate based on the physical and geotechnical site conditions. The site should also be examined for R/W or utility constraints that would restrict the type of excavation or limit the use of some equipment. In addition, the accessibility to the site for construction and contractor staging areas should be considered.

Table 210.2 summarizes the various reinforced earth slopes and earth retaining systems that are currently available for use, along with the method in which they are constructed.

Table 210.2

Types of Reinforced Earth Slopes and Earth Retaining Systems[1]

EARTH RETAINING SYSTEM	Construction Method[2]	PS&E By	Typical Facing Material	Recommended Maximum Vertical Height, ft	Ability to Tolerate Differential Settlement[3]
Reinforced Earth Slopes					
Reinforced Embankments	BU	District PE	Vegetation/Soil	160	E
Rock/Soil Anchors	TD	District PE	Soil/Rock	130	E
State Designed Earth Retaining Systems with Standard Plans					
Concrete Cantilever Wall, Type 1 & 1A	BU	District PE	Concrete	36, 12, 22[4]	P
Concrete L-Type Cantilever Wall, Type 5	BU	District PE	Concrete	12[4]	P
Concrete Masonry Wall, Type 6	BU	District PE	Masonry	6[4]	P
State Designed Earth Retaining Systems Which Require Special Designs					
Standard Plan Walls with modified wall geometry, foundations or loading conditions	BU	Structure PE	Concrete, Steel, Timber	50	P-F
Non-Gravity Cantilevered Walls					
Sheet Pile Wall	TD	Structure PE	Steel	20	F
Soldier Pile Wall with Lagging	TD/BU	Structure PE	Concrete, Steel, Timber	20	F-G
Tangent Soldier Pile Wall	TD/BU	Structure PE	Concrete	30	F
Secant Soldier Pile Wall	TD	Structure PE	Concrete	30	F
Slurry Diaphragm Wall	TD	Structure PE	Concrete, Shotcrete	80[5]	F
Deep Soil Mixing Wall	TD	Structure PE	Shotcrete	80[5]	F-G
Anchored Wall (Structural or Ground Anchors)	TD	Structure PE	Concrete, Steel, Timber	80[6]	F-G
Gravity Walls					
Concrete Gravity Wall	BU	Structure PE	Concrete	6	P
Rock Gravity Wall	BU	District PE	Rock	13	E
Gabion Basket Wall	BU	District PE	Wire & Rock	26	E
Soil Reinforcement Systems					
Mechanically Stabilized Embankment	BU	Structure PE	Concrete	50	G
Salvaged Material Retaining Wall	BU	District PE	Steel, Timber	16	G
Soil Nail Wall	TD	Structure PE	Concrete, Shotcrete	80	F
Tire Anchored Timber Wall	BU	District PE	Timber	32	G
Proprietary Earth Retaining Systems (Pre-approved)					
The list of Pre-approved systems is available at the website shown in Index 210.2(3)(c).					
Proprietary Earth Retaining Systems (Pending)					
These systems are under review by DES-BD. For more information, see Index 210.2(3)(d).					
Experimental State Designed Earth Retaining Systems					
Geosynthetic Reinforced Walls	BU	Structure PE/ District PE	Concrete Blocks, Steel, Vegetation, Fabric	65	E
Mortarless Concrete Blocks Gravity Walls	BU	District PE	Concrete Blocks	8	P

NOTES:
1. Comparative cost data is available from DES-BD.
2. BU = Bottom Up; TD = Top Down
3. E = Excellent; G = Good; F = Fair; P = Poor
4. Maximum Design Height
5. Anchors may be required
6. With lagging

(2) Reinforced Earth Slopes (PS&E by District PE)

Reinforced earth slopes incorporate metallic or non-metallic reinforcement in construction of embankments and cut slopes with a slope angle flatter than 70 degrees from the horizontal plane. Reinforced earth slopes should be used in conjunction with erosion mitigation measures to minimize future maintenance costs. The slope face is typically erosion protected with the use of systems such as geosynthetics, bio-stabilization, rock slope protection, or reinforced concrete facing.

(3) Earth Retaining Systems

Earth retaining systems can be divided into five major categories depending upon the nature of the design and whether they are designed by the owner (State designed), a Proprietary vendor or a combination thereof. The term “State designed” as referenced herein is utilized to encompass earth retaining systems that are designed by the State or by Local or Private entities on behalf of the State.

No assignment of roles and responsibilities is intended. The five categories are as follows:

(a) State Designed Earth Retaining Systems which utilize Standard Plans (PS&E by District PE).

Standard Plans are available for a variety of earth retaining systems (retaining walls). Loading conditions and foundation requirements are as shown on the Standard Plans. For sites with requirements that are not covered by the Standard Plans, a special design is required. To assure conformance with the specific Standard Plan conditions and requirements, and subsequent completion of the PS&E in a timely fashion, the District PE should request a foundation investigation for each location where a retaining wall is being considered. Retaining walls that utilize Standard Plans are as follows:

- Retaining Wall Types 1 and 1A (Concrete Cantilever). These walls have design heights up to 36 feet and 12 feet respectively, but are most economical below 20 feet. Concrete cantilever walls can accommodate traffic barriers, and drainage facilities efficiently. See Standard Plans for further details.
- Retaining Wall Type 5 (Concrete L-Type Cantilever). This wall has a design height up to 12 feet. Although more costly than cantilever walls, these walls may be required where site restrictions do not allow for a footing projection beyond the face of the wall stem. See Standard Plans for further details.
- Retaining Wall Type 6 (Concrete Masonry Walls). These walls may be used where the design height of the wall does not exceed 6 feet. These walls are generally less costly than all other standard design walls or gravity walls. Where traffic is adjacent to the top of the wall, guardrail should be set back as noted in the Standard Plans. See Standard Plans or further details.

(b) State Designed Earth Retaining Systems which requires Special Designs.

Some locations will require a special design to accommodate ground contours, traffic, utilities, man-made features, site geology, economics, or aesthetics.

Some special design earth retaining systems are as follows:

- Standard Plan Walls (PS&E by Structure PE). The design loadings, heights, and types of walls in the Standard Plans cover frequent applications for earth retaining systems. However, special designs are necessary if the imposed loading exceeds that shown on the Standard Plan. Railroad live loads; building surcharge; loads imposed by sign structures, electroliers, or noise barriers are examples of loading conditions that will require special designs. Foundation conditions that require pile support for the wall and angle points in the wall geometry necessitate a special design.
- Non-Gravity Cantilevered Walls (PS&E by Structure PE). These walls include sheet pile walls, soldier pile walls with lagging, tangent soldier pile walls, secant soldier pile walls, slurry diaphragm walls, and deep soil mixing walls. These walls are most practical in cut sections and are best suited for situations where excavation for a retaining wall with a footing is impractical because of traffic, utilities, existing buildings, or R/W restrictions. In embankment sections, a non-gravity cantilevered wall is a practical solution for a roadway widening where design heights are less than 15 feet. They are also practical for slip-out corrections. Non-gravity cantilevered walls can consist of concrete, steel, timber, or cemented soil piles that may be either driven into place or placed in drilled holes and trenches.
- Anchored Walls (PS&E by Structure PE). These walls are typically composed of the same elements as non-gravity cantilevered walls, but derive additional lateral resistance from ground anchors (tiebacks), concrete anchors, or pile anchors. These anchors are located behind the potential failure surfaces in the retained soil and are connected to the wall structurally. The method of support and anchorage depends on site conditions, design height, and loading imposed. The cost of these walls is variable depending on earth retaining requirements, site geology, aesthetic consideration, and site restraints, but is generally higher than "Standard Design Walls" for the same wall geometry and loading conditions. Anchored walls may be used to stabilize an unstable site provided that adequate material exists at the site for the anchors. Economical wall heights up to 80 feet are feasible.
- Gravity Wall Systems that require special designs are Concrete Gravity, Rock Gravity, and Gabion Basket Walls. Concrete Gravity Walls (PS&E by Structure PE). Concrete gravity walls are most economical at design heights below 4 feet. However, they may be constructed at heights up to 6 feet. These walls can be used in connection with a cantilever wall if long lengths of wall with design heights of less than 4 feet are required.
- Rock Gravity Walls (PS&E by District PE). Rock gravity walls consist of rocks that are 100 pounds to 200 pounds, stacked on top of each other at slight batter. These walls are typically used in areas where a rock appearance is desirable for aesthetic reasons. Wall heights range from 1 foot 6 inches to 15 feet, but are most economical for heights less than 10 feet.

- Gabion Basket Walls (PS&E by District PE). Gabion basket walls use compartmented units filled with stones and can be constructed up to 26 feet in height. Each unit is a rectangular basket made of galvanized steel wire. The stone fill is 4 inches to 16 inches in size. Gabion basket walls are typically used for soil and stream bank stabilization. Service life of the gabion basket wall is highly dependent on the environment in which they are placed. Corrosion, abrasion, rock impact, fire and vandalism are examples of site-specific factors that would influence the service life of the wall and should be taken into consideration by the District PE during the design of the project. See Standard Plans for further details.
- Soil Reinforcement Systems. Soil reinforcement systems consist of facing elements and soil reinforcing elements incorporated into a compacted or in situ soil mass. The reinforced soil mass functions similar to a gravity wall.

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

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

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

  Soil reinforcement systems that require special design are as follows:
- Mechanically Stabilized Embankment (MSE) (PS&E by Structure PE). This system uses welded steel wire mats, steel strips or polymeric materials as soil reinforcing elements. The facing elements are precast concrete. In many cases, this system can be constructed using on-site backfill materials.

  When the bottom-up construction method is possible and other conditions permit their use, these systems are generally the most economical choice for wall heights greater than 20 feet. They may also be the most economical system for wall heights in the 10-foot to 20-foot range, depending on the specific project requirements.

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

  Steel elements used in this method are sized to provide sacrificial steel to compensate for anticipated corrosion; and may be galvanized to provide additional protection.
- Salvaged Material Retaining Wall (PS&E by District PE). This system utilizes C-channel sections as soil reinforcement. Galvanized guardrail elements, timber posts or concrete panels are used as facing elements. Often these materials can be salvaged from projects. The District Recycle Coordinator should be consulted as to the availability of salvaged materials.

- Soil Nail Wall (PS&E by Structure PE). This system reinforces either the original ground or an existing embankment during the excavation process. Soil nailing is always accomplished from the top-down in stages that are typically 4 feet to 6 feet in height. After each stage of excavation, corrosion protected soil reinforcing elements, "soil nails", are placed and grouted into holes which have been drilled at angles into the in situ material. The face of each stage of excavation is protected by a layer of reinforced shotcrete. After the full height of wall has been excavated and reinforced, a finish layer of concrete facing is placed either by the shotcreting method or by casting within a face form.

  When top-down construction is possible and conditions permit its use, soil nail wall systems are generally the most economical choice for wall heights greater than 10 feet. Wall heights in excess of 80 feet are feasible in specific locations.

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

  Steel "soil nails" used in this method are protected against corrosion either by being epoxy coated or encapsulated within a grout filled corrugated plastic sheath, and surrounded by portland cement grout placed during construction. Soil nail lengths typically range from 80 to 100 percent of the wall height, the actual length depends on the nail spacing used and the competency of the in situ soil.

- Recycled Tire Anchor Timber (TAT) Walls (PS&E by District PE). This system utilizes steel bars with recycled tire sidewalls attached by cross bars as soil reinforcing elements. The facing elements are treated timber. TAT walls have a rustic appearance, which makes them suitable in rural environments. The length of commercially available timber post generally controls the height of wall but heights up to 32 feet are feasible.

(c) Proprietary Earth Retaining Systems (Pre-approved).

These conventional retaining walls and soil reinforcement systems are designed, manufactured, and marketed by vendors. These systems are termed “proprietary” because they are patented. “Pre-approval” status means that these systems may be listed in the Special Provisions of the project as an Alternative Earth Retaining System (AERS), see Index 210.3, when considered appropriate for a particular location. For a proprietary system to be given “pre-approval” status, the vendor must submit standard plans and design calculations to the DES-BD for their review and approval. The Proprietary earth retaining systems that have been pre-approved are included in the Department’s Authorized Material List, located on the following website: http://www.dot.ca.gov/aml/.

Design details and specifications of “pre-approved” proprietary earth retaining systems may be found on the vendor websites listed in the Authorized Material List. New systems are added to the website list once they are pre-approved for use.

(d) Proprietary Earth Retaining Systems (Pending).

The systems in this category have been submitted by vendors to DES-BD for evaluation. Upon approval of DES-BD, pending systems are added to the website list of “pre-approved” proprietary earth retaining systems and included in the project specific Special Provisions.

If a proprietary system is the only retaining system deemed appropriate for use at a specific location, the construction of that system must be justified or designated an experimental construction feature in accordance with existing Departmental Policy concerning sole source purchases. See Index 110.10 for additional guidance on the use of proprietary items.

(e) Experimental State Designed Earth Retaining Systems.

Every earth retaining system is evaluated before being approved for routine use by the Department. Newly introduced designs, unproven combinations of proprietary and non-proprietary designs or products, are considered experimental. Once an experimental system has been evaluated and approved, it will be made available for routine use. The use of these systems is only permitted upon consultation with the Division of Engineering Services – Geotechnical Services (DES-GS).

Some earth retaining systems which are currently considered experimental follow:

- Geosynthetic Reinforced Walls (PS&E by District PE). These systems utilize geosynthetic material as the soil reinforcing elements. The face of these walls can be left exposed if the geosynthetic material has been treated to prevent decay from ultra-violet rays. Concrete panels, mortarless masonry, tar emulsion, or air blown mortar may be used as facing materials or the face may be seeded if a more aesthetic treatment is preferred. Design is by DES-GS.
- Mortarless Concrete Block Gravity Walls (PS&E by District PE). These wall types consist of vertically stacked, dry cast, concrete blocks. This system utilizes the friction and shear developed between the blocks and the combined weight of the blocks to retain the backfill. Some of these walls have been used as erosion protection at abutments and on embankments. They can be used as an aesthetic treatment for geosynthetic material reinforced walls. All of these walls require a batter. Design is by the DES-GS.

210.3 Alternative Earth Retaining Systems (AERS)

Using the Alternative Earth Retaining Systems (AERS) procedure encourages competitive bidding and potentially results in project cost savings. Therefore, AERS must be considered in all projects where earth retaining systems are required.

The AERS procedure may result in one or more earth retaining systems being included in the contract bid package. Under this procedure, a fully detailed State designed earth retaining system will be provided for each location, and will be used as the basis for payment. Additional systems may be presented in the contract documents as alternatives to the fully detailed State design and can be considered for use at specified locations. The fully detailed State designed earth retaining system may be either a Standard Plan system or a special design system. Alternative systems may also be State designed systems, “pre-approved” proprietary systems or experimental systems, as appropriate. The State designed alternative systems, both Standard Plan walls and special design systems, are to be completely designed and specified in the PS&E. Alternative systems are to be listed in the Special Provisions as AERS.

The AERS procedure requires the involvement of the District PE, DES-BD, and the DES-GS. The District PE should submit pertinent site information (site plans, typical sections, etc.) to DES-GS for a feasibility study as early as possible in the project development process.

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

- Contract plans for State designed systems can be prepared by the District PE (Standard Plan systems), the DES-GS (special design soil reinforcement systems and experimental systems), or the Structure PE (Standard Plan systems and special design systems).
- “Pre-approved” proprietary systems that are determined, based on consultation with DES-BD, to be appropriate alternatives to the State designed earth retaining system, are to be listed in the Special Provisions.
- Specifications and Estimates shall be developed for the fully detailed State designed system, which will be used as the basis for payment.

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

210.4 Value Engineering Change Proposal (VECP)

Sometimes Contractors submit proposals for an earth retaining system under Section 4-1.07 of the Standard Specifications, “Value Engineering.” The Contractor proposed system may modify or replace the earth retaining system permitted by the contract. The VECP process allows vendors of proprietary earth retaining systems an alternative method for having their systems used prior to obtaining “pre-approval” (see Index 210.2(3)(c)). VECP submittals are administered by the Resident Engineer. However, Contract Change Orders are not to be processed until the VECP is approved by Headquarters Construction with review assistance provided by the District or Structure PE as appropriate.

210.5 Aesthetic Consideration

The profile of the top of wall should be designed to be as pleasing as the site conditions permit. All changes in the slope at the top of cast-in-place concrete walls should be rounded with vertical curves at least 20 feet in length. Abrupt changes in the top of the wall profile should be avoided by using vertical curves, slopes, steps, or combinations thereof. Side slopes may be flattened or other adjustments made to provide a pleasing profile.

Where walls are highly visible, special surface treatments or provisions for landscaping should be considered. The aesthetic treatment of walls should be discussed with the District Landscape Architect and when necessary referred to DES Structures for additional study by the Office of Transportation Architecture.

The wall area between the grade line and 6 feet above it shall be free of any designed indentations or protrusions that may snag errant vehicles.

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

210.6 Safety Railing, Fences, and Concrete Barriers

Cable railing should be installed for employee protection in areas where employees may work adjacent to and above vertical faces of retaining walls, wingwalls, abutments, etc. where the vertical fall is 4 feet or more.

If cable railing is required on a wall which is less than 4 feet 6 inches tall and that wall is located within the clear recovery zone, then the cable railing should be placed behind the wall. See Standard Plan B11-47 for details of cable railing.

Special designs for safety railing may be considered where aesthetic values of the area warrant special treatment. In addition, if the retaining wall is accessible to the public and will have pedestrians or bicycles either above or below the retaining wall, then the provisions of Index 208.10 shall apply.

Concrete barriers may be mounted on top of retaining walls. Details for concrete barriers mounted on top of retaining walls are shown in the Standard Plans and Bridge Standard Details. A concrete barrier slab is required if a concrete barrier is to be used at the top of a special design earth retaining system. DES-BD should be contacted for preparation of the plans involved in the special design.

Retaining walls joining right of way fences should be a minimum of 6 feet clear height.

The District PE should examine the proposed retaining wall location in relation to the provisions of Index 309.1 to ensure adequate horizontal clearances to the structure or to determine the type and placement of the appropriate roadside safety devices.

210.7 Design Responsibility

The Structure PE has primary responsibility for the structural design and preparation of the contract documents (PS&E) for special design earth retaining systems involving Standard Plans non-gravity cantilevered walls, anchored walls, concrete and rock gravity walls, mechanically stabilized embankment, and soil nail walls. The DES-GS has primary responsibility for the geotechnical design of all reinforced earth slopes and earth retaining systems. DES-BD will prepare the Specifications and Engineer's Estimate for contracts when the AERS procedure is used. DES-BD reviews and approves standard plan submittals for proprietary earth retaining systems submitted by vendors. DES-BD and DES-GS assist Headquarters Construction in evaluating the VECP submitted by contractors.

Districts may prepare contract plans, specifications, and engineer's estimate for Standard Plan retaining walls provided the foundation conditions and site requirements permit their use. A foundation investigation is required for all reinforced earth slopes and earth retaining systems. PS&E's for slurry walls, deep soil mixing walls, gabion walls, tire anchored timber walls, salvaged material walls, and experimental walls will be prepared by the District PE with assistance from DES-GS. Earth retaining systems may be included in the PS&E as either highway or structure items.

The time required for DES-BD to provide the special design of a retaining system is site and project dependent. Therefore, the request for a special design should be submitted by the District PE to DES-BD as far in advance as possible, but not less than 6 months prior to PS&E delivery. At least 3 months is required to conduct a foundation investigation for an earth retaining system. A site plan, index map, cross sections, vertical and horizontal alignment, and utility and drainage requirements should be sent along with the request.

DES-GS has the responsibility for preparing a feasibility study for AERS. The District PE should submit project site information (site plans, typical sections, etc.) as early in the planning stage as possible so that determination of the most appropriate earth retaining system to use can be made.

210.8 Guidelines for Type Selection and Plan Preparation

(1) *Type Selection.* Type selection for reinforced earth slopes and earth retaining systems should be based on considerations set forth in Index 210.2.

The District PE should request a feasibility study for a reinforced slope or earth retaining system from DES-GS as early as possible in the project development process. After the feasibility study, the District PE should request an Advanced Planning Study (APS) from DES-BD for all special design earth retaining systems that DES-BD may be required to include in the PS&E.

If the District PE decides that the course of action favors an earth retaining system in which the PS&E will be delivered by DES-BD, then a Bridge Site Data Submittal – Non-Standard Retaining Wall/Noise Barrier must be submitted to DES-Structures and Engineering Services – Office of Photogrammetry and Preliminary Investigations – Preliminary Investigations (PI) Branch. A copy of this submittal will be forwarded to DES-BD and DES-GS by the PI Branch.

The Structure PE, with input from DES-GS and the District PE, will then type select the appropriate earth retaining system for the site and project. After an earth retaining system has been type selected, then DES-GS will prepare a Geotechnical Design Report.

The process for type selecting and developing the PS&E for reinforced earth slopes and earth retaining systems is set forth in Figure 210.8.

All appropriate State designed and proprietary earth retaining systems should be considered for inclusion in the contract documents to promote competitive bidding, which can result in cost savings.

(2) *Foundation Investigations.* DES-GS should be requested to provide a foundation recommendation for all sites involving a reinforced slope or an earth retaining system. Any log of test boring sheets accompanying the foundation reports must be included with the contract plans as project information, for the bidders use.

(3) *Earth Retaining Systems with Standard Plans.* The following guidelines should be used to prepare the contract plans for earth retaining systems, which are found in the Standard Plans:

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

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

- Distance between steps should be in multiples of 8 feet.
- A minimum number of steps should be used even if a slightly higher wall is necessary. Small steps, less than 1 foot in height, should be avoided unless the distance between steps is 96 feet or more. The maximum height of steps should be held to 4 feet. If the footing thickness changes between steps, the bottom of footing elevation should be adjusted so that the top of footing remains at the same elevation.

