

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
Caltrans or Department	California Department of Transportation
CFR	Code of Federal Regulations
CTC or Commission	California Transportation Commission
DES District	Division of Engineering Services 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 Pavement
OCPPF	Office of Concrete Pavement and Pavement Foundations
PP	Pavement Program
PS&E	Plans, Specifications, and Estimate
PUC	Public Utilities Commission
SD	Structure Design
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.

(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) *On-Street Parking.* In urban, and rural main street place types where parking in the shoulder of the roadway is permitted and expected for access to local business or residences. Permitted parking in the shoulder on a rural non-main street is not considered "on-street" parking for the purposes of this manual although it is legal.
- (7) *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.
- (8) *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.
- (9) *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.
- (10) *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 bicyclists and pedestrians, see the guidance in this manual as well as DIB 82.
- (11) *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.
- (12) *Traveled Way.* The portion of the roadway for the movement of vehicles and bicycles, exclusive of shoulders.

62.2 Highway Structures

- (1) *Illustration of Types of Structures.* Figure 62.2 illustrates the names given to common types of structures used in highway construction. This nomenclature must be used in all phases of planning.
- (2) *Bridges.* Structures that span more than 20 feet, measured along the centerline of the road between undercopings of abutments, and multiple span structures, including culverts, where the total measurement of the individual spans are in excess of 20 feet, measured from center to center of supports along the centerline of the road and the distance between individual culvert barrels is less than one-half the culvert diameter. Culverts that fit the definition of a bridge will be designed and maintained by the Division of Engineering Services - Structures Design and assigned a bridge number.
- (3) *Culverts.* See Index 806.2.

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.

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.
- (2) *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.

- (3) *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.
- (4) *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 or town center, a suburban area or an urban area.
 - (d) *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 area in urban and suburban areas.
 - (e) *Divided Highway*--A highway with separated roadbeds for traffic traveling in opposing directions.
 - (f) *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.
 - (g) *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.
- (5) *Parkway.* An arterial highway for non-commercial vehicles, with full or partial

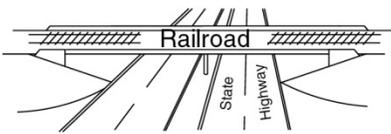
control of access, which is typically located within a park or a ribbon of park-like development.

- (6) *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.
- (7) *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 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.

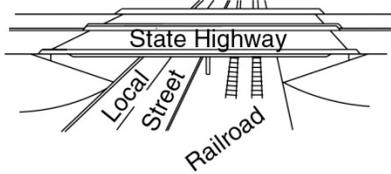
62.4 Interchanges and Intersections at Grade

- (1) *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.

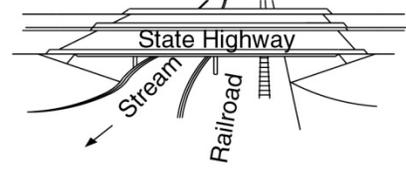
Figure 62.2
Types of Structures



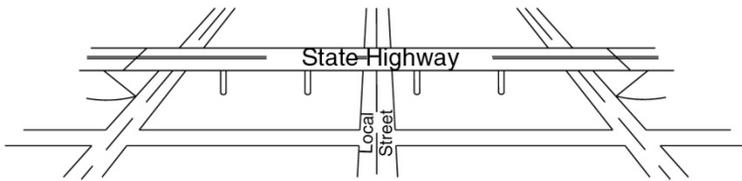
UNDERPASS



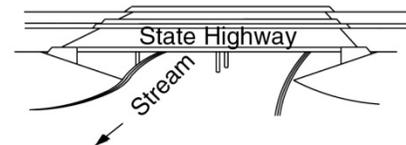
OVERHEAD



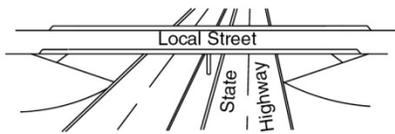
BRIDGE & OVERHEAD



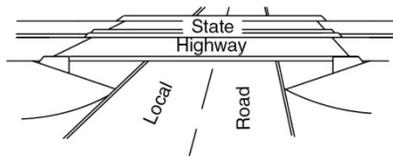
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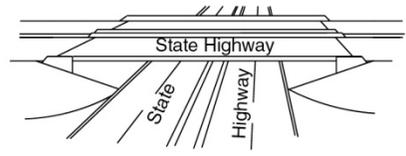
BRIDGE



OVERCROSSING



UNDERCROSSING



SEPARATION

- (2) *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.
- (3) *Geometric Design*. The arrangement of the visible elements of a road, such as alignment, grades, sight distances, widths, slopes, etc.
- (4) *Gore*. The area immediately beyond the divergence of two roadbeds bounded by the edges of those roadbeds.
- (5) *Grade Separation*. A crossing of two highways, highway and local road, or a highway and a railroad at different levels.
- (6) *Interchange*. A system of interconnecting roadways in conjunction with one or more grade separations that provides for the movement of vehicles between two or more roadways on different levels.
- (7) *Interchange Elements*.
- (a) Branch Connection--A multilane connection between two freeways.
 - (b) Freeway-to-freeway Connection--A single or multilane connection between freeways or any two high speed facilities.
 - (c) Ramp--A connecting roadway between a freeway or expressway and another highway, road, or roadside area.
- (8) *Intersection*. The general area where two or more roadways join or cross, including the roadway and roadside facilities for movements in that area.
- (9) *Island*. A defined area between roadway lanes for control of vehicle movements or for pedestrian refuge. Within an intersection a median or an outer separation is considered an island.
- (10) *Minimum Turning Radius*. The radius of the path of the outer front wheel of a vehicle making its sharpest turn.
- (11) *Offset Left-Turn Lanes*. Left-turn lanes are shifted as far to the left as practical rather than aligning the left-turn lane exactly parallel with and adjacent to the through lane.
- (12) *Offtracking*. The difference between the paths of the front and rear wheels of a vehicle as it negotiates a turn.
- (13) *Pedestrian Refuge*. A small section of pavement or sidewalk, completely surrounded by asphalt or other road materials, where users can stop before completing the crossing of a road.
- (14) *Roundabout*. A type of circular intersection with specific geometric and traffic control features that combine low speed operations and lower speed differentials among all users immediately prior to, through, and beyond the intersection. Vehicle speed is controlled by deflection in the path of travel, and the "yield upon entry" rule for traffic approaching the roundabout's circulatory roadway. Curves and deflections that limit operating speeds to 30 mph or less. See Chapter 400 for additional information and reference to technical publications.
- (15) *Skew Angle*. The complement of the acute angle between two centerlines which cross.
- (16) *Swept width*. The total width needed by the vehicle body to traverse a curve; it is the distance measured along the curve radius from the outer front corner of the body to the inner rear corner of the body as the vehicle traverses around a curve. This width is used to determine clearance to objects, such as signs, poles, etc., as well as vehicles, bicycles, and pedestrians.
- (17) *Tracking width*. The total width needed by the tires to traverse a curve; it is the distance measured along the curve radius from the outer front tire track to the inner rear tire track as the vehicle traverses around a curve. This width is used to determine the minimum width required for the vehicle turning. Consideration

for additional width may be needed for other vehicles, bicycles and pedestrians.

- (18) *Weaving Section.* A length of roadway, designed to accommodate two traffic streams merging and dividing within a short distance.
- (19) *Wheelbase.* For single-unit vehicles, the distance from the first axle to the single rear axle or, in the case of a tandem or triple set of rear axles, to the center of the group of rear axles. See Topic 404

62.5 Landscape Architecture

- (1) *"A" Soil Horizon.* Formed below the "O" soil horizon layer, defined in part (9) below, where mineral matter is mixed with decayed organic matter.
- (2) *Classified Landscaped Freeway.* A classified landscaped freeway is a planted section of freeway that meets the criteria established by the California Code of Regulations Outdoor Advertising Regulations, Title 4, Division 6. This designation is used in the control and regulation of outdoor advertising displays.
- (3) *Duff.* A vegetative material that has been collected and removed from the project during clearing and grubbing activities, chipped or ground up and stockpiled for reapplication to the final slope surface.
- (4) *Highway Planting.* Highway planting addresses safety requirements, provides compliance with environmental commitments, and assists in the visual integration of the transportation facility within the existing natural and built environment. Highway planting provides planting to satisfy legal mandates, environmental mitigation requirements, Memoranda of Understanding or Agreement between the Department and local agencies for aesthetics or erosion control. Highway planting also includes roadside management strategies that improve traveler and worker safety by reducing the frequency and duration of maintenance worker exposure.
- Highway planting required due to the impacts of a roadway construction project must be programmed and funded by the parent roadway project.
- Highway planting, funded and maintained by the Department on conventional highways, is limited to planting that provides: safety improvements, erosion control/storm water pollution prevention, revegetation, and required mitigation planting. Highway planting on freeways, controlled access highways and expressways, funded and maintained by the Department, is limited to areas that meet specific criteria. See Chapter 29 "Landscape Architecture" of the Project Development Procedures Manual (PDPM) for more detailed information regarding warranted planting.
- (5) *Highway Planting Restoration.* Highway planting restoration provides for replacement, restoration, and rehabilitation of existing vegetation damaged by weather, acts of nature or deterioration, to integrate the facility with the adjacent community and surrounding environment. Highway planting restoration also provides erosion control to comply with National Pollutant Discharge Elimination System (NPDES) permit requirements. These projects include strategies designed to protect the safety of motorists and maintenance workers by minimizing recurrent maintenance activities.
- (6) *Highway Planting Revegetation.* Highway planting revegetation provides planting as mitigation for native vegetation damaged or removed due to a roadway construction project. Highway planting revegetation may include irrigation systems as appropriate. Highway planting revegetation, required due to the impacts of a roadway construction project, must be programmed and funded by the parent roadway project.
- (7) *Imported Topsoil.* Soil that is delivered onto a project from a commercial source and is fertile, friable soil of loamy character that contains organic matter.
- (8) *Local Topsoil.* Existing soil obtained from the "A" and "O" soil horizons within the project limits, typically during excavation activities.
- (9) *"O" Soil Horizon.* The surface layer consisting of loose and partly decaying organic matter.

- (10) *Park and Ride*. A paved area for parking which provides a connection point for public access to a variety of modal options. See Topic 905.
- (11) *Replacement Highway Planting*. Replacement highway planting replaces vegetation installed by the Department or others, that has been damaged or removed due to transportation project construction. Replacement highway planting may also include irrigation modifications and/or replacement. Replacement highway planting required due to the impacts of a roadway construction project must be programmed in conjunction with and funded from the parent roadway project.
- (12) *Required Mitigation Planting*. Required mitigation planting provides planting and other work necessary to mitigate environmental impacts due to roadway construction. The word “required” indicates that the work is necessary to meet legally required environmental mitigation or permit requirements. Required mitigation planting may be performed within the operational right of way, immediately adjacent to the highway or at an offsite location as determined by the permit. A planting project for required mitigation due to the impacts of a roadway construction project must be programmed and funded by the parent roadway project.
- (13) *Safety Roadside Rest Area System*. The safety roadside rest area system is a component of the highway system providing roadside areas where travelers can stop, rest and manage their travel needs. Planned with consideration of alternative stopping opportunities such as truck stops, commercial services, and vista points, the rest area system provides public stopping opportunities where they are most needed, usually between large towns and at entrances to major metropolitan areas. Within the safety roadside rest system, individual rest areas may include vehicle parking, picnic tables, sanitary facilities, telephones, water, tourist information panels, traveler service information facilities and vending machines. See Topic 903.
- (14) *Street Furniture*. Features such as newspaper boxes, bicycle racks, bus shelters, benches, art or drinking fountains that occupy space on or alongside pedestrian sidewalks.
- (15) *Vista Point*. Typically a paved dedicated area beyond the shoulder that permits travelers to stop and view a scenic area. In addition to parking areas, amenities such as trash receptacles, interpretive displays, and in some cases, rest rooms, drinking water and telephones may be provided. See Topic 904.

62.6 Right of Way

- (1) *Acquisition*. The process of obtaining right of way.
- (2) *Air Rights*. The property rights for the control or specific use of a designated airspace involving a highway.
- (3) *Appraisal*. An expert opinion of the market value of property including damages and special benefits, if any, as of a specified date, resulting from an analysis of facts.
- (4) *Business District (or Central Business District)*. The commercial and often the geographic heart of a city, which may be referred to as “downtown.” Usually contains retail stores, theatres, entertainment and convention venues, government buildings, and little or no industry because of the high value of land. Historic sections may be referred to as “old town.”
- (5) *Condemnation*. The process by which property is acquired for public purposes through legal proceedings under power of eminent domain.
- (6) *Control of Access*. The condition where the right of owners or occupants of abutting land or other persons to access in connection with a highway is fully or partially controlled by public authority.
- (7) *Easement*. A right to use or control the property of another for designated purposes.
- (8) *Eminent Domain*. The power to take private property for public use without the owner's consent upon payment of just compensation.

- (9) *Encroachment.* Any structure, object, or activity of any kind or character which is within the right of way, but not a part of the State facility, or serving a transportation need.
- (10) *Inverse Condemnation.* The legal process which may be initiated by a property owner to compel the payment of just compensation, where the property has been taken for or damaged by a public purpose.
- (11) *Negotiation.* The process by which property is sought to be acquired for project purposes through mutual agreement upon the terms for transfer of such property.
- (12) *Partial Acquisition.* The acquisition of a portion of a parcel of property.
- (13) *Relinquishment.* A transfer of the State's right, title, and interest in and to a highway, or portion thereof, to a city or county.
- (14) *Right of Access.* The right of an abutting land owner for entrance to or exit from a public road.
- (15) *Severance Damages.* Loss in value of the remainder of a parcel which may result from a partial taking of real property and/or from the project.
- (16) *Vacation.* The reversion of title to the owner of the underlying fee where an easement for highway purposes is no longer needed.
- (3) *Asphalt Treated Permeable Base (ATPB).* A highly permeable open-graded mixture of crushed coarse aggregate and asphalt binder placed as the base layer to assure adequate drainage of the structural section, as well as structural support.
- (4) *Base.* A layer of selected, processed, and/or treated aggregate material that is placed immediately below the surface course. It provides additional load distribution and contributes to drainage and frost resistance.
- (5) *Basement Soil/Material.* See Subgrade.
- (6) *Borrow.* Natural soil obtained from sources outside the roadway prism to make up a deficiency in excavation quantities.
- (7) *California R-Value.* A measure of resistance to deformation of the soils under saturated conditions and traffic loading as determined by the stabilometer test (CT301). The California R-value, also referred to as R-value, measures the supporting strength of the subgrade and subsequent layers used in the pavement structure. For additional information, see Topic 614.
- (8) *Capital Preventive Maintenance.* Typically, Capital Preventive Maintenance (CAPM) consists of work performed to preserve the existing pavement structure utilizing strategies that preserve or extend pavement service life. The CAPM program is divided into pavement preservation and pavement rehabilitation. For further discussion see Topic 603.
- (9) *Cement Treated Permeable Base (CTPB).* A highly permeable open-graded mixture of coarse aggregate, portland cement, and water placed as the base layer to provide adequate drainage of the structural section, as well as structural support.
- (10) *Composite Pavement.* These are pavements comprised of both rigid and flexible layers. Currently, for purposes of the procedures in this manual, only flexible over rigid composite pavements are considered composite pavements.
- (11) *Crack.* Separation of the pavement material due to thermal and moisture variations,

62.7 Pavement

The following list of definitions includes terminologies that are commonly used in California as well as selected terms from the "AASHTO Guide for the Design of Pavement Structures" which may be used by FHWA, local agencies, consultants, etc. in pavement engineering reports and research publications.

- (1) *Asphalt Concrete.* See Hot Mix Asphalt (HMA).
- (2) *Asphalt Rubber.* A blend of asphalt binder, reclaimed tire rubber, and certain additives in which the rubber component is at least 15 percent by weight of the total blend and has reacted in the hot asphalt binder sufficiently to cause swelling of the rubber particles.

- consolidation, vehicular loading, or reflections from an underlying pavement joint or separation.
- (12) *Crack, Seat, and Overlay (CSO)*. A rehabilitation strategy for rigid pavements. CSO practice requires the contractor to crack and seat the rigid pavement slabs, and place a flexible overlay with a pavement reinforcing fabric (PRF) interlayer.
- (13) *Crumb Rubber Modifier (CRM)*. Scrap rubber produced from scrap tire rubber and other components, if required, and processed for use in wet or dry process modification of asphalt paving.
- (14) *Deflection*. The downward vertical movement of a pavement surface due to the application of a load to the surface.
- (15) *Dense Graded Asphalt Concrete (DGAC)*. See Hot Mix Asphalt (HMA).
- (16) *Depression*. Localized low areas of limited size that may or may not be accompanied by cracking.
- (17) *Dowel Bar*. A load transfer device in a rigid slab usually consisting of a plain round steel bar.
- (18) *Edge Drain System*. A drainage system, consisting of a slotted plastic collector pipe encapsulated in treated permeable material and a filter fabric barrier, with unslotted plastic pipe vents, outlets, and cleanouts, designed to drain both rigid and flexible pavement structures.
- (19) *Embankment*. A prism of earth that is constructed from excavated or borrowed natural soil and/or rock, extending from original ground to the grading plane, and designed to provide a stable support for the pavement structure.
- (20) *Equivalent Single Axle Loads (ESAL's)*. The number of 18-kip standard single axle load repetitions that would have the same damage effect to the pavement as an axle of a specified magnitude and configuration. See Index 613.3 for additional information.
- (21) *Flexible Pavement*. Pavements engineered to transmit and distribute vehicle loads to the underlying layers. The highest quality layer is the surface course (generally asphalt binder mixes) which may or may not incorporate underlying layers of base and subbase. These types of pavements are called "flexible" because the total pavement structure bends or flexes to accommodate deflection bending under vehicle loads. For further discussion, see Chapter 630.
- (22) *Grading Plane*. The surface of the basement material upon which the lowest layer of subbase, base, pavement surfacing, or other specified layer, is placed.
- (23) *Gravel Factor (G_f)*. Refers to the relative strength of a given material compared to a standard gravel subbase material. The cohesiometer values were used to establish the G_f currently used by Caltrans.
- (24) *Hot Mix Asphalt (HMA)*. Formerly known as asphalt concrete (AC), HMA is a graded asphalt concrete mixture (aggregate and asphalt binder) containing a small percentage of voids which is used primarily as a surface course to provide the structural strength needed to distribute loads to underlying layers of the pavement structure.
- (25) *Hot Recycled Asphalt (HRA)*. The use of reclaimed flexible pavement which is combined with virgin aggregates, asphalt, and sometimes rejuvenating agents at a central hot-mix plant and placed in the pavement structure in lieu of using all new materials.
- (26) *Joint Seals*. Pourable, extrudable or premolded materials that are placed primarily in transverse and longitudinal joints in concrete pavement to deter the entry of water and incompressible materials (such as sand that is broadcast in freeze-thaw areas to improve skid resistance).
- (27) *Lean Concrete Base*. Mixture of aggregate, portland cement, water, and optional admixtures, primarily used as a base for portland cement concrete pavement.
- (28) *Longitudinal Joint*. A joint normally placed between roadway lanes in rigid pavements to control longitudinal cracking; and the joint between the traveled way and the shoulder.