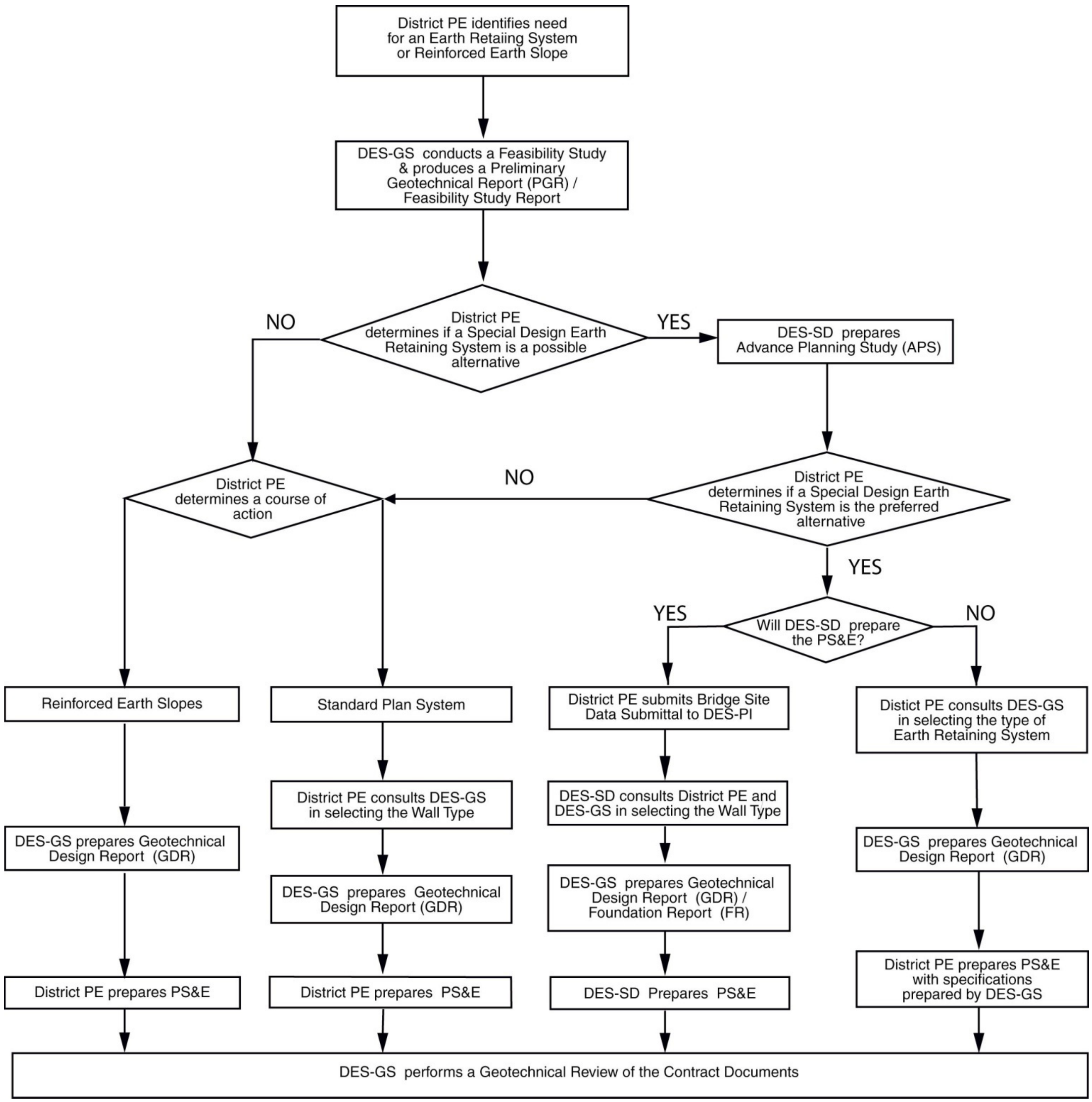
(c) Sloping Footings. The following criteria should be used for layout of sloping footings.

- The maximum permissible slope for reinforced concrete retaining walls is 3 percent. Maximum footing slope for masonry walls is 2 percent.
- When sloping footings are used, form and joint lines are permitted to be perpendicular and parallel to the footing for ease of construction.
- In cases where vertical electroliers or fence posts are required on top of a wall, the form and joint lines must also be vertical. A sloping footing should not be used in this situation since efficiency of construction would be lost.

Sloping footing grades should be constant for the entire length of the wall. Breaks in footing grade will complicate forming and result in loss of economy. If breaks in footing grade are necessary, a level stepped footing should be used for the entire wall.

Figure 210.8

Type Selection and PS&E Process for Reinforced Earth Slopes and Earth Retaining Systems



(d) Wall Joints. General details for required wall joints on wall Types 1, 1A, 2, and 5 are shown on Standard Plan B0-3. Expansion joints, Bridge Detail 3-3, should be shown at maximum intervals of 96 feet. Shorter spaces should be in multiples of 8 feet. Expansion joints generally should be placed near angle points in the wall alignment. When concrete barriers are used on top of retaining walls, the waterstop in the expansion joint must be extended 6 inches into the barrier. This detail should be shown or noted on the wall plans. Weakened plane joints, Bridge Detail 3-2, should be shown at nearly equal spaces between joints.

(e) Drainage. Gutters should be used behind walls in areas where it is necessary to carry off surface water or to prevent scour. Low points in wall vertical alignment or areas between return walls must be drained by downspouts passing through the walls. Standard Plan B3-6 shows typical drainage details. Special design of surface water drainage facilities may be necessary depending on the amount of surface water anticipated. Where ground water is likely to occur in any quantity, special provisions must be made to intercept the flow to prevent inundation of the backfill and unsightly continuous flow through weep holes.

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

(4) *Soil Reinforcement Systems.* The following guidelines should be used to prepare the contract plans for soil reinforcement systems:

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

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

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

(c) Quantities. When the AERS procedure is not utilized, quantities for each item of work are usually developed for payment. Bid items must include, but not be limited to, excavation and backfill for the embedment depth, soil reinforcement, facing elements, and concrete for leveling pad construction. Additional bid items for inclusion are any drainage system, pervious backfill, concrete barrier, railings, and concrete gutters. Quantities should be tabulated on the plans for each wall.

(5) *Earth Retaining Systems.* The following miscellaneous details are applicable to all earth retaining systems:

(a) Utilities. Provisions must be made to relocate or otherwise accommodate utilities conflicting with the retaining wall. A utility opening for a Type 1 wall is shown on Standard Plan B3-6. Any other utility openings will require special design details and should be reviewed by DES-BD.

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

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

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

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

CHAPTER 300 – GEOMETRIC CROSS SECTION

The selection of a cross section is based upon the joint use of the transportation corridor by vehicles, including trucks, public transit, cyclists and pedestrians. Designers should recognize the implications of this sharing of the transportation corridor and are encouraged to consider not only vehicular movement, but also movement of people, distribution of goods, and provision of essential services. Designers need also to consider the plan for the future of the route, consult Transportation Concept Reports for state routes.

Topic 301 – Traveled Way Standards

The traveled way width is determined by the number of lanes required to accommodate operational needs, terrain, safety and other concerns. The traveled way width includes the width of all lanes, but does not include the width of shoulders, sidewalks, curbs, dikes, gutters, or gutter pans. See Topic 307 for State highway cross sections, and Topic 308 for road cross sections under other jurisdictions.

Index 301.1 – Lane Width

The minimum lane width on two-lane and multilane highways, ramps, collector-distributor roads, and other appurtenant roadways shall be 12 feet, except as follows:

- **For conventional State highways with posted speeds less than or equal to 40 miles per hour and AADTT (truck volume) less than 250 per lane that are in urban areas or rural towns (rural main streets), the minimum lane width shall be 11 feet.** The preferred lane width is 12 feet. See Index 81.3 for place type definitions.

  Where a 2-lane conventional State highway connects to a freeway within an interchange, the lane width shall be 12 feet.

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

- For highways, ramps, and roads with curve radii of 300 feet or less, widening due to offtracking in order to minimize bicycle and vehicle conflicts must be considered. See Index 404.1 and Table 504.3.
- For lane widths on roads under other jurisdictions, see Topic 308.

301.2 Class II Bikeway (Bike Lane) Lane Width

(1) *General.* **Class II bikeways (bike lanes), for the preferential use of bicycles, may be established within the roadbed and shall be located immediately adjacent to a traffic lane as allowed in this manual.** A buffered bike lane may also be established within the roadbed, separated by a marked buffer between the bike lane and the traffic lane or parking lane. See the California MUTCD for further buffered bike lane marking and signing guidance. Contraflow bike lanes are designed for bike travel

in the opposite direction as adjacent vehicular traffic, and are only allowed on one-way streets. See the California MUTCD for contraflow bike lane marking and signing guidance. Typical Class II bikeway configurations are illustrated in Figure 301.2A. A bikeway located behind on-street parking, physical separation, or barrier within the roadway is a Class IV bikeway (separated bikeway). See DIB 89 for Class IV bikeway (separated bikeway) design guidance. **The minimum Class II bike lane width shall be 4 feet, except where:**

- Adjacent to on-street parking, the minimum bike lane should be 5 feet.
- Posted speeds are greater than 40 miles per hour, the minimum bike lane should be 6 feet, or
- **On highways with concrete curb and gutter, a minimum width of 3 feet measured from the bike lane stripe to the joint between the shoulder pavement and the gutter shall be provided.**

Class II bikeways may be included as part of the shoulder width See Topic 302.

As grades increase, downhill bicycle speeds can increase, which increases the width needed for the comfort of bicycle operation. If bicycle lanes are to be marked, additional bike lane width is recommended to accommodate these higher bicycle speeds. See Index 204.5(4) for guidance on accommodating bicyclists on uphill grades where a Class II bikeway is not included.

If bike lanes are to be located on one-way streets, they may be placed on either or both sides of the street. When only one bicycle lane is provided, it should be located on the side of the street that presents the lowest number of conflicts for bicyclists which facilitates turning movements and access to destinations on the street.

(2) *On-Street Parking Adjacent to Class II Bikeways.* Parking adjacent to bike lanes is discussed in subsection (1) above and addressed in Table 302.1, Note (7). Part-time bike lanes with part-time on-street parking is discouraged. This type of bike lane may only be considered if the majority of bicycle travel occurs during the hours of parking prohibition. When such an installation is being considered refer to the California MUTCD and traffic operations for direction regarding proper signing and marking.

(3) *Reduction of Cross Section Elements Adjacent to Class II Bikeways.* There are situations where it may be desirable to reduce the width of the lanes in order to add or widen bike lanes or shoulders. In determining the appropriateness of narrower traffic lanes, consideration should be given to factors such as motor vehicle speeds, truck volumes, alignment, bike lane width, sight distance, and the presence of on-street parking. When on-street parking is permitted adjacent to a bike lane, or on a shoulder where bicycling is not prohibited, reducing the width of the adjacent traffic lane may allow for wider bike lanes or shoulders, to provide greater clearance between bicyclists and driver-side doors when opened.

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

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	A	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 the National Cooperative Highway Research Program Report 672 entitled “Roundabouts: An Informational Guide, 2nd ed.” 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 as integral curb shape at end of sidewalk of combination bridge rails with integral raised sidewalk on bridge decks and structure approach slabs in conjunction with Type A curbs next to sidewalks on approach roadway. Type A3 curbs typically used on median islands on bridge decks and structure approach slabs with corresponding Type A curbs on median island on approach roadway. Type B3 curbs typically used on median islands on bridge deck and structure approach slabs with corresponding Type B curbs on approach roadway.

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 initiation document 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 at intersections lessen the risk of pedestrian exposure to traffic. See Index 405.4(3) and DIB 82 for pedestrian refuge guidance.

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

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

(1) Freeways and Expressways.

(a) Urban Areas. Where 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, <u>the</u>

minimum median width for multilane freeways and expressways in urban areas should be 36 feet.

(b) Rural Areas. The minimum median width for multilane 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 12 feet. However, this width would not provide room for left-turn lanes at intersections with raised curb medians, nor left-turn lanes in striped medians with room for pedestrian refuge areas. Posted speed and left shoulder width can also affect median width. See Table 302.1.

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 DES-BD.

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.

CHAPTER 400 – INTERSECTIONS AT GRADE

Intersections are planned points of conflict where two or more roadways join or cross. At-grade intersections are among the most complicated elements on the highway system, and control the efficiency, capacity, and safety for motorized and non-motorized users of the facility. The type and operation of an intersection is important to the adjacent property owners, motorists, bicyclists, pedestrians, transit operators, the trucking industry, and the local community.

There are two basic types of at grade intersections: crossing and circular. It is not recommended that intersections have more than four legs. Occasionally, local development and land uses create the need for a more complex intersection design. Such intersections may require a specialized intersection design to handle the specify traffic demands at that location. In addition to the guidance in this manual, see Traffic Operations Policy Directive (TOPD) Number 13-02: Intersection Control Evaluation (ICE) for direction and procedures on the evaluation, comparison and selection of the intersection types and control strategies identified in Index 401.5. Also refer to the publication Complete Intersections: A Guide to Reconstructing Intersections and Interchanges for Bicyclists and Pedestrians for further information.

Topic 401 – Factors Affecting Design

Index 401.1 – General

At-grade intersections must handle a variety of conflicts among users, which includes truck, transit, pedestrians, and bicycles. These recurring conflicts play a major role in the preparation of design standards and guidelines. Arriving, departing, merging, turning, and crossing paths of moving pedestrians, bicycles, truck, and vehicular traffic have to be accommodated within a relatively small area. The objective of designing an intersection is to effectively balance the convenience, ease, and comfort of the users, as well as the human factors, with moving traffic (automobiles, trucks, motorcycles, transit vehicles, bicycles, pedestrians, etc.).The safety and mobility needs of motorist, bicyclist and pedestrians as well as their movement patterns in intersections must be analyzed early in the planning phase and then followed through appropriately during the design phase of all intersections on the State highway. It is Departmental policy to develop integrated multimodal projects in balance with community goals, plans, and values.

The Complete Intersections: A Guide to Reconstructing Intersections and Interchanges for Bicyclists and Pedestrians contains a primer on the factors to consider when designing intersections. It is published by the California Division of Traffic Operations.

401.2 Human Factors

(1) *The Driver.* An appreciation of driver performance is essential to proper highway design and operation. The suitability of a design rests as much on how safely and efficiently drivers are able to use the highway as on any other criterion.

Motorist’s perception and reaction time set the standards for sight distance and length of transitions. The driver’s ability to understand and interpret the movements and crossing times of the other vehicle drivers, bicyclists, and pedestrians using the intersection is equally important when making decisions and their associated reactions. The designer needs to keep in mind the user's limitations and therefore design intersections so that they meet user expectation.

(2) *The Bicyclist.* Bicyclist experience, skills and physical capabilities are factors in intersection design. Intersections are to be designed to help bicyclists understand how to traverse the intersection. Chapter 1000 provides intersection guidance for Class I and Class III bikeways that intersect the State highway system. The guidance in this chapter specifically relates to bicyclists that operate within intersections on the State highway system.

(3) *The Pedestrian.* Understanding how pedestrians will use an intersection is critical because pedestrian volumes, their age ranges, physical ability, etc. all factor in to their startup time and the time it takes them to cross an intersection and thus, dictates how to design the intersection to avoid potential conflicts with bicyclists and motor vehicles. The guidance in this chapter specifically relates to pedestrian travel within intersections on the State highway system. See Topic 105, Pedestrian Facilities, Design Information Bulletin 82 - "Pedestrian Accessibility Guidelines for Highway Projects," the AASHTO Guide for the Planning, Design, and Operation of Pedestrian Facilities, and the California Manual on Uniform Traffic Control Devices (California MUTCD) for additional guidance.

401.3 Traffic Considerations

Good intersection design clearly indicates to bicyclists and motorists how to traverse the intersection (see Figure 403.6A). Designs that encourage merging traffic to yield to through bicycle and motor vehicle traffic are desirable.

The size, maneuverability, and other characteristics of bicycles and motorized vehicles (automobiles, trucks, transit vehicles, farm equipment, etc.) are all factors that influence the design of an intersection. The differences in operating characteristics between bicycles and motor vehicles should be considered early in design.

Table 401.3 compares vehicle characteristics to intersection design elements.

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

Transit vehicles and how their stops interrelate with an intersection, pedestrian desired walking patterns and potential transfers to other transit facilities are another critical factor to understand when designing an intersection. Transit stops and their placement needs to take into account the required maintenance operations that will be needed and usually supplied by the Transit Operator.

401.4 The Physical Environment

In highly developed urban areas, where right of way is usually limited, the volume of vehicular traffic, pedestrians, and bicyclists may be large, street parking exists, and transit stops (for both buses and light rail) are available. All interact in a variety of movements that contribute to and add to the complexity of a State highway and can result in busy intersections.

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

Rural areas where farming occurs may require special attention for specialized farm equipment. In addition, rural towns (rural main streets) also require special attention.

Figure 405.1
Corner Sight Distance (b)

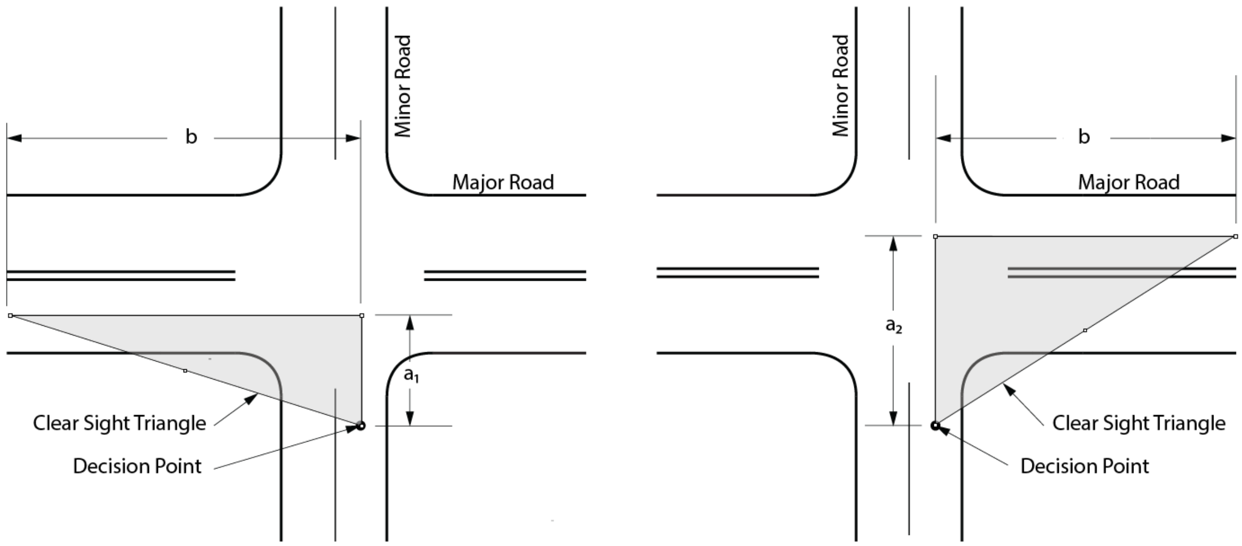


Table 405.1A
Corner Sight Distance Time Gap (T_g) for Unsignalized Intersections

Design Vehicle	Left-turn from Stop (s) [4]	Right-turn from Stop and Crossing Maneuver (s)
Passenger Car Private Road Intersection Rural Driveway	7½	6½
Single-Unit Truck Public Road Intersection	9½	8½
Combination Truck Major and Minor Roads on Routes: National Network Terminal or Service Access California Legal KPRA Advisory	11½	10½

Notes: Time gaps are for a stopped vehicle to turn left, right or cross a two-lane highway with no median and with minor road grades of 3 percent or less. The table values should be adjusted as follows:

[1]For multilane highways—When crossing or making a left-turn onto a two-way major road with more than two lanes, add 0.5 s for passenger cars or 0.7 s for trucks for each additional lane to be crossed. Median widths should be converted to an equivalent number of lanes in applying the 0.5 s and 0.7 s criteria. For example, an 18-foot wide median is equivalent to 1.5 lanes; this requires an additional 0.75 s for a passenger car to cross or an additional 1.05 s for a truck to cross.

[2]For minor road approach grades—If the minor road approach grade is an upgrade that exceeds 3 percent and the rear wheels of the design vehicle are on the grade exceeding 3 percent, add 0.2 s for each percent grade for left-turns and crossing maneuvers; or add 0.1 s for each percent grade for right-turns. For example, a passenger car is turning right from a minor road and at the stop location its rear wheels are on a 4 percent upgrade; this requires an additional 0.4 s for the right-turn.

[3]Unique situations may necessitate a different design vehicle for a particular minor road than those listed here (e.g., predominant combination trucks out of a rural driveway). Additionally, for intersections at skewed angles less than 60 degrees, a further adjustment is needed. See the AASHTO "A Policy on Geometric Design of Highways and Streets" for guidance.

[4]Time gap for vehicles approaching from the left can be the same as the right-turn from stop maneuver.

- turning volumes
- horizontal curve radii
- sight distance
- proximity of adjacent intersections
- types of adjacent intersections

For additional information and guidance, refer to AASHTO, A Policy on Geometric Design of Highways and Streets, the District Traffic Engineer or designee, the District Design Liaison, and the Project Delivery Coordinator.

405.2 Left-turn Channelization

(1) General. The purpose of a left-turn lane is to expedite the movement of through traffic by, controlling the movement of turning traffic, increasing the capacity of the intersection, and improving safety characteristics.

The District Traffic Branch normally establishes the need for left-turn lanes.

(2) Design Elements.

(a) Lane Width – **The lane width for both single and double left-turn lanes on State highways shall be 12 feet.**

For conventional State highways with posted speeds less than or equal to 40 miles per hour and AADTT (truck volume) less than 250 per lane that are in urban areas or rural towns (rural main streets), the minimum lane width shall be 11 feet.

When considering lane width reductions adjacent to curbed medians, refer to Index 303.5 for guidance on effective roadway width, which may vary depending on drivers' lateral positioning and shy distance from raised curbs.

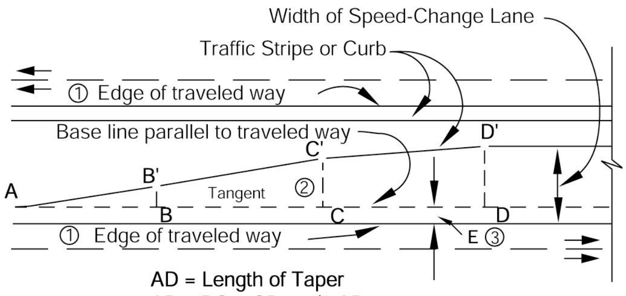
(b) Approach Taper – On conventional highways without a median, an approach taper provides space for a left-turn lane by moving traffic laterally to the right. The approach taper is unnecessary where a median is available for the full width of the left-turn lane. Length of the approach taper is given by the formula on Figures 405.2A, B and C.

Figure 405.2A shows a standard left-turn channelization design in which all widening is to the right of approaching traffic and the deceleration lane (see below) begins at the end of the approach taper. This design should be used in all situations where space is available, usually in rural and semi-rural areas or in urban areas with high traffic speeds and/or volumes.

Figures 405.2B and 405.2C show alternate designs foreshortened with the deceleration lane beginning at the 2/3 point of the approach taper so that part of the deceleration takes place in the through traffic lane. Figure 405.2C is shortened further by widening half (or other appropriate fraction) on each side. These designs may be used in urban areas where constraints exist, speeds are moderate and traffic volumes are relatively low.

Table 405.2A

Bay Taper for Median Speed-change Lanes



AD = Length of Taper
AB = BC = CD = 1/3 AD
AB' & C'D' are Parabolic Curves

	LENGTH OF TAPER - feet			OFFSET DISTANCE			
	60	90	120	DD' = 10'	DD' = 11'	DD' = 12'	
	Distance From Point "A"						
	-	-	-	0.00	0.00	0.00	
	5	7.5	10.0	0.16	0.17	0.19	
	10	15.0	20.0	0.62	0.69	0.75	
	15	22.5	30.0	1.41	1.55	1.69	
B'	20	30.0	40.0	2.50	2.75	3.00	B'
	30	45.0	60.0	5.00	5.50	6.00	
C'	40	60.0	80.0	7.50	8.25	9.00	C'
	45	67.5	90.0	8.59	9.45	10.31	
	50	75.0	100.0	9.38	10.31	11.25	
	55	82.5	110.0	9.84	10.83	11.81	
	60	90.0	120.0	10.00	11.00	12.00	

NOTES:

(1) The table gives offsets from a base line parallel to the edge of traveled way at intervals measured from point "A". Add "E" for measurements from edge of traveled way.

(2) Where edge of traveled way is a curve, neither base line nor taper between B & C will be a tangent. Use proportional offsets from B to C.

(3) The offset "E" is usually 2 ft along edge of traveled way for curbed medians; Use "E" = 0 ft. for striped medians.

Table 405.2B

Deceleration Lane Length

Design Speed (mph)	Length to Stop (ft)
30	235
40	315
50	435
60	530

(3) Double Left-turn Lanes. At signalized intersections on multilane conventional highways and on multilane ramp terminals, double left-turn lanes should be considered if the left-turn demand is 300 vehicles per hour or more. The lane widths and other design elements of left-turn lanes given under Index 405.2(2) applies to double as well as single left-turn lanes.

The design of double left-turn lanes can be accomplished by adding one or two lanes in the median. See "Complete Intersections: A Guide to Reconstructing Intersections and Interchanges for Bicyclists and Pedestrians", published by Headquarters, Division of Traffic Operations, for the various treatments of double left-turn lanes.

(4) Two-way Left-turn Lane (TWLTL). The TWLTL consists of a striped lane in the median of an arterial and is devised to address the special capacity and safety problems associated with high-density strip development. It can be used on 2-lane highways as well as multilane highways. Normally, the District Traffic Operations Branch should determine the need for a TWLTL.

The minimum width for a TWLTL shall be 12 feet (see Index 301.1). The preferred width is 14 feet. Wider TWLTL's are occasionally provided to conform with local agency standards. However, TWLTL's wider than 14 feet are not recommended, and in no case should the width of a TWLTL exceed 16 feet. Additional width may encourage drivers in opposite directions to use the TWLTL simultaneously.

405.3 Right-turn Channelization

(1) General. For right-turning traffic, delays are less critical and conflicts less severe than for left-turning traffic. Nevertheless, right-turn lanes can be justified on the basis of capacity, analysis, and crash experience.

In rural areas a history of high speed rear-end collisions may warrant the addition of a right-turn lane.

In urban areas other factors may contribute to the need such as:

- High volumes of right-turning traffic causing backup and delay on the through lanes.
- Conflicts between crossing pedestrians and right-turning vehicles and bicycles.
- Frequent rear-end and sideswipe collisions involving right-turning vehicles.

Where right-turn channelization is proposed, lower speed right-turn lanes should be provided to reduce the likelihood of conflicts between vehicles, pedestrians, and bicyclists.

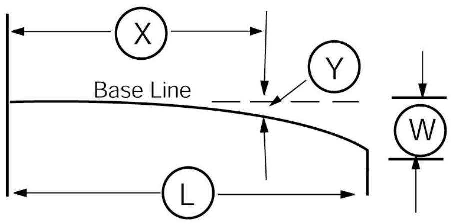
(2) Design Elements.

(a) Lane and Shoulder Width – **Index 301.1 shall be used for right-turn lane width requirements. Shoulder width shall be a minimum of 4 feet.** Although not desirable, lane and shoulder widths less than those given above can be considered for right-turn lanes under the following conditions pursuant to Index 82.2:

- In urban areas or rural towns (rural main streets) with posted speeds less than 40 miles per hour in severely constrained situations, if truck or bus use is low, consideration may be given to reducing the right-turn lane width to 10 feet.
- Shoulder widths may also be considered for reduction under constricted situations. Whenever possible, at least a 2-foot shoulder should be provided where the right-turn lane is adjacent to a curb. Entire omission of the shoulder should only be considered in constrained situations and where an 11-foot lane can be constructed.

Table 405.4

Parabolic Curb Flares Commonly Used



$$Y = \frac{W X^2}{L^2}$$

(L) = Length of flare in feet

(W) = Maximum offset in feet

(X) = Distance along base line in feet

(Y) = Offset from base line in feet

(W) is shown in table thus (shaded cell)

OFFSET IN FEET FOR GIVEN "X" DISTANCE																
o	10	15	20	25	30	40	45	50	60	70	75	80	90	100	110	120
1:5 FLARES																
25	0.8	1.8	3.2	5.0												
50	0.4		1.6		3.6	6.4		10.								
1:10 FLARES																
50	0.2		0.8		1.8	3.2		5.0								
100	0.1		0.4		0.9	1.6		2.5	3.6	4.9		6.4	8.1	10.		
1:15 FLARES																
45	0.1		0.5		1.3	2.3	3.0									
75	0.0		0.3		0.8	1.4		2.2	3.2	4.3	5.0					
90	0.0		0.3		0.6	1.1		1.8	2.6	3.6		4.7	6.0			
120	0.0		0.2		0.5	0.8		1.3	2.0	2.7		3.5	4.5	5.5	6.7	8.0

(3) *Pedestrian Refuge.* Pedestrian refuge islands allow pedestrians to cross fewer lanes at a time while judging conflicts separately. They also provide a refuge so slower pedestrians can wait for a gap in traffic while reducing total crossing distance.

At unsignalized intersections in rural towns (rural main streets), suburban, or urban areas, a pedestrian refuge should be provided between opposing traffic where pedestrians are allowed to cross 2 or more through traffic lanes in one direction of travel, at marked or unmarked crosswalks. Pedestrian islands at signalized crosswalks should be considered, taking into account crossing distance and pedestrian activity. Note that signalized pedestrian crossings must be timed to allow for pedestrians to cross. See the California MUTCD, Chapter 4E, for further guidance.

Traffic islands used as pedestrian refuge are to be large enough to provide a minimum of 6 feet in the direction of pedestrian travel, without exception.

All traffic islands placed in the path of a pedestrian crossing must be accessible, refer to DIB 82 and the Standard Plans for further guidance. An example of a traffic island that serves as a pedestrian refuge is shown on Figure 405.4.

405.5 Median Openings

(1) *General.* Median openings, sometimes called crossovers, provide for crossings of the median at designated locations. Except for emergency passageways in a median barrier, median openings are not allowed on urban freeways.

(2) *Spacing and Location.* By a combination of interchange ramps and emergency passageways, provisions for access to the opposite side of a freeway may be provided for law enforcement, emergency, and maintenance vehicles to avoid extreme out-of-direction travel. Access should not be more frequent

Figure 405.4

Pedestrian Refuge Island

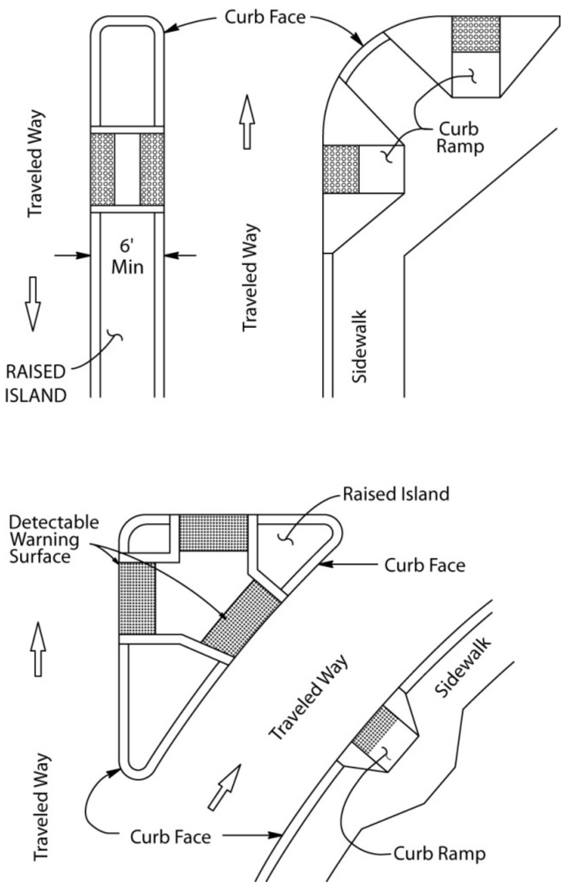
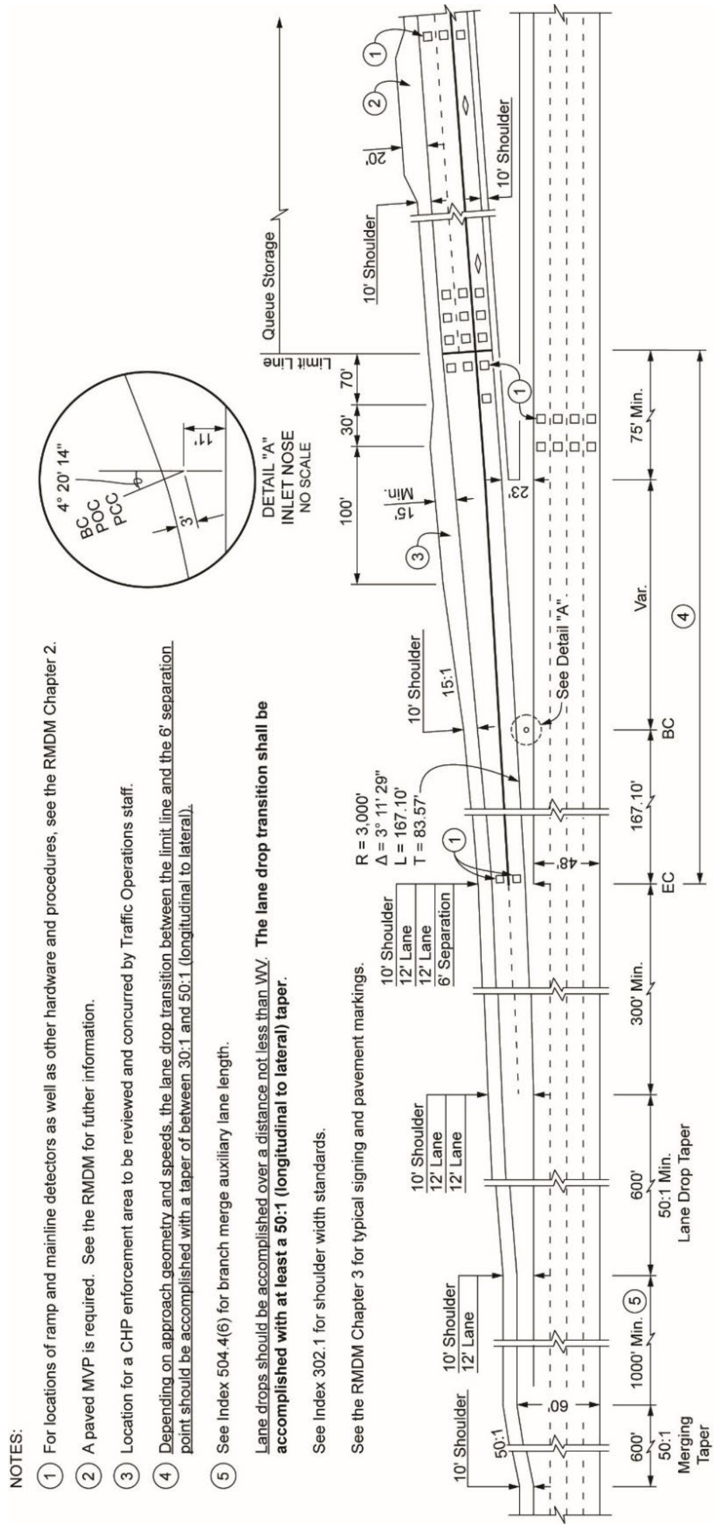


Figure 504.3H

Typical Freeway-to-Freeway Connector Ramp Metering (2 GP Lanes + 1 HOV Preferential Lane)



considering conversion of a HOV preferential lane to a GP lane at a metered entrance ramp.

(j) Enforcement Areas and Maintenance Pullouts.

Division of Traffic Operations policy requires a paved enforcement area to be provided on all projects that include new or reconstructed metered entrance ramps or connectors.

See the RMDM for exception procedures to this policy.

Enforcement areas are used by the California Highway Patrol (CHP) to enforce minimum vehicle occupancy requirements. The paved enforcement area should be placed on the right side of a metered entrance ramp, downstream of the metering signals, and as close to the limit line as practical to facilitate CHP enforcement. See Figures 504.3A to 504.3H for the typical layout and dimensions of enforcement areas.

The District Traffic Operations Branch responsible for ramp metering must coordinate enforcement issues with the CHP. The CHP Area Commander must be contacted during the development of the project report or PA & ED phase, prior to design, to discuss any variations needed to the CHP enforcement area designs shown in this manual. Variations to enforcement area dimensions or location require the review and concurrence of the CHP and the Caltrans District Traffic Operations Branch responsible for ramp metering.

Division of Traffic Operations policy requires a paved Maintenance Vehicle Pullout (MVP) to be provided at a location for maintenance and operations personnel to access controller cabinets. The MVP should be placed upstream or next to controller cabinets. The MVP and the controller cabinets should be placed on the same side of the entrance ramp. At loop entrance ramps, locate the MVP to the inside of the loop ramp. A paved walkway should be provided between the MVP and the controller cabinets. See RMDM Section 2.4 for controller cabinet placement. See Topic 309, Clearances, for placement guidance of fixed objects such as controller cabinets. See the RMDM for exception procedures to this policy.

(3) Location and Design of Ramp Intersections on the Crossroads.

Factors which influence the location of ramp intersections on the crossroads include sight distance, construction and right of way costs, bicycle and pedestrian mobility, circuitous travel for left-turn movements, crossroads gradient at ramp intersections, storage requirements for left-turn movements off the crossroads, and the proximity of other local road or bicycle path intersections.

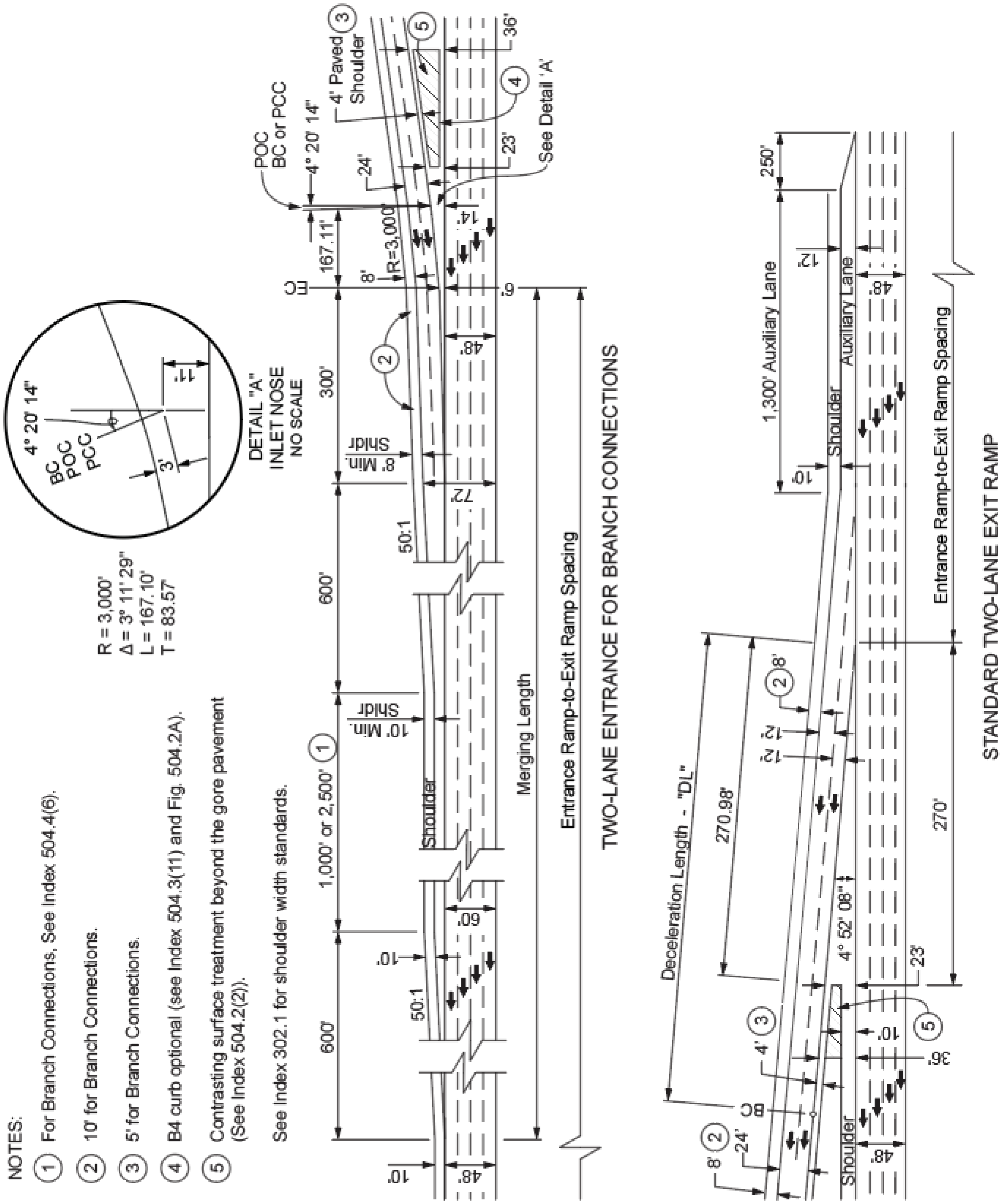
Ramp intersections with local roads are intersections at grade. Chapter 400 and the references therein contain general guidance. For ramp intersections, a wrong-way movement onto an off-ramp can have severe consequences. The California MUTCD also contains guidance for signing and striping to deter wrong-way movements.

Interchange Types L-7, L-8, and L-9 are partial cloverleaf designs with ramps at a right angle to the crossroad where the off-ramps and on-ramps are adjacent to each other on the same side of the crossroad that offer benefits for non-motorized travel modes; however, additional design considerations as follows may be appropriate in order to deter wrong-way movements:

- The entrance and exit ramps should be clearly visible from the crossroad. Concrete barrier or guardrail placed between the ramps can block the view from the crossroad. If feasible, the concrete barrier or guardrail channelization feature should be set back from the crossroad edge of shoulder 20 to 50 feet with a raised traffic island placed from the

Figure 504.3K

Two-Lane Connectors and Entrance/Exit Ramps



Radii for loop ramps should normally range from 150 feet to 200 feet. Increasing the radii beyond 200 feet is typically not cost effective as the slight increase in design speed is usually outweighed by the increased right of way requirements and the increased travel distance. Curve radii of less than 120 feet should also be avoided. Extremely tight curves lead to increased off-tracking by trucks and increase the potential for vehicles to enter the curve with excessive speed. Therefore, consider providing the ramp lane pavement structure on shoulders for curves with a radius less than 300 feet (see Indexes 626.1 and 636.1).

Of particular concern in the design of loop ramps are the constraints imposed on large trucks. Research indicates that trucks often enter loops with excessive speed, either due to inadequate deceleration on exit ramps or due to driver efforts to maintain speed on entrance ramps to facilitate acceleration and merging. Where the loop is of short radius and is also on a steep descent (over 6 percent), it is important to develop the standard 2/3 full superelevation rate by the beginning of the curve (see Index 504.2(5)). When accommodating design vehicles in Rural Transitional Corridors that are largely composed of industrial, commercial or retail buildings located separately from housing, the following considerations may be necessary to meet the standard 2/3 full superelevation rate on loop entrance ramps:

- Begin the ramp with a short tangent (75 feet to 100 feet) that diverges from the cross street at an angle of 4 to 9 degrees.
- Provide additional tangent length as site conditions allow.

The Angle of Intersection guidance in Index 403.3 applies to all on-ramps including loops.

(9) Distance Between Successive On-ramps. The minimum distance between two successive on-ramps to a freeway lane should be the distance needed to provide the standard on-ramp acceleration taper shown on Figure 504.2A. <u>This distance should be about 1,000 feet unless the upstream ramp adds an auxiliary lane in which case the downstream ramp should merge with the auxiliary lane in a standard 50:1 (longitudinal to lateral) convergence</u>. The distance between on-ramp noses will then be controlled by interchange geometry.

(10)Distance Between Successive Exits. <u>The minimum distance between successive exit ramps for guide signing should be 1,000 feet on the freeway and 600 feet on collector-distributor roads</u>.

(11)Curbs. Curbs should not be used on ramps except in the following locations:

(a) A Type D curb or 4-inch Type B curb (see Index 303.2) may be used on both sides of the separation between freeway lanes and a parallel collector-distributor road.

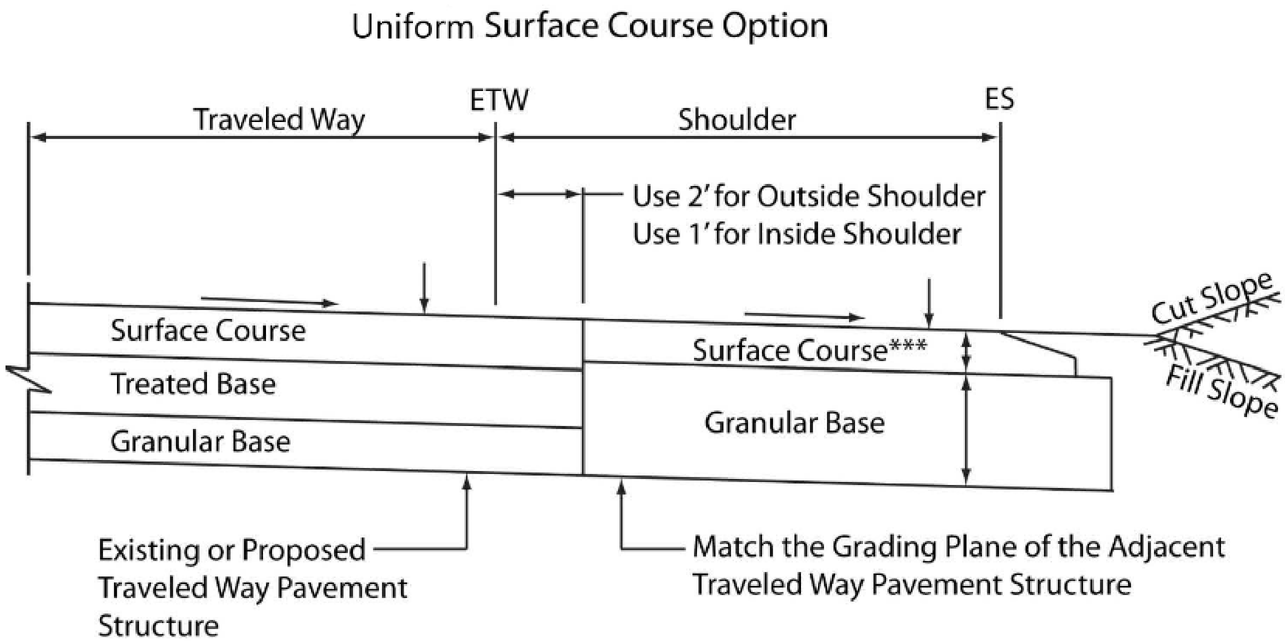
(b) A B4 curb may be used as shown in Figure 504.2A to control drainage or where the gore cross slope would be greater than allowed in Index 504.2(5). When the optional B4 curb is used at the entrance ramp inlet nose, the shoulder adjacent to the curb should be the same width as the ramp shoulder approaching the curb. The B4 gutter pan can be included as part of the shoulder width. As stated in Index 405.4(2), curbs are typically discouraged where posted speeds are over 40 miles per hour. Curbs at gore areas must be determined on a case-by-case basis.