- (29) *Maintenance*. The preservation of the entire roadway, including pavement structure, shoulders, roadsides, structures, and such traffic control devices as are necessary for its safe and efficient utilization.
- (30) *Open Graded Asphalt Concrete (OGAC)*. See Open Graded Friction Course (OGFC).
- (31) *Open Graded Friction Course (OGFC)*. Formerly known as open graded asphalt concrete (OGAC), OGFC is a wearing course mix consisting of asphalt binder and aggregate with relatively uniform grading and little or no fine aggregate and mineral filler. OGFC is designed to have a large number of void spaces in the compacted mix as compared to hot mix asphalt. For further discussion, see Topic 631.
- (32) *Overlay*. An overlay is a layer, usually hot mix asphalt, placed on existing flexible or rigid pavement to restore ride quality, to increase structural strength (load carrying capacity), and to extend the service life.
- (33) *Pavement*. The planned, engineered system of layers of specified materials (typically consisting of surface course, base, and subbase) placed over the subgrade soil to support the cumulative vehicle loading anticipated during the design life of the pavement. The pavement is also referred to as the pavement structure and has been referred to as pavement structural section.
- (34) *Pavement Design Life*. Also referred to as performance period, pavement design life is the period of time that a newly constructed or rehabilitated pavement is engineered to perform before reaching a condition that requires CAPM, (see Index 603.4). The selected pavement design life varies depending on the characteristics of the highway facility, the objective of the project, and projected vehicle volume and loading.
- (35) *Pavement Drainage System*. A drainage system used for both asphalt and rigid pavements consisting of a treated permeable base layer and a collector system which includes a slotted plastic pipe encapsulated in treated permeable material and a filter fabric barrier with unslotted plastic pipe as vents, outlets and cleanouts to rapidly drain the pavement structure. For further discussion, see Chapter 650.
- (36) *Pavement Preservation*. Work done, either by contract or by State forces to preserve the ride quality, safety characteristics, functional serviceability and structural integrity of roadway facilities on the State highway system. For further discussion, see Topic 603.
- (37) *Pavement Service Life*. Is the actual period of time that a newly constructed or rehabilitated pavement structure performs satisfactorily before reaching its terminal serviceability or a condition that requires major rehabilitation or reconstruction. Because of the many independent variables involved, pavement service life may be considerably longer or shorter than the design life of the pavement. For further discussion, see Topic 612.
- (38) *Pavement Structure*. See Pavement.
- (39) *Pumping*. The ejection of base material, either wet or dry, through joints or cracks, or along edges of rigid slabs resulting from vertical movements of the slab under vehicular traffic loading. This phenomena is especially pronounced with saturated structural sections.
- (40) *Raveling*. Progressive disintegration of the surface course on asphalt concrete pavement by the dislodgement of aggregate particles and binder.
- (41) *Rehabilitation*. Work undertaken to extend the service life of an existing facility. This includes placement of additional surfacing and/or other work necessary to return an existing roadway, including shoulders, to a condition of structural or functional adequacy, for the specified service life. This might include the partial or complete removal and replacement of portions of the pavement structure. Rehabilitation is divided into pavement rehabilitation activities and roadway rehabilitation activities (see Indexes 603.3 and 603.4).

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

62.8 Highway Operations

- (1) *Annual Average Daily Traffic*. The average 24-hour volume, being the total number

during a stated period divided by the number of days in that period. Unless otherwise stated, the period is a year. The term is commonly abbreviated as ADT or AADT.

- (2) *Delay*. The time lost while road users are impeded by some element over which the user has no control.
- (3) *Density*. The number of vehicles per mile on the traveled way at a given instant.
- (4) *Design Vehicles*. See Topic 404.
- (5) *Design Volume*. A volume determined for use in design, representing traffic expected to use the highway. Unless otherwise stated, it is an hourly volume.
- (6) *Diverging*. The dividing of a single stream of traffic into separate streams.
- (7) *Headway*. The time in seconds between consecutive vehicles moving past a point in a given lane, measured front to front.
- (8) *Level of Service*. A rating using qualitative measures that characterize operational conditions within a traffic stream and their perception by users.
- (9) *Managed Lanes*. Lanes that are proactively managed in response to changing operating conditions in efforts to achieve improved efficiency and performance. Typically employed on highways with increasing recurrent traffic congestion and limited resources.
 - (a) High-Occupancy Vehicle (HOV) Lanes--An exclusive lane for vehicles carrying the posted number of minimum occupants or carpools, either part time or full time.
 - (b) High Occupancy Toll (HOT) Lanes--An HOV lane that allows vehicles qualified as carpools to use the facility without a fee, while vehicles containing less than the required number of occupants to pay a toll. Tolls may change based on real time conditions (dynamic) or according to a schedule (static).
 - (c) Express Toll Lanes--Facilities in which all users are required to pay a toll, although

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

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

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

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

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

CHAPTER 100 BASIC DESIGN POLICIES

Topic 101 - Design Speed

Index 101.1 - Selection of Highway Design Speed

Design speed is defined as: "a speed selected to establish specific minimum geometric design elements for a particular section of highway". These design elements include vertical and horizontal alignment, and sight distance. Other features such as widths of pavement and shoulders, horizontal clearances, etc., are generally not directly related to design speed.

In California the majority of projects only modify existing facilities. On those projects observed motor vehicle speed (operating speed) is the primary factor requiring consideration by the designer. Generally the posted speed is a reliable indicator of operating speed although operating speeds frequently exceed posted speeds. Speed limits and speed zones are discussed in Chapter 2 of the California MUTCD, which include references to the California Vehicle Code.

On projects where posted speeds or observational data is not available, the choice of design speed is influenced principally by the character of terrain, economic considerations, environmental factors, type and anticipated volume of vehicular traffic, presence of non-motorized traffic, functional classification of the highway, existing and future adjacent land use, and whether the area is rural or urban. A highway in level or rolling terrain justifies a higher design speed than one in mountainous terrain. As discussed under Topic 109, scenic values are also a consideration in the selection of a design speed.

In addition, the selected design speed should be consistent with the operating speeds that are likely to be expected on a given highway facility. Drivers and bicyclists adjust their speed based on their perception of the physical limitations of the highway and its vehicular and bicycle traffic. In addition, bicycling and walking can be encouraged

when bicyclists and pedestrians perceive an increase in safety due to lower design speeds.

Where a reason for limiting speed is obvious to approaching drivers or bicyclists, they are more apt to accept a lower operating speed than where there is no apparent reason for it.

A highway carrying a higher volume of traffic may justify a higher design speed than a lower classification facility in similar topography, particularly where the savings in user operation and other costs are sufficient to offset the increased cost of right of way and construction. A lower design speed; however, should not be assumed for a secondary road where the topography is such that drivers are likely to travel at higher speeds.

Subject to the above discussion, on high-speed facilities as high a design speed as feasible should be used. Highway context in terms of area place type, land use, types of users, etc. need to also be considered when determining the appropriate design speed for lower speed facilities.

It is preferable that the design speed for any section of highway be a constant value. However, during the detailed design phase of a project, special situations may arise in which engineering, economic, environmental, or other considerations make it impractical to provide the minimum elements established by the design speed. See Index 82 for documenting localized exception to features preventing the standard design speed.

The cost to correct such restrictions may not be justified. Technically, this will result in a reduction in the effective design speed at the location in question. **Such technical reductions in design speed shall be discussed with and documented as required by the Design Coordinator.**

Local streets or roads within the State right of way, including facilities which will be relinquished after construction (such as frontage roads), shall have minimum design speeds conforming to AASHTO standards, as per the functional classification of the facility in question. If the local agency having jurisdiction over the facility in question maintains design standards that exceed AASHTO standards, then the local agency standards should apply.

Where the local facility connects to a freeway or expressway (such as ramp terminal intersections), the design speed of the local facility shall be a minimum of 35 miles per hour. However, the design speed should be 45 miles per hour when feasible.

Every effort should be made to avoid decreasing the design speed of a local facility through the State's right of way, and all due consideration should be given to local plans to upgrade or improve the facility in the near future.

101.2 Highway Design Speed Standards

Selection of Design speed should always be equal to or exceed the posted speed limit for the facility. Preferred is 10 to 15 miles per hour over posted speed. For existing facilities design speeds should reflect operating speeds.

The following table shows appropriate ranges of design speeds that shall be used for various conditions:

**Table 101.2
Vehicular Design Speed**

Facility	Design Speed (mph)
LIMITED ACCESS TYPES	
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
City or Town Centers (Main Streets)	30-40
Urban	
Arterial streets, Non-Main Streets	40-60
Arterial streets, Main Streets in Community Centers and Downtown Cores	30-40
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 ^M /45 ^A
	M=Mandatory A=Advisory

- (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 of 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.

102.2 Design Capacity and Quality of Service (Pedestrians and Bicycles)

Sidewalks are to accommodate pedestrians at a Level of Service (LOS) equal to that of vehicles using the roadway, or better. More detailed guidance on design capacity for sidewalks is available in the "Highway Capacity Manual" (HCM), published by the Transportation Research Board. The HCM also has guidance regarding LOS for bicycle facilities for both on- and off-street applications. The LOS for on-street bicycle facilities should be equal to that of vehicles using the roadway or better. The design of off-street bicycle facilities can use the LOS methodology in the HCM when conditions justify deviations from the standards in Chapter 1000.

Topic 103 - Design Designation

103.1 Relation to Design

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

$$\begin{aligned}
 \text{ADT (2015)} &= 9800 & D &= 60\% \\
 \text{ADT (2035)} &= 20\,000 & T &= 12\% \\
 \text{DHV} &= 3000 & V &= 70 \text{ mph} \\
 \text{ESAL} &= 4\,500\,000 & \text{TI}_{20} &= 11.0
 \end{aligned}$$

CLIMATE REGION = Desert

The notation above is explained as follows:

ADT (2015) -- The average daily traffic, in number of vehicles, for the construction year.

ADT (2035) -- The average daily traffic for the future year used as a target in design.

CLIMATE REGION – Climate Region as defined in Topic 615. In addition to establishing design requirements for the project, this information is used by the Resident Engineer during construction to determine which clauses in the Standard Specifications apply to the project.

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

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

ESAL – The equivalent single axle loads forecasted for pavement engineering. See Topic 613.

T -- The truck traffic volume expressed as a percent of the DHV (excluding recreational vehicles).

TI₂₀ – Traffic Index used for pavement engineering. The number in the subscript is the pavement design life used for pavement design. See Index 613.3(3).

V -- Design speed in miles per hour.

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

- (a) The design hourly traffic warrants a change in the number of lanes, or
- (b) A change in conditions dictates a change in design speed.
- (c) The design daily truck traffic warrants a change in the Traffic Index.

The design designation should be stated in Project Initiation Documents and Project Reports and should appear on the typical cross section for all new, reconstructed, or rehabilitation (including Capital Preventative Maintenance) highway construction projects.

103.2 Design Period

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

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

Complimentary to the design period, various components of a project (e.g., drainage facilities, structures, pavement structure, etc.) have a design life that may differ from the design period. For pavement design life requirements, see Topic 612.

Topic 104 - Control of Access

104.1 General Policy

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

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

104.2 Access Openings

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

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

104.3 Frontage Roads

(1) *General Policy.*

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

- Control access to the through lanes, thus increasing safety for traffic.
- Provide access to abutting land ownerships.
- Provide or restore continuity of the local street or road systems.
- Provide for bicycle and pedestrian traffic that might otherwise need to use the freeway.

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

(c) Access Openings--Direct access to the through lanes is allowable on expressways. When the number of access openings on one side of the expressway exceeds three in 1,600 feet, a frontage road should be provided (see Index 104.2).

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

(3) *Existing Alignment.* Where a freeway or expressway is developed parallel to an existing highway or local street, all or part of

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

(4) *Railroad Crossings.* Frontage roads on one or both sides of a freeway or expressway on new alignment, owing to safety and cost considerations, frequently are terminated at the railroad right of way. When terminating a frontage road at the railroad crossing, bicycle and pedestrian traffic still needs to have reasonable access through the community.

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

(5) *Frontage Roads Financed by Others.* Frontage roads which are not a State responsibility under this policy may be built by the State upon request of a local political subdivision, a private agency, or an individual. Such a project must be covered by an agreement under which the State is reimbursed for all construction, right of way, and engineering costs involved.

104.4 Protection of Access Rights

For proper control of acquired access rights, fencing or other approved barriers shall be installed on all controlled access highways except as provided in Index 701.2(3)(e).

104.5 Relation of Access Opening to a Median Opening

Access openings should not be placed within 300 feet of a median opening unless the access opening is directly opposite the median opening.

Details on access openings are given under Index 205.1.

104.6 Maintaining Local Community Access

When planning and designing a new freeway or expressway, the designer needs to consider the impacts of an access controlled facility on the local community. Closing non-expressway local road connections may negatively impact access for pedestrians, bicyclists and equestrians. A new facility may inadvertently sever local non-motorized access creating long out of direction travel. Designers need to coordinate with local agencies for access needs across an access controlled facility.

104.7 Cross References

- (a) Access Control at Intersections at Grade (see Index 405.6).
- (b) Access Control at Interchanges (see Index 504.8).

Topic 105 - Pedestrian Facilities

105.1 General Policy

Pedestrians, unless restricted by law, are allowed to use conventional highways and some expressways for transportation purposes. Connections between different modes of travel should be considered when designing highway facilities, as all people may become pedestrians when transferring to a transit based facility. Pedestrian use near transit facilities should be considered during the planning phase of transportation improvement projects. See DIB 82 for accessibility guidance of pedestrian facilities. See also Topic 115 and 116 for guidance regarding designing for bicycle traffic.

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 the Division of Engineering Services - Structure Design (DES-SD), 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.

105.3 Pedestrian Grade Separations

- (1) Pedestrian grade separation takes the form of pedestrian overcrossings or undercrossings.

These grade separations are suitable for crossing freeways, rivers, railroads, canyons and other obstacles for which no other crossing opportunities exist.

See Index 208.6 for design guidance for pedestrian and bicycle overcrossings and undercrossings.

The need for a pedestrian grade separation is based on a study of the present and future needs of a particular area or community. Each situation should be investigated and considered on its own merits. The study should cover pedestrian generating sources in the area, pedestrian crossing volumes, type of highway to be crossed, location of adjacent crossing facilities, circuitry, zoning, land use, sociological and cultural factors, and the predominant age of persons expected to utilize the facility.

Pedestrian patterns should be maintained across freeway routes where these patterns have been previously established. Where vehicular crossings are inadequate for pedestrians, separate structures should be provided. In general, if a circuitous route is involved, a pedestrian separation may be justified even though the number of pedestrians is small.

State participation in the financing of pedestrian separations at ramp terminals is not normally justified because of the crash history at these locations. Exceptions to this general policy should be considered only in special circumstances where no less expensive alternative is feasible.

Where a pedestrian grade separation is justified, an overcrossing is preferred. Undercrossings tend to provide less visibility which provides more opportunities for vandalism and criminal activity. Consideration may be given to an undercrossing when specifically requested in writing by a local agency. Unobstructed visibility should be provided through the structure and approaches.

See Index 105.4 for discussion of provisions for persons with disabilities.

(2) *Financing.*

- (a) Freeways--Where the pedestrian grade separation is justified prior to award of the freeway contract, the State should pay the full cost of the pedestrian facility. In some cases, construction of the separation may be deferred; however, where the need has been established to the satisfaction of the Department prior to award of the freeway contract, the State should pay the entire cost of the separation.

Local jurisdictions have control (by zoning and planning) of development that influences pedestrian traffic patterns. Therefore, where a pedestrian grade separation is justified after the award of a freeway contract, the State's share of the total construction cost of the separation should not exceed 50 percent. The State must enter into a cooperative agreement with the local jurisdiction on this basis.

- (b) Conventional Highways--Grade separations are not normally provided for either cars or pedestrians on conventional highways. However, in those rare cases where pedestrian use is extensive, where it has been determined that placement and configuration of the grade separation will result in the majority of pedestrians using it, and where the local agency has requested in writing that a pedestrian separation be constructed, an overcrossing may be considered. The State's share of the total construction cost of the pedestrian facility should not exceed 50 percent. The State must enter into a cooperative agreement with the local jurisdiction on this basis.

105.4 Accessibility Requirements

(1) *Background.*

The requirement to provide equivalent access to facilities for all individuals, regardless of disability, is stated in several laws adopted at both the State and Federal level. Two of the most notable references are The Americans with Disabilities Act of 1990 (ADA) which was enacted by the Federal Government and

took effect on January 26, 1992, and Section 4450 of the California Government Code.

(a) Americans with Disabilities Act Highlights.

- Title II of the ADA prohibits discrimination on the basis of disability by state and local governments (public entities). This means that a public entity may not deny the benefits of its programs, activities and services to individuals with disabilities because its facilities are inaccessible. A public entity's services, programs, or activities, when viewed in their entirety, must be readily accessible to and usable by individuals with disabilities. This standard, known as "program accessibility," applies to all existing facilities of a public entity.
- Public entities are not necessarily required to make each of their existing facilities accessible. Public entities may achieve program accessibility by a number of methods (e.g., providing transit as opposed to structurally accessible pedestrian facilities). However, in many situations, providing access to facilities through structural methods, such as alteration of existing facilities and acquisition or construction of additional facilities, may be the most efficient method of providing program accessibility.
- Where structural modifications are required to achieve program accessibility, a public entity with 50 or more employees is required to develop a transition plan setting forth the steps necessary to complete such modifications.
- In compliance with the ADA, Title 28 of the Code of Federal regulations (CFR) Part 35 identifies all public entities to be subject to the requirements for ADA regardless of funding source. It further states that the Uniform Federal Accessibility

Standards (UFAS) and the Americans with Disabilities Act Accessibility Guidelines for Buildings and Facilities (ADAAG) are acceptable design guidelines that may be used. However, FHWA has directed Caltrans to use the ADAAG as the Federal design guidelines for pedestrian accessibility.

(b) California Government Code 4450 et seq. Highlights.

- Sections 4450 (through 4460) of the California Government Code require that buildings, structures, sidewalks, curbs, and related facilities that are constructed using any State funds, or the funds of cities, counties, or other political subdivisions be accessible to and usable by persons with disabilities. Section 4450 says that facilities are to be constructed in conformance with the California Building Code. The California Building Code is part of Title 24 of the California Code of Regulations. The Department of General Services (DGS), through the Division of the State Architect, and Caltrans have the authority to review and approve plans for facilities covered under Section 4450.
- California Building Code has been revised to generally conform to the ADAAG. In most cases, the accessibility standards in Title 24 are more stringent than those in ADAAG, but in some cases they are less so.

(2) *Policy.*

It is Caltrans policy to:

- Comply with the ADA and the Government Code 4450 et seq. by making all State highway facilities accessible to people with disabilities to the maximum extent feasible. In general, if a project on State right of way is providing a pedestrian facility, then accessibility must be addressed.

- Follow the requirements of both the ADAAG and Title 24 for new construction and alterations of existing facilities. Both requirements should be reviewed to determine if differences exist. Where there are differences between Title 24 and the ADAAG, the guidelines that provide the higher accessibility may be used as long as at least the ADAAG is satisfied. The ADAAG allows the use of other design standards, i.e., a local agency's adopted accessibility standard, where the standard used will provide substantially equivalent or greater access to and usability of the facility. The decision to identify and use an equivalent or higher accessibility standard than the ADAAG or Title 24 should be documented for projects on the State highway system.

(3) *Procedures.*

- (a) The engineer will consider pedestrian accessibility needs in the Project Initiation Documents (PSRs, PSSRs, etc.) for all projects where applicable.
- (b) All State highway projects administered by Caltrans or others with facilities subject to the ADA and Title 24 must be designed in accordance with the requirements in Design Information Bulletin 82, "Pedestrian Accessibility Guidelines for Highway Projects."
- (c) The details of the pedestrian facilities and their relationship to the project as a whole should be clearly depicted and submitted as described in DIB-82.

ADA compliance must be noted in PS&E Transmittal, Attachment A, on State-administered projects. Appropriate project records should document the fact that necessary review and approvals have been obtained as required above.

disabilities are to be provided across curbs that are constructed or replaced at pedestrian crosswalks. This includes all marked and unmarked crosswalks, as defined in Section 275 of the Vehicle Code.

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

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

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

On new construction, two curb ramps should be installed at each corner as shown on the Standard Plans. The usage of the one-ramp design should be restricted to those locations where the volume of pedestrians and vehicles making right turns is low. This will reduce the potential frequency of conflicts between turning vehicles and persons with disabilities entering the common crosswalk area to cross either street.

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

- (3) *Ramp Design.* Curb ramp designs should conform to current Standard Plans. See Index 105.4(3) for review procedures.

105.5 Guidelines for the Location and Design of Curb Ramps

- (1) *Policy.* On all State highway projects adequate and reasonable access for the safe and convenient movement of persons with

Topic 106 - Stage Construction and Utilization of Local Roads

106.1 Stage Construction

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

- (a) Shorten the proposed improvement, or divide it into segments for construction in successive years;
- (b) Reduce number of lanes for initial construction. For example, a 4-lane freeway in a rural area with low current traffic volumes might be staged for two lanes initially with capacity adequate for at least 10 years after construction. Similarly, a freeway might be constructed initially four or six lanes wide with provision for future widening in the median to meet future traffic needs.
- (c) Stage pavement structure. For flexible pavement, this could be done by reducing the surface course thickness with provision for a future overlay to bring the pavement to full design depth. For rigid pavement, the base and subbase layers could initially be built (if the base is built with HMA) and then overlaid later with a Portland cement concrete slab. In each case, life-cycle cost should be considered before using a staging option.
- (d) Down scope geometric design features. This last expedient should be considered only as a last resort; geometric features such as alignment, grade, sight distance, weaving, or merging distance, are difficult and expensive to change once constructed. All nonstandard features need to comply with Index 82.2

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

106.2 Utilization of Local Roads

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

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

- (a) Temporarily adopting the local road system as a traversable State highway, or
 - (b) Designating the local road system as a detour until the next or final stage is constructed.
- (1) *Temporary Adoption of Local Roads as State Routes.* Temporary adoption of a local road system as a traversable route requires CTC action. Temporary adoption should be implemented where, for example, one unit of the freeway construction has been completed and the District wishes to route all users over the new roadway without waiting for completion of the next succeeding units, and the use of local roads is necessary to connect the freeway with the old State highway. Temporary adoption is useful where construction of the next freeway unit is a number of years in the future.