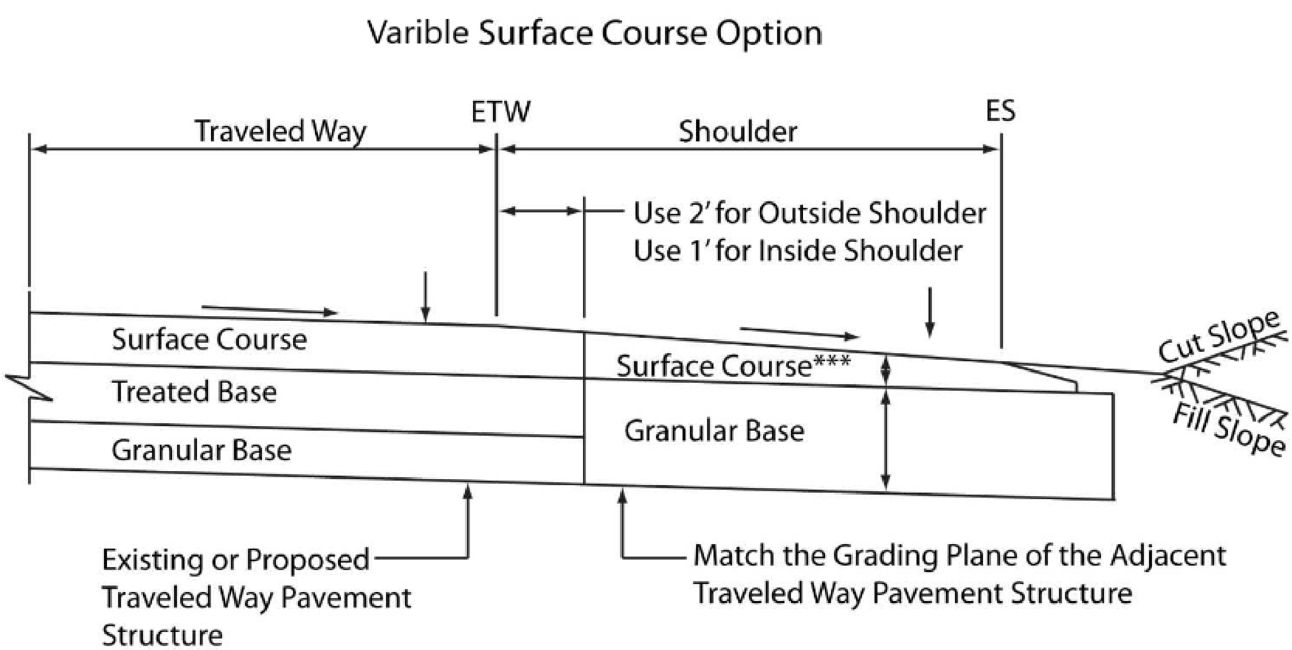
(c) Curbs may be used where necessary at the ramp connection with the local street for the protection of pedestrians, for channelization, and to provide compatibility with the local facility.

(d) The Type E curb may be used only in special drainage situations, for example, where drainage parallels and flows against the face of a retaining wall.

Figure 613.4B

Shoulder Design for Design Traffic or TI Less Than Adjacent Lane Design Traffic or TI





NOTES:

*** For rigid pavement, the minimum thickness of surface course depends on climate region and shoulder type (Table 626.2). For flexible pavement, minimum thickness of surface course is 0.35.

For asphalt shoulders, the thickness of the asphalt layer (not including nonstructural wearing surface) should not be less than 0.35 foot.

For concrete shoulders, see Index 626.2 and Table 626.2 for recommended thicknesses.

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 613.4B).

Bases and subbases for new or reconstructed shoulders should extend at least 1 foot from beyond the edge of shoulder as shown in Figures 613.4A and 613.4B.

(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 613.4(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 613.4(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,
- Limited 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 also be considered either prior to an overlay or as a stand-alone action.

construction, sufficient access during closures for construction hauling of material into and out of the work zone, construction windows when the project must be completed, adequate work area, and other constructability 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 constructability during the project development process. The recommendations given by Construction should be weighed against other recommendations and requirements for the pavement. Constructability recommendations should be accommodated where practical, provide minimum performance requirements, safety, and maintainability. Some constructability items that should be addressed in the project include:

- Clearance width of paving machines to barriers and hinge points should be provided for good control of paving operation and smoothness. A minimum of 2.5 feet from limits of paving to temporary barrier system for paving machine and survey control is to be provided Access for delivery trucks and construction equipment. Delivery of consistent material is important for the paving machine to operate at a constant rate to construct smooth and long lasting pavement.
- 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, although 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, combining these layers has a negative impact on the pavement performance and will lead to untimely failure.
- Distance to material batch plant should be taken into consideration. If one is not accessible to the project site, a staging area of no less than 200 by 200 feet should be provided to produce consistent concrete or asphalt mixes and ensure proper moisture levels in aggregate mix as they are essential in creating sound and smooth pavement.
- Maximize lane closure times or utilize detours to provide consistent paving operations. Paving short sections causes more pavement tie-ins and more start-stop operations, both of which create greater potential for pavement roughness and lower durability. In lieu of short duration closures of less than 10 hours, the following traffic handling strategies should be considered for major pavement operations such as widening, rehabilitation, or reconstruction:
  - Extended weekend closures (55-hour, 48-hour, 24-hour, etc.).
  - Median widening to temporarily detour traffic.
  - Diverting some or all traffic to the opposite direction (split roadway) and using movable barriers, if needed, to maintain peak traffic flows.

- Long-term lane closures. Some roads can be at least partially closed for 2 weeks or more during light travel seasons or during entire construction.

- Order of work should be taken into consideration to ensure smooth and durable pavement. For example, diamond grinding should be done after individual slab replacement work is completed. However, for concrete pavement widening, diamond grind the adjacent existing lane prior to beginning the widening work.

Topic 619 – Pavement Life-Cycle

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 alternatives
- Different pavement design lives (20 vs. 40).

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 available on the Department Pavement website. LCCA must be completed for any project with a pavement cost component except for the following:

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

CHAPTER 620 – RIGID PAVEMENT

Topic 621 – Types of Rigid Pavements

621.1 Continuously Reinforced Concrete Pavement (CRCP)

CRCP uses reinforcement rather than transverse joints for crack control. Longitudinal joints are still used. Transverse random cracks are expected in the slab, usually at 2 to 7-foot intervals (see Figure 621.1). The continuous reinforcement in the pavement holds the cracks tightly together.

CRCP may be used in new construction, reconstruction, and rehabilitation as concrete overlays, lane replacement and widening, in all climate regions except High Mountain and High Desert. CRCP may cost more initially than other types of cast in place pavement due to the added cost of the reinforcement, but can be more cost-effective over the life of the pavement on high volume routes due to improved long-term performance and reduced maintenance.

Because there are no sawn transverse joints, CRCP should provide better ride quality and less maintenance than Jointed Plain Concrete Pavement (JPCP).

621.2 Jointed Plain Concrete Pavement (JPCP)

JPCP is the most common type of rigid pavement used by the Department. JPCP uses longitudinal and transverse joints to control where cracking occurs in the slabs (see Figure 621.1), and does not contain reinforcement other than tie bars and dowel bars (see Index 622.4). The initial cost of constructing JPCP is typically less than CRCP but CRCP can be more cost effective over the life of the pavement. JPCP is recommended for all truck routes, ramps, urban streets, pavements in High Mountain and High Desert climate regions and in other regions where there is not sufficient space or time to construct CRCP.

When JPCP is placed as a Concrete Overlay over Asphalt (COA) and the truck volume is low to medium (typically AADTT below 1000), the thickness of the concrete slabs can be thin (0.35 to 0.60 ft) and therefore need to be short (less than 8 ft). This special design will be called Short JPCP-COA or SJPCP-COA. The recommended slab length is 6 ft while the slab width should be 6 ft but the slab in the outer half-lane can be up to 8 ft to provide a widened lane with 1 to 2 ft into the shoulder.

Typically, SJPCP-COA technique requires partial-depth milling of the existing pavement surface to remove surface defects and enhance the adhesion potential of the asphalt. Other reasons for milling include matching geometric requirements such as bridge clearances and providing an even surface to achieve a uniform concrete overlay thickness if payment for concrete overrun is not the selected option.

A minimum of 0.25 ft of sound asphalt (in fair to good condition) is recommended before placing the concrete overlay. When the asphalt that remains after the milling operation is less than 0.25 ft or it is in poor condition, approval from the Caltrans Office of Concrete Pavements is required, unless one of the two following options are adopted:

- Add an asphalt overlay, 0.10 to 0.25 ft thick, on top of the existing asphalt surface, milled or not. The thickness of the asphalt overlay plus the remaining sound asphalt must be at least 0.25 ft. Either HMA Type A or RHMA-G can be used for constructing this overlay.
- Cold recycling (CR) of the existing asphalt pavement by using full-depth recycling with foamed asphalt (FDR-FA) or partial-depth recycling with emulsified or foamed asphalt (PDR-EA or PDR-FA). The performance of SJPCP-COA with a CR base has not been verified yet. Consequently, the implementation of this rehabilitation alternative with CR base also requires approval from the Caltrans Office of Concrete Pavements and should be closely monitored.

621.3 Precast Concrete Pavement (PCP)

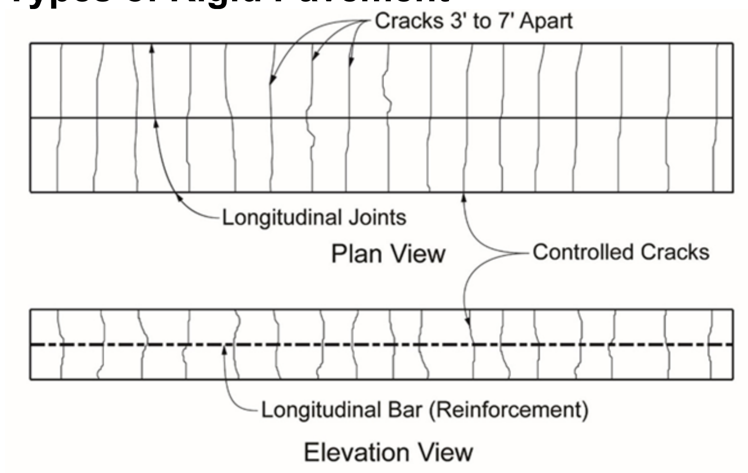
PCP uses panels that are precast off-site instead of cast in-place, which is the primary difference between PCP and JPCP. Figure 621.1 does not show PCP because after installing the panels the section views of PCP are same as JPCP. The precast panels are linked together with dowel bars and should have tied bars like JPCP, at least in the outer or inner lanes. PCP offers the following advantages:

- Improved concrete mixing and curing as they are controlled in a precast yard.
- Shorter lane closure times than using conventional concrete for JPCP, which is beneficial when there are short construction windows.

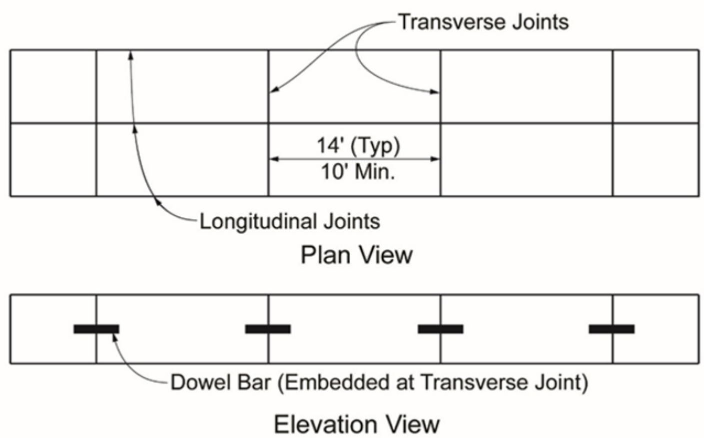
The primary disadvantage of PCP is the high cost of fabrication, transportation and installation. PCP also needs a leveling system at the base underneath the precast panels during construction to even out the loads on the slab and avoid uneven deflections or stresses that could lead to faulting, slab settlement, and/or premature cracking. Although PCP is not currently included in the Standard Specs and Plans, it has been used since 2010 in California and should be considered.

Figure 621.1

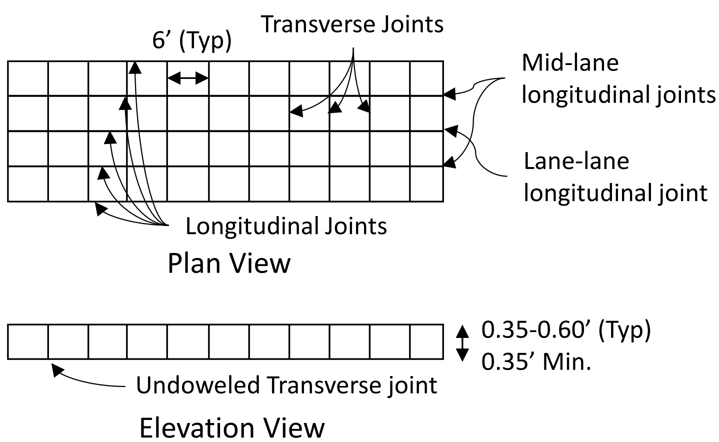
Types of Rigid Pavement



Continuously Reinforced Conrete Pavement (CRCP)



Jointed Plain Concrete Pavement (JPCP)



Short JPCP - Concrete Overlay over Asphalt (SJPCP-COA)

Topic 622 – Engineering Requirements

622.1 Engineering Properties

Various types of Portland cement are used with Type II with Type II/V being most common. Type 1L gaining quickly. types of hydraulic cement are sometimes used for special considerations such as rapid strength concrete (RSC), which can be made of Type III Portland cement, Calcium Sulfoaluminate (CSA) cement, or other proprietary rapid setting cements.

Table 622.1 shows the concrete engineering properties that were used to develop the rigid pavement design catalog in this chapter. The values are based on Department specifications and experience with materials used in California.

622.2 Performance Factors

The end-of-design life performance factors used to develop concrete pavement structure design catalog found in this chapter are presented in Table 622.2. The design catalog is intended to ensure that concrete pavements are engineered to meet or exceed the performance factors in Table 622.2 (i.e., the pavement structure will last longer before reaching these thresholds).

622.3 Types of Concrete

(1) *Portland Cement Concrete (PCC).* Portland cement concrete is the most common concrete used. It is composed of Portland cement, supplementary cementitious materials, aggregate, water and sometimes chemical admixtures. It is typically produced by weighing materials in batches that are charged into a rotary drum mixer. For pavements, the mixer is usually stationary and the concrete is loaded into dump trucks for delivery. The concrete is normally placed and consolidated using a paving machine which incorporates internal vibrators, grade control and the screed among other things. Initial setting of the concrete is normally about 4 to 6 hours; however, accelerators can be added to make the time much shorter. Strength gain allows conventional Portland cement concrete pavement to be opened to traffic as early as 3 days and strength continues to increase for an extended period. Portland cement concrete is designed to resist environmentally induced degradation for over 100 years. Typical use for Portland cement concrete is new pavement, widening, reconstruction and rehabilitation.

Table 622.1

Concrete Properties Used in Developing the Rigid Pavement Design Catalog

Property	Values
Unit weight	147 lb/ft^3
Poisson's ratio	0.20
Coefficient of thermal expansion	4.8 x 10^{-6}/ °F
Thermal conductivity	$1.25 \frac{\text{Btu}}{\text{hr-ft-}°F}$
Heat capacity	$0.28 \frac{\text{Btu}}{\text{lbm-}°F}$
Permanent curl/warp effective temperature difference	Top of slab is 10 °F cooler than bottom of slab
Surface shortwave absorptivity	0.85
Cement type	Type II Portland cement
Cementitious material content	24 lb/ft^3 (600 lb/yd^3)
Water to cementitious material ratio	0.42
Curing method	Curing compound
PCC zero-stress temperature (internally calculated)	105 °F
Ultimate shrinkage (internally calculated)	646 microstrains
Reversible shrinkage (% of ultimate shrinkage)	50%
Time to develop ultimate shrinkage	35 days
Modulus of rupture or flexural strength (28 days)	637 psi

Table 622.2

Concrete Pavement Performance Factors

Factor	Value
General	
Design Life	Determined per Topic 612 (40 years for JPCP and CRCP; 20 years for SJPCP-COA)
Reliability	95%
Terminal IRI [(1)] at end of design life	170 in/mile max
JPCP only	
Transverse cracking at end of design life	10% of slabs max
Average joint faulting at end of design life	0.15 inch max
SJPCP-COA only	
Longitudinal cracking at end of design life	10% of slabs 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.

(2) *Rapid Strength Concrete (RSC).* Rapid strength concrete is used in cases where rapid construction (typically 3 days or less) and accelerated opening to traffic is the most important consideration. RSC is either highly accelerated Portland cement concrete without supplementary cementitious materials or concrete made with a proprietary hydraulic cement which sets and gains strength extremely fast. It is produced either by weighing batches that are charged into a rotary drum mixer truck and then accelerated with chemicals at the pavement site or by volumetric proportioning and continuous mixing at the pavement site. The concrete is typically placed into forms or an excavated area and consolidated using hand held vibrators. Finishing is normally done with a roller screed and hand tools. The final finish is typically rougher than Portland cement concrete and grinding to achieve smoothness is typically needed. Strength gain allows the pavement to be opened to traffic in hours where it continues to gain strength for several days. Rapid strength concrete is designed for rapid return to service. Because these products are relatively new to pavements, their long-term durability (40 or more years) has yet to be substantiated. Typical use for rapid strength concrete is JPCP replacement, punch-out repair, reconstruction or widening in locations where traffic cannot be diverted for at least 3 days.

(3) *Roller Compacted Concrete (RCC).* Roller compacted concrete is Portland cement concrete that is produced with water content diminished to the point that it must be consolidated with a vibratory roller, similar to asphalt pavement. The initial finish looks similar to an HMA surface. It is typically produced by volumetric proportioning and continuous mixing in a stationary plant and the concrete is loaded into dump trucks for delivery. The concrete is placed and shaped by a paving machine similar to an asphalt paving machine in lifts up to 0.80 ft. The concrete is compacted by a 10-ton vibratory roller. It is not as smooth as pavement placed with concrete paving machines. Strength gain allows the pavement to be opened to light traffic in 24 hours and heavy traffic (trucks) in 3 days. It will continue to gain strength for an extended period. Roller compacted concrete is designed to resist environmentally induced degradation for over 100 years. Roller compacted concrete is only used on State highways for shoulders and temporary detours.

622.4 Pavement Joints

(1) *Construction.* Construction joints are joints between sections of concrete slabs that result when concrete is placed at different times. Construction joints can be transverse or longitudinal and are constructed in all types of concrete pavements. Except for precast pavement, the joint is formed by placing a metal or wooden header board that is set vertical to the surface and at right angle or parallel to the centerline and it is of sufficient length and height so that it conforms to the cross section of the pavement.

For CRCP, construction joints allow for some paving breaks in the continuous concrete paving operation. On a subsequent paving day the joints are used to extend the pavement in-kind. Transverse construction joints typically include additional longitudinal reinforcement to keep construction cracks from widening. Holes are drilled in the header board to allow the longitudinal reinforcing bars to pass through the header board.

For JPCP, construction joints occur at planned transverse joints and longitudinal joints. They are typically placed by the contractor to facilitate their paving operation. Details and instructions for how to place construction joints in JPCP are found in the Standard Plans and Standard Specifications. Tie bars are typically used at longitudinal construction joints to connect the adjoining slabs together so that the construction joint will be tightly closed. Dowel bars are used at transverse construction joints to provide load transfer.

(2) *Contraction.* Longitudinal and transverse contraction joints (also known as weakened plane joints) are sawed into new pavement to control the location and geometry of shrinkage, curling, and thermal cracking.

CRCP is constructed without transverse contraction joints. Transverse cracks are allowed to form but are held tightly together with continuous reinforcing steel.

JPCP contains contraction joints that create a weakened line across the slab to control the location of the expected natural cracks. The concrete is supposed to crack at the contraction joints and not elsewhere in the slabs. The Standard Plans show the typical spacing details for transverse contraction joints. For special situations, such as intersections and ramps, spacing layout will be needed. See HDM Index 626.3 for special consideration when engineering a rigid pavement intersection.

(3) *Isolation.* Isolation joints are used to separate dissimilar pavements/structures in order to reduce compressive stresses that could cause cracking. Examples of dissimilar pavements/structures include different joint patterns, different types of concrete pavement (e.g., CRCP/JPCP), structure foundations, drainage inlets, drainage inlet depressions, manholes and manhole frame and cover. Isolation joints keep cracks from propagating through the joint and are sealed to prevent water/dirt infiltration. Isolation

joints are most commonly placed along pavement longitudinal joints. Because of different arrangements for structure foundations, drainage inlets, drainage inlet depressions, and utility frames and covers, isolation joints are necessary to provide isolation to relieve stresses in the abutting faces of dissimilar pavements/structures.

(4) *Expansion.* Expansion joints are used in CRCP as part of the expansion terminal joint system where there is a need to allow for a large expansion, greater than one half inch, between approach slabs and other types of pavements. They are typically placed in the transverse direction. Like isolation joints, expansion joints are sealed to prevent water and dirt infiltration. For CRCP, expansion joints are typically used where CRCP abuts up to bridges, structure approach slabs or other types of rigid pavements, including an existing CRCP. Expansion joints are typically not used with JPCP.

Typical joint spacing patterns can be found in the Standard Plans. In some cases such as intersections and parking lots, joint spacing patterns need to be engineered and included on project construction details. See Topic 626 for further details.

622.5 Transition Panels, Terminal Joints and End Anchors

Transition panels and end anchors are used at transverse joints to minimize deterioration or faulting of the joint where rigid pavement abuts to flexible pavement, a different type of rigid pavement, or a structure approach. The following types of transition joints and anchors should be used where applicable:

(1) *Concrete Pavement Transition Panel.* The concrete pavement transition panel is used to provide a smooth transition between concrete and asphalt pavements by minimizing distortion of asphalt at the joint. It can also be used as a transition between structure approach slabs and asphalt pavement.

The transition panel is a 12-foot long reinforced concrete panel placed between the existing or new asphalt pavement and the concrete pavement or approach slab. It is not always possible to build this panel due to short construction windows and limited space. Where building this panel is not possible, a JPCP End Anchor or CRCP terminal joint type C should be used.

(a) End Anchor - Use when JPCP abuts to asphalt or composite pavement and Concrete Pavement Transition Panel is not used. Also recommended where JPCP abuts to structure approach slabs. Consists of a 14-foot long end panel which varies in thickness from the designed thickness to 2 feet. Base type and thickness under the end anchor is the same as base under JPCP.

(2) *Continuously Reinforced Concrete Pavement*. For CRCP, expansion terminal joint systems (ETJS) shall be used at all transitions to or from structure approach slabs, whereas terminal joint type G shall be used at all transitions with another pavement as shown in Table 622.5. Where a construction joint is not used to connect two segments of CRCP, a terminal joint G must be used, which includes an expansion joint. As indicated in Table 622.5, use an expansion terminal joint system (ETJS) or a terminal joint type G to accommodate and minimize the movement of the end of a CRCP section when it encounters a structure approach slab, abutment, or another pavement. The Standard Plans include a variety of details for these transitions.

Table 622.5

Use of Terminal Joints and Expansion Joints in CRCP

Type	Structure Approach Slab or Abutment	New or Existing JPCP or Existing CRCP
Terminal Joint Type G	No	Yes
Expansion Terminal Joint System (ETJS) (1)	Yes	No

NOTE:

(1) Includes a Terminal Joint Type F.

Depending on the CRCP terminal type to be used, Figure 622.5 shows the schematic diagrams of Expansion Terminal Joint System between CRCP and existing structure approach slab.

The following types of joints and anchors are used for CRCP:

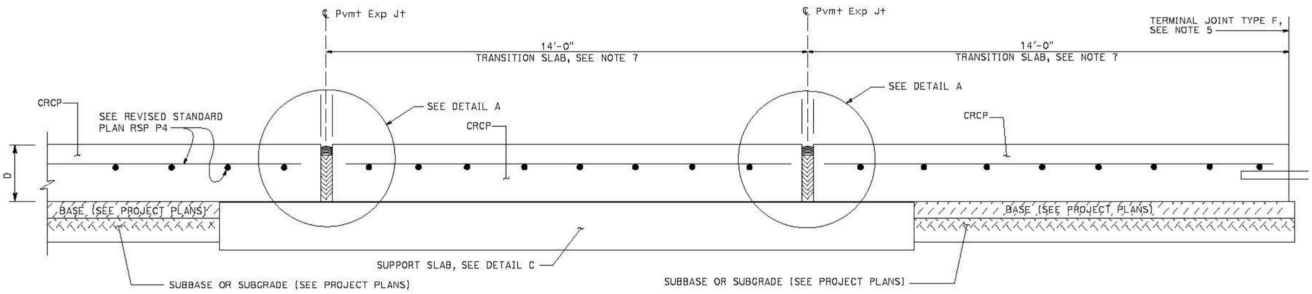
(a) Terminal Joints – Terminal joints are used in CRCP to transition to another pavement type or to a structure approach slab. It is found at the beginning and end of all CRCP. Its function is to isolate CRCP and adjacent pavement types or approach slab to prevent damage and faulting at the transverse joint. The following are terminal joint types for CRCP:

- Terminal Joint Type (A) - Use when constructing new CRCP next to existing asphalt pavement and if a concrete pavement transition panel is not viable.
- Terminal Joint Type (B) - Use when the newly constructed CRCP terminates at future pavement construction. CRCP at the terminus will be supported with a reinforced concrete support slab and backfilled with backing material and later removed when the new pavement will be constructed.
- Terminal Joint Type (C) - Use when the newly constructed CRCP terminates at a proposed temporary asphalt pavement construction for traffic staging. CRCP at the terminus will be supported with a reinforced concrete support slab.
- Terminal Joint Type (F) - Use when constructing new CRCP next to a structure approach slab.
- Terminal Joint Type (G) - Use when constructing new CRCP next to new or existing JPCP, PCP, or existing CRCP.

(b) Expansion Terminal Joint System (ETJS) - ETJS is a series of two 14-ft reinforced slabs with two full depth, full width transverse expansion joints designed to absorb the pavement expansion without damaging adjacent structures. These two expansion joints are placed on a 24-ft long support slab to provide load transfer (see Figure 622.5)

Figure 622.5

Expansion Terminal Joint System Between CRCP and Structure Approach Slab



NO SCALE

(3) *Jointed Plain Concrete Pavement.* The following types of transition joints and anchors are used only for JPCP:

(a) Terminal Joint Type 1 – Use when constructing new JPCP next to existing concrete pavement or structure approach slab. It consists of a transverse construction joint with dowel bars drilled and bonded to existing concrete.

(b) Terminal Joint Type 2 – Use when constructing new JPCP next to new structure approach slabs or concrete to asphalt transition panel. It consists of a transverse construction joint with dowel bars placed at the joint of new concrete pavement or structure approach slabs and the new concrete.

622.6 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 or filled 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, except SJPCP-COA.
- Transverse joints in JPCP in all desert and mountain climate regions, except SJPCP-COA.

(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. The condition of the existing joints and joint seals should be reviewed with the District Maintenance or District Materials Engineer to determine if joint seal replacement is warranted. *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.

622.7 Dowel Bars and Tie Bars

(1) Dowel bars are smooth round bars that act as load transfer devices across pavement joints.

Dowel bars shall be placed within the traveled way pavement structure at the following joints:

- All transverse terminal joints in CRCP at new and existing JPCP or structure approach slabs.
- All transverse contraction joints in JPCP, except for SJPCP-COA.
- All transverse construction joints.
- All transverse transition joints regardless of concrete pavement type where concrete pavement abuts to structure approach slabs or other concrete pavement type.

Dowel bars should not be used on shoulders except within the limits of widened slabs and for tied concrete shoulders that are engineered to be converted to a future lane in conformance with Index 613.5(2). When dowel bars are used, they must meet the same requirements as the traveled way.

For JPCP slab replacements, the placement of dowel bars is determined on a project-by-project basis based on proposed design life, condition or remaining service life of adjacent slabs, whether original pavement was constructed doweled or undoweled, and other pertinent factors. Details for doweling slab replacements for JPCP can be found in the Standard Plans.

In limited situations, dowel bars are placed across longitudinal joints. See Standard Plans for further details.

(2) *Tie Bars*. Tie bars are deformed bars (i.e., rebar) or connectors that are used to hold the faces of abutting rigid slabs in contact. Tie bars are typically placed across longitudinal joints. Tie bars shall be placed at longitudinal joints except at the following locations:

- Adjacent concrete pavement when the spacing of transverse joints of adjacent slabs is not the same.
- Roller compacted concrete.
- Do not tie more than 50 feet width of JPCP 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, the Standard Plans include details for placing dowel bars in the longitudinal joint within the travelled way for this situation.
- Individual slab replacements.

Further details regarding tie bars can be found in the Standard Plans.

622.8 Base Interlayer

When concrete pavement is placed on a concrete base without an engineered interlayer (a.k.a. bond breaker) uncontrolled cracking can occur. In areas of bonding, the pavement and base act as a monolithic mass causing sawn joints to be ineffective due to insufficient depth. This causes cracks to occur in the pavement surface in unexpected areas. To prevent bonding and subsequent crack formation, use a base interlayer between concrete pavement and concrete bases, including lean concrete base, cement treated permeable base, and cement treated base.

Several methods are available for using an interlayer including sufficient application of wax curing compound, geosynthetic, or asphalt binder. When using rapid strength concrete, plastic sheeting or paper may also be suitable alternatives. Asphalt pavement interlayers can be used but it is more efficient to use asphalt base for construction than require two separate products. The Standard Specifications and Standard Special Provisions provide the options for the Contractor to select but the designer should specify them on the plans if a specific interlayer is to be used. For design, the engineer needs to identify on the typical sections when the interlayer is to be installed.

622.9 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. Grinding on new pavement may be required to achieve smoothness requirements.

622.10 Pavement Smoothness

Pavement smoothness, which is also referred to as ride quality, is an important surface characteristic. Smoother pavements provide the following benefits:

- Improved ride quality.
- Extended pavement life.
- Reduced highway travel user costs, such as fuel usage and vehicle maintenance costs.
- Lower pavement maintenance costs and fewer work zone activities.

Pavement smoothness, or ride quality, is measured in terms of the International Roughness Index (IRI). For new construction, reconstruction or widening/lane replacement projects, the concrete pavement is engineered and built to meet an IRI target. For additional information, see the pavement smoothness page on the Department Pavement website.

Topic 623 – Engineering Procedure for New, Widening, and Reconstruction Projects

Topic 623 includes the procedure for determining the minimum concrete pavement thicknesses of the traveled way for new construction, widening, reconstruction and overlay projects. New Construction involves a design with a new alignment. Widening involves the construction of additional lanes to improve traffic flow and increase capacity on an existing highway. Reconstruction is the replacement of the entire existing pavement structure by an equivalent or increased new pavement structure along an existing alignment. Overlay is when a concrete pavement is placed directly on an existing pavement like SJPCP-COA. Refer to Topic 603 for more details about types of pavement projects.

For pavement structures at locations other than the traveled way, such as shoulders and parking lots, see Topic 626.

623.1 Catalog

The Caltrans Rigid Pavement Design Catalog is based on a comprehensive database created from runs of version 2.5.5 of the AASHTOWare Pavement Mechanistic-Empirical Design (PMED) software covering different combinations of concrete pavement types, local design factors, and design features expected in the Caltrans road network.

The rigid pavement design is based on the following factors:

- Pavement type (JPCP, CRCP, or SJPCP-COA).
- Performance factors (Table 622.2):
    - Distress type and limit, specific to each type of pavement.
    - Design life, specific to each type of pavement.
    - Design reliability, fixed to 95% for Caltrans pavement design.
- Local design factors:

  - Climate region. Caltrans considers nine climate regions for pavement design and management: North Coast (NC), Central Coast (CC), South Coast (SC), Low Mountain (LM), High Mountain (HM), South Mountain (SM), Inland Valley (IV), Desert (DE), and High Desert (HD). Climate is discussed in Topic 615.
  - Traffic characteristics:
    - Initial AADTT of the design lane. This value results from applying directional and lane distribution factors to the two-way AADTT.
    - WIM spectra. Caltrans considers five different truck traffic groups for pavement design and management: WIM-1, WIM-2, WIM-3, WIM-4, and WIM-5. The five WIM spectra span the truck traffic characteristics that exist on the Caltrans road network, with WIM-1 being the lightest and WIM-5 being the heaviest.
    - Traffic linear growth rate (AADTT equivalent linear yearly growth). This factor is fixed to 3% when using the collection of Tables 623.1A through 623.1F.
    - Refer to Topic 613 for more details about traffic considerations.
  - Subgrade soil. Soil types for existing subgrade shall be classified according to the Unified Soil Classification System (USCS). If more than one soil type are present in the subgrade, then the user should choose the more conservative design based on the less stable soil. Subgrade is discussed in Topic 614.
- Pavement design features:
  - Base type, with options specific to each type of pavement.
  - Base thickness, user-input only for SJPCP-COA.
  - Subbase type, user-input only for SJPCP-COA.
  - Shoulder type, with options specific to each type of pavement.

The JPCP thickness reported by the Rigid Pavement Design Catalog is exclusively based on slab transverse cracking. The sections included in the following tables have been verified for faulting and IRI.

The CRCP thickness reported by the Rigid Pavement Design Catalog is not based on the *PMED* CRCP punchout model. Instead, it is based on the corresponding JPCP thickness for the same performance factors, local design factors, and design features, assuming 10 punchouts per mile is equivalent to 10% transverse cracking. The CRCP design assumes 0.7% longitudinal steel reinforcement following Caltrans Standard Plan P4 (2019 revision).

The SJPCP-COA thickness reported by the Rigid Pavement Design Catalog is exclusively based on slab longitudinal cracking. *PMED* does not model SJPCP-COA faulting and IRI.

In addition to the concrete properties shown in Table 622.1 and the performance factors shown in Table 622.2, the Rigid Pavement Design Catalog is based on a number of *PMED* modeling assumptions. The assumptions are summarized in Tables 623.1A and 623.1B for JPCP and SJPCP-COA designs, respectively.

Table 623.1A

Assumptions Adopted in *PMED* for JPCP Design

Factor	Value [1]
Transverse joint spacing	14 ft
Slab-base bonding	Debonded
Lane-shoulder load transfer efficiency	Function of shoulder type: • Untied concrete: 0% • Tied concrete: 50%
Widened slab width	14 ft
Permanent curl/warp	-10°F
Cracking calibration coefficients [2]	C4 = 0.52; C5 = -2.17
Cracking reliability, standard error formula [2]	3.5522 * Cracking(%)^0.3415 + 0.75
Provision for grinding [3]	0.06 ft
Minimum slab thickness	0.65 ft
Transverse joints	Doweled
Dowels diameter (ϕ) [4]	Function of slab thickness (Caltrans Standard Plan P10): • ≤0.65 ft thickness: ϕ = 1 in. • 0.70-0.85 ft thickness: ϕ = 1.25 in. • ≥0.90 ft thickness: ϕ = 1.5 in.
Initial IRI	Function of project type: • New or reconstruction: 67.5 in./mile • Widening or lane replacement: 75 in./mile
Hot mix asphalt base	*PMED* default asphalt concrete with PG 64-10 binder. Erodibility Class 2 (very erosion resistant material) adopted for the faulting calculation.
Lean concrete base	*PMED* default chemically stabilized material with 2 million psi resilient modulus. Erodibility Class 2 (very erosion resistant material) adopted for the faulting calculation.

(1) The rationale for the selection of the different values can be found in the UCPRC Tech Memo UCPRC-TM-2021-03 available at eScholarship web site.

(2) PMED defaults, 2006 National calibration.

(3) Two blanket grinding operations.

(4) The dowel diameter does not have any effect on *PMED* predicted JPCP cracking and, consequently, on the thickness determined by the Rigid Pavement Design Catalog. The dowel diameter has a large impact on *PMED* predicted faulting and IRI.

Table 623.1B

Assumptions Adopted in *PMED* for SJPCP-COA Design

Factor	Value [(1)]
Slab size	6×6 ft
Slab-base bonding	Bonded
Permanent curl/warp	-10°F
Cracking calibration coefficients [(2)]	C4 = 0.40; C5 = -2.21
Cracking reliability, standard error formula [(2)]	3.5522 * Cracking(%)^0.4315 + 0.5
Provision for grinding [(3)]	0.03 ft
Minimum slab thickness	0.33 ft
Maximum slab thickness	0.60 ft
Transverse joints	Undoweled
Load transfer efficiency of transverse joints	70%
Hot mix asphalt base	*PMED* default asphalt concrete with PG 64-10 binder
Cold recycling base	*PMED* default asphalt concrete with PG 64-40 binder

(1) The rationale for the selection of the different values can be found in the UCPRC Tech Memo UCPRC-TM-2021-02 available at eScholarship web site.
(2) PMED defaults, 2016 National calibration.
(3) One blanket grinding operation.

Tables 623.1C(a) through (i) contain the minimum thickness for concrete pavement surface layers, base, and subbase of the traveled way for all types of projects. The concrete thickness in the tables includes a provision for future grinding (sacrificial thickness) of 0.06 ft. The concrete thickness is rounded to the nearest 0.05 feet. Each table contains different combinations of base and shoulder types. The tables are categorized by climate regions and Weigh In-Motion (WIM) spectra. The catalog is categorized by climate regions and Weigh In-Motion (WIM) spectra, as follows:

- Table 623.1C(a): Group I climate and WIM 1-2
- Table 623.1C(b): Group I climate and WIM 3
- Table 623.1C(c): Group I climate and WIM 4-5
- Table 623.1C(d): Group II climate and WIM 1-2

- Table 623.1C(e): Group II climate and WIM 3
- Table 623.1C(f): Group II climate and WIM 4-5
- Table 623.1C(g): Group III climate and WIM 1-2
- Table 623.1C(h): Group III climate and WIM 3
- Table 623.1C(i): Group III climate and WIM 4-5

The climate groups for JPCP and CRCP design are defined as follows:

- Group I: SC and NC
- Group II: CC, LM, SM, HM, and HD
- Group III: IV and DE

Two base types are included in the JPCP and CRCP tables: HMA (hot mix asphalt) and LCB (lean concrete base). See Table 623.4 for further base requirements.

The JPCP and CRCP design tables consider any of the following subgrades:

- Type I: Coarse-grained soils SC, SP, SM, SW, GC, GP, GM, and GW (USCS)
- Type II: Fine-grained soils CL, MH, and ML (USCS)
- Type III: Fine-grained soil CH (USCS) stabilized with lime or cement

Type I includes subgrades made of coarse-grained soils that are primarily sand (S) and gravel (G), regardless of whether they are well (W) or poorly (P) graded or have silt (M) or clay (C) in them. Type II includes subgrades made of fine-grained soils with low (L) and high (H) plasticity. Finally, Type III includes subgrades made of fine-grained soil CH (clay with high plasticity). The Type III subgrades must be stabilized with lime or cement for JPCP or CRCP construction.

Depending on the quality of the subgrade, a class 2 aggregate subbase should be provided for construction purposes, as specified in Table 623.5. Alternatively, the subgrade should be stabilized lime, cement, asphalt emulsion, or another stabilizer that is appropriate for the subgrade material.

Table 623.1C(a)

Group I Climate (SC and NC) and WIM 1-2

	Minimum Thickness of Concrete Surface Layer (ft)							
	Widened Slab			Tied Concrete Shoulder			Untied Shoulder	
AADTT [1]	JPCP LCB	JPCP HMA	CRCP HMA	JPCP LCB	JPCP HMA	CRCP HMA	JPCP LCB	JPCP HMA
100	0.65	0.65		0.65	0.65		0.70	0.65
200	0.65	0.65		0.65	0.65		0.70	0.70
500	0.65	0.65		0.70	0.70		0.75	0.75
1,000	0.70	0.65	0.75	0.75	0.70	0.75	0.80	0.80
2,000	0.70	0.70	0.75	0.80	0.75	0.75	0.80	0.80
4,000	0.75	0.75	0.75	0.80	0.80	0.75	0.85	0.85
8,000	0.80	0.75	0.75	0.85	0.80	0.80	0.90	0.90
12,000	0.80	0.80	0.80	0.85	0.85	0.80	0.90	0.95
16,000	0.80	0.80	0.80	0.85	0.85	0.85	0.95	0.95
20,000	0.80	0.85	0.80	0.90	0.90	0.85	0.95	0.95

[1] Initial (year 1) AADTT of the design lane.

Table 623.1C(b)

Group I Climate (SC and NC) and WIM 3

	Minimum Thickness of Concrete Surface Layer (ft)							
	Widened Slab			Tied Concrete Shoulder			Untied Shoulder	
AADTT [1]	JPCP LCB	JPCP HMA	CRCP HMA	JPCP LCB	JPCP HMA	CRCP HMA	JPCP LCB	JPCP HMA
100	0.65	0.65		0.65	0.65		0.70	0.65
200	0.65	0.65		0.65	0.65		0.70	0.70
500	0.65	0.65		0.70	0.70		0.75	0.75
1,000	0.70	0.65	0.75	0.75	0.70	0.75	0.80	0.80
2,000	0.70	0.70	0.75	0.75	0.75	0.75	0.80	0.80
4,000	0.75	0.70	0.75	0.80	0.80	0.75	0.85	0.90
8,000	0.80	0.80	0.75	0.80	0.85	0.80	0.90	0.95
12,000	0.80	0.80	0.80	0.85	0.90	0.85	0.95	0.95
16,000	0.80	0.85	0.80	0.90	0.90	0.85	0.95	1.00
20,000	0.85	0.90	0.85	0.90	0.95	0.90	1.00	1.00

[1] Initial (year 1) AADTT of the design lane.

Table 623.1C(c)

Group I Climate (SC and NC) and WIM 4-5

	Minimum Thickness of Concrete Surface Layer (ft)							
	Widened Slab			Tied Concrete Shoulder			Untied Shoulder	
AADTT [1]	JPCP LCB	JPCP HMA	CRCP HMA	JPCP LCB	JPCP HMA	CRCP HMA	JPCP LCB	JPCP HMA
100	0.65	0.65		0.65	0.65		0.70	0.65
200	0.65	0.65		0.65	0.65		0.70	0.70
500	0.65	0.65		0.70	0.70		0.75	0.75
1,000	0.70	0.65	0.75	0.75	0.70	0.75	0.80	0.80
2,000	0.70	0.70	0.75	0.75	0.75	0.75	0.80	0.85
4,000	0.75	0.75	0.75	0.80	0.80	0.80	0.85	0.90
8,000	0.80	0.80	0.80	0.85	0.85	0.85	0.90	0.95
12,000	0.80	0.85	0.80	0.85	0.90	0.85	0.95	1.00
16,000	0.85	0.90	0.85	0.90	0.95	0.90	1.00	1.00
20,000	0.85	0.90	0.85	0.90	0.95	0.90	1.00	1.05

[1] Initial (year 1) AADTT of the design lane.

Table 623.1C(d)

Group II Climate (CC, LM, SM, HM, and HD) and WIM 1-2

	Minimum Thickness of Concrete Surface Layer (ft)							
	Widened Slab			Tied Concrete Shoulder			Untied Shoulder	
AADTT [1]	JPCP LCB	JPCP HMA	CRCP HMA	JPCP LCB	JPCP HMA	CRCP HMA	JPCP LCB	JPCP HMA
100	0.65	0.65		0.65	0.65		0.70	0.65
200	0.65	0.65		0.70	0.65		0.75	0.70
500	0.65	0.65		0.75	0.70		0.80	0.75
1,000	0.70	0.70	0.75	0.75	0.75	0.75	0.80	0.80
2,000	0.75	0.70	0.75	0.80	0.75	0.75	0.85	0.85
4,000	0.75	0.75	0.75	0.80	0.80	0.80	0.90	0.90
8,000	0.80	0.80	0.80	0.85	0.85	0.80	0.90	0.95
12,000	0.80	0.85	0.80	0.85	0.90	0.85	0.95	0.95
16,000	0.85	0.85	0.85	0.90	0.90	0.85	0.95	1.00
20,000	0.85	0.90	0.85	0.90	0.95	0.90	1.00	1.00

[1] Initial (year 1) AADTT of the design lane.

Table 623.1C(e)

Group II Climate (CC, LM, SM, HM, and HD) and WIM 3

	Minimum Thickness of Concrete Surface Layer (ft)							
	Widened Slab			Tied Concrete Shoulder			Untied Shoulder	
AADTT [1]	JPCP LCB	JPCP HMA	CRCP HMA	JPCP LCB	JPCP HMA	CRCP HMA	JPCP LCB	JPCP HMA
100	0.65	0.65		0.65	0.65		0.70	0.65
200	0.65	0.65		0.70	0.65		0.75	0.70
500	0.65	0.65		0.70	0.70		0.80	0.75
1,000	0.70	0.65	0.75	0.75	0.70	0.75	0.80	0.80
2,000	0.75	0.70	0.75	0.80	0.75	0.75	0.85	0.85
4,000	0.75	0.75	0.75	0.80	0.80	0.80	0.90	0.90
8,000	0.80	0.85	0.80	0.85	0.90	0.85	0.95	1.00
12,000	0.85	0.90	0.85	0.90	0.95	0.90	0.95	1.00
16,000	0.85	0.90	0.85	0.90	0.95	0.90	1.00	1.05
20,000	0.90	0.95	0.90	0.95	1.00	0.90	1.00	1.05

(1) Initial (year 1) AADTT of the design lane.