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

Normally, the Department will finance any needed improvement required to accommodate all users during the period the local road system is a traversable State route. Financing by the local agency is not required. However, adoption of the local road by the

CTC must precede State financing and construction of the proposed improvements.

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

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

If the local agency wants more improvements than are needed to accommodate 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 at project

initiation. 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 a 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. See Standard Plan H9 for a typical MVP layout plan and section detail.

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 days 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 PUC, 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. Transit loading facilities must be approved by the District Director with concurrence from the Design Coordinator (see Topic 82 for approvals).

(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.

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 PUC, 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-Structure Design 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. 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.
- (f) A cooperative agreement should be used to document the understanding between the Department and any local agency which desires a transit facility. The agreement covers items such as funding, ownership, maintenance, and legal responsibility.
- (g) Detailed design requirements can be obtained from the transit authority having jurisdiction over the transit facility. See Index 504.3(6) for design standards related to bus loading facilities on freeways.
- (2) *Conventional Highway Application.* This guidance is applicable to projects involving transit loading facilities on conventional highways as authorized in Section 148 of the Streets and highways Code. Instructions pertaining to the provisions for Bus Rapid Transit (BRT) in conventional highway corridors are covered in other Departmental policy and directives.
- (a) The selection of transit facilities on conventional highways should follow the general outline as noted above for transit facilities on freeways. Transit facilities shall be approved by the District Director as part of the authorizing document (PSR/PP, PR, PSSR, etc.).
- (b) A cooperative agreement should be used to document the understanding between the Department and any local agency which desires a transit facility. The agreement covers items such as funding, ownership, maintenance, and legal responsibility.
- (c) Detailed design requirements can be obtained from the transit authority having jurisdiction over the transit facility.

(d) See also DIB 82 for instructions on submitting rail and transit station plans to the Department of General Services – Division of the State Architect (DS) 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 for persons with disabilities, 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 with wheelchairs, walkers and other mobility aides. See Topic 404 for guidance regarding the Design Vehicle, and Index 626.4(3) for structural section guidance for bus pads.

108.3 Commuter and Light Rail Facilities Within State Right of Way

- (1) *General.* These facilities may cross or operate parallel to a highway or other multi modal facility owned and operated by the Department. The following guidance covers all rail facilities, and all transportation facilities owned and operated by the Department. See the Project Development Procedures Manual for additional information and procedures regarding encroachments within State right of way. See Index 309.1(4) for high speed rail guidance.
- (2) *Rail Crossings.* Ideally, rail crossings of transportation facilities should be grade separated. Grade separations must not impact the ability of the Department to operate and maintain its facilities, which includes the ability to expand the existing transportation facilities in the future. All rail crossings are to be concurred with by the Design Coordinator prior to the approval of the PID. See the California MUTCD for guidance regarding traffic controls for grade crossings.

- (3) *Parallel Rail Facilities.* Rail facilities may be sited within Department right of way when feasible alternatives do not exist for separate facilities. As necessary, rail facilities may be located within the median. If rail facilities are located in the median, they must not impact the ability of the Department to reasonably operate and maintain its facilities, which includes the ability to expand the existing transportation facilities in the foreseeable future. All parallel rail facilities are to be concurred with by the Design Coordinator prior to the approval of the PID.

- (4) *Design Standards.* Transit facilities are to be designed and constructed per the standards contained elsewhere in this manual and exceptions are to be documented as discussed in Chapter 80.

- (5) *Cooperative Agreements.* The design and construction of rail facilities within the Department right of way should be covered in a cooperative agreement. Subsequent maintenance and operations requirements should be addressed in a maintenance agreement or encroachment permit as necessary.

108.4 Bus Loading Facilities

- (1) *General.* A bus stop is a marked location for bus loading and unloading. Bus stops may be midblock, adjacent to, but before an intersection (near side) or adjacent to but after an intersection (far side). The far side location is preferred as pedestrians may cross the intersection behind the bus, allowing the bus to re-enter the travel stream following a break in traffic caused by the signal timing.

- (2) *Design Standards.* Transit facilities are to be designed and constructed per the standards contained elsewhere in this manual and exceptions are to be documented as discussed in Chapter 80.

Bus stops and busbays (see Index 303.4(3) for busbays) should have pavement structures designed in accordance with Index 626.4(3). See the “Guide for Geometric Design of Transit Facilities on Highways and Streets”,

AASHTO, for guidance on the selection and design of transit loading facilities.

- (3) *Cooperative Agreements.* Close coordination with the transit provider(s) is required for the successful design and operation of bus stops and other transit facilities.

108.5 Bus Rapid Transit

For the purpose of design and coordination, Bus Rapid Transit (BRT) is to be considered the same as commuter and light rail facilities with regards to approvals and design guidance.

BRT often makes use of the existing infrastructure for its operation within State right of way. As a joint user of the State right of way, BRT may not eliminate pedestrian or bicycle facilities. Because of potential conflicts, BRT facilities located on conventional highways and expressways should follow, as appropriate, the guidance for traffic control in the California MUTCD for light rail facilities. Transit Cooperative Report Program (TCRP) Report Numbers 90, 117 and 118 have additional guidance on BRT planning, design, and implementation. BRT located on freeways should be designed in accordance with the HOV Guidelines.

- (1) *Design Standards.* Transit facilities are to be designed and constructed per the standards contained elsewhere in this manual, and exceptions are to be documented as discussed in Chapter 80.
- (2) *Cooperative Agreements.* The design and construction of BRT facilities within the Department right of way should be covered in a cooperative agreement. Subsequent maintenance and operations requirements should be addressed in a maintenance agreement or encroachment permit as necessary.

108.6 High-Occupancy Toll and Express Toll Lanes

- (1) *General.* This guidance is applicable to projects involving High-Occupancy Toll (HOT) and Express Toll Lanes on freeways. These facilities are operated by a local agency under statutory authority or with the approval

of the California Transportation Commission. The HOV Guidelines are to be consulted when considering the design and operation of these facilities.

- (2) *Design Standards.* HOT and Express Toll Lane facilities are to comply with the standards contained elsewhere in this manual. Exceptions are to be documented as discussed in Chapter 80. Therefore, caution must be exercised when using other Department publications such as the HOV Guidelines if conflicts in design standards are identified.
- (3) *Cooperative Agreements.* A cooperative agreement is to be used to document the understanding between the Department and any local agency which will operate the HOT or Express Toll Lane Facility. The agreement must cover items such as funding, design, construction, ownership, maintenance, and legal responsibility.

108.7 Coordination with the FHWA

FHWA representatives should be contacted as indicated by the Joint Stewardship and Oversight Agreement.

- (1) *General.* As early in the design process as possible, FHWA should be kept informed of proposed activities on Federal-aid routes. See the Appendix of the Project Development Procedures Manual for a complete list of FHWA involvement.
- (2) *Approvals.* The District Directors are responsible for obtaining formal FHWA approval for the following items on Federal-aid routes, see the Project Development Procedures Manual and the FHWA Joint Stewardship Oversight Agreement for a more complete list:
- (a) Route Adoption. See the Project Development Procedures Manual for a discussion of procedures to be followed to NEPA and design approvals.
- (b) Exceptions to design standards are required for all design elements which do not meet minimum standards related to any of the FHWA's 13 controlling criteria

for projects which are on the Interstate System. See Index 82.2.

- (c) Changes in access control lines, changes in locations of connection points, adding connection points, or deleting connection points on the Interstate System (even when no Federal money is involved).
- (d) Addition of or changes in locked gates under certain conditions See Index 701.2.
- (e) Partial interchanges on the Interstate system. See Index 502.2.
- (f) Design-life on Interstates System projects.

Normally, major nonparticipating items are identified at the time of design approval. Approximately twelve months prior to PS&E submittal, a project review should be arranged by the District with the Design Coordinator and the FHWA representative to discuss nonparticipating items and unusual or special design features to resolve any differences or to determine if additional FHWA approvals are necessary. The importance of early contact is emphasized to avoid delays when final plans are prepared.

For additional information, see the Project Development Procedures Manual.

Topic 109 - Scenic Values in Planning and Design

109.1 Basic Precepts

For any highway, having a pleasing appearance is an important consideration. Scenic values must be considered along with safety, utility, economy, and all the other factors considered in planning and design. This is particularly true of the many portions of the State Highway System situated in areas of natural beauty. The location of the highway, its alignment and profile, the cross section design, and other features should be in harmony with the setting.

109.2 Design Speed

The design speed should be carefully chosen as it is the key element which establishes standards for the

horizontal alignment and profile of the highway. These requirements in turn directly influence how well the highway blends into the landscape. Scenic values, particularly in areas of natural scenic beauty must play a part along with the other factors set forth under Index 101.1 in selecting a design speed.

109.3 Aesthetic Factors

Throughout planning and design consider the following:

- (a) The location of the highway should be such that the new construction will preserve the natural environment and will lead to and unfold scenic positions. In some cases, additional minor grading not required for roadbed alignment may expose an attractive view or hide an unsightly one.
- (b) The general alignment and profile of the highway should fit the character of the area traversed so that unsightly scars of excavation and embankment will be held to a minimum. Curvilinear horizontal alignment should be coordinated with vertical curvature to achieve a pleasing appearance.
- (c) Existing vegetation (e.g., trees, specimen plants, diminishing native species or historical plantings) should be preserved and protected to the maximum extent feasible during the planning, design, and construction of transportation projects. Whenever specimen or mature trees are present, especially in forested areas, a tree survey should be made to provide accurate data on the variety, condition, location, size, and ground elevations of trees affected.
- (d) Appropriate replacement planting should be provided when existing planting is removed. When native or specimen trees are removed, replacement planting should reflect the visual importance of the plantings lost. Where the visual impact of tree removal is substantial, replacement with large transplants or specimen size trees may be appropriate. If not, an appropriate quantity of smaller replacements may be required to ensure eventual survival of an adequate number of plants.

- Provisions for watering and establishment of replacement planting should also be considered. The District Landscape Architect should be consulted early in the planning and design process so that appropriate conservation and revegetation measures are incorporated.
- (e) Existing vegetation such as trees or large brush may be selectively thinned or removed to open up scenic vistas or provide a natural looking boundary between forest and cleared areas. Vegetation removal for aesthetic purposes should be undertaken only with the concurrence of the District Landscape Architect.
 - (f) Vista points should be provided when views and scenery of outstanding merit occur and feasible sites can be found. (See Topic 904 for site selection criteria.)
 - (g) Whenever feasible, wide medians and independent roadways should be provided on multilane facilities as these features add scenic interest and relieve the monotony of parallel roadways.
 - (h) Bridges, tunnels, and walls merit consideration in lieu of prominent excavation and embankment slopes when costs of such alternates are not excessive.
 - (i) Slopes should be flattened and rounded whenever practical and vegetation provided so that lines of construction are softened.
 - (j) Structures should be located and designed to give the most pleasing appearance.
 - (k) Scars from material sites should be avoided. Planting compatible with the surroundings should be undertaken to revegetate such scars when they are unavoidable.
 - (l) Drainage appurtenances should be so located that erosion, sumps, and debris collection areas are hidden from view or eliminated when site conditions permit.
 - (m) Interchange areas should be graded as flat as reasonable with slope rounding and contouring to provide graceful, natural looking appearance. The appearance can be further enhanced by planting a vegetative cover appropriate to the locality, being careful to maintain driver visibility.
 - (n) In locations where graffiti has been excessive, concepts such as limiting accessibility, planting, and surface treatments should be considered to deter graffiti.
 - (o) Roadsides should be designed to deter weed growth along the traveled way, and to provide for mechanical litter collection.

Topic 110 - Special Considerations

110.1 Design for Overloaded Material Hauling Equipment

Sometimes bid costs can be reduced by allowing the hauling of overloads on a construction contract. The savings may warrant designing structures and structural sections of new roadways to carry the heavier loads and also reconstructing roadbeds used by overloaded material hauling equipment.

In general, hauling of overloads is restricted to the project limits. However, overloads are permitted on portions of existing highways which are to be abandoned, repaired or reconstructed with a new structural section, if the overloads do not affect the design of the reconstructed structural section.

Any overload requirements should be determined before detailed plans are prepared. The District should request from the Division of Engineering Services – Structures Design (DES - SD) the estimated additional cost of the structures to carry overloads and use this information in making economic comparisons.

Factors to be considered in making the comparisons should include the costs of strengthening structures, haul costs, amount of material to be hauled, repair or reconstruction of structural sections, construction of separate haul roads or structures, strengthening of the new structural section, sequence of construction operations, and other pertinent factors. In some cases, consideration should be given for requiring the contractor to construct a separate haul structure over a heavily traveled surface street when large quantities of material are involved.

The comparison and all factors leading to the decision should be complete, fully documented, and retained in the project files.

The design of structures for overloads will normally be governed by one of the following categories:

- (1) *Category 1.* Structures definitely planned to carry overloads. This category should be used only when the structures are to be constructed under a separate contract prior to a grading contract and the estimated savings in grading costs exceed the extra structure costs. The District must request the DES - SD to design for the permissible overloading.
- (2) *Category 2.* Structures which are designed to allow the contractor the option of strengthening to carry overloads. The contract plans will include alternative details for strengthening the structure and the contractor can decide at the time of bidding whether to haul around the structure, build his own haul road structures, use "legal load" equipment on the unstrengthened structure, or construct the structure in accordance with the strengthened alternative design. The District should notify the DOS regarding structures to have optional designs. Undercrossings, overheads, separations, and stream crossings are most likely to be in this category.
- (3) *Category 3.* Structures which will not be designed to carry overloads. Most overcrossing, ramp, and frontage road structures are in this category.

The District should consult with the DOS early in the design phase when determining the design overload category of each bridge in the project. Each case where hauling of overloads is permitted must be specifically described in the Special Provisions. Each structure designed under Categories 1 and 2 must also be designated in the Special Provisions. The design load must not exceed the weight limitation of Section 7-1.02, "Weight Limitations", of the Standard Specifications. The District Director or designated representative must approve the overload category for each structure.

110.2 Control of Water Pollution

Water pollution related to the construction of highways and to the drainage of completed highways should be limited to the maximum extent practicable. This objective should be considered from the early planning, through the detailed design phase, to the end of construction of each project.

Proposed alterations of existing drainage patterns and creation of disturbed soil areas should consider the potential for erosion and siltation. Where interdisciplinary analysis (engineering, biology, geology, chemical) indicates that harmful physical, chemical, or biological pollution of streams, rivers, lakes, reservoirs, coastal waters, or groundwater may occur, preventive measures and practices will be required. These measures include temporary erosion control features during construction, scheduling of work, as well as the permanent facilities to be built under the contract. The control of erosion associated with permanent drainage channels and ditches is covered in Chapter 860, Open Channels.

The Department's Project Planning and Design Guide identifies the procedures and practices to be employed in order for projects to comply with the Storm Water Management Plan and the National Pollutant Discharge Elimination System Permit, issued by the State Water Resources Control Board.

Districts must initiate contact with the appropriate agencies responsible for water quality as early as feasible in development of transportation projects to ensure full identification of pollution problems, and to ensure full cooperation, understanding, and agreement between the Department and the other agencies. The agencies to be contacted will vary from project to project depending on the nature of the project, the aquatic resources present, and the uses of the water. The agencies that may be interested in a project include but are not limited to the following: U.S. Army Corps of Engineers, U.S. Fish and Wildlife Service, U.S. Environmental Protection Agency, California Regional Water Quality Control Boards, California Department of Fish and Game, Flood Control Districts, and local water districts. The District Environmental Unit can provide assistance in determining which agencies should be contacted.

Recommendations for mitigation measures or construction and operational controls contained in the project's Storm Water Data Report should receive full consideration in the development of the project. The Department is legally bound to comply with the appropriate permits as outlined in the California Permit Handbook. The Department is also legally bound to comply with any water quality mitigation measures specified in the project's environmental document. Plans and specifications should reflect water quality protection measures in a manner that is enforceable in contracts.

On almost all projects, early contact should be established between the District project development personnel, Landscape Architecture, biologists, geologists, and other specialists available in the Headquarters Environmental Program, the Division of Engineering Services (DES) Office of Structural Foundations, FHWA, or other Districts, to ensure optimum development of water quality control measures.

Because siltation resulting from erosion is recognized as a major factor in water pollution, continuous efforts should be made to improve erosion control practices.

(1) *Project Planning Phase.* When project planning studies are started, consideration should be given to the items in the following list:

- (a) Identify all waters in the vicinity of a highway project which might affect construction, maintenance and operational activities.

The environmental factors that might affect preconstruction activities should be looked into for the benefit of the resident engineer and contractor. An example would be relocation of drilling of pile foundations in a sensitive stream to prevent possible impacts.

- (b) Identify for each project all waters, both fresh and saline, surface and underground, where water quality may be affected by the proposed construction.

- (c) Determine if any watersheds, aquifers, wells, reservoirs, lakes, or streams are sources for domestic water supplies.
 - (d) Determine if any sensitive fishery, wildlife, recreational, agricultural, or industrial aquatic resources are located in the vicinity of the project.
 - (e) Consider possible relocation or realignment that could be made to avoid or minimize the possibility of pollution of existing waters.
 - (f) Identify variations in the erosive characteristics of the soils in the area, and consider relocation or grade changes that would minimize erosion.
 - (g) Where possible, avoid unstable areas where construction may cause future landslides.
 - (h) Identify construction season preference of regulatory agencies.
 - (i) Evaluate the need for additional right of way to allow for flatter, less erosive slopes.
- (2) *Design Phase.* During the design phase, the items listed above should again be considered. More specific items for consideration are presented in the following checklist:
- (a) Provide for the preservation of roadside or median vegetation beyond the limits of construction by special provisions and depiction on the plans.
 - (b) Design slopes as flat as is reasonable with slope rounding, landforming/geomorphic grading, contouring, or stepping to minimize erosion and to promote plant growth. Consider retaining walls when practical to reduce slope length and steepness. Include standard special provisions or approved special provisions which will require the contractor to remove or excavate, stockpile, and apply topsoil and/or duff on the final slope to promote plant growth. For information on landforming/geomorphic grading see:

<http://www.dot.ca.gov/hq/LandArch/webinars/index.htm> and work with district landscape architecture.

- (c) Provide erosion control to all soil areas to be disturbed by construction activities. Consider the need to require the contractor to apply permanent erosion control in phases, as slopes become substantially complete, instead of allowing all erosion control to be applied at the end of the construction project. Prior to winterizing the project, the designer must plan for temporary erosion control on slopes not substantially complete. Native plants should be considered for all plantings.

If a highway planting project is anticipated immediately following roadway construction, disturbed soil areas cannot be left unprotected. The use of mulch could be considered as an erosion control method during the interim. Contact the District Landscape Architect for assistance.

- (d) When planning for temporary erosion control, consider the use of vegetation, mulches, fiber mats, fiber rolls, netting, dust palliatives, crust forming chemicals, silt fences, plastic sheets or any other procedure that may be necessary to prevent erosion. The District Storm Water Coordinator, District Landscape Architect, and the District Storm Water Unit can assist in the selection and design of temporary erosion control measures.
- (e) Design overside drains, surface, subsurface, and cross drains so that they will discharge in locations and in such a manner that surface and subsurface water quality will not be affected. The outlets may require aprons, bank protection, desilting basins, or energy dissipators.
- (f) Provide for adequate fish passage through highway culverts or under bridges when necessary to protect or enhance fishery resources.

- (g) Provide bank protection where the highway is adjacent to rivers, streams, lakes, or other bodies of water.
- (h) Where required, provide slope protection or channel lining, energy dissipators, etc. for channel changes.
- (i) Where the State has made arrangements for materials, borrow, or disposal sites, grading plans should be provided and revegetation required. Special provisions should require the contractor to furnish plans for grading and replanting of sites.
- (j) Check right of way widths for adequate space to reduce slope gradients and minimize slope angles, for rounding at tops of cuts and bottoms of fills, for adequate slope protection ditches and for incorporation of treatment control measures (e.g., infiltration basins, detention basins, traction sand traps). Also consider right of way or encroachment rights for temporary work such as desilting basins, stream diversion, or stream crossing protection.
- (k) All ditches should be designed to minimize erosion. These treatments include but are not limited to grass lining, fiber mats, rock lining (with or without geotextile underlayment), and paving. The District Hydraulics Unit can assist with the selection and design of ditch treatment. Consideration should be given to using soil stabilization materials in median ditches or other wide drainage areas that cannot be vegetated.
- (l) Temporary construction features for water pollution control that can be predicted should be made a part of the plans, specifications, and contract pay items. Such items as mulching and seeding of slopes, berms, dikes, ditches, pipes, dams, silt fences, settling basins, stream diversion channels, slope drains, and crossings over live streams should be considered. Since all contingencies probably cannot be foreseen, supplemental work funds should be set up for each project. Pay items for temporary

erosion control should not be adjusted for increased or decreased quantity.