Table 623.1C(f)

Group II Climate (CC, LM, SM, HM, and HD) and WIM 4-5

	Minimum Thickness of Concrete Surface Layer (ft)							
	Widened Slab			Tied Concrete Shoulder			Untied Shoulder	
AADTT [1]	JPCP LCB	JPCP HMA	CRCP HMA	JPCP LCB	JPCP HMA	CRCP HMA	JPCP LCB	JPCP HMA
100	0.65	0.65		0.65	0.65		0.70	0.65
200	0.65	0.65		0.70	0.65		0.75	0.70
500	0.65	0.65		0.70	0.70		0.80	0.75
1,000	0.70	0.70	0.75	0.75	0.75	0.75	0.80	0.80
2,000	0.75	0.70	0.75	0.80	0.80	0.75	0.85	0.90
4,000	0.80	0.80	0.75	0.80	0.85	0.80	0.90	0.95
8,000	0.80	0.85	0.85	0.85	0.90	0.85	0.95	1.00
12,000	0.85	0.90	0.85	0.90	0.95	0.90	1.00	1.05
16,000	0.90	0.95	0.90	0.95	1.00	0.90	1.05	1.05
20,000	0.90	0.95	0.90	0.95	1.00	0.95	1.05	1.10

(1) Initial (year 1) AADTT of the design lane.

Table 623.1C(g)

Group III Climate (IV and DE) and WIM 1-2

	Minimum Thickness of Concrete Surface Layer (ft)							
	Widened Slab			Tied Concrete Shoulder			Untied Shoulder	
AADTT [1]	JPCP LCB	JPCP HMA	CRCP HMA	JPCP LCB	JPCP HMA	CRCP HMA	JPCP LCB	JPCP HMA
100	0.65	0.65		0.65	0.65		0.70	0.65
200	0.65	0.65		0.65	0.65		0.70	0.70
500	0.65	0.65		0.70	0.70		0.75	0.75
1,000	0.70	0.65	0.75	0.75	0.70	0.75	0.80	0.80
2,000	0.70	0.70	0.75	0.80	0.75	0.75	0.85	0.85
4,000	0.75	0.75	0.75	0.80	0.80	0.80	0.90	0.90
8,000	0.80	0.80	0.80	0.85	0.85	0.85	0.95	0.95
12,000	0.80	0.85	0.80	0.90	0.90	0.85	0.95	1.00
16,000	0.85	0.90	0.85	0.90	0.95	0.90	1.00	1.00
20,000	0.85	0.90	0.85	0.90	0.95	0.90	1.00	1.05

(1) Initial (year 1) AADTT of the design lane.

Table 623.1C(h)

Group III Climate (IV and DE) and WIM 3

	Minimum Thickness of Concrete Surface Layer (ft)							
	Widened Slab			Tied Concrete Shoulder			Untied Shoulder	
AADTT [1]	JPCP LCB	JPCP HMA	CRCP HMA	JPCP LCB	JPCP HMA	CRCP HMA	JPCP LCB	JPCP HMA
100	0.65	0.65		0.65	0.65		0.70	0.65
200	0.65	0.65		0.65	0.65		0.70	0.70
500	0.65	0.65		0.70	0.70		0.75	0.75
1,000	0.70	0.65	0.75	0.75	0.70	0.75	0.80	0.85
2,000	0.70	0.70	0.75	0.80	0.80	0.75	0.85	0.90
4,000	0.75	0.80	0.80	0.80	0.85	0.80	0.90	0.95
8,000	0.80	0.85	0.85	0.90	0.90	0.85	0.95	1.00
12,000	0.85	0.90	0.85	0.90	0.95	0.90	1.00	1.05
16,000	0.90	0.95	0.90	0.95	1.00	0.90	1.05	1.05
20,000	0.90	0.95	0.90	0.95	1.00	0.95	1.05	1.10

(1) Initial (year 1) AADTT of the design lane.

Table 623.1C(i)

Group III Climate (IV and DE) and WIM 4-5

	Minimum Thickness of Concrete Surface Layer (ft)							
	Widened Slab			Tied Concrete Shoulder			Untied Shoulder	
AADTT [1]	JPCP LCB	JPCP HMA	CRCP HMA	JPCP LCB	JPCP HMA	CRCP HMA	JPCP LCB	JPCP HMA
100	0.65	0.65		0.65	0.65		0.70	0.65
200	0.65	0.65		0.65	0.65		0.70	0.70
500	0.65	0.65		0.70	0.70		0.80	0.80
1,000	0.70	0.70	0.75	0.75	0.75	0.75	0.80	0.85
2,000	0.75	0.75	0.75	0.80	0.80	0.80	0.90	0.90
4,000	0.80	0.85	0.80	0.85	0.90	0.85	0.95	0.95
8,000	0.85	0.90	0.85	0.90	0.95	0.90	1.00	1.05
12,000	0.90	0.95	0.90	0.95	1.00	0.90	1.05	1.05
16,000	0.90	0.95	0.90	0.95	1.00	0.95	1.05	1.10
20,000	0.95	1.00	0.90	1.00	1.05	0.95	1.10	1.10

(1) Initial (year 1) AADTT of the design lane.

Table 623.1D

Requirements for JPCP and CRCP Bases

Base	Material	Minimum Thickness
HMA [1] [2]	Hot mix asphalt, type A Standard Specifications Section 39	0.25 ft
LCB [3] [4] [5]	Lean concrete base Standard Specifications Section 28	0.35 ft

(1) If an asphalt treated permeable base (ATPB) is needed to perpetuate an existing treated permeable layer, place the ATPB between the concrete 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.

(2) The HMA binder grade may be either PG 64-10 or PG 64-16, regardless of the climate zone. Other PG grades may be used to prevent rutting associated to construction traffic, in case considerable construction traffic is expected. Refer to Topic 632 for more details regarding asphalt binder selection.

(3) Use only with JPCP.

(4) Portland cement concrete may be substituted for LCB when justified for constructability 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.

(5) Place an interlayer between the concrete surface layer (JPCP) and the LCB in all cases.

Table 623.1E

Requirements for JPCP and CRCP Subbases

Subgrade Soil (USCS)	Subgrade Type	Minimum Class 2 Aggregate Subbase Thickness
GW	Type I	Subbase not required
GP	Type I	Subbase not required
GM	Type I	Subbase not required
GC	Type I	0.35 ft
SW	Type I	0.35 ft
SP	Type I	0.35 ft
SM	Type I	0.35 ft
SC	Type I	0.35 ft
ML	Type II	0.50 ft
CL	Type II	0.50 ft
MH	Type II	0.75 ft
CH	Type III	Requires stabilization

Tables 623.1F(a) through (d) provide the minimum concrete thickness for SJPCP-COA traveled way. The concrete thickness in the tables includes a provision for future grinding (sacrificial thickness) of 0.03 ft. The concrete thickness is rounded to the nearest 0.05 feet. Each table contains different combinations of base type and thickness and subbase type. The tables are categorized by subgrade type and climate region:

- Table 623.1F(a): Type I subgrade and Group I climate
- Table 623.1F(b): Type I subgrade and Group II climate
- Table 623.1F(c): Type II subgrade and Group I climate
- Table 623.1F(d): Type II subgrade and Group II climate

The climate groups for SJPCP-COA design are defined as follows:

- Group I: CC and NC
- Group II: SM, DE, HD, IV, LM, SC, and HM

Two base types are included in the SJPCP-COA tables: HMA (hot mix asphalt) and CR (cold recycling). The CR alternative includes full-depth recycling with foamed asphalt (FDR-FA) and partial-depth recycling with emulsified or foamed asphalt (PDR-EA or PDR-FA).

The asphalt base thickness is defined as follows:

- HMA alternative: The thickness of sound asphalt that remains after milling (if milling is conducted) plus any HMA or rubberized gap-graded hot mix asphalt (RHMA-G) overlay that may be added to improve the asphalt base structural capacity and/or surface condition.
- CR alternative:
  - For FDR-FA: The thickness of the full-depth recycling.
  - For PDR-EA or PDR-FA: The thickness of sound asphalt that remains after milling plus the thickness of the partial-depth recycling.

The SJPCP-COA design tables consider the following subbasses:

- Cement-treated base (CTB)
- Lean concrete base (LCB)
- Others (aggregate base, asphalt treated permeable base, etc.)

The SJPCP-COA design tables consider the following subgrades:

- Type I: Coarse-grained soils SC, SP, SM, SW, GC, GP, GM, and GW (USCS)
- Type II: Fine-grained soils CL, MH, and ML (USCS)
- Type III: Fine-grained soil CH (USCS) stabilized with lime or cement; these subgrades can be assimilated into Type I subgrades to determine the concrete thickness
- Type III: Fine-grained soil CH (USCS) unstabilized and without drainage issues; these subgrades can be assimilated into Type II subgrades to determine the concrete thickness

The “Not applicable” (N.A.) concrete thickness in Tables 623.6A through D indicates that the required concrete thickness is over 0.60 ft and, consequently, standard JPCP rather than SJPCP-COA design should be considered.

Table 623.1F(a)

Type I Subgrade and Group I Climate (CC and NC)

AADTT [(1)]	Subbase	Minimum Thickness of Concrete Surface Layer (ft)					
		HMA Base			CR Base		
		HMA 0.25 ft	HMA 0.35 ft	HMA 0.45 ft	CR 0.25 ft	CR 0.35 ft	CR 0.45 ft
50	CTB, LCB	0.35	0.35	0.35	0.40	0.35	0.35
	Others	0.35	0.35	0.35	0.45	0.40	0.35
100	CTB, LCB	0.40	0.35	0.35	0.45	0.40	0.35
	Others	0.40	0.35	0.35	0.45	0.40	0.35
200	CTB, LCB	0.40	0.35	0.35	0.45	0.45	0.40
	Others	0.45	0.35	0.35	0.50	0.45	0.40
500	CTB, LCB	0.45	0.35	0.35	0.50	0.45	0.45
	Others	0.45	0.40	0.35	0.50	0.50	0.45
1,000	CTB, LCB	0.50	0.40	0.35	0.55	0.50	0.45
	Others	0.50	0.45	0.35	0.55	0.50	0.50
2,000	CTB, LCB	0.50	0.45	0.35	0.55	0.55	0.50
	Others	0.50	0.45	0.35	0.55	0.55	0.50

(1) Initial (year 1) AADTT of the design lane.

Table 623.1F(b)

Type I Subgrade and Group II Climate (SM, DE, HD, IV, LM, SC, and HM)

AADTT [(1)]	Subbase	Minimum Thickness of Concrete Surface Layer (ft)					
		HMA Base			CR Base		
		HMA 0.25 ft	HMA 0.35 ft	HMA 0.45 ft	CR 0.25 ft	CR 0.35 ft	CR 0.45 ft
50	CTB, LCB	0.40	0.35	0.35	0.45	0.40	0.40
	Others	0.40	0.40	0.35	0.45	0.40	0.40
100	CTB, LCB	0.45	0.40	0.35	0.45	0.45	0.40
	Others	0.45	0.40	0.35	0.45	0.45	0.40
200	CTB, LCB	0.45	0.45	0.35	0.50	0.45	0.45
	Others	0.45	0.45	0.40	0.50	0.45	0.45
500	CTB, LCB	0.50	0.45	0.40	0.50	0.50	0.50
	Others	0.50	0.50	0.45	0.55	0.50	0.50
1,000	CTB, LCB	0.55	0.50	0.45	0.55	0.55	0.50
	Others	0.55	0.50	0.50	0.55	0.55	0.50
2,000	CTB, LCB	0.55	0.50	0.50	0.60	0.55	0.55
	Others	0.55	0.55	0.50	0.60	0.55	0.55

(1) Initial (year 1) AADTT of the design lane.

Table 623.1F(c)

Type II Subgrade and Group I Climate (CC and NC)

		Minimum Thickness of Concrete Surface Layer (ft)					
		HMA Base			CR Base		
AADTT [1]	Subbase	HMA 0.25 ft	HMA 0.35 ft	HMA 0.45 ft	CR 0.25 ft	CR 0.35 ft	CR 0.45 ft
50	CTB, LCB	0.50	0.40	0.35	0.50	0.50	0.45
	Others	0.50	0.45	0.35	0.55	0.50	0.50
100	CTB, LCB	0.50	0.45	0.35	0.55	0.50	0.45
	Others	0.50	0.45	0.35	0.55	0.55	0.50
200	CTB, LCB	0.55	0.45	0.35	0.55	0.55	0.50
	Others	0.55	0.50	0.40	0.60	0.55	0.55
500	CTB, LCB	0.55	0.50	0.40	0.60	0.55	0.55
	Others	0.60	0.55	0.45	0.60	0.60	0.55
1,000	CTB, LCB	0.60	0.55	0.45	N.A.	0.60	0.55
	Others	0.60	0.55	0.50	N.A.	0.60	0.60
2,000	CTB, LCB	0.60	0.55	0.50	N.A.	N.A.	0.60
	Others	N.A.	0.60	0.55	N.A.	N.A.	0.60

(2) Initial (year 1) AADTT of the design lane.

Table 623.1F(d)

Type II Subgrade and Group II Climate (SM, DE, HD, IV, LM, SC, and HM)

		Minimum Thickness of Concrete Surface Layer (ft)					
		HMA Base			CR Base		
AADTT [1]	Subbase	HMA 0.25 ft	HMA 0.35 ft	HMA 0.45 ft	CR 0.25 ft	CR 0.35 ft	CR 0.45 ft
50	CTB, LCB	0.50	0.45	0.40	0.55	0.50	0.45
	Others	0.50	0.50	0.45	0.55	0.55	0.50
100	CTB, LCB	0.55	0.50	0.45	0.55	0.55	0.50
	Others	0.55	0.50	0.50	0.55	0.55	0.55
200	CTB, LCB	0.55	0.50	0.50	0.60	0.55	0.55
	Others	0.55	0.55	0.50	0.60	0.60	0.55
500	CTB, LCB	0.60	0.55	0.50	0.60	0.60	0.55
	Others	0.60	0.60	0.55	N.A.	0.60	0.60
1,000	CTB, LCB	0.60	0.60	0.55	N.A.	0.60	0.60
	Others	N.A.	0.60	0.60	N.A.	N.A.	0.60
2,000	CTB, LCB	N.A.	0.60	0.60	N.A.	N.A.	0.60
	Others	N.A.	N.A.	0.60	N.A.	N.A.	N.A.

(2) Initial (year 1) AADTT of the design lane.

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.
- Dowel bar retrofit.
- Grinding or grooving to maintain ride quality and/or restore surface texture.
- Special surface treatments (such as methacrylate, hardeners, and others).

Rigid pavement preventive maintenance strategies are discussed further in the Concrete Pavement Guide.

624.2 Capital Pavement Maintenance (CAPM)

A CAPM project is warranted if any of the following criteria is met:

(1) Continuously Reinforced Concrete Pavement

- Number of punchouts with high severity cracking is between 1 and 10 per mile.

(2) Jointed Plain Concrete Pavement

- Number of slabs with 3rd stage cracking between 1 and 10 percent of a given travel lane-mile. Note, 3rd stage cracking is any slab with two or more intersecting cracks of at least ¾ inch in width.
- Combination of corner, longitudinal, and traverse cracking and/or spalling between 1 and 15 percent of travel lane-miles. Note, corner, longitudinal, or transverse cracks that are at least ¾ inch in width. Also note, spalling is regarded as a joint or crack which spalls at least 6 inches wide as measured from centerline of joint or spall.

(3) All Concrete Pavements

- International Roughness Index (IRI) is more than 170 with no or minor distress.
- Faulting greater than ¼ inch.

CAPM strategies include the following or combinations of the following:

(a) Individual slab replacement (for JPCP) and punchout repair (for CRCP). The use of rapid strength concrete in the replacement of concrete slabs should be considered to minimize traffic impacts and open the facility to traffic in a minimal amount of time. Individual slab replacements and punchout repair may include replacing existing cement treated base or lean concrete base with rapid setting concrete lean concrete base or rapid strength concrete.

(b) Spall repair. Spall repair is a corrective maintenance treatment that replaces loss of concrete, typically around joints or cracks, with polyester or fast-setting concrete. Depending on the existing pavement condition, spall repairs can be used as the primary project treatment or in combination with other preventive, corrective, or rehabilitation strategies. Typical cases when spall repair may be needed include repair of spalled joints and cracks on individual slab replacement projects, as a pre-overlay repair of a distress pavement surface, or prior to grinding or joint sealing projects.

(c) Grinding to correct faulting or poor ride. To improve ride quality, diamond grind the concrete pavement to correct ride smoothness to an acceptable level. If the existing pavement has an IRI > 170 inches per mile, restore ride quality to an IRI that is 40 percent improvement. If individual slab replacement is part of the project, diamond grind the concrete pavement after slab replacement is completed. The pavement must maintain an IRI of less than 170 inches per mile throughout its service life.

(d) Asphalt overlay strategies for CAPM in Index 635.2 may also apply to concrete pavement where appropriate.

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 information regarding CAPM policies can be found in PDPM Appendix H and Design Information Bulletin (DIB) 81 "Capital Preventive Maintenance Guidelines." Additional details for scoping and designing these strategies can be found in the Concrete Pavement Guide.

Topic 625 – Engineering Procedures for Pavement Rehabilitation

625.1 Rehabilitation Warrants

A rehabilitation project is warranted if any of the following criteria is met:

Jointed Plain Concrete Pavement

- Number of slabs with 3rd stage cracking between 1 and 10 percent of a given travel lane-mile. Note, 3rd stage cracking is any slab with two or more intersecting cracks of ¾ inch in width.
- Combination of corner, longitudinal, and traverse cracking and/or spalling exceeding 15 percent of given travel lane-miles. Note, corner, longitudinal, or transverse cracks are at least ¾ inch in width. Also note, spalling is regarded as a joint or crack which spalls at least 6 inches wide as measured from centerline of joint or spall.

  When the number of slabs that warrant slab replacement per the above criteria is between 10 and 20 percent, perform a life cycle cost analysis per Topic 619 comparing roadway rehabilitation to CAPM. This analysis should account for the future costs of the pavement that is not replaced. If CAPM has lower life cycle cost, pursue the project as a CAPM project.

625.2 Rigid Pavement Rehabilitation Strategies

(1) Strategies. Some rehabilitation strategies include the following or combinations of the following:

(a) Concrete overlay. 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 asphalt interlayer between the concrete overlay and the existing concrete pavement. The interlayer may need to be thicker if it is used temporarily for traffic handling.

(b) Lane replacement. Lane replacements are engineered using the catalog found in Index 623.1. Attention should be given to maintaining existing drainage patterns underneath the surface layer, (see Chapter 650 for further guidance).

(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 for Overlay. Existing pavement distresses should be repaired before overlaying the pavement. Cracks 3/8 inch or wider 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.

(4) Selection. The selection of the appropriate strategy should be based upon life-cycle cost analysis, load transfer efficiency of the joints, materials testing, ride quality, safety, maintainability, constructability, 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 and flexible pavement constructed with aggregates found near the proposed project and subjected to similar physical and environmental conditions.

(5) Smoothness. For rehabilitation projects, restore the ride quality to the IRI specified on the concrete pavement specifications. Additional information on smoothness can be found on the pavement smoothness page on the Department Pavement website.

Topic 626 – Other Considerations

626.1 Traveled Way

(1) Mainline. No additional considerations.

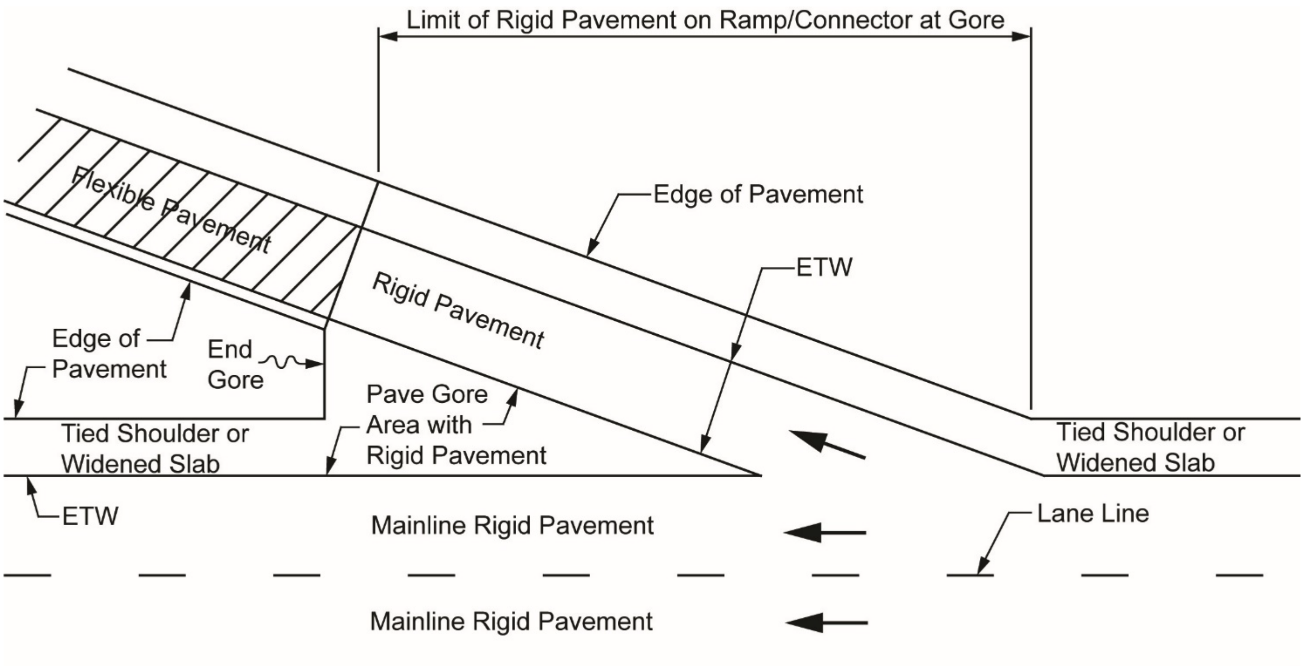
(2) Ramps and Connectors. If tied rigid shoulders or widened slabs are used on the mainline, then the ramp or connector gore area (including ramp traveled way adjacent to the gore area) should also be constructed with rigid pavement (see Figure 626.1). This will minimize deterioration of the joint between the 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 shoulders, 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 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.

Figure 626.1

Preferred Limits of Rigid Pavement at Flexible Pavement Ramp or Connector Gore Area



NOTES:

(1) Not all details shown.

(2) Off ramp shown. Same conditions apply for on ramps.

626.2 Shoulder

The types of shoulders that are used for rigid pavements can be categorized into the following three types:

(1) *Tied Concrete 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 construction joints). This will create aggregate interlock between the lane and shoulder, which provides increased lateral support.