- (m) Special consideration should be given to using vegetated ditches to remove highway runoff pollutants. The District Hydraulics and Landscape Architecture Units can provide assistance in designing and constructing vegetated ditches.
 - (n) Mandatory order of work clauses sometimes result in increased costs or longer time limits, but they must be considered where their use would eliminate the expense of temporary construction or where they result in earlier protection of erodible areas, or improved handling of site runoff.
- (3) *Abandonment and Destruction of Water Wells.* The abandonment and destruction of water wells within the highway right of way must be handled in accordance with requirements established by statute and by agreement with the Department of Water Resources (DWR) to avoid pollution of underground water and ensure public safety. Sections 13700 to 13806 of the California Water Code deal, in general, with the construction and destruction of wells. Section 24400 to 24404 of the Health and Safety Code require that abandoned wells be covered, filled, or fenced for safety reasons. Statewide standards for construction, maintenance and destruction of water wells, monitoring wells and cathodic protection wells have been issued by the California DWR in Bulletin 74 - 81, "Water Well Standards: State of California", dated December, 1981, and Bulletin 74 - 81", dated January, 1990. Pursuant to these standards and interagency agreement with DWR, the following procedures are to be followed to determine requirements for abandonment and destruction of wells within State highway rights of way.
- (a) Before producing water wells within the highway right of way are abandoned, a determination should be made of the possible future uses of the wells. Such future uses include landscape irrigation, roadside rests, vista points, maintenance facilities, truck weighing facilities, and others. Also see Index 706.4.
 - (b) The District Project Development and Right of Way Branches determine the location of water wells that will be affected by highway construction on a project basis.
 - (c) The District submits a letter to the Director, Department of Water Resources, 1416 Ninth Street, Sacramento, CA. 95814 Attention: Water Resources Evaluation Section, Division of Resources Development, listing the wells to be abandoned and any information that may be known about them. The letter should include the scheduled PS&E date and the anticipated advertising date for the project. Two copies of a map, or maps, showing the location of each well accurately enough so it can be located in the field should be included with the letter. A copy of this package should also be provided to Headquarters Construction.
 - (d) DWR will investigate the wells and write a report recommending procedures to be used in destruction of the wells within the highway right of way. The interagency agreement provides for reimbursement of the DWR's cost for these investigations and reports.
 - (e) DWR will forward its report to the District.
 - (f) Provisions for destruction of abandoned wells occasioned by highway construction and planting projects must be included in the District PS&E report. The work, usually done by filling and sealing, normally should be included in the contract Special Provisions. Steps must be taken to insure that wells are left in a safe condition between the time the site is acquired by the State and the time the well is sealed.
 - (g) In some cases, local ordinances or conditions will require the filling and sealing of the well prior to the highway contract in order to leave the well in a safe condition.

- (h) The contractor who does the work to abandon the well must file the Notice of Intent (Form DWR 2125) and the Water Well Drillers Report (Form DWR 188) required by the Department of Water Resources.
 - (i) Also, under California Water Code Section 13801, after January 15, 1990, all cities and counties are required to have adopted ordinances that require prior acquisition of permits for all well construction, reconstruction and destruction and requiring possession of an active C-57 contractors license as the minimum qualification for persons permitted to work on wells.
- (4) *Summary.* To prevent pollution of all waters that could be affected by a highway construction project, it is desirable to avoid involvement with the water or avoid the construction of erodible features. Since it is seldom possible to avoid all such features, the design of effective erosion and sediment control measures should be included with the project. Material resulting from erosion should either be discharged in locations where no negative environmental impacts will occur, or be deposited in locations that are accessible to maintenance forces for removal. District Landscape Architecture can provide technical assistance in assessing the impacts of erosion and in designing erosion control features.

Project Development personnel should ensure that all aspects of erosion control and other water quality control features considered during design are fully explained to the Resident Engineer. Such data is essential for review of the contractor's water pollution control program. Judgment must be used in differentiating between planned temporary protection features and work which the contractor must perform in order to fulfill their responsibility to protect the work from damage.

To reduce contract change orders and ensure erosion control goals are met, important protection should not be left to the contractor's judgment. It is desirable that all predictable

temporary protection measures be incorporated in the plans and specifications and items for payment included in the contract items of work.

Topsoil should be stripped, stockpiled, and restored to disturbed slopes because existing soil nutrients and native seeds contained within the topsoil are beneficial for establishing vegetative cover and controlling erosion.

In addition, the abandonment of water wells must be given special attention in accordance with Section (3) above.

110.3 Control of Air Pollution

Air pollution associated with the construction of highways and to completed highway facilities should be held to the practical minimum. The designer should consider the impacts of haul roads, disposal sites, borrow sites, and other material sources in addition to construction within the highway right of way.

- (1) *Control of Dust.* Many of the items listed under Index 110.2, Control of Water Pollution, are applicable to dust control. Consideration should be given to these items and additional material presented in the following list:
 - (a) See Index 110.2(2)(a), (c), (d), (k) and (n).
 - (b) Flat areas not normally susceptible to erosion by water may require erosion control methods such as planting, stabilizing emulsion, protective blankets, etc., to prevent wind erosion.
 - (c) Cut and or fill slopes can be sources of substantial wind erosion. They will require planting or other control measures even if water erosion is only a minor consideration.
 - (d) In areas subject to dust or sand storms, vegetative wind breaks should be considered to control dust. Use of soil sealant may also be considered.
 - (e) Special provisions should be used requiring the contractor to restore material, borrow, or disposal sites, and

temporary haul roads to a condition such that their potential as sources of blowing dust or other pollution is no greater than in their original condition. Work for this purpose that can be predicted should be made a part of the PS&E, which should require submission of the contractors plan for grading, seeding, mulching or other appropriate action.

- (f) Stockpiling and respreading topsoil may speed revegetation of the roadside and reduce wind erosion.
- (2) *Control of Burning.* Health and Safety Code provisions and rules issued by Air Pollution Control Boards will preclude burning on most highway projects. Off-site disposal of debris must not create contamination problems and should not be specified simply as an expedient resolution of the problem without imposing adequate controls on how such disposal site is to be handled. Designers should seek disposal site locations within the right of way where it will be permissible to dispose of debris. Proper procedures, including compaction and burial, should be specified. Debris should not be disposed of within the normal roadway. Burying within the right of way should be done in such a fashion that the layers of debris will not act as a permeable layer or otherwise be detrimental to the roadway. Acceptable alternates based on economic, aesthetic, safety, and other pertinent considerations should be included in the contract if possible.

On projects where burning will not be permitted and disposal of debris within the right of way is not possible, optional disposal sites should be made available. Information on such site arrangements should be made available in the "Materials Information" furnished to prospective bidders. Reference is made to the applicable portion of Index 111.3 and 111.4 for handling this requirement. Special requirements for disposal of debris and final appearance of the disposal site should be covered in the Special Provisions. The intent of this instruction is that the designer should make sure that prospective bidders have adequate information on which

to make a realistic bid on clearing and grubbing.

When feasible, tree trunks, branches, and brush should be reduced to chips and incorporated with the soil, spread on fill slopes, used as a cover mulch or disposed of in other ways compatible with the location. In forest areas where they will not look out of place, limbs and trunks of trees that are too large for chipping may be limbed and cut to straight lengths and the pieces lined up at the toes of the slope. An earth cover may be necessary for aesthetic reasons, or to reduce fire hazards. Under certain conditions salvage of merchantable timber may be desirable, or may be required by right of way commitments. Whenever merchantable timber is to be salvaged, appropriate specifications should be provided. Stumps and unsightly clumps of debris should be chipped or buried in areas where they will not create future problems.

Care should be taken not to block drainage or to interfere with maintenance operations.

Before proposing chipping as the method of disposal, the designer should investigate to determine if plant disease or insect pests will be spread to disease-free or insect-free areas. Procedures to decontaminate such chips before use should be included in the contract if necessary. Designers should seek advice from local experts and County Agricultural Extension Offices to determine the extent of such problems and the procedures and chemicals to be specified.

The U.S. Forest Service and the State Division of Forestry should be contacted during the design stage to ascertain the requirements that these agencies will make upon any disposal methods to be used in areas under their control.

It will be noted that under certain limited conditions the prohibition against burning may be eliminated from the Special Provisions.

There will be some areas of the State where Air Pollution Control Boards may consider issuing a permit for open burning where the effect on air quality is expected to be

negligible and few if any residents would be affected. The individual situation should be studied and appropriate special provisions prepared for each project to fully cover all possible methods of disposal of debris that will be available to the contractor.

The local Air Pollution Control Board should be contacted to determine the current regulations.

- (3) *Summary.* Special consideration should be given to the direction of prevailing winds or high-velocity winds in relation to possible sources of dust and downwind residential, business, or recreational areas. Every practical means should be incorporated in the design of the highway and in the provisions of the contract to prevent air pollution resulting from highway construction and operation.

110.4 Wetlands Protection

The Nation's wetlands are recognized on both the Federal and State level as a valuable resource. As such, there have been several legislative and administrative actions which provide for special consideration for the preservation of wetlands. These are embodied on the Federal level in Executive Order 11990, DOT Order 5660.1A, Section 404 of the Clean Water Act, including Section 404(b)(1) guidelines, and the NEPA 404 Integration Process for Surface Transportation Projects, and the August 24, 1993 Federal Wetlands Policy. Wetlands are covered on the State level by the Porter-Cologne Water Quality Act and the Resources Agency's Wetlands Policy. The District Environmental Unit can provide assistance with permitting strategies, identifying wetlands, determining project impacts, and recommending mitigation measures, in coordination with the District Landscape Architect.

110.5 Control of Noxious Weeds - Exotic and Invasive Species

Highway corridors provide the opportunity for the transportation of exotic and invasive weed species through the landscape. Species that have the ability to harm the environment, human health or the economy are of particular concern. In response to the impact of exotic and invasive species,

Executive Order 13112 was signed, which directs Federal Agencies to expand and coordinate efforts to combat the introduction and spread of non-native plants and animals. Grading, excavation, and fill operations during construction may introduce invasive species or promote their spreading. Because of this, the FHWA implemented guidance for State Departments of Transportation for preventing the introduction and controlling the spread of invasive plant species on highway rights of way on transportation improvement projects. District Environmental Unit and Landscape Architecture can provide assistance in identifying invasive or exotic species which should be controlled, and in recommending mitigation or control methods to be included in appropriate highway improvement projects.

110.6 Earthquake Consideration

Earthquakes are naturally occurring events that have a high potential to cause damage and destruction. While it is not possible to completely assure earthquake proof facilities, every attempt should be made to limit potential damage and prevent collapse.

There are certain measures that should be considered when a project is to be constructed in or near a known zone of active faulting.

Early in the route location process, active and inactive faults should be mapped by engineering geologists. A general assessment of the seismic risk of various areas within the study zone should then be prepared. The DOS and Office of Structural Foundations are available to assist in the assessment of seismic risk.

Strong consideration must be given to the location of major interchanges. They must be sited outside of heavily faulted areas unless there are exceptional circumstances that make it impractical to do so. Where close seismic activity is highly probable, consideration should be given to avoiding complex multilevel interchanges in favor of simple designs with low skew, short span structures close to the original ground, and maximum use of embankment. Single span bridges which are designed to tolerate large movements are desirable.

Early recognition of seismic risk may lead the designer to modify alignment or grade in order to

minimize high cuts, fills, and bridge structures in the area. Slopes should be made as flat as possible both for embankment stability and to reduce slide potential in cuts. Buttress fills can be constructed to improve cut stability. The DOS and the Office of Structural Foundations, should be consulted early when considering various alternatives to obtain recommendations for mitigating earthquake damage.

When subjected to an earthquake, fills may crack, slump, and settle. In areas of high water table, liquefaction may cause large settlement and shifting of the roadway. It is not economically feasible to entirely prevent this damage. One possible mitigation for existing soils would be to have the contract Special Provisions provide for removal of loose and compressible material from fill foundation areas, particularly in canyons, sidehill fills, and ravines and for foundation preparation on existing hillsides at the transition between cut and fill.

No modification is necessary in the design of the pavement structural sections for the purpose of reducing damage due to future earthquakes. Normally it is not possible to reduce this damage, since the structural section cannot be insulated from movements of the ground on which it rests. In active fault areas, consideration should be given to the use of flexible pipes or pipes with flexible couplings for cross drains, roadway drainage and conduits.

Additional expenditure for right of way and construction to make highways and freeways more earthquake resistant in a known active fault area should be kept in balance with the amount of impact on the traveling public if the facility may be put out of service following a disastrous earthquake. Loss of a major interchange, however, may have a tremendous influence on traffic flow and because of the secondary life-safety and economic impacts some additional expenditure may be justified.

110.7 Traffic Control Plans

This section focuses mainly on providing for vehicular traffic through the work zone; however, providing for bicyclists, pedestrians, and transit

through the work zone is also necessary when they are not prohibited.

A detailed plan for moving all users of the facility through or around a construction zone must be developed and included in the PS&E for all projects to assure that adequate consideration is given to the safety and convenience of motorists, transit, bicyclists, pedestrians, and workers during construction. Design plans and specifications must be carefully analyzed in conjunction with Traffic, Construction, and Structure personnel (where applicable) to determine in detail the measures required to warn and guide motorists, transit, bicyclists, and pedestrians through the project during the various stages of work. Starting early in the design phase, the project engineer should give continuing attention to this subject, including consideration of the availability of appropriate access to the work site, in order that efficient rates of production can be maintained. In addition to reducing the time the public is exposed to construction operations, the latter effort will help to hold costs to a minimum.

The traffic control plans should be consistent with the California MUTCD, and the philosophies and requirements contained in standard lane closure plans developed by the Headquarters Division of Traffic Operations for use on State highways and should cover, as appropriate, such items as:

- Signing.
- Flagging.
- Geometrics of detours.
- Methods and devices for delineation and channelization.
- Application and removal of pavement markings.
- Placement and design of barriers and barricades.
- Separation of opposing vehicular traffic streams (See 23 CFR 630J).
- Maximum lengths of lane closures.
- Speed limits and enforcement.
- Use of COZEEP (see Construction Manual Section 2-215).

- Use of pilot cars.
- Construction scheduling.
- Staging and sequencing.
- Length of project under construction at any one time.
- Methods of minimizing construction time without compromising safety.
- Hours of work.
- Storage of equipment and materials.
- Removal of construction debris.
- Treatment of pavement edges.
- Roadway lighting.
- Movement of construction equipment.
- Access for emergency vehicles.
- Clear roadside recovery area.
- Provision for disabled vehicles.
- Surveillance and inspection.
- Needed modifications of above items for inclement weather or darkness.
- Evaluate and provide for as appropriate the needs of bicyclists and pedestrians (including ADA requirements; see Index 105.4).
- Provisions to accommodate continued transit service.
- Consideration of complete facility closure during construction.
- Consideration of ingress/egress requirements for construction vehicles.
- Any other matters appropriate to the safety objective.

Normally, not all the above items will be pertinent to any one traffic control plan. Depending on the complexity of the project and the volume of traffic affected, the data to be included in the traffic control plan can vary from a simple graphic alignment of the various sequences to the inclusion of complete construction details in the plans and special provisions. In any event, the plans should clearly depict the exact sequence of operation, the

construction details to be performed, and the traveled way to be used by all modes of traffic during each construction phase. Sufficient alignment data, profiles, plan dimensions, and typical sections should be shown to ensure that the contractor and resident engineer will have no difficulty in providing traffic-handling facilities.

In some cases, where the project includes permanent lighting, it may be helpful to install the lights as an early order of work, so they can function during construction. In other cases, temporary installations of high-level area lighting may be justified.

Temporary roadways with alignment and surfacing consistent with the standards of the road which has just been traveled by the motorist should be provided if physically and economically possible.

Based on assessments of safety benefits, relative risks and cost-effectiveness, consideration should be given to the possibility of including a bid item for continuous traffic surveillance and control during particular periods, such as:

- (a) When construction operations are not in progress.
- (b) When lane closures longer than a specified length are delineated by cones or other such nonpermanent devices, whether or not construction operations are in progress.
- (c) Under other conditions where the risk and consequences of traffic control device failure are deemed sufficient.

Potentially hazardous working conditions must be recognized and full consideration given to the safety of workers as well as the general public during construction. This requirement includes the provision of adequate clearance between public traffic and work areas, work periods, and lane closures based on careful consideration of anticipated vehicle traffic volumes, and minimum exposure time of workers through simplified design and methods.

If a Transportation Management Plan (TMP) is included in the project, the traffic control plans (TCP) may need to be coordinated with the public information campaign and the transportation demand management elements. Any changes in TMP or TCP must be made in harmony for the

plans to succeed. The “TMP Guidelines”, available from HQ, Traffic Operational Systems Branch, should be reviewed for further guidance.

Traffic control plans along with other features of the design should be reviewed by the District Safety Review Committee prior to PS&E as discussed in Index 110.8.

The cost of implementing traffic control plans must be included in the project cost estimate, either as one or more separate pay items or as extra work to be paid by force account.

It is recognized that in many cases provisions for traffic control will be dependent on the way the contractor chooses to execute the project, and that the designer may have to make some assumptions as to the staging or sequence of the contractor's operations in order to develop definite temporary traffic control plans. However, safety of the public and the workers as well as public convenience demand that designers give careful consideration to the plans for handling all traffic even though a different plan may be followed ultimately. It is simpler from a contract administration standpoint to change a plan than to add one where none existed. The special provisions should specify that the contractor may develop alternate traffic control plans if they are as sound or better than those provided in the contract PS&E.

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

110.8 Safety Reviews

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

(1) *Policy.* During the planning stage all projects must be reviewed by the District Safety Review Committee prior to approval of the

appropriate project initiation document (PSR, PSSR, NBSSR, etc.).

During design, each major project with an estimated cost over the Minor A limit must be reviewed by the District Safety Review Committee.

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

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

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

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

Reviews, evaluating safety from the perspectives of the motorists, bicyclists, and pedestrians, should include qualitative and/or quantitative safety considerations of such items as:

- Exposure of employees to vehicular and bicycle traffic.
- Traffic control plans.
- Transportation Management Plans.

- Traversability of roadsides.
- Elimination or other appropriate treatment of fixed objects.
- Susceptibility to wrong-way moves.
- Safety of construction and maintenance personnel.
- Sight distance.
- ADA design.
- Guardrail.
- Run off road concerns.
- Superelevation, etc.
- Roadside management and maintenance reduction.
- Access to facilities from off of the freeway.
- Maintenance vehicle pull-out locations.

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

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

110.9 Value Analysis

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

110.10 Proprietary Items

Although the use of new materials, methods, or products may involve specifying a patented or brand name method, material, or product, use of

such proprietary items is discouraged in the interest of promoting competitive bidding. If three or more products or materials are called out for one contract item, they are not considered proprietary.

When proprietary items are needed and beneficial to the State, their use must be approved by the District Director or by the Deputy District Director of Design (if such approval authority has been specifically delegated by the District Director). The Deputy Division Chief of Engineering Services, Structure Design, approves the use of proprietary materials on structures and other design elements under their jurisdiction. The use of proprietary items requires approval (i.e., Public Interest Finding) by the Federal Highway Administration (FHWA) Division Office if the project is on the National Highway System (NHS), including the Interstate Highway System. The Department's policy and guidelines on the use of proprietary items are covered in the Office Engineer's Ready to List and Construction Contract Award Guide (RTL Guide) under "Trade Names." This policy is based on Public Contract Code, Division 2, Chapter 3, Article 5, Paragraph 3400. It is also consistent with FHWA regulatory requirements. The use of proprietary materials, methods, or products will not be approved unless:

- (a) There is no other known material of equal or better quality that will perform the same function, or
- (b) There are overwhelming reasons for using the material or product in the public's interest, which may or may not include cost savings, or
- (c) It is essential for synchronization with existing highway or adjoining facilities, or
- (d) Such use is on an experimental basis, with a clearly written plan for "follow-up and evaluation."

If the proprietary item is to be used experimentally and there is Federal participation, the request for FHWA approval must be submitted to the Chief, Office of Resolution of Necessity, Encroachment Exceptions, and Resource Conservation in the Division of Design. The request must include a Construction Evaluated Work Plan (CEWP), which indicates specific functional managers, and units, which have been assigned responsibility for

objective follow-up, evaluation, and documentation of the effectiveness of the proprietary item. See Section 3-404 Scope of Work (“Construction-Evaluated Research”) of the Construction Manual for further details on the work plan and the approval procedure.

110.11 Conservation of Materials and Energy

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

- (1) *Rigid Pavement.* The crushing and reuse of old rigid pavement as aggregate in new rigid or flexible pavement does not now appear to be a cost-effective alternate, primarily because of the availability of good mineral aggregate in most areas of California. However, if this is a feasible option, because of unique project conditions or the potential lack of readily available materials, it may be included in a cost comparison of alternate solutions.
- (2) *Flexible Pavement.* Recycling of existing flexible pavement must be considered, in all cases, as an alternative to placing 100 percent new flexible pavement.
- (3) *Use of Flexible Pavement Grindings, Chunks and Pieces.* When constructing transportation facilities, the Department frequently uses asphalt in mixed or combined materials such as flexible pavement. The Department also uses recycled flexible grindings and chunks. There is a potential for these materials to reach the waters of the State through erosion or inappropriate placement during construction. Section 5650 of the Fish and Game Code states that it is unlawful to deposit asphalt, other petroleum products, or any material deleterious to fish, plant life, or bird life where they can pass into the waters of the State. In addition, Section 1601 of the Fish

and Game Code requires notification to the California Department of Fish and Game (DFG) prior to construction of a project that will result in the disposal or deposition of debris, waste, or other material containing crumbled, flaked, or ground pavement where it can pass into any river, stream, or lake designated by the DFG.

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

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

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

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

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

Specific Understandings contained in the MOU are:

- **Asphalt Use in Embankments**
The Department may use flexible pavement chunks and pieces in embankments when these materials are placed where they will not enter the waters of the State.
- **Use of flexible pavement grindings as Shoulder Backing**
The Department may use flexible pavement grindings as shoulder backing when these materials are placed where they will not enter the waters of the State.
- **Streambed Alteration Agreements**

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

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

110.12 Tunnel Safety Orders

Projects and work activities that include human entry into tunnels, shafts or any of a variety of underground structures to conduct construction activities must address the requirements of the California Code of Regulations (CCR), Title 8, Subchapter 20 – Tunnel Safety Orders (TSO). Activities that can be considered of a maintenance nature, such as cleaning of sediment and debris from culverts or inspection (either condition inspection for design purposes or inspection as a part of construction close-out) of tunnels, shafts or other underground facilities are not affected by these regulations.

TSO requires the Department, as owner of the facility, to request the Department of Industrial Relations, Division of Occupational Safety and Health (Cal-OSHA), Mining and Tunneling Unit,

to review and classify tunnels and shafts for the potential presence of flammable gas and vapors prior to bidding. The intent of the TSO regulations are to protect workers from possible injury due to exposure to hazardous conditions. Failure to comply is punishable by fine. The complete TSO regulations are available at the following website: (<http://www.dir.ca.gov/title8/sub20.html>), with Sections 8403 and 8422 containing information most applicable to project design.

The TSO regulations require classification whenever there is human entry into a facility defined as a tunnel or entry into, or very near the entrance of, a shaft. Some of the common types of activities where human entry is likely and that will typically require classification include:

- Pipe jacking or boring operations
- Culvert rehabilitation
- Large diameter pile construction, as described in the following text
- Pump house vaults
- Cut-and-cover operations connected to ongoing underground construction and are covered in a manner that creates conditions characteristic of underground construction
- Well construction
- Cofferdam excavations
- Deep structure footings/shafts/casings, as described in the following text

Virtually any project that will lead to construction or rehabilitation work within a pipe, caisson, pile or underground structure that is covered by soil is subject to the TSO regulations. This typically applies to underground structures of 30 inches or greater diameter or shaft excavations of 20 feet or more in depth. Since a shaft is defined as any excavation with a depth at least twice its greatest cross section, the regulations will apply to some structure footing or cofferdam excavations.

Cut and cover operations (typical of most pipe, junction structure and underground vault construction) do not fall under the TSO regulations as long as worker entry to the pipe or system (usually for grouting reinforced concrete pipe, tightening bolts on structural plate pipe, etc.) is

conducted prior to covering the facility with soil. Connecting new pipe to existing buried pipe or structures does fall under the TSO regulations unless the existing pipe system is physically separated by a bulkhead to prevent entry into the buried portion. Designers must either incorporate requirements for such separation of facilities into the PS&E or they must obtain the required classification from Cal-OSHA. For any project that requires classification, specifications must be included that alert the Contractor to the specific location and classification that Cal-OSHA has provided.

The TSO regulations should be viewed as being in addition to, and not excluding, other requirements as may apply to contractor or Department personnel covered in the Construction Safety Orders (see CCR, Title 8, Subchapter 4, Article 6 at <http://www.dir.ca.gov/title8/sub4.html>), safety and health procedures for confined spaces (see Chapter 14 of the Caltrans Safety Manual), or any other regulations that may apply to such work.

Prior to PS&E submittal on a project that includes any work defined in CCR Section 8403, a written request must be submitted for classification to the appropriate Mining and Tunneling (M&T) Unit office. Each M&T Unit office covers specific counties as shown on Figure 110.12. Classification must be obtained individually for each separate location on a project. For emergency projects or other short lead-time work, it is recommended that the appropriate M&T Unit office be contacted as soon as possible to discuss means of obtaining classification prior to the start of construction activities.

The request must include all pertinent and necessary data to allow the M&T Unit to classify the situation. The data specified under paragraph (a) of Section 8422 (complete text of Section 8422 reprinted below) is typical of new construction projects, however for culvert rehabilitation and other type of work affecting an existing facility, not all of the indicated items are typically available or necessary for submittal. The appropriate M&T Unit office should be contacted for advice if there is any question regarding data to submit.

In many instances it may not be known during design if there will be human entry into facility

types that would meet the definition of a tunnel or shaft. If there is any anticipation that such entry is likely to occur, classification should be requested. As permit acquisition is typically the responsibility of the District, it is imperative that there be close coordination between District and Structures Design staff regarding the inclusion of any facilities in the structures PS&E that could be defined as a tunnel or shaft and have potential for human entry. The following text is taken directly from Section 8422:

8422 Tunnel Classifications

- (a) When the preliminary investigation of a tunnel project is conducted, the owner or agency proposing the construction of the tunnel shall submit the geological information to the Division for review and classification relative to flammable gas or vapors. The preliminary classification shall be obtained from the Division prior to bidding and in all cases prior to actual underground construction. In order to make the evaluation, the following will be required:
 - (1) Plans and specifications;
 - (2) Geological report;
 - (3) Test bore hole and soil analysis log along the tunnel alignment;
 - (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) Extrahazardous, 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 extrahazardous 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 extrahazardous 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
 - (B) The identification of any specific changes and/or conditions that have occurred subsequent to the initial classification criteria such as geological information, bore hole sampling results, underground tanks or utilities, ventilation system, air quality records, and/or evidence of no intrusions of explosive gas or vapor into the underground atmosphere.

NOTE: The Division shall respond within 10 working days for any such request. Also, the Division may request additional information and/or require specific conditions in order to work under a lower level of classification.

Topic 111 - Material Sites and Disposal Sites

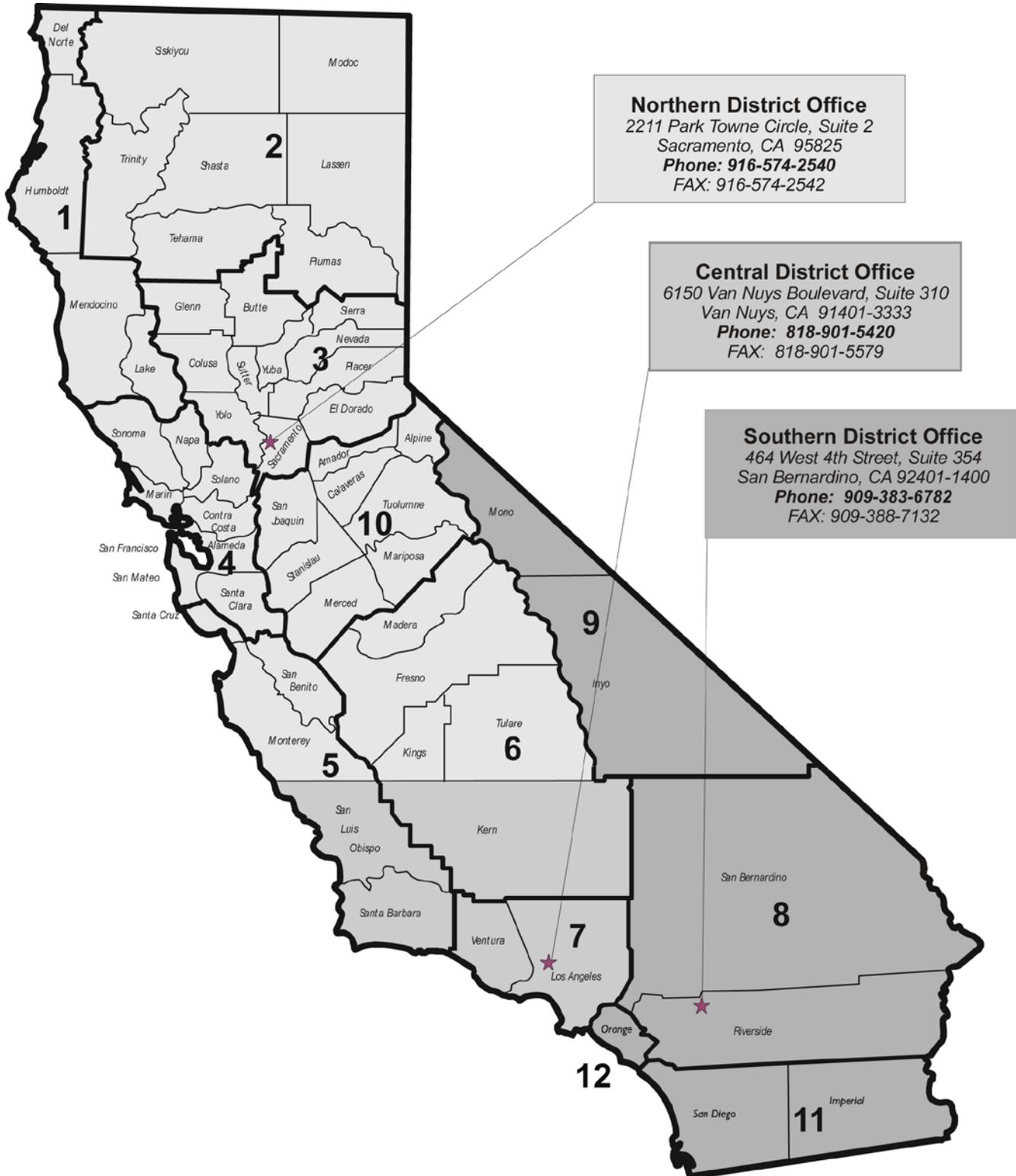
111.1 General Policy

The policies and procedures concerning material sites and disposal sites are listed below. For further information concerning selection and procedures for disposal, staging and borrow sites, see DIB 85.

- (a) Materials investigations and environmental studies of local materials sources should be made to the extent necessary to provide a basis for study and design. Location and capacity of available disposal sites should be determined for all projects requiring disposal of more than 10,000 cubic yards of clean material. Sites for disposal of any significant amount of material in sensitive areas should be considered only where there is no practical alternative.

- (b) Factual information obtained from such investigations should be made readily available to prospective bidders and contractors.
- (c) The responsibility for interpreting such information rests with the contractor and not with the State.
- (d) Generally, the designation of optional material sites or disposal sites will not be included in the special provisions. Mandatory sites must be designated in the special provisions or Materials Information Handout as provided in Index 111.3 of this manual and Section 2-1.03 of the Standard Specifications. A disposal site within the highway right of way (not necessarily within the project limits) should be provided when deemed in the best interest of the Department as an alternative to an approved site for disposal of water bearing residues generated by grinding or grooving operations, after approval is obtained from the Regional Water Quality Control Board (RWQCB) having jurisdiction over the area.
- (e) Material agreements or other arrangements should be made with owners of material sites whenever the absence of such arrangements would result in restriction of competition in bidding, or in other instances where it is in the State's interest that such arrangements be made.
- (f) The general policy of Caltrans is to avoid specifying mandatory sources unless data in support of such sources shows certain and substantial savings to the State. Mandatory sources must not be specified on Federal-aid projects except under exceptional circumstances, and prior approval of the FHWA is required. Supporting data in such cases should be submitted as early as possible. This policy also applies to disposal sites.
- (g) It is the policy of Caltrans to cooperate with local authorities to the greatest practicable extent in complying with environmental requirements for all projects. Any corrective measures wanted by the local authorities should be provided through the permit process. Any unusual requirements, conditions, or situations should be submitted to the Division of Design for review (see Indexes 110.2 and 110.3).

Figure 110.12
California Mining and Tunneling Districts



- (h) The use of any materials site requires compliance with environmental laws and regulations, which is normally a part of the project environmental documentation. If the need for a site occurs after approval of the project environmental document, a separate determination of environmental requirements for the materials site may be required.
- (i) If the materials site is outside the project limits and exceeds 1-acre in size, or extraction will exceed 1,000 cubic yards, it must comply with the Surface Mining and Reclamation Act of 1975 (SMARA) and be included on the current "AB 3098 List" published by the Department of Conservation before material from that site can be used on a State project. There are limited exceptions to this requirement and the District Materials Engineer should be consulted.

111.2 Investigation of Local Materials Sources

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

List". Sufficient sampling of sites must be performed to indicate the character of the material and the elevation of the ground water surface, and to determine changes in the character of the material, both laterally and vertically. Sampling must be done in such a manner that individual samples can be taken from each horizon or layer. Composite samples of two or more different types of material are unsatisfactory, as there is no assurance that the materials would be so combined if the materials source were actually used. Testing of blends of two or more types of materials is permissible, provided the test report clearly indicates the combination tested. The test report must clearly indicate the location of the sample and the depth represented. The fact that materials sites are not designated in the Special Provisions does not reduce the importance of thorough exploration and testing.

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

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

- (a) There has been no change in test procedures subsequent to the time the earlier tests were made.
- (b) The materials source has not been altered by stream action, weathering, or other natural processes.
- (c) The material sampled and represented by the tests has not been removed.
- (d) There has been no change in SMARA status, or inclusion or exclusion on the "AB 3098 List".

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

111.3 Materials Information Furnished to Prospective Bidders

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

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

- (b) A vicinity map showing the location of investigated materials sites and disposal sites in relation to the project.
- (c) A map of each material site showing the location and identification of boring or test pits.
- (d) A tabulation of the test data for each material site, showing complete information on the location, depth, and processing of each sample tested, together with all test results.
- (e) Copies of all options or agreements with owners of the material sites, if such arrangements have been made.
- (f) Soil survey sheets or suitable terrain maps showing borings and tests along the highway alignment.
- (g) A tabulation of which sites comply with environmental laws and regulations and are included on the current "AB 3098 List".
- (h) Material site grading and reclamation plan and disposal site grading plans, if they have been prepared.
- (i) Copies of local use permits and clearances (when they have been obtained by the State) such as environmental clearances, mining permits, Forest Service Fire Regulations, water quality control clearances, etc. If documents are of unusual length, a statement should be included that they have been obtained and are available for inspection at the District office or Sacramento Plans Counter.

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

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

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

111.4 Materials Arrangements

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

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

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

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

111.5 Procedures for Acquisition of Material Sites and Disposal Sites

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

(1) *General Procedure.*

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

- The project or projects on which the site is to be used and programming of proposed construction.

- The location and description of the property, zoning, and site restoration/reclamation proposals including necessary vicinity and site maps.
- The amount and quality of material estimated to be available in the site and amount needed for the project or projects, or amount of excess material to be disposed of and the capacity of the site or sites.
- An economic analysis using the estimated purchase price and value of land after removal of material or deposit of excess material. The total estimated savings over other possible alternatives must be clearly demonstrated. Alternatives must be shown from the standpoint of what would have to be done if the site was not purchased. Alternatives could be changes in location or grade as well as alternative sources of material.
- A statement as to whether or not the use of the site should be mandatory, with a separate statement regarding the effect for each proposed project for which mandatory use of the site is considered necessary, including complete justification for the mandatory specification (see Index 111.6). Three copies of each map or other attachment, folded letter size, are required for mandatory sites on all Federal-aid projects.
- A statement of the type of environmental documentation.
- Other justification.

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

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

Engineer and one copy to Division of Design.

- (c) If the estimated purchase price is over \$300,000, the District should include the item in the STIP and corresponding budget.
 - (d) When the proposed purchase has been approved, the Project Engineer should notify the District Division of Right of Way, District Environmental Division and the District Materials Unit and request that Right of Way purchase the site (or obtain a Materials Agreement; the Materials Unit should assist in the development of the agreement) and the Environmental Division obtain environmental authorization to proceed.
 - (e) The District must include the cost of purchase in the proper fiscal year program and/or budget as part of the District targets.
 - (f) After budgeting, the District must submit an expenditure authorization to cover purchase of the site. This could be concurrent if the project is added to the budget during a fiscal year. The expenditure authorization request should be processed through the District Project Management and Administration Units and obtain District Director approval.
 - (g) After issuance of an expenditure authorization, the District Division of Right of Way will complete purchase of the site.
- (2) *Material and Disposal Sites in Federal Lands.* The applicable sections of the Federal Highway Act of 1958 for procurement of borrow or disposal sites, Sections 107(d) and 317, are set forth in Section 8.18.02.00 of the Right of Way Manual; Section 107(d) applies to the Interstate System while Section 317 applies to other Federal-aid highways. Whenever Federal public lands are required for a material or a disposal site, and after preliminary negotiations at the local level with the Federal agency having jurisdiction, the District must submit a letter report to the

FHWA. This report should observe the requirements of Index 111.5 of this manual and Section 8.18.02.03 of the Right of Way Manual.

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

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

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

Section 635.407 of 23 CFR 635D states in part:

"The designation of a mandatory material source may be permitted based on environmental considerations, provided the environment would be substantially enhanced without excessive cost."

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

Topic 112 - Contractor's Yard and Plant Sites

112.1 Policy

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

112.2 Locating a Site

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

Topic 113 - Geotechnical Design Report

113.1 Policy

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

113.2 Content

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

113.3 Submittal and Review

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

Topic 114 - Materials Report

114.1 Policy

A Materials Report must be prepared for all projects that involve any of the following components:

- Pavement structure recommendations and/or pavement studies
- Culverts (or other drainage materials)

- Corrosion studies
- Materials disposal sites
- Side prone areas with erosive soils

The Materials Report may be either a single report or a series of reports that contains one or several of the components listed above. Materials Reports are prepared for Project Initiation Documents, Project Reports, and PS&E. Materials Report(s) are signed and stamped with an engineers seal by the engineer in responsible charge for the findings and recommendations. The District Materials Engineer will either prepare the Materials Report or review and accept Materials Report(s) prepared by others. The Material Report is signed by the Registered Engineer that prepared the report.

114.2 Requesting Materials Report(s)

The Project Engineer (or equivalent) is responsible for requesting a Materials Report. The District Materials Engineer can assist the Project Engineer in identifying what components need to be addressed, when to request them, and what information is needed. At a minimum, the following information needs to be included in all requests:

- (1) *Project location.*
- (2) *Scope of work.* Project Engineer should spell out the type of work to be done that will affect materials. If pavements are involved, state type of pavement work. Provide type of project, such as new construction, widening, or rehabilitation. Note if culverts will be installed, extended, or replaced. Note if material or disposal sites are needed, see Topic 111 for criteria.
- (3) *Proposed design life for pavements and culverts.*
- (4) *Design Designation.* Include for projects involving pavement structural enhancements. Does not apply to pavement preservation activities.
- (5) *Special Considerations or Limitations.* Include any information that may affect the materials recommendations. Examples include traffic management requirements or environmental restrictions.

114.3 Content

All Materials Reports must contain the location of the project, scope of work, and list of special conditions and assumptions used to develop the report. Materials Reports must contain the following information when the applicable activity is included in the scope of the project.

- (1) *Pavement.* The Materials Report must document the design designation and climate zone or climate data used to prepare the report and recommendations. Document studies, tests, and cores performed to collect data for the report. Include deflection studies for flexible pavement rehabilitation projects (see Index 635.1). Also include pavement structure recommendations. The report should also outline special material requirements that should be incorporated such as justifications for using (or not using) particular materials in the pavement structure.
- (2) *Drainage Culverts or Other Materials.* The Materials Report must contain a sufficient number of alternatives that materially meet or exceed the culvert design life (and other drainage related) standards for the Project Engineer to establish the most maintainable, constructable, and cost effective alternative in conformance with FHWA regulations (23 CFR 635D).
- (3) *Corrosion.* Corrosion studies are necessary when new culverts, culvert rehabilitation, or culvert extensions are part of the scope of the project. Studies should satisfy the requirements of the "Corrosion Guidelines". Copies of the guidelines can be obtained from the Corrosion Technology Branch in DES Materials Engineering and Testing Services or on the DES Materials Engineering and Testing Services website.
- (4) *Materials or Disposal Sites.* See Topic 111 "Material and Disposal Sites" for conditions when sites need to be identified and how to document.