The pavement structure for the tied rigid shoulder should match the pavement structure of the adjacent traffic lane at the edge of traveled way. 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.

The locations to use tied concrete shoulders is discussed under Selection Criteria of this Index. Tied concrete shoulders are also the most adaptable to future widening and conversion to a lane. Where there is an identified documented plan (such as Regional Transportation Plan, Metropolitan Transportation Plan and Interregional Transportation Plan) to convert the shoulder into a traffic lane within the next 20 years, the shoulder may be built to the same geometric and pavement standards as the lane. See Index 613.5(2) for criteria and requirements.

(2) *Widened Slab.* Widened slabs involve constructing the concrete panel for the lane adjacent to the shoulder 14-feet wide on the outside and 13-feet wide on the inside 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 are most useful in areas where lateral support is desired but future widening is not anticipated.

(3) *Untied Shoulders.* Untied shoulders are shoulders that are not tied to the adjacent lane and do not provide lateral support to the adjacent lane. All new construction, reconstruction and rehabilitation shall not have untied shoulders unless a widened lane is constructed.

(4) *Selection Criteria.* Shoulders should be constructed of the same material as the traveled way pavement (in order to facilitate construction, improve pavement performance, and reduce maintenance cost). Shoulders adjacent to rigid pavement traffic lanes can be rigid with the following conditions:

(a) Tied concrete 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 concrete shoulders or widened slabs shall be used for:

- continuously reinforced concrete pavement.
- horizontal radii 300 feet or less.
- truck and bus only lanes.

- desert climate regions. Where widened slabs are used, the remaining shoulder width shall also be concrete pavement.

Where tied concrete shoulders or widened slabs are used, they shall continue through ramp and gore areas (see Figure 626.2A). Paving the gore area and adjacent ramp with concrete is preferred (see Figure 626.1).

The shoulder pavement structure selected must meet or exceed the pavement design life standards in Topic 612 and meet requirements for shoulders in Index 613.5(2). Table 626.2 and Figure 626.2B show rigid pavement shoulder design thicknesses for widened slabs and untied shoulders which meet these requirements. For untied concrete shoulders and portions of shoulders built within widened lane, use the thicknesses in Table 626.2.

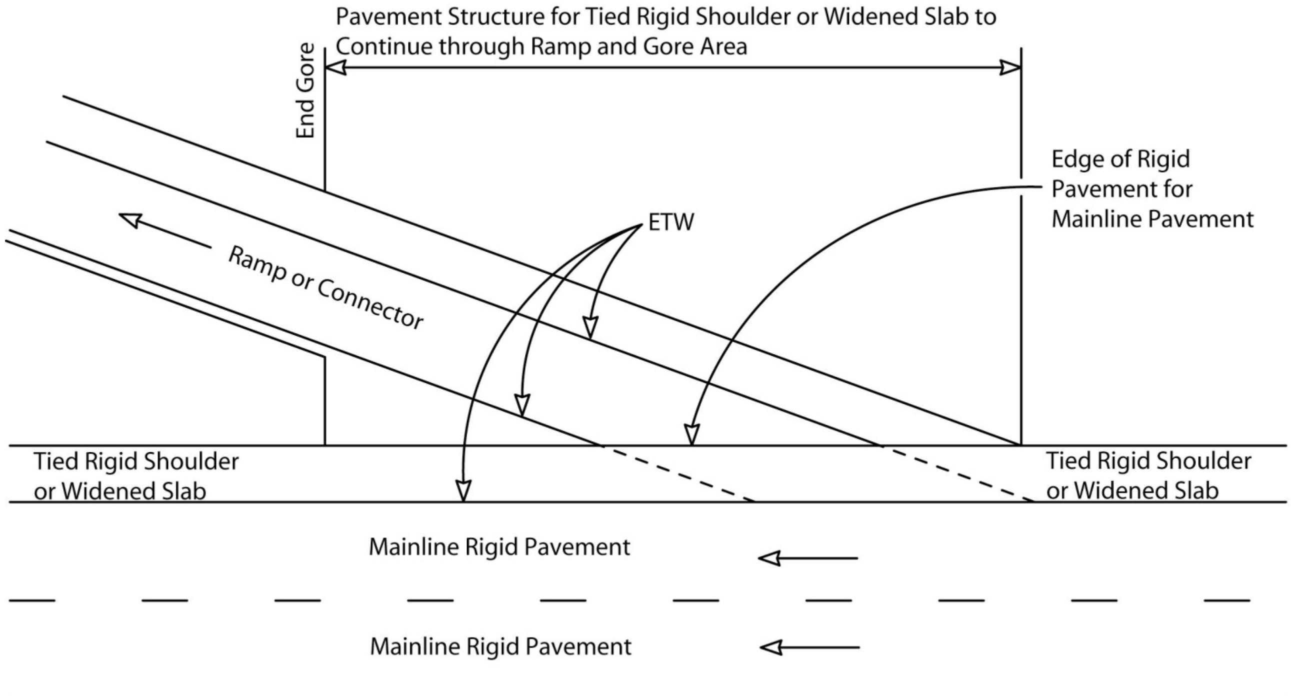
Table 626.2

Shoulder Concrete Pavement Designs ("S" Dimension)

Climate Region	S(ft) (Based on TI ≤ 9, unsupported edge)
North Coast	0.70
South Coast / Central Coast	0.75
Inland Valley	0.80
Desert	0.80
Low Mountain / South Mountain	0.75
High Mountain / High Desert	0.90

Figure 626.2A

Rigid Shoulders Through Ramp and Gore Areas

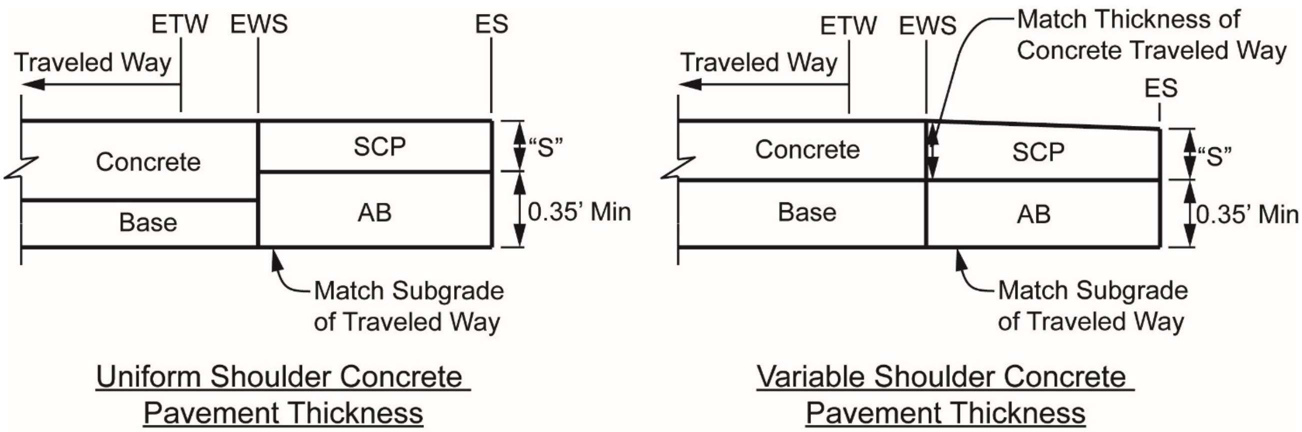


NOTES:

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

Figure 626.2B

Widened Slab Shoulder with Concrete Remainder Designs



NOTES:

No Scale
"S" = Shoulder Concrete Pavement thickness dimension
SCP = Shoulder Concrete Pavement
AB = Aggregate Base
TI = Traffic Index
ETW = Edge of traveled way
EWS = Edge of widened slab
ES = Edge of shoulder

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.

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. Treated bases such as lean concrete base and hot mix asphalt base should not be used for Traffic Indices less than 12.

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 should be doweled in two directions. 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) *Bicycle Facilities.* For bicycle facilities independent of the vehicular roadway use local standards where available and where local agencies will be maintaining the facility. Otherwise, for stand-alone bike paths, use the following thicknesses:

- 0.35 foot minor concrete and 0.50 foot aggregate base for bike paths not available to maintenance vehicles, or
- 0.50 foot minor concrete and 0.50 foot aggregate base for bike paths accessible to maintenance vehicles.

Place longitudinal joints at centerline for 2-way bikeways and no more than 8 feet for one way bikeways. Transverse joints should be placed such that the transverse slab dimension relative to longitudinal dimension is between 1:1 and 1:1.25. Construction is similar to sidewalks or pathways so dowel bars and tie bars should not be used.

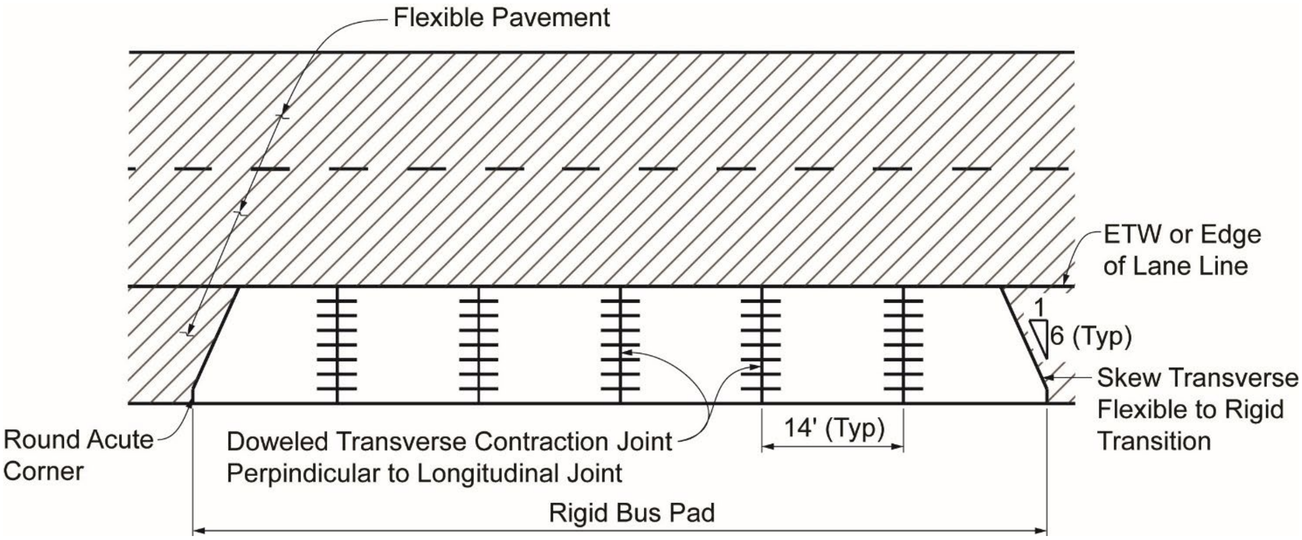
(3) *Bus Pads.* Bus pads are subjected to similar stresses as intersections; however, it is not practical to engineer rigid bus pads according to the Traffic Index, or according to bus counts. The minimum pavement structure for bus pads should be 0.85 foot JPCP with dowel bars at transverse joints on top of 0.5 foot aggregate base. 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.

A JPCP end anchor is not required, but may improve long-term performance at the flexible-to-rigid pavement transition. Doweled transverse joints should be perpendicular to the longitudinal joint at maximum 14 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 reinforced or 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



NOTES:

(1) Not all details shown.

selected to meet the expected project climatic conditions, traffic speed and volume, as well as desired performance reliability. Therefore, the PG system uses a common set of tests to measure physical properties of the binder that can be directly related to field performance of the pavement at its service temperatures. For example, a binder identified as PG 64-10 (64 minus 10) must meet certain performance criteria at an average seven-day maximum pavement temperature of 64ºC, at a minimum pavement temperature of –10ºC, and also at an intermediate temperature of 31ºC.

Although modified asphalt binder is more expensive than unmodified binder, it can provide improved performance and durability for sensitive climate conditions. While unmodified binder is adequate for most applications, improved resistance to rutting, thermal cracking, fatigue damage, stripping, and temperature susceptibility have led polymer modified binders to be substituted for unmodified asphalt binders in many paving and maintenance applications.

632.2 Binder Selection

Table 632.1 shows the PG binder that is to be used for each climatic region for general application. For HMA, values are given for typical and special conditions. For a few select applications such as dikes and tack coats, PG binder requirements are found in the applicable Standard Specifications or Standard Special Provisions.

For locations of each pavement climate region see Topic 615.

Binder selection based on climate region is crucial for improving the pavement resistance to temperature extremes that cause rutting and low-temperature cracking during its service life. The intermediate temperature part of the PG specification limits binder stiffness at temperatures at which most fatigue damage occurs. The intermediate specification limiting stiffness is applicable for applications of new HMA or overlays that are approximately 0.33 ft or thinner where softer binder allows the HMA to bend without excessive damage. For the same reason, polymer modified mixes which have good rutting resistance and good resistance to crack propagation, but which have low stiffness at intermediate temperatures, should not be used more than 0.25 ft below the surface of the pavement (not including open-graded mix thickness). Stiffer binder and mixes are generally preferred for thicker applications because the stiffness helps limit the amount of bending. These considerations are included in *CalME* thickness design for new pavement and rehabilitation.

Special conditions in Table 632.1 are defined as those roadways or portions of roadways that need additional attention due to conditions where slow traffic and turning movements increase the risk of rutting, such as:

- Heavy truck/bus traffic (over 10 million ESALs for 20 years.)
- Truck/bus stopping areas (parking area, rest area, loading area, etc.)

Table 632.1
Asphalt Binder Performance Grade Selection

Climate Region[6]	Binder Grade for Hot Mixed Asphalt (HMA)[1, 2]				
	Dense Graded HMA		Open Graded HMA		Gap and Open Graded Rubberized Hot Mix Asphalt (RHMA)
			Placement Temperature		
	Typical	Special[3]	> 70°F	≤ 70°F	
South Coast Central Coast Inland Valley	PG 64-10	PG 70-10 or PG 64-28 M	PG 64-10	PG 58-34 M	PG 64-16
North Coast	PG 64-16	PG 64-28 M	PG 64-16	PG 58-34 M	PG 64-16
Low Mountain South Mountain	PG 64-16	PG 64-28 M	PG 64-16	PG 58-34 M	PG 64-16
High Mountain High Desert	PG 64-28	PG 58-34 M[4]	PG 64-28	PG 58-34 M	PG 58-22
Desert	PG 70-10	PG 64-28 M	PG 70-10	PG 58-34 M or PG 64-28 M[5]	PG 64-16

NOTES:

(1) PG = Performance Grade

(2) M = Modified (Polymers, crumb rubber, or both)

(3) PG 76-22 M may be specified for conventional dense graded hot mix asphalt for special conditions in all climate regions when specifically requested by the District Materials Engineer.

(4) PG 64-28 M may be specified when particularly requested by the District Materials Engineer.

(5) Consult with the District Materials Engineer for which binder grade to use.

(6) Refer to Topic 615 for determining climate region for project.

objectionable. If it is concluded that the objection is valid, a more compatible facility may be substituted, subject to the following controls:

- Preference should be given to retaining the standard fence along the ramp to the end of the curb return or beginning of the taper on the local road. Where this is not reasonable, there may be substituted a fence or wall of equal or better durability and utility that is at least 4 feet high relative to the grade of freeway right of way line. Walls, ornamental iron fences with closely spaced members, or chain link fences are examples of acceptable possibilities.
- Along the local road, beyond the end of the curb return or the beginning of the taper, a facility of somewhat lower standards may be employed, if considered appropriate. The minimum allowable height is 2.5 feet above the grade at the edge of the right of way. In addition to the fence types suitable for use along the ramp, split rail fences, wooden picket fences, and permanent planter boxes are examples of possibilities. The intent is to delineate the access control line and discourage access violations in an effective manner.
- Generally, all costs for the removal of the existing freeway fence and the installation and future maintenance of a nonstandard fence are to be the property owner's responsibility under the terms of the encroachment permit authorizing the substitution. On new construction, the property owner is to assume similar costs and responsibilities subject to a credit for the value of a standard fence.

(4) *Location of Fences.* Normally, fences on freeways should be placed adjacent to, but on the freeway side of the right of way line.

Fences in the outer separation normally should be placed so that the area outside of the fence may be relinquished to the local agency. Typical fence placement should be at the freeway right of way line per Figure 307.4B.

When viewed at a flat angle, chain link fencing restricts sight distance. This fact should be considered in the location of such fencing at intersections. To eliminate hand maintenance, right-angle jogs should be avoided.

(5) *Locked Gates.* Locked gates may be provided in access control fences in special situations. A proposal for a locked gate must address a necessity. Although openings controlled by locked gates do not constitute access breaks in the usual sense of access control, they must be shown on the plans. When locked gates are proposed there must be a specific reason for each gate. All gates must be kept locked and secured. Locked gates fall into two categories:

(a) Locked gates to be used exclusively for access by highway maintenance forces on Interstate require FHWA approval. Locked gates to be used exclusively for access by highway maintenance forces on non-Interstate may be approved by the District Director. The integrity and security of this access must always be assured. Maintenance forces must also keep gates locked when not being used for the access of persons or equipment. When locked gates are to be used exclusively by highway maintenance forces, one or more of the following criteria apply:

- A circuitous route would be eliminated.
- The gate access would minimize the exposure of maintenance workers to highway traffic.
- Parking is available outside the gate.
- The gate would allow slow moving equipment to be kept off the highway.

- The site is not accessible to maintenance personal or equipment from the freeway.

(b) Proposals for locked gates to be used by utility companies, non-utility entities, or public agencies on non-Interstate must be submitted to the District Director for approval. The gate submittal must present all pertinent facts and alternate solutions.

Locked gates to be used by utility companies, non-utility entities, or public agencies require FHWA approval if the gate is on an Interstate route.

When proposals for locked gates requiring FHWA approval are included in the plans for new construction, including landscaping projects, FHWA approval of such gates should occur early in the project development process. Subsequent installations requiring FHWA approval must be submitted separately to FHWA by the Division of Design after recommendation for approval by the Chief, Office of Project Support, Division of Design. See Chapter 17 of the Project Development Procedures Manual for more information.

701.3 Private Fences

(1) Placement. Caltrans will construct or pay the cost of fences on private property only as a right of way consideration to mitigate damages. Caltrans' construction of such fences should be limited to:

(a) The reconstruction or replacement of existing fences.

(b) The construction of fences across property that had been previously enclosed by fences.

These criteria apply to all private as well as public lands.

(2) Private Fences Inside the State Right of Way. Private fences may be constructed within the State right of way via Encroachment Permit to restrict access to facilities (e.g., canals) crossing under or through Department-owned property. A Maintenance Agreement must be executed to provide for future maintenance of the fence and allow access to the private utility.

701.4 Temporary Fences

(1) Placement. Temporary fences are located where necessary in accordance with construction contractor activities and where the right of way rights have been acquired.

(2) Types of Fences. Temporary fence design should conform to the needs of the situation and the length of time to be used. In most access control or demarcation applications the fence fabric will conform to permanent fence standards, while lesser requirements may apply to posts and post footings to more readily accommodate removal when no longer needed.

Temporary fence used during reconstruction of private fences must be of a type adequate to meet the permanent private fence purposes.

701.5 Other Fences

(1) ESA and Species Protection Fences. District Environmental Unit staff must specify the required placement limits and locations for ESA and species protection fences.

ESA fence material requirements are described in Section 14 of the Standard Specifications.

The following measures are commonly used to prolong the maintenance-free service life of steel culverts:

(a) Galvanizing. Under most conditions plain galvanizing of steel pipe is all that is needed; however, the presence of corrosive or abrasive elements may require additional protection.

- Protective Coatings – The necessity for any coating should be determined considering hydraulic conditions, local experience, possible environmental impacts, and long-term economy. Approved protective coatings are polymeric sheet, which can be applied to the inside and/or outside of the pipe; and polyethylene for composite steel spiral ribbed pipe which is a steel spiral ribbed pipe externally pre-coated with a polymeric sheet, and internally polyethylene lined. All of these protective coatings are typically shop-applied prior to delivery to the construction site. Polymeric sheet coating provides much improved corrosion resistance and can be considered to typically allow achievement of a 50-year maintenance-free service life without need to increase thickness of the steel pipe. To ensure that a damaged coating does not lead to premature catastrophic failure, the base steel thickness for pipes that are to be coated with a polymeric sheet must be able to provide a minimum 10-year service life prior to application of the polymeric material.

  Bituminous coatings are no longer used as protective coatings for metal pipes. Citing Section 5650 of the Fish and Game Code, the Department of Fish and Game (DFG) has restricted the use of bituminous coatings on the interior of pipes if they are to be placed in streams that flow continuously or for an extended period (more than 1 to 2 days) after a rainfall event. Their concern is that abraded particles of asphalt could enter the stream and degrade the fish habitat. Where abrasion is unlikely, DFG concerns should be minimal. DFG has indicated that they have no concerns regarding interior application of polymeric sheet coatings, even under abrasive conditions.

  Where the materials report indicates that soil side corrosion is expected, an exterior application of polymeric sheet, as provided in the Standard Specifications, combined with galvanizing of steel, is usually effective in forestalling accelerated corrosion on the backfill side of the pipe. Where soil side corrosion is the only, or primary, factor leading to deterioration, a polymeric sheet coating is typically expected to provide up to 50 years of service life to an uncoated pipe. For locations where water side corrosion and/or abrasion is of concern, protective coatings, or protective coatings with pavings, or protective coatings with linings, in combination with galvanizing will add to the culvert service life to a variable degree, depending upon site conditions and type of coating selected. Refer to Index 855.2 Abrasion, and Index 855.3 Corrosion. If hydraulic conditions at the culvert site require a lining on the inside of the pipe or a coating different than that indicated in the Standard Specifications, then the different requirements must be described in the Special Provisions.

- Extra Metal Thickness. – Added service life can be achieved by adding metal thickness. However, this should only be considered after protective coatings and pavings have been considered. Since 0.052 inch thick steel culverts is the minimum steel pipe Caltrans allows, it must be limited to locations that are nonabrasive.

See Table 855.2C for estimating the added service life that can be achieved by coatings and invert paving of steel pipes based upon abrasion resistance characteristics.

(b) Aluminized Steel (Type 2). Evaluations of aluminized steel (type 2) pipe in place for over 40 years have provided data that substantiate a design service life with respect to corrosion resistance equivalent to aluminum pipe. Therefore, for pH values between 5.5 and 8.5, and minimum resistivity values in excess of 1500 ohm-cm, 0.064 inch aluminized steel (type 2) is considered to provide a 50 year design service life. Where abrasion is of concern, aluminized steel (type 2) is considered to be roughly equivalent to galvanized steel. A concrete invert may also be considered where abrasion is of concern.

For pH ranges outside the 5.5 and 8.5 limits or minimum resistivity values below 1500 ohm-cm, aluminized steel (type 2) should not be used. In no case should the thickness of aluminized steel (type 2) be less than the minimum structural requirements for a given diameter of galvanized steel. Refer to Index 855.2 Abrasion, and Index 855.3 Corrosion.