114.4 Preliminary Materials Report

Because resources and/or time are sometimes limited, it is not always possible to complete all the

tests and studies necessary for a final Materials Report during the planning/scooping phase. In these instances, a Preliminary Materials Report may be issued using the best information available and good engineering judgment. Accurate traffic projections and design designations are still required for the Preliminary Materials Report. Preliminary Materials Reports should not be used for project reports or PS&E development. When used, Preliminary Materials Reports must document the sources of information used and assumptions made. It must clearly state that the Preliminary Materials Report is to be used for planning and initial cost estimating only and not for final design. The Department Pavement website contains supplemental guidance for developing preliminary pavement structures.

114.5 Review and Retention of Records

A copy of the Draft Materials Report is to be submitted for review and comment to the District Materials Engineer. The District Materials Engineer reviews the document for the Department to assure that it meets the standards, policies, and other requirements found in Department manuals, and supplemental district guidance (Index 604.2(2)). If it is found that the document meets these standards, the District Materials Engineer accepts the Materials Report. If not, the report is returned with comments to the submitter.

After resolution of the comments, a final copy of the Materials Report is submitted to the District Materials Engineer who then furnishes it to the Project Engineer. The original copy of the Materials Report must be permanently retained in the District's project history file and be accessible for review by others when requested.

Topic 115 - Designing for Bicycle Traffic

115.1 General

Under the California Vehicle Code, bicyclists generally have the same rights and duties that motor vehicle drivers do when using the State highway system. For example, they make the same merging and turning movements, they need adequate sight distance, they need access to all

destinations, etc. Therefore, designing for bicycle traffic and designing for motor vehicle traffic are similar and based on the same fundamental transportation engineering principles. The main differences between bicycle and motor vehicle operations are lower speed and acceleration capabilities, as well as greater sensitivity to out of direction travel and steep uphill grades. Design guidance that addresses the safety and mobility needs of bicyclists on Class II bikeways (bike lanes) is distributed throughout this manual. See Chapter 1000 for additional bicycle guidance for Class I bikeways (bike paths) and Class III bikeways (bike routes).

All city, county, regional and other local agencies responsible for bikeways or roads except those freeway segments where bicycle travel is prohibited shall equal or exceed the minimum bicycle design criteria contained in this and other chapters of this manual (see the Streets and Highways Code, Section 891). The decision to develop bikeways should be made in consultation and coordination with local agencies responsible for bikeway planning to ensure connectivity and network development.

Generally speaking, bicycle travel can be enhanced by bikeways or improvements to the right-hand portion of roadways, where bicycles are required to travel. When feasible, a wider shoulder than minimum standard should be considered since bicyclists are required to ride to as far to the right as possible, and shoulders provide bicyclists an opportunity to pull over to let faster traffic pass.

All transportation improvements are an opportunity to improve safety, access, and mobility for the bicycle mode of travel.

Topic 116 - Bicyclists and Pedestrians on Freeways

116.1 General

Seldom is a freeway shoulder open to bicycle, pedestrian or other non-motorized travel, but they can be opened for use if certain criteria assessing the safety and convenience of the freeway, as compared with available alternate routes, is met. However, a freeway should not be opened to

bicycle or pedestrian use if it is determined to be incompatible. The Headquarters Traffic Liaison and the Design Coordinator must approve any proposals to open freeways to bicyclists, pedestrian or other non-motorized use. See the California MUTCD and CVC Section 21960.

When a new freeway segment is to remain open or existing freeway segment is to be reopened to these modes, it is necessary to evaluate the freeway features for their compatibility with safe and efficient travel, including:

- Shoulder widths
- Drainage grates; see Index 1003.5(2)
- Expansion joints
- Utility access covers on shoulders
- Frequency and spacing of entrance/exit ramps
- Multiple-lane entrance/exit ramps
- Traffic volumes on entrance/exit ramps and on lanes merging into exit ramps
- Sight distance at entrance/exit ramps
- Freeway to freeway interchanges
- The presence and design of rumble strips
- Longitudinal edges and joints

If a freeway segment has no suitable non-freeway alternative and is closed because certain features are considered incompatible, the feasibility of eliminating or reducing the incompatible features should be evaluated. This evaluation may include removal, redesign, replacement, relocation or retrofitting of the incompatible feature, or installation of signing, pavement markings, or other traffic control devices.

Where no reasonable, convenient and safe non-freeway alternative exists within a freeway corridor, the Department should coordinate with local agencies to develop new routes, improve existing routes or provide parallel bicycle and pedestrian facilities within or adjacent to the freeway right of way. See Project Development Procedures Manual Chapter 1, Article 3 (Regional and System Planning) and Chapter 31 (Nonmotorized Transportation Facilities) for

discussion of the development of non-freeway transportation alternatives.

CHAPTERS 600 – 670 PAVEMENT ENGINEERING

CHAPTER 600 GENERAL ASPECTS

Topic 601 - Introduction

Pavement engineering involves the determination of the type and thickness of pavement surface course, base, and subbase layers that in combination are cost effective and structurally adequate for the projected traffic loading and specific project conditions. This combination of roadbed materials placed in layers above the subgrade (also known as basement soil) is referred to as the "pavement" or the "pavement structure".

The Department guidelines and standards for pavements described in this manual are based on extensive engineering research and field experience, including the following:

- Theoretical concepts in pavement engineering and analysis.
- Data obtained from test track studies and experimental sections.
- Research on materials characteristics, testing methods, and equipment.
- Observation of performance throughout the State and the nation.

The pavement should be engineered using the standards and guidance described in this manual to ensure consistency throughout the State and provide a pavement structure that will have adequate strength, ride quality, and durability to carry the projected traffic loads for the design life of each project. The final pavement structure for each project should be based on a thorough investigation of specific project conditions including subgrade soils and structural materials, environmental conditions, projected traffic, cost effectiveness, and the performance of other pavements in the same area or similar climatic and traffic conditions. These factors are discussed in Chapter 610 of this manual.

The guidelines and standards found in this manual should be considered minimum standards and should not preclude sound engineering judgment based on experience and knowledge of the local conditions. Sound engineering judgment must still be used to determine if more stringent standards are required.

Topic 602 – Pavement Structure Layers

Index 602.1 Description

Pavement structures are comprised of one or more layers of select materials placed above the subgrade. The basic pavement layers of the roadway are shown in Figure 602.1 and discussed below.

- (1) *Subgrade*. Also referred to as basement soil, the subgrade is that portion of the roadbed consisting of native or treated soil on which surface course, base, subbase, or a layer of any other material is placed. Subgrade may be composed of either in-place material that is exposed from excavation, or embankment material that is placed to elevate the roadway above the surrounding ground. Subgrade soil characteristics are discussed in Topic 614.
- (2) *Subbase*. Unbound or treated aggregate/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. The subbase generally consists of lower quality materials than the base but better than the subgrade soils. Subbase may not be needed in areas with higher quality subgrade (California R-value > 40) or where it is more cost effective to build a thicker base layer. Further discussion on subbase materials and concepts can be found in Chapter 660.
- (3) *Base*. Select, processed, and/or treated aggregate material that is placed immediately below the surface course. It provides additional load distribution and contributes to

drainage and frost resistance. Base may be one or multiple layers treated with cement, asphalt or other binder material, or may consist of untreated aggregate. In some cases, the base may include a drainage layer to drain water that seeps into the base. The aggregate in base is typically a higher quality material than that used in subbase. Further discussion on base materials and concepts can be found in Chapter 660.

- (4) *Surface Course.* One or more layers of the pavement structure engineered to accommodate and distribute traffic loads, provide skid resistance, minimize disintegrating effects of climate, reduce tire/pavement noise, improve surface drainage, and minimize infiltration of surface water into the underlying base, subbase and subgrade. Sometimes referred to as the surface layer, the surface course may be composed of a single layer, constructed in one or more lifts of the same material, or multiple layers of different materials.

Depending on the type of base or subbase layers, surface courses are used to characterize pavements into the following three categories:

- (a) *Flexible Pavements.* These are pavements engineered to bend or flex when loaded. Flexible pavements transmit and distribute traffic loads to the underlying layers. The highest quality layer is the surface course, which typically consists of one or more layers of asphalt binder mixes and may or may not incorporate underlying layers of base and/or subbase. These types of pavements are called "flexible" because the total pavement structure bends (or flexes) to accommodate deflection bending under traffic loads. Procedures for flexible pavements can be found in Chapter 630.
- (b) *Rigid Pavements.* These are pavements with a rigid surface course typically a slab of Portland cement concrete (or a variety of specialty hydraulic cement concrete mixes used for rapid strength concrete) over underlying layers of stabilized or unstabilized base or subbase materials.

These types of pavements rely on the substantially higher stiffness of the concrete slab to distribute the traffic loads over a relatively wide area of underlying layers and the subgrade. Some rigid concrete slabs have reinforcing steel to help resist cracking due to temperature changes and repeated loading. Procedures for rigid pavements can be found in Chapter 620.

- (c) *Composite Pavements.* These are pavements comprised of both flexible (asphalt binder mixes) and rigid (cement concrete) layers over underlying layers of stabilized or unstabilized base or subbase materials. Currently, for purposes of the procedures in this manual, only pavements with a flexible layer over a rigid surface layer are considered to be composite pavements. In California, such pavements consist mostly of existing rigid pavements (typically Portland cement concrete) that have had a flexible surface course overlay such as hot mix asphalt (HMA) (formerly known as asphalt concrete), open graded friction course (OGFC) (formerly known as open graded asphalt concrete), or rubberized hot mix asphalt (RHMA) (formerly known as rubberized asphalt concrete). See Chapter 640 for additional information on composite pavements.
- (5) *Non-Structural Wearing Course.* On some pavements, a non-structural wearing course is placed to protect the surface course from wear and tear from tire/pavement interaction, the weather, and other environmental factors. Examples of non-structural wearing courses include OGFC, various types of surface seals, and added surface course thickness to allow for chain wear or grinding. Although non-structural wearing courses are not given a structural value in the procedures and tables found in this manual, they will improve the service life of the pavement by protecting it from traffic and environmental effects.
- (6) *Others.* Depending on the type of pavement built and the subgrade or existing soil conditions encountered, additional layers may

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

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

Topic 603 – Types of Pavement Projects

603.1 New Construction

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

603.2 Widening

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

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

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

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

603.3 Pavement Preservation

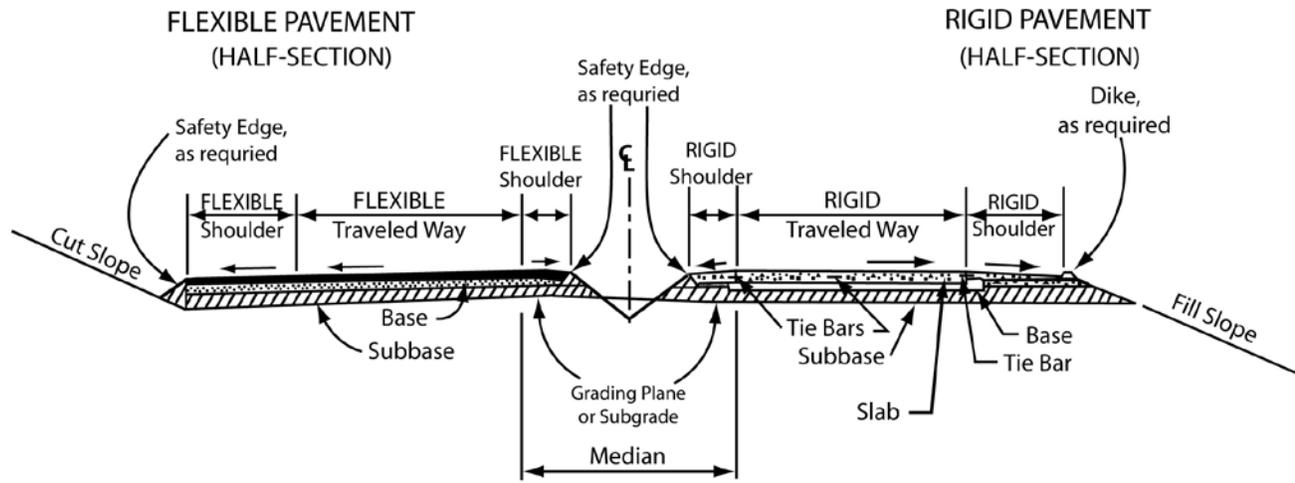
Pavement Preservation has two main categories or programs:

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

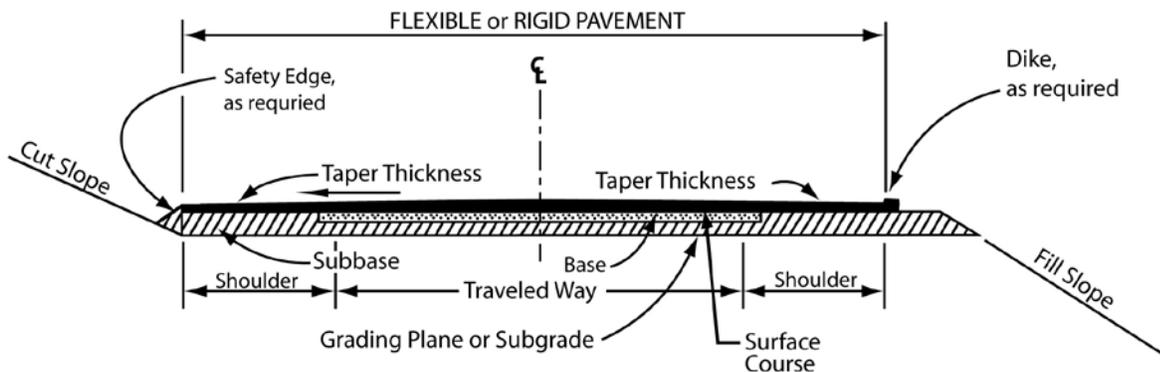
- Removal and replacement of a non-structural wearing course (for example, open graded friction courses);
- Thin non-structural overlays less than or equal to 0.08 foot (or 0.10 foot when needed to enhance compaction in colder temperatures);

Figure 602.1

Basic Pavement Layers of the Roadway



DIVIDED HIGHWAYS



UNDIVIDED HIGHWAYS

NOTES:

1. These illustrations are only to show nomenclature and are not to be used for geometric cross section details. For these, see Chapter 300.
2. Pavement drainage design, both on divided and undivided highways, are illustrated and discussed under Chapter 650.
3. Only flexible and rigid pavements shown. Composite pavements are the same as rigid pavements with a flexible layer overlay.
4. See Index 626.2 for criteria for when and how to use flexible or rigid shoulders.

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

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

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

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

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

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

Examples of CAPM projects include:

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

Items that are not considered CAPM include:

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

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

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

603.4 Roadway Rehabilitation

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

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

Examples of roadway rehabilitation projects include:

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

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

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

603.5 Reconstruction

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

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

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

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

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

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

603.6 Temporary Pavements and Detours

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

Topic 604 - Roles and Responsibilities

604.1 Roles and Responsibilities for Pavement Engineering

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

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

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

The PE coordinates with the Structures District Liaison Engineer and Division of Engineering Services (DES) staff for the proper selection and engineering of any structure approach system including the adequacy of all drainage ties between the structure approach drainage features and other new or existing drainage facilities. The PE should contact the Structures District Liaison Engineer as early as possible in the project development process to facilitate timely review and project scheduling.

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

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

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

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

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

Reports based upon studies and information supplied by the District.

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

604.2 Other Resources

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

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

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

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

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

Topic 605 – Record Keeping

605.1 Documentation

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

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

605.2 Subsequent Revisions

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

Topic 606 - Research and Special Designs

606.1 Research and Experimentation

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

606.2 Special Designs

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

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

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

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

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

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

606.3 Mechanistic-Empirical Design

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

606.4 Proprietary Items

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

CHAPTER 610 PAVEMENT ENGINEERING CONSIDERATIONS

Topic 611 - Factors In Selecting Pavement Type

Index 611.1 Pavement Type Selection

The types of pavement generally considered for new construction and rehabilitation in California are rigid, flexible and composite pavements. Rigid pavement should be considered as a potential alternative for all Interstate and other high traffic volume interregional freeways. Flexible pavement should be considered as a potential alternative for all other State highway facilities. Composite pavement, which consists of a flexible layer over a rigid pavement have mostly been used for maintenance and rehabilitation of rigid pavements on State highway facilities.

611.2 Selection Criteria

Because physical conditions and other factors considered in selecting pavement type vary significantly from location to location, the Project Engineer must evaluate each project individually to determine the most appropriate and cost-effective pavement type to be used. The evaluation should be based on good engineering judgment utilizing the best information available during the planning and design phases of the project together with a systematic consideration of the following project specific conditions:

- Pavement design life
- Traffic considerations
- Soils characteristics
- Weather (climate zones)
- Existing pavement type and condition
- Availability of materials
- Recycling
- Maintainability
- Constructibility

- Cost comparisons (initial and life-cycle)

The above factors should be thoroughly investigated when selecting a pavement structure and addressed specifically in all project documents (PSSR, PSR, PR, PS&E, etc). The final decision on pavement type should be the most economical design based on life-cycle cost analysis (see Topic 619.)

The principal factors considered in selecting pavement structures are discussed as follows in Topics 612 through 619.

Topic 612 - Pavement Design Life

612.1 Definition

Pavement design life, also referred to as performance period, is the period of time that a newly constructed or rehabilitated pavement is engineered to perform before reaching a condition that requires CAPM, (see Index 603.4). The selected pavement design life varies depending on the characteristics of the highway facility, the objective of the project, and projected traffic volume and loading. The strategy or pavement structure selected for any project should provide the minimum pavement design life that meets or exceeds the objective of the project as described in Topics 612 through 619.

612.2 New Construction and Reconstruction

The minimum pavement design life for new construction and reconstruction projects shall be no less than the values in Table 612.2 or the project design period (see Index 103.2), whichever is greater.

612.3 Widening

Additional consideration is needed when determining the design life for pavement widening. Factors to consider include the remaining service life of the adjacent pavement, planned future projects (including maintenance and rehabilitation), and future corridor plans for any additional lane widening and shoulders. **The pavement design life for widening projects shall either match the remaining pavement service**

Table 612.2

Pavement Design Life for New Construction and Reconstruction

Facility	Pavement Design Life (Years)	
	AADT ⁽³⁾ <150,000 ⁽¹⁾ and AADTT ⁽⁴⁾ <15,000 ⁽¹⁾	AADT ≥ 150,000 ⁽¹⁾ or AADTT ≥ 15,000 ⁽¹⁾
Mainline Traveled Way	20 or 40 ⁽²⁾	40
Ramp Traveled Way	20 or 40 ⁽²⁾	40
Shoulders:		
≤5 ft wide	Match adjacent traveled way	40
>5 ft wide: First 2 ft	Match adjacent traveled way	40
Remaining width ⁽⁵⁾	20	20
Intersections	20 or 40 ⁽²⁾	40
Roadside Facilities	20	20

NOTES:

- (1) Projected mainline AADT and AADTT in both directions, 20 years after construction
- (2) Use design life with lowest life-cycle cost (See Topic 619)
- (3) Annual Average Daily Traffic (AADT)
- (4) Annual Average Daily Truck Traffic (AADTT)
- (5) If the shoulder is expected to be converted to a traffic lane with the pavement design life, it should be engineered to match the same pavement design life as the adjacent traveled way.

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

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

612.4 Pavement Preservation

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

612.5 Roadway Rehabilitation

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

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

612.6 Temporary Pavements and Detours

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

612.7 Non-Structural Wearing Courses

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

Topic 613 - Traffic Considerations

613.1 Overview

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

considered to have negligible effect when determining traffic loads.

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

613.2 Traffic Volume Projections

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

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

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

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

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

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

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

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

613.3 Traffic Index Calculation

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

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

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

These lane distribution factors are shown in Table 613.3B.

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

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

Where:

TI = Traffic Index

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

LDF = Lane Distribution Factor (see Table 613.3B)

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

613.4 Axle Load Spectra

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

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

Table 613.3A
ESAL Constants

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

Table 613.3B
Lane Distribution Factors for Multilane Highways

Number of Mixed Flow Lanes in One Direction	Factors to be Applied to Projected Annual Average Daily Truck Traffic (AADTT)			
	Mixed Flow Lanes (see Notes 1-6)			
	Lane 1	Lane 2	Lane 3	Lane 4
One	1.0	-	-	-
Two	1.0	1.0	-	-
Three	0.2	0.8	0.8	-
Four	0.2	0.2	0.8	0.8

NOTES:

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

Table 613.3C
Conversion of ESAL to Traffic Index

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

Notes:

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

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

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

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

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

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

613.5 Specific Traffic Loading Considerations

(1) *Traveled Way.*

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

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

(c) **Ramps and Connectors:**

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

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

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

The three ramp classifications are defined as follows:

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

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

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

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

NOTE:

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

(a) Purpose and Objectives.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

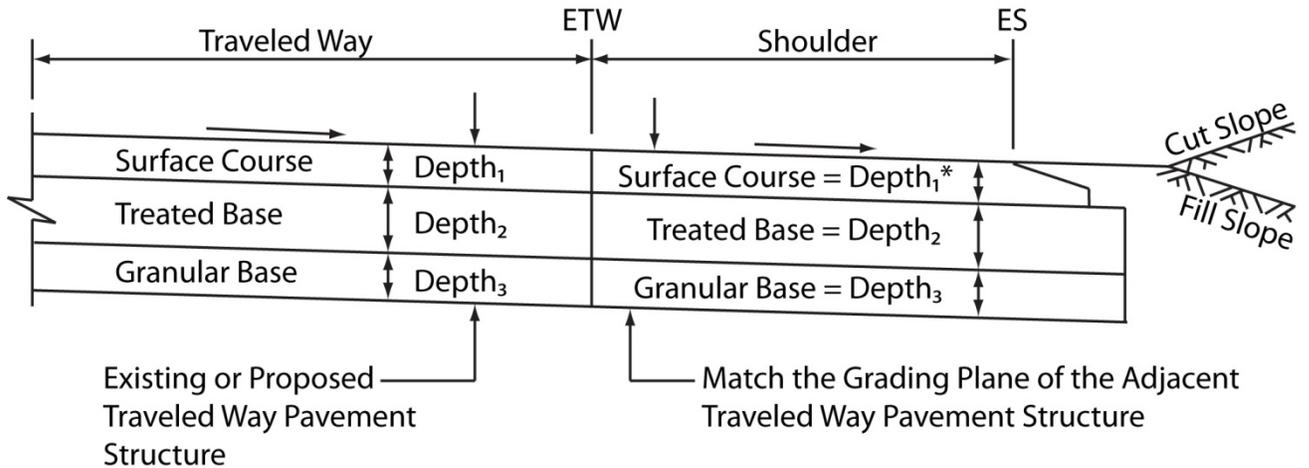
The total depth of the shoulder pavement structure (depth from the surface to the subgrade) shall match the pavement structure grading plane of the adjacent traffic lane.

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

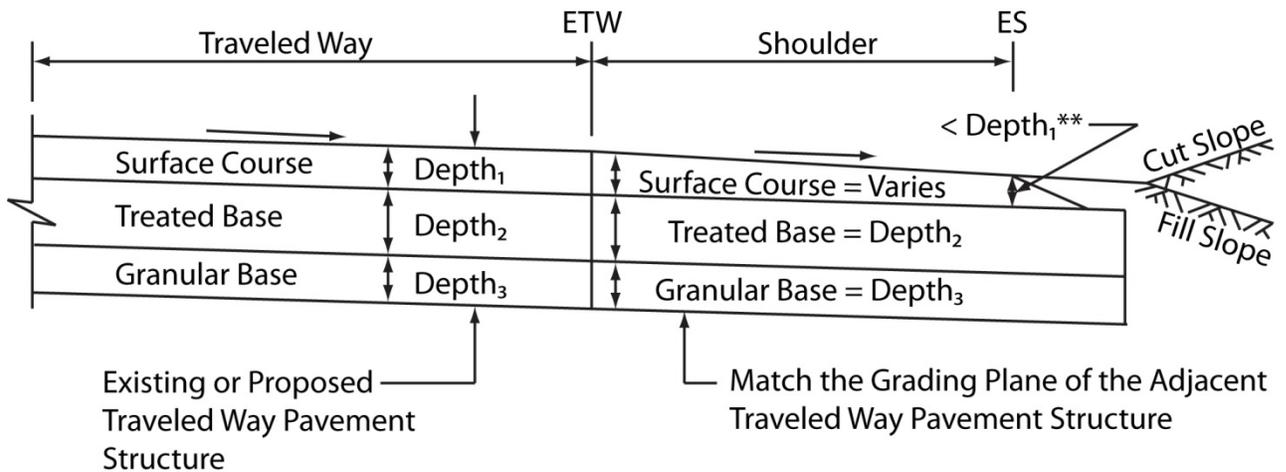
Figure 613.5A

Shoulder Design for TI Equal to Adjacent Lane TI

Shoulder Pavement Structure is the Same as Traveled Way Structure



Variable Shoulder Thickness Option for Asphalt Pavement

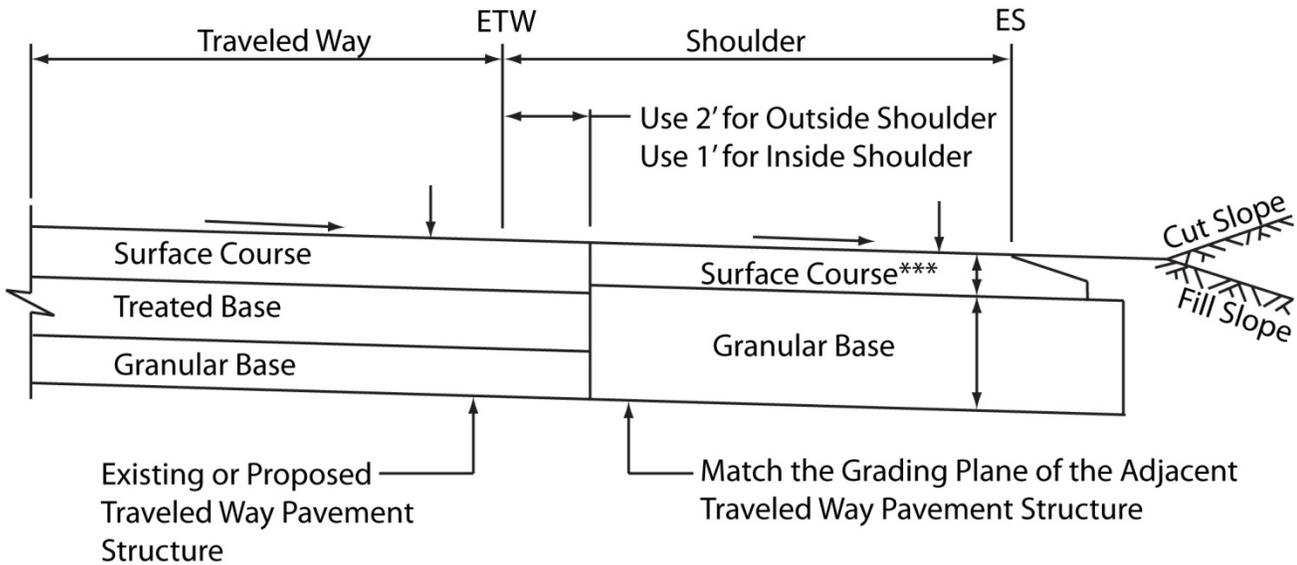


NOTES:

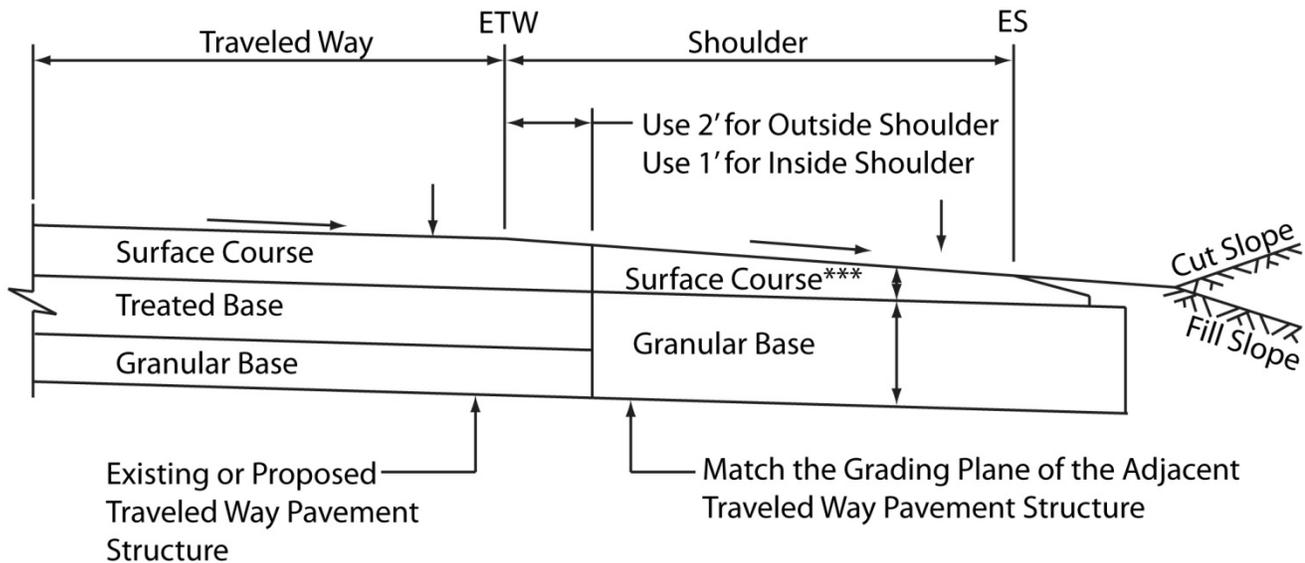
- * Applies to concrete and asphalt pavements.
- ** For asphalt pavement, minimum thickness of surface course $\geq 0.35'$.

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

Variable Surface Course Option



Uniform Surface Course Option



NOTES:

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

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

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

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

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

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

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

(c) Widening.

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

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

pavement structure of the existing shoulder.

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

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

(d) Pavement Preservation.

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

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

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

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

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

(e) Roadway Rehabilitation.

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

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

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

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

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

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

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

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

(f) Temporary Detours.

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

(g) Conversion to Lane.

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

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

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

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

(h) Other.

- Tracking and Sweep Width Lines.

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

- Minimizing Worker Exposure.

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

- Concrete shoulders and asphalt pavement structure.

Do not place concrete shoulders adjacent to asphalt pavement structure.

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

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

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

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

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

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

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

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

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

- 100 feet.

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

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

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

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

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

NOTE:

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

Topic 614 - Soil Characteristics

614.1 Engineering Considerations

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

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

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

614.2 Unified Soil Classification System (USCS)

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

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

614.3 California R-Value

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

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

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

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

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

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

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

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

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

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

construction costs that exceed potential materials cost savings.

614.4 Expansive soils

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

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

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

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

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

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

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

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

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

614.5 Subgrade Enhancement Geotextile (SEG)

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

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

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

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

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

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

614.6 Other Considerations

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

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

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

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

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

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

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

Topic 615 - Climate

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

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

- Desert
- High Desert

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

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

Topic 616 - Existing Pavement Type and Condition

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

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

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

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

Topic 617 - Materials

617.1 Availability of Materials

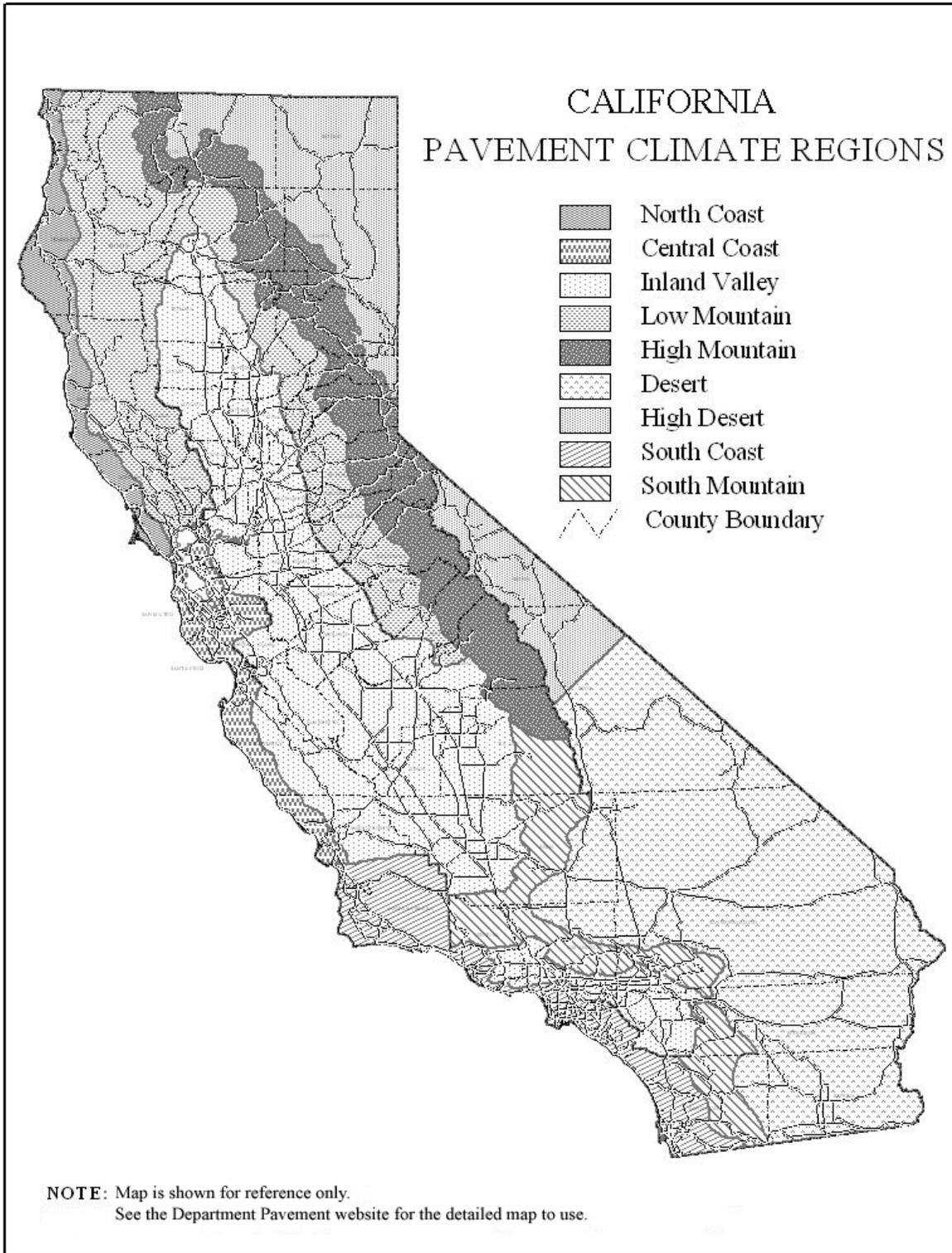
The availability of suitable materials such as subbase and base materials, aggregates, binders, and cements for pavements should be considered in the selection of pavement type. The availability of commercially produced mixes and the equipment capabilities of area contractors may also influence the selection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

617.2 Recycling

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

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

**Figure 615.1
Pavement Climate Regions**



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

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

Topic 618 - Maintainability and Constructibility

618.1 Maintainability

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

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

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

618.2 Constructibility

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

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

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

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

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

Topic 619 - Life-Cycle Cost Analysis

619.1 Life-Cycle Cost Analysis

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

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

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

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

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

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

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

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

CHAPTER 620 RIGID PAVEMENT

Topic 621 - Types of Rigid Pavements

Index 621.1 Jointed Plain Concrete Pavement (JPCP)

JPCP is the most common type of rigid pavement used by the Department. JPCP is engineered with longitudinal and transverse joints to control where cracking occurs in the slabs (see Figure 621.1). JPCPs do not contain steel reinforcement, other than tie bars and dowel bars (see Index 622.4 for tie bars and dowel bars). Additional guidance for JPCP can be found in the “Guide for Design and Construction of New Jointed Plain Concrete Pavements” on the Department Pavement website.

621.2 Continuously Reinforced Concrete Pavement (CRCP)

Although the Department has used CRCP on a limited basis in the past, CRCP is still a relatively new concept to California. For this reason, the Department has decided not to use CRCP for TIs less than 11.5 or in High Mountain and High Desert climate regions. Since CRCP uses reinforcing steel rather than weakened plane joints for crack control, saw cutting of transverse joints is not required for CRCP. Longitudinal joints are still used. Transverse random cracks are expected in the slab, usually at 3-foot to 5-foot intervals (see Figure 621.1). The continuous reinforcement in the pavement holds the cracks tightly together. CRCP typically costs more initially than JPCP due to the added cost of the reinforcement. However, CRCP is typically 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, properly built CRCP should have better ride quality and less maintenance than JPCP. Additional CRCP guidance are under development and when completed will be posted in the “Continuously Reinforced Concrete Pavement Design Guide” on the Department Pavement website.

621.3 Precast Panel Concrete Pavement (PPCP)

PPCPs use panels that are precast off-site instead of cast-in-place. The precast panels can be linked together with dowel bars and tie bars or can be post-tensioned after placement. PPCP offers the advantages of:

- Improved concrete mixing and curing in a precast yard.
- Reduced pavement thicknesses, which is beneficial when there are profile grade restrictions such as vertical clearances.
- Shorter lane closure times, which is beneficial when there are short construction windows.

The primary disadvantage of PPCP is the high cost of precasting. PPCP also needs a smoothly leveled base underneath the precast panels during construction to even out the loads on the slab and avoid uneven deflection that could lead to faulting at the joints, slab settlement, and premature cracking. PPCP is currently used on an experimental basis in California, and must follow the procedures for experimental projects and special designs discussed in Topic 606.

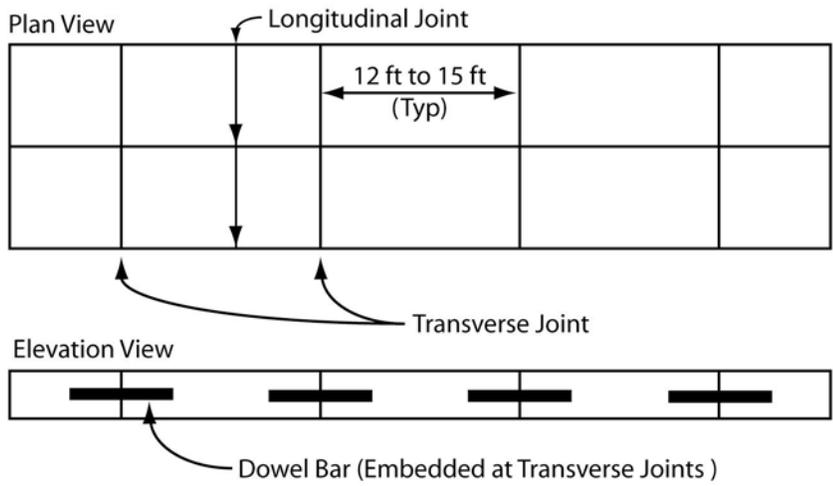
Topic 622 - Engineering Requirements

622.1 Engineering Properties

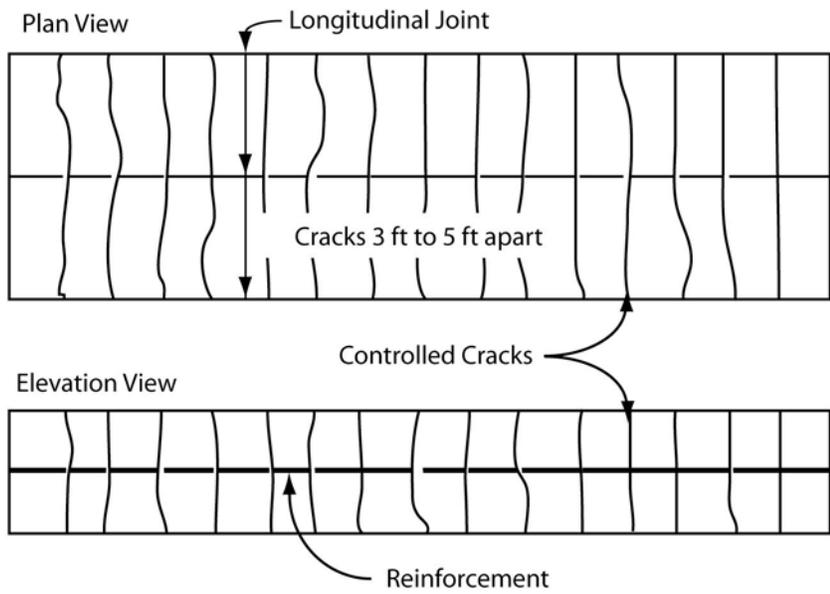
Table 622.1 shows the rigid pavement engineering properties that were used to develop the rigid pavement catalog in Index 623.1. The values are based on Department specifications and experience with materials used in California. The predominant type of concrete used in California for rigid pavement is Portland cement concrete. Other types of hydraulic cement concrete are sometimes used for special conditions such as rapid strength concrete.