The AltPipe Computer Program is also available to help designers estimate service life for various corrosive/abrasive conditions. See https://dot.ca.gov/programs/design/hydraulics-stormwater/bsa-alternative-pipe-culvert-selection-altpipe.

(3) Strength Requirements. The strength requirements for corrugated steel pipes and pipe arches, fabricated under acceptable methods contained in the Standard Specifications, are given in Tables 856.3A, B, C, & D. For steel spiral rib pipe see Tables 856.3E, F & G.

(a)Design Standards.

- Corrugation Profiles – Corrugated steel pipe and pipe arches are available in 2⅔" x ½", 3" x 1", and 5" x 1" profiles with helical corrugations, and 2⅔" x ½" profiles with annular corrugations. Corrugated steel spiral rib pipe is available in a ¾" x ¾" x 7½" or ¾" x 1" x 11½" helical corrugation pattern. For systems requiring large diameter and/or deeper fill capacity a ¾" x 1" x 8½" helical corrugation pattern is available. Composite steel spiral rib pipe is available in a ¾" x ¾" x 7½" helical ribbed profile.

  Metal Thickness - Corrugated steel pipe and pipe arches are available in the thickness as indicated on Tables 856.3A, B, C & D. Corrugated steel spiral rib pipe is available in the thickness as indicated on Tables 856.3E, F & G. Where a maximum overfill is not listed on these tables, the pipe or arch size is not normally available in that thickness. All pipe sections provided in Table 856.3 meet handling and installation flexibility requirements of AASHTO LRFD. Composite steel spiral rib pipe is available in the thickness as indicated on Table 856.3G.

- Height of Fill – The allowable overfill heights for corrugated steel and corrugated steel spiral rib pipe and pipe arches for the various diameters or arch sizes and metal thickness are shown on Tables 856.3A, B, C, & D. For corrugated steel spiral rib pipe, overfill heights are shown on Tables 856.3E, F & G. Table 856.3G gives the allowable overfill height for composite steel spiral rib pipe.

(4) Shapes. Corrugated steel pipe, steel spiral rib pipe and pipe arches are available in the diameters and arch shapes as indicated on the maximum height of cover tables. For larger diameters, arch spans or special shapes, see Index 852.5.

(5) Invert Protection. Refer to Index 855.2 Abrasion. Invert protection should be considered for corrugated steel culverts exposed to excessive wear from abrasive flows or corrosive water. Severe abrasion usually occurs when the flow velocity exceeds 12 feet per second to 15 feet per second and contains an abrasive bedload of sufficient volume. When severe

abrasion or corrosion is anticipated, special designs should be investigated and considered. Typical invert protection includes invert paving with portland cement concrete with wire mesh reinforcement, and invert lining with metal plate. The paving limits for invert linings are site specific and should be determined by field review. Additional metal thickness will increase service life. Reducing the velocity within the culvert is an effective method of preventing severe abrasion. Index 853.6 provides additional guidance on invert paving with concrete.

(6) *Spiral Rib Steel.* Galvanized steel spiral rib pipe is fabricated using sheet steel and continuous helical lock seam fabrication as used for helical corrugated metal pipe. The manufacturing complies with Section 66, “Corrugated Metal Pipe,” of the Standard Specifications, except for profile and fabrication requirements. Spiral rib pipe is fabricated with either: three rectangular ribs spaced midway between seams with ribs 3/4" wide x 3/4" high at a maximum rib pitch of 7-1/2 inches, two rectangular ribs and one half-circle rib equally spaced between seams with ribs 3/4" wide x 1" high at a maximum rib pitch of 11-1/2 inches with the half-circle rib diameter spaced midway between the rectangular ribs, or two rectangular ribs equally spaced between seams with ribs 3/4" wide x 1" high at a maximum rib pitch of 8-1/2 inches.

Aluminized steel spiral rib pipe, type 2 (ASSRP) is available in the same sizes as galvanized steel spiral rib and will support the same fill heights (the aluminizing is simply a replacement coating for zinc galvanizing that allows thinner steel to be placed in certain corrosive environments. See Figure 855.3A for the acceptable pH and resistivity ranges for placement of aluminized steel pipes). Tables 856.3E, F & G give the maximum height of overfill for steel spiral rib pipe constructed under the acceptable methods contained in the Standard Specifications and essentials discussed in Index 829.2.

852.4 Corrugated Aluminum Pipe, Aluminum Spiral Rib Pipe and Pipe Arches

Corrugated aluminum pipe, aluminum spiral rib pipe and pipe arches are available in the diameters and arch shapes as indicated on the maximum height of cover tables. For larger diameters, arch spans or special shapes see Index 852.6. Corrugated aluminum pipe and pipe arches are available in various corrugation profiles with helical and annular corrugations. Helical corrugated pipe must be specified if anticipated heights of cover exceed the tabulated values for annular corrugated pipe. Non-standard pipe diameters and arch sizes are also available. Aluminum spiral rib pipe is similar to spiral rib steel and is available in several helical corrugation patterns.

(1) *Hydraulics*. Corrugated aluminum pipe comes in various corrugated profiles. Annular and helical corrugated aluminum pipe configurations are applicable in the situations where velocity reduction is important or if a culvert is being designed with an inlet control condition. Spiral rib pipe, on the other hand, may be more appropriate for use in stormdrain situations or if a culvert is being designed with an outlet control condition. Spiral rib pipe has a lower roughness coefficient (Manning's “n”) than other corrugated metal pipe profiles.

(2) *Durability.* Aluminum culverts or stormdrains may be specified as an alternate culvert material. When a 50-year maintenance-free service life of aluminum pipe is required the pH and minimum resistivity, as determined by California Test Method 643, must be known and the following conditions met:

(a) The pH of the soil, backfill, and effluent is within the range of 5.5 and 8.5, inclusive. For corrosion protection or abrasion resistance, a concrete invert lining may be considered.

Abrasive potential must be estimated from bed material that is present and anticipated flow velocities. Refer to Index 855.1 for a discussion of maintenance-free service life and Index 855.2 Abrasion, and Index 855.3 Corrosion prior to selecting aluminum as an allowable alternate.

(b) The minimum resistivity of the soil, backfill, and effluent is 1500 ohm-cm or greater.

(c) Aluminum culverts should not be installed in an environment where other aluminum culverts have exhibited significant distress, such as extensive perforation or loss of invert, for whatever reason, apparent or not.

(d) Aluminum may be considered for side drains in environments having the following parameters:

- When pH is between 5.5 and 8.5 and the minimum resistivity is between 500 and 1500 ohm-cm.
- When pH is between 5.0 and 5.5 or between 8.5 and 9.0 and the minimum resistivity is greater than 1500 ohm-cm.

For these conditions, the Corrosion Technology Branch in METS should be contacted to confirm the advisability of using aluminum on specific projects.

(e) Aluminum must not be used as a section or extension of a culvert containing steel sections.

(3) Strength Requirements. The strength requirements for corrugated aluminum pipe and pipe arches fabricated under the acceptable methods contained in the Standard Specifications, are given in Tables 856.3H, I & J. See Table 856.3K and Table 856.3L for aluminum spiral rib pipe. Tables 856.3H through L are based on the material properties of H-32 temper aluminum. Additional cover heights can be achieved for an aluminum section when H-34 temper material is used. Contact DES-Structures Design for a special design using H-34 temper material.

(a) Design Standards.

- Corrugation Profiles - Corrugated aluminum pipe and pipe arches are available in 2⅔" x ½" and 5" x 1" profiles with helical or annular corrugations. Aluminum spiral rib pipe is available in a ¾" x ¾" x 7½" or a ¾" x 1" x 11½" helical corrugation profile.
- Metal thickness - Corrugated aluminum pipe and pipe arches are available in the thickness as indicated on Tables 856.3H, I & J. Where a maximum overfill is not listed on these tables, the pipe or pipe arch is not normally available in that thickness. All pipe sections provided in Table 856.3 meet handling and installation flexibility requirements of AASHTO LRFD. Aluminum spiral rib pipe are available in the thickness as indicated on Tables 856.3K & L.
- Height of Fill - The allowable overfill heights for corrugated aluminum pipe and pipe arches for various diameters and metal thicknesses are shown on Tables 856.3H, I & J. For aluminum spiral rib pipe, overfill heights are shown on Tables 856.3K, & L.

(4) Shapes. Corrugated aluminum pipe, aluminum spiral rib pipe and pipe arches are available in the diameters and arch shapes as indicated on the maximum height of cover tables. Helical corrugated pipe must be specified if anticipated heights of cover exceed the tabulated values for annular corrugated pipe.

For larger diameters, arch spans or special shapes, see Index 852.5. Non-standard pipe diameters and arch sizes are also available.

(5) Invert Protection. Invert protection of corrugated aluminum is not recommended.

Estimating Years to Perforation of Steel Culverts," is part of a Standard California Department of Transportation Test Method derived from highway culvert investigations. This chart alone is not used for determining service life because it does not consider the effects of abrasion or overfill; it is for estimating the years to the first corrosion perforation of the wall or invert of the CSP. Additional gauge thickness or invert protection may be needed if the thickness for structural requirements (i.e., for overfill) is inadequate for abrasion potential.

Table 855.2E indicates relative abrasion resistance properties of pipe and lining materials and summarizes the findings from "Evaluations of Abrasion Resistance of Pipe and Pipe Lining Materials Final Report FHWA /CA/TL-CA01-0173 (2007)". This report may be viewed at the following web address: https://rosap.ntl.bts.gov/view/dot/27517. See Figure 855.2.

Figure 855.2

Abrasion Test Panels

Various culvert material test panels shown in Figure 855.2 after 1 year of wear at site with moderate to severe abrasion (velocities generally exceed 13 ft/s with heavy bedload). The report included HDPE and PVC plastic pipe materials, but not PP. Additional studies have shown that PP abrasion resistance could exceed that of HDPE, however industry recommends using the abrasion values assigned to corrugated HDPE for PP pipe until specific abrasion resistance data can be obtained.

Table 855.2F is based on Tables 855.2D and 855.2E and constitutes a guide for selecting the minimum material thickness of abrasive resistant invert protection for various materials to achieve 50 years of maintenance-free service life.

Structural metal plate pipe and arches provide a viable option for large diameter pipes (60 inches or larger) in abrasive environments because increased thickness can be specified for the lower 90 degrees or invert plates. If the thickness for structural requirements is inadequate for abrasion potential, it is recommended to apply the increased thickness to the lower 90 degrees of the pipe only. Arches, which have a relatively larger invert area than circular pipe, generally will provide a lower abrasion potential from bedload being less concentrated.

Table 855.2A

Abrasion Levels and Materials

Abrasion Level	General Site Characteristics	Allowable Pipe Materials and Lining Alternatives
Level 1	• Bedloads of silts and clays or clear water with virtually no abrasive bed load. No velocity limitation.	All pipe materials listed in Table 857.2 allowable for this level. No abrasive resistant protective coatings listed in Table 855.2C needed for metal pipe.
Level 2	• Moderate bed loads of sand or gravel • Velocities ≥ 1 ft/s and ≤ 5 ft/s (See Note 1)	All allowable pipe materials listed in Table 857.2 with the following considerations: • Generally, no abrasive resistant protective coatings needed for steel pipe. • Polymericcoating or an additional gauge thickness of metal pipe may be specified if existing pipes in the same vicinity have demonstrated susceptibility to abrasion and thickness for structural requirements is inadequate for abrasion potential.
Level 3	• Moderate bed load volumes of sands, gravels and small cobbles. • Velocities > 5 ft/s and ≤ 8 ft/s (See Note 1)	All allowable pipe materials listed in Table 857.2 with the following considerations: • Steel pipe may need one of the abrasive resistant protective coatings listed in Table 855.2C or additional gauge thickness if existing pipes in the same vicinity have demonstrated susceptibility to abrasion and thickness for structural requirements is inadequate for abrasion potential. • Aluminum pipe may require additional gauge thickness for abrasion if thickness for structural requirements is inadequate for abrasion potential. • Aluminized steel (type 2) not recommended without invert protection or increased gauge thickness (equivalent to galv. Steel) where pH < 6.5 and resistivity < 20,000. Lining alternatives: • PVC, • Corrugated or Solid Wall HDPE, • Dual Wall PP, • CIPP

Note:

(1) If bed load volumes are minimal, a 50% increase in velocity is permitted.

Under similar conditions, aluminum culverts will abrade between one and a half to three times faster than steel culverts. Therefore, aluminum culverts are not recommended where abrasive materials are present, and where flow velocities would encourage abrasion to occur. Culvert flow velocities that frequently exceed 5 feet per second where abrasive materials are present should be carefully evaluated prior to selecting aluminum as an allowable alternate. In a corrosive environment, Aluminum may display less abrasive wear than steel depending on the volume, velocity, size, shape, hardness and rock impact energy of the bed load. However, if it is deemed necessary to place aluminum pipe in abrasion levels 4 through 6 in Table 855.2C, contact Headquarters Office of State Highway Drainage Design for assistance.

Aluminized Steel (Type 2) can be considered equivalent to galvanized steel for abrasion resistance and therefore does not have the same limitations as aluminum in abrasive environments.

Concrete pipes typically counter abrasion through increased minimum thickness over the steel reinforcement, i.e., by adding additional sacrificial material. See Table 855.2F. However, there are significantly fewer limitations involved in increasing the invert thickness of RCB in the field verses increasing minimum thickness over the steel reinforcement of RCP in the plant. Therefore, RCP is typically not recommended in abrasive flows greater than 10 feet per second but may be considered for higher velocities if the bedload is insignificant (e.g. storm drain systems and most.

Table 855.2C

Guide for Anticipated Service Life Added to Steel Pipe by Abrasive Resistant Protective Coating[2]

Flow Velocity (ft/s)	Channel Materials	Paved Invert (yrs.)	Polymeric Sheet Coating (yrs.)	Polyethylene (CSSRP) (yrs.)
	Non-Abrasive	15	*	*
≥ 1 – ≤ 8 [1]	Abrasive	15-2	30-5	*
> 8 – ≤ 12	Abrasive	2-0	5-0	70-35
> 12 – ≤ 15	Abrasive	**	**	35-8***
> 12 – ≤ 20	Abrasive & heavy bedloads	****	****	****

* Provides adequate abrasion resistance to meet or exceed a 50-year design service life.
** Abrasive resistant protective coatings not recommended, increase steel thickness to 10 gage.
*** Not recommended above 14 fps flow velocity.
**** Contact District Hydraulics Branch. See Table 855.2F.

Notes:
[1] Where there are increased velocities with minor bedload volumes, much higher velocities may be applicable.
[2] Range of additional service life commensurate with flow velocity range.

Table 855.2D

Guide for Anticipated Wear to Metal Pipe by Abrasive Channel Materials

Flow Velocity (ft/s)	Channel Materials	Anticipated Wear (mils/yr)		
		Plain Galvanized	Aluminized Steel (Type 2)	Aluminum**
	Non-Abrasive	0*	0*	0
≥ 1 – ≤ 8	Abrasive	0*	0*	0 – 1.5
> 8 – ≤ 12	Abrasive	0.5 – 1	0.5 – 1	1.5 – 3
> 12 – ≤ 15	Abrasive	1 – 3.5	1 – 3.5	3 – 10.5
> 12 – ≤ 20	Abrasive & Heavy bedloads	2.5 – 10	2.5 – 10	7.5 – 30

* Refer to California Test 643 and Figure 855.3B.
** Refer to Figure 855.3A.
Note:
1 mil = 0.001"

Table 855.2E

Relative Abrasion Resistance Properties of Pipe and Lining Materials*

Material	Relative Wear (dimensionless)
Steel	1
Aluminum	1.5 – 3
PVC	2
Polyester Resin (CIPP)	2.5 – 4
HDPE	4 – 5
Concrete (RCP 4000 – 7000 psi)	75 – 100
Calcium Aluminate (Mortar)	30-40
Calcium Aluminate (Concrete)	20 – 25
Basalt Tile	1
Polyethylene (CSSRP)	1 – 2

* Evaluation of Abrasion Resistance of Pipe and Pipe Lining Materials Final Report FHWA/CA/TL-CA01-0173 (2007).

Corrosion can also be caused by excessive acidity in the water conveyed by the pipe. Water pH can vary considerably between watersheds and seasons.

Because failure can occur at any point along the length of the pipe (e.g. tidal zones), the designer must look at the conditions and how they may vary along the pipe length - and select for input into AltPipe those conditions that represent the most severe situation along the length.

AltPipe operates based on some fairly basic assumptions for corrosion and minimum resistivity that are part of California Test 643. Altpipe will list all viable alternatives for achieving design service life. Where enhanced soilside corrosion protection is needed, aluminum or aluminized pipe (if within acceptable pH/min. resistivity ranges), or polymeric sheet coating should be considered.

Aluminum, and the aluminum coating provided by Aluminized Steel (Type 2) pipe, corrodes differently than steel and will provide adequate durability to meet the 50-year service life criterion within the acceptable pH range of 5.5-8.5 and minimum resistivity greater than 1500 ohm-cm without need for specifying a thicker gauge or additional coating, whereas under the same range galvanized steel may need a protective coating or an increase in thickness to provide a 50-year maintenance-free service life (with respect to corrosion). Figure 855.3A should be used to determine the limitations on the use of corrugated aluminum pipe for various levels of pH and minimum resistivity. The minimum thickness (0.060 inch) of aluminum pipe obtained from the chart only satisfies corrosion requirements. Overfill requirements for minimum metal thickness must also be satisfied. The metal thickness of corrugated aluminum pipe should satisfy both requirements.

Figure 855.3A should be used to determine the minimum thickness and limitation on the use of corrugated steel and spiral rib pipe for various levels of pH and minimum resistivity. For example, given a soil environment with pH and minimum resistivity levels of 6.5 and 15,000 ohm-cm, respectively, the minimum thicknesses for the various metal pipes are: 1) 0.109 inch (12 gage) galvanized steel, 2) 0.064 inch (16 gage) aluminized steel (type 2) and 3) 0.060 inch (16 gage) aluminum. The minimum thickness of metal pipe obtained from the figure only satisfies corrosion requirements. Overfill requirements for minimum metal thickness must also be satisfied. The metal thickness of corrugated pipe and steel spiral rib pipe that satisfies both requirements should be used.

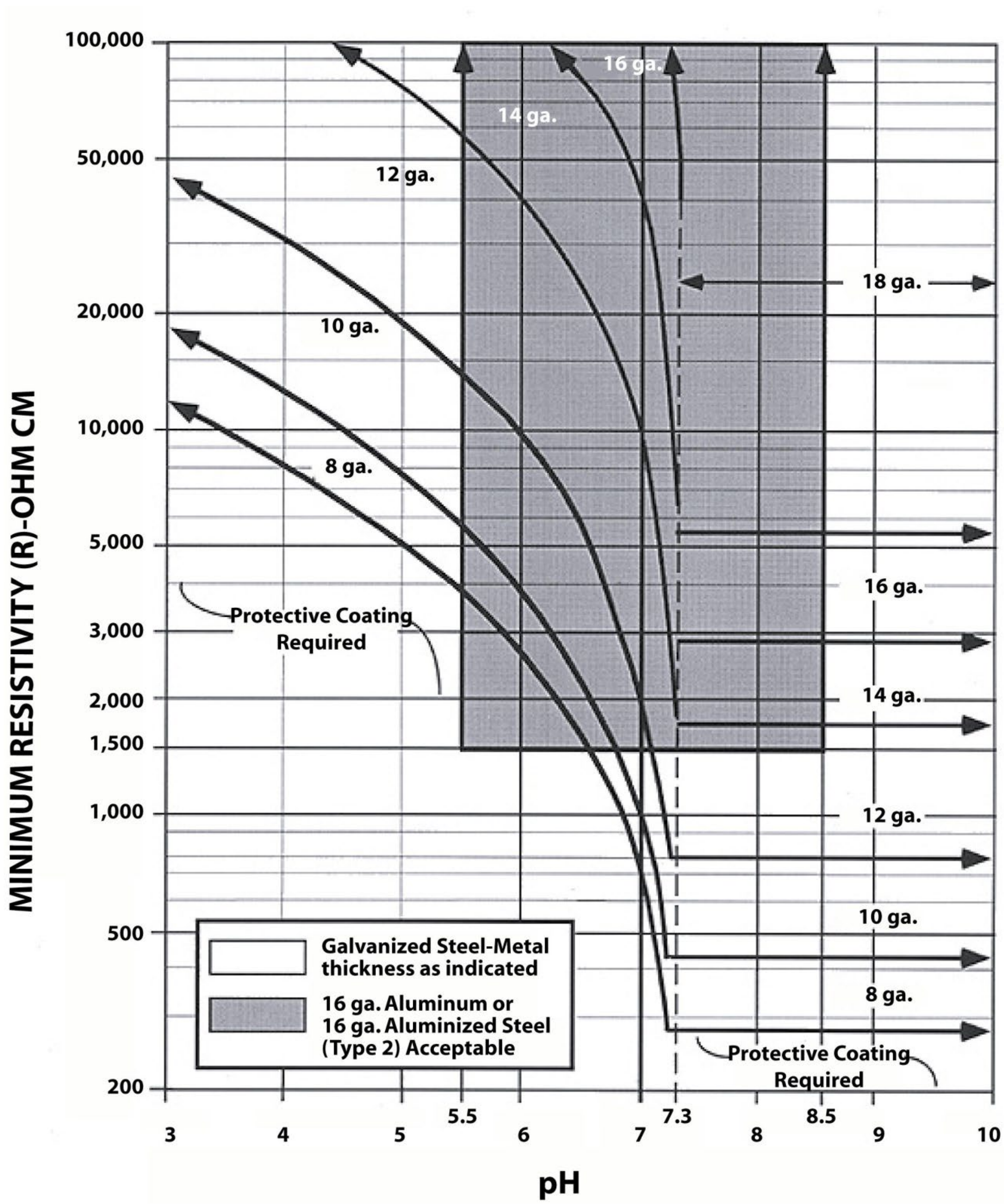
Figure 855.3B, “Chart for Estimating Years to Perforation of Steel Culverts,” is part of a Standard California Department of Transportation Test Method derived from highway culvert investigations. This chart alone is not used for determining service life because it does not consider the effects of abrasion or overfill; it is for estimating the years to the first corrosion perforation of the wall or invert of the CSP.

855.4 Protection of Concrete Pipe and Drainage Structures from Acids, Chlorides and Sulfates

Table 855.4A indicates the limitation on the use of concrete by acidity of soil and water. Table 855.4A is also a guide for designating cementitious material restrictions and water content

Figure 855.3A

Minimum Thickness of Metal Pipe for 50-Year Maintenance-Free Service Life [(2)]



Notes:

(1) For pH and aluminum resistivity levels not shown refer to Fig. 855.3B steel pipes. (California Test 643)
(2) Service life estimate are for various corrosive conditions only.
(3) Refer to Index 852.3(2) and 852.4(2) for appropriate selection of metal thickness and protection coating to achieve service life requirements.

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