Figure 621.1

Types of Rigid Pavement



Jointed Plain Concrete Pavement (JPCP)



Continuous Reinforced Concrete Pavement (CRCP)

- (1) *Smoothness.* The smoothness of a pavement impacts its ride quality, overall durability, and performance. Ride quality (measured by the smoothness of ride) is also the highest concern listed in public surveys on pavement condition. Smoothness specifications have been improved and incentive/disincentive specifications have been developed to assure that smoothness values are achieved in construction. Incentive/disincentive specifications can be used where the project meets the warrants for the smoothness specification. For up to date, additional information on smoothness and application of specifications see the smoothness page on the Department Pavement website.

622.2 Performance Factors

The performance factors used to engineer rigid pavements are shown in Table 622.2. The pavement structure in Index 623.1 is expected to meet or exceed all of the performance factors in Table 622.2. The performance factors in the table are end-of-design life criteria.

622.3 Pavement Joints

- (1) *Construction.* Construction joints (sometimes called contact or cold joint) are joints between slabs that result when concrete is placed at different times. Construction joints can be transverse or longitudinal and are constructed in all types of rigid pavements. Tie bars are typically used at construction joints to connect the adjoining slabs together so that the construction joint will be tightly closed.
- (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.
- (3) *Isolation.* Isolation joints are used to separate dissimilar pavements/structures in order to lessen compressive stresses that could cause excessive cracking. Examples of dissimilar pavements/structures include different joint patterns, different types of rigid pavement (e.g., CRCP/JPCP), structure approach slabs, building foundations, drainage inlets, and

manholes. Isolation joints are filled with a joint filler material to keep cracks from propagating through the joint and to prevent water/dirt infiltration.

- (4) *Expansion.* Expansion joints (known previously as pressure relief joints) are similar in purpose to isolation joints except they are used where there is a need to allow for a large expansion, greater than ½ inch, between slabs or pavements. Expansion joints are typically used where CRCP abuts up to bridges, structure approach slabs or other types of rigid pavements. Expansion joints are also used with PPCP. Expansion joints are typically not used with JPCP.

Additional information on rigid pavement joints and when, where, and how to place them can be found in the Standard Plans, Standard Specifications/Special Provisions, Pavement Interactive Guide, and the Department Pavement website.

622.4 Dowel Bars and Tie Bars

Dowel bars are smooth round bars that act as load transfer devices across pavement joints. Dowel bars are typically placed across transverse joints of jointed plain and precast panel concrete pavement. In limited situations, dowel bars are placed across longitudinal joints. See Standard Plans for further details. 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. Further details regarding dowel bars and tie bars can be found in the Standard Plans and Pavement Technical Guidance on the Department Pavement website.

New or reconstructed rigid pavements and lane replacements shall be doweled except as noted below:

- Rigid shoulders placed or reconstructed next to a nondoweled rigid lane may be nondoweled.
- Rigid shoulders placed or reconstructed next to a widened slab may be nondoweled and untied (see Standard Plan P-2).

Table 622.1
Rigid Pavement Engineering Properties

Property	Values
Transverse joint spacing	13.5 ft average
Initial IRI immediately after construction	63 in/mile max
Reliability	90%
Unit weight	150 lb/ft ³
Poisson's ratio	0.20
Coefficient of thermal expansion	6.0 x 10 ⁻⁶ / °F
Thermal conductivity	1.25 $\frac{\text{Btu}}{\text{hr} \cdot \text{ft} \cdot \text{°F}}$
Heat capacity	0.28 $\frac{\text{Btu}}{\text{lbm} \cdot \text{°F}}$
Permanent curl/warp effective temperature difference	Top of slab is 10 °F cooler than bottom of slab
Surface layer/base interface	Unbonded
Surface shortwave absorptivity	0.85
Cement type	Type II Portland Cement
Cement material content (cement + flyash)	24 lb/ft ³
Water: cementitious material ratio	0.42
PCC zero-stress temperature	100.9 °F
Ultimate shrinkage at 40% relative humidity	537 microstrain
Reversible shrinkage (% of ultimate shrinkage)	50%
Time to develop ultimate shrinkage	35 days
Modulus of rupture or flexural strength (28 days)	625 psi
Dowel bar diameter	1.5 in (1.25 in for rigid pavement thickness < 0.70 ft)

Table 622.2
Rigid Pavement Performance Factors

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

NOTE:

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

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

622.5 Joint Seals

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

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

- Project environment.

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

- Type of roadway.

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

- Condition of existing reservoir.

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

- Expected performance.

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

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

- Cost effectiveness.

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

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

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

622.6 Bond Breaker

When placing rigid pavement over a lean concrete base, it is important to avoid bonding between the two layers. Bonding can cause cracks and joints in the lean concrete base to reflect through the rigid pavement, which will lead to premature cracking. Several methods are available for preventing

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

622.7 Texturing

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

622.8 Transitions and Anchors

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

Topic 623 - Engineering Procedure for New and Reconstruction Projects

623.1 Catalog

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

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

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

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

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

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

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

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

NOTES:

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

Legend

PI = Plasticity Index

623.2 Mechanistic-Empirical Method

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

Figure 623.1
Rigid Pavement Catalog Decision Tree

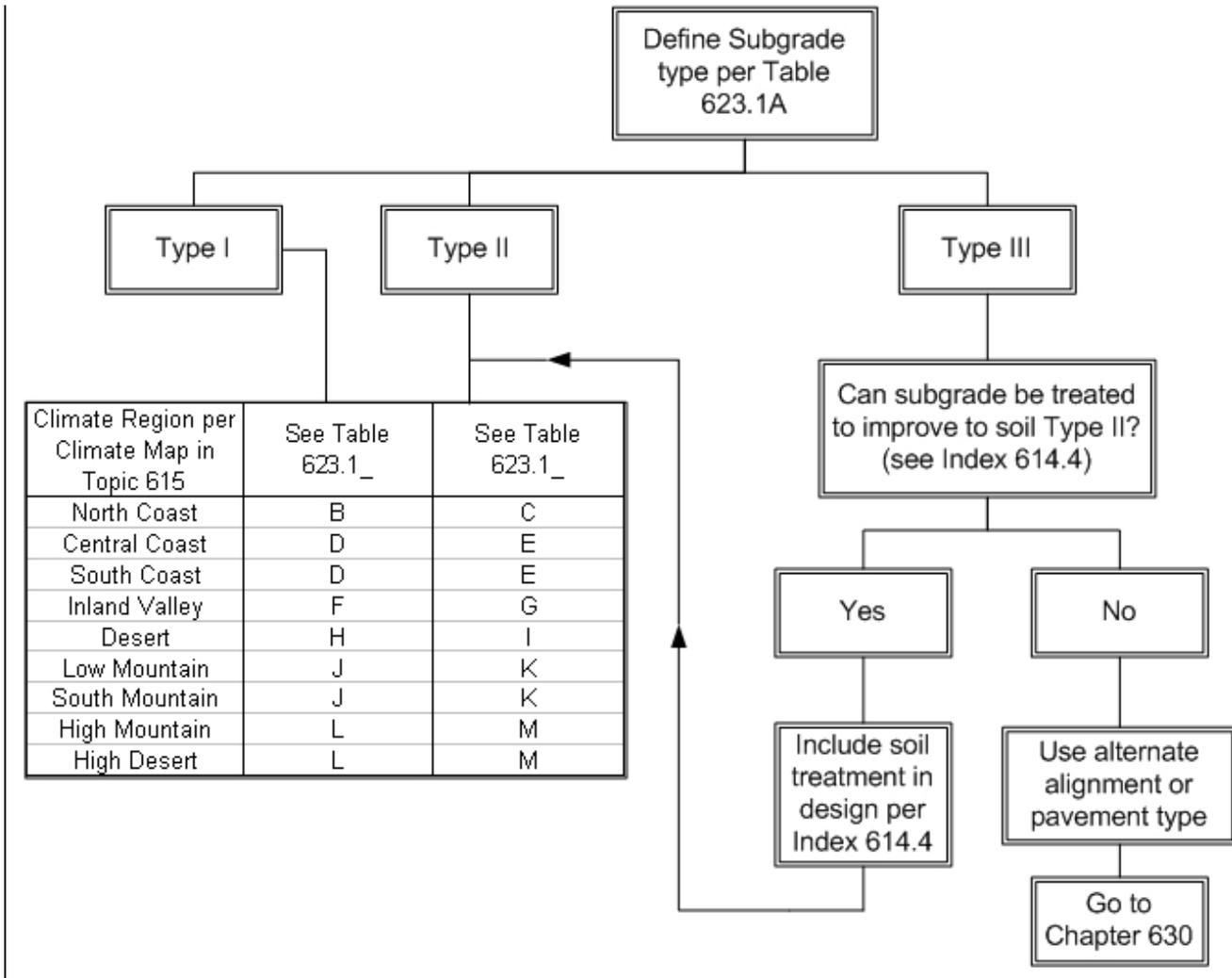


Table 623.1B
Rigid Pavement Catalog (North Coast, Type I Subgrade Soil)^{(1), (2), (3), (4),(5)}

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

NOTES:

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

Legend:

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

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

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

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

NOTES:

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

Legend:

JPCP = Jointed Plain Concrete Pavement

CRCP = Continuously Reinforced Concrete Pavement

LCB = Lean Concrete Base

HMA-A = Hot Mix Asphalt (Type A)

ATPB = Asphalt Treated Permeable Base

AB = Class 2 Aggregate Base

AS = Class 2 Aggregate Subbase

TI = Traffic Index

Table 623.1D
Rigid Pavement Catalog
(South Coast/Central Coast, Type I Subgrade Soil) (1), (2), (3), (4), (5)

TI	Rigid Pavement Structural Depth							
	With Lateral Support (ft)				Without Lateral Support (ft)			
< 9	0.70 JPCP 0.35 LCB	0.70 JPCP 0.25 HMA-A	0.70 JPCP 0.50 AB	0.70 JPCP 0.35 ATPB 0.35 AB	0.70 JPCP 0.35 LCB	0.70 JPCP 0.25 HMA-A	0.75 JPCP 0.50 AB	0.75 JPCP 0.35 ATPB 0.35 AB
9.5 to 10	0.70 JPCP 0.35 LCB	0.70 JPCP 0.25 HMA-A	0.75 JPCP 0.60 AB	0.75 JPCP 0.35 ATPB 0.40 AB	0.75 JPCP 0.35 LCB	0.75 JPCP 0.25 HMA-A	0.80 JPCP 0.60 AB	0.80 JPCP 0.35 ATPB 0.40 AB
10.5 to 11	0.75 JPCP 0.35 LCB	0.75 JPCP 0.25 HMA-A	0.80 JPCP 0.70 AB		0.80 JPCP 0.35 LCB	0.80 JPCP 0.25 HMA-A	0.85 JPCP 0.70 AB	
11.5 to 12	0.80 JPCP 0.35 LCB	0.80 JPCP 0.25 HMA-A	0.80 CRCP 0.25 HMA-A		0.85 JPCP 0.35 LCB	0.85 JPCP 0.25 HMA-A	0.80 CRCP 0.25 HMA-A	
12.5 to 13	0.85 JPCP 0.35 LCB	0.85 JPCP 0.25 HMA-A	0.80 CRCP 0.25 HMA-A		0.90 JPCP 0.35 LCB	0.90 JPCP 0.25 HMA-A	0.85 CRCP 0.25 HMA-A	
13.5 to 14	0.85 JPCP 0.35 LCB	0.85 JPCP 0.25 HMA-A	0.80 CRCP 0.25 HMA-A		0.95 JPCP 0.35 LCB	0.95 JPCP 0.25 HMA-A	0.90 CRCP 0.25 HMA-A	
14.5 to 15	0.90 JPCP 0.35 LCB	0.90 JPCP 0.25 HMA-A	0.85 CRCP 0.25 HMA-A		1.00 JPCP 0.35 LCB	1.00 JPCP 0.25 HMA-A	0.95 CRCP 0.25 HMA-A	
15.5 to 16	0.95 JPCP 0.35 LCB	0.90 JPCP 0.25 HMA-A	0.85 CRCP 0.25 HMA-A		1.05 JPCP 0.35 LCB	1.05 JPCP 0.25 HMA-A	0.95 CRCP 0.25 HMA-A	
16.5 to 17	1.00 JPCP 0.35 LCB	0.95 JPCP 0.25 HMA-A	0.90 CRCP 0.25 HMA-A		1.10 JPCP 0.35 LCB	1.10 JPCP 0.25 HMA-A	1.00 CRCP 0.25 HMA-A	
> 17	1.05 JPCP 0.35 LCB	1.05 JPCP 0.25 HMA-A	0.95 CRCP 0.25 HMA-A		1.15 JPCP 0.35 LCB	1.15 JPCP 0.25 HMA-A	1.00 CRCP 0.25 HMA-A	

NOTES:

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

Legend:

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

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

Table 623.1E
Rigid Pavement Catalog
(South Coast/Central Coast, Type II Subgrade Soil) ^{(1), (2), (3), (4), (5)}

TI	Rigid Pavement Structural Depth							
	With Lateral Support (ft)				Without Lateral Support (ft)			
< 9	0.70 JPCP	0.70 JPCP	0.70 JPCP	0.70 JPCP	0.70 JPCP	0.70 JPCP	0.75 JPCP	0.75 JPCP
	0.35 LCB	0.25 HMA-A	1.00 AB	0.35 ATPB	0.35 LCB	0.25 HMA-A	1.00 AB	0.35 ATPB
	0.50 AS	0.50 AS		0.80 AB	0.50 AS	0.50 AS		0.80 AB
9.5 to 10	0.70 JPCP	0.70 JPCP	0.75 JPCP	0.75 JPCP	0.75 JPCP	0.75 JPCP	0.80 JPCP	0.80 JPCP
	0.35 LCB	0.25 HMA-A	1.00 AB	0.35 ATPB	0.35 LCB	0.25 HMA-A	1.00 AB	0.35 ATPB
	0.50 AS	0.50 AS		0.80 AB	0.50 AS	0.50 AS		0.80 AB
10.5 to 11	0.75 JPCP	0.75 JPCP	0.80 JPCP		0.80 JPCP	0.80 JPCP	0.85 JPCP	
	0.35 LCB	0.25 HMA-A	1.30 AB		0.35 LCB	0.25 HMA-A	1.30 AB	
	0.60 AS	0.60 AS			0.60 AS	0.60 AS		
11.5 to 12	0.80 JPCP	0.80 JPCP	0.80 CRCP		0.85 JPCP	0.85 JPCP	0.80 CRCP	
	0.35 LCB	0.25 HMA-A	0.25 HMA-A		0.35 LCB	0.25 HMA-A	0.25 HMA-A	
	0.60 AS	0.60 AS	0.60 AS		0.60 AS	0.60 AS	0.60 AS	
12.5 to 13	0.85 JPCP	0.85 JPCP	0.80 CRCP		0.90 JPCP	0.90 JPCP	0.85 CRCP	
	0.35 LCB	0.25 HMA-A	0.25 HMA-A		0.35 LCB	0.25 HMA-A	0.25 HMA-A	
	0.70 AS	0.70 AS	0.70 AS		0.70 AS	0.70 AS	0.70 AS	
13.5 to 14	0.85 JPCP	0.85 JPCP	0.80 CRCP		0.95 JPCP	0.95 JPCP	0.90 CRCP	
	0.35 LCB	0.25 HMA-A	0.25 HMA-A		0.35 LCB	0.25 HMA-A	0.25 HMA-A	
	0.70 AS	0.70 AS	0.70 AS		0.70 AS	0.70 AS	0.70 AS	
14.5 to 15	0.90 JPCP	0.90 JPCP	0.85 CRCP		1.00 JPCP	1.00 JPCP	0.95 CRCP	
	0.35 LCB	0.25 HMA-A	0.25 HMA-A		0.35 LCB	0.25 HMA-A	0.25 HMA-A	
	0.70 AS	0.70 AS	0.70 AS		0.70 AS	0.70 AS	0.70 AS	
15.5 to 16	0.95 JPCP	0.90 JPCP	0.85 CRCP		1.05 JPCP	1.05 JPCP	0.95 CRCP	
	0.35 LCB	0.25 HMA-A	0.25 HMA-A		0.35 LCB	0.25 HMA-A	0.25 HMA-A	
	0.70 AS	0.70 AS	0.70 AS		0.70 AS	0.70 AS	0.70 AS	
16.5 to 17	1.00 JPCP	0.95 JPCP	0.90 CRCP		1.10 JPCP	1.10 JPCP	1.00 CRCP	
	0.35 LCB	0.25 HMA-A	0.25 HMA-A		0.35 LCB	0.25 HMA-A	0.25 HMA-A	
	0.70 AS	0.70 AS	0.70 AS		0.70 AS	0.70 AS	0.70 AS	
> 17	1.05 JPCP	1.05 JPCP	0.95 CRCP		1.15 JPCP	1.15 JPCP	1.00 CRCP	
	0.35 LCB	0.25 HMA-A	0.25 HMA-A		0.35 LCB	0.25 HMA-A	0.25 HMA-A	
	0.70 AS	0.70 AS	0.70 AS		0.70 AS	0.70 AS	0.70 AS	

NOTES:

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

Legend:

JPCP =	Jointed Plain Concrete Pavement	ATPB =	Asphalt Treated Permeable Base
CRCP =	Continuously Reinforced Concrete Pavement	AB =	Class 2 Aggregate Base
LCB =	Lean Concrete Base	AS =	Class 2 Aggregate Subbase
HMA-A =	Hot Mix Asphalt (Type A)	TI =	Traffic Index

Table 623.1F
Rigid Pavement Catalog (Inland Valley, Type I Subgrade Soil) (1), (2), (3), (4), (5)

TI	Rigid Pavement Structural Depth							
	With Lateral Support (ft)				Without Lateral Support (ft)			
< 9	0.70 JPCP 0.35 LCB	0.70 JPCP 0.25 HMA-A	0.75 JPCP 0.50 AB	0.70 JPCP 0.35 ATPB 0.35 AB	0.75 JPCP 0.35 LCB	0.75 JPCP 0.25 HMA-A	0.80 JPCP 0.50 AB	0.75 JPCP 0.35 ATPB 0.35 AB
9.5 to 10	0.70 JPCP 0.35 LCB	0.70 JPCP 0.25 HMA-A	0.80 JPCP 0.60 AB	0.75 JPCP 0.35 ATPB 0.40 AB	0.80 JPCP 0.35 LCB	0.85 JPCP 0.25 HMA-A	0.90 JPCP 0.60 AB	0.85 JPCP 0.35 ATPB 0.40 AB
10.5 to 11	0.75 JPCP 0.35 LCB	0.75 JPCP 0.25 HMA-A	0.85 JPCP 0.70 AB		0.85 JPCP 0.35 LCB	0.90 JPCP 0.25 HMA-A	0.95 JPCP 0.70 AB	
11.5 to 12	0.85 JPCP 0.35 LCB	0.85 JPCP 0.25 HMA-A	0.80 CRCP 0.25 HMA-A		0.95 JPCP 0.35 LCB	0.95 JPCP 0.25 HMA-A	0.85 CRCP 0.25 HMA-A	
12.5 to 13	0.85 JPCP 0.35 LCB	0.90 JPCP 0.25 HMA-A	0.80 CRCP 0.25 HMA-A		1.00 JPCP 0.35 LCB	1.00 JPCP 0.25 HMA-A	0.90 CRCP 0.25 HMA-A	
13.5 to 14	0.95 JPCP 0.35 LCB	0.95 JPCP 0.25 HMA-A	0.85 CRCP 0.25 HMA-A		1.05 JPCP 0.35 LCB	1.05 JPCP 0.25 HMA-A	0.95 CRCP 0.25 HMA-A	
14.5 to 15	1.00 JPCP 0.35 LCB	1.00 JPCP 0.25 HMA-A	0.90 CRCP 0.25 HMA-A		1.15 JPCP 0.35 LCB	1.15 JPCP 0.25 HMA-A	1.00 CRCP 0.25 HMA-A	
15.5 to 16	1.05 JPCP 0.35 LCB	1.05 JPCP 0.25 HMA-A	0.95 CRCP 0.25 HMA-A		1.20 JPCP 0.35 LCB	1.20 JPCP 0.25 HMA-A	1.05 CRCP 0.25 HMA-A	
16.5 to 17	1.10 JPCP 0.35 LCB	1.10 JPCP 0.25 HMA-A	0.95 CRCP 0.25 HMA-A		1.25 JPCP 0.35 LCB	1.25 JPCP 0.25 HMA-A	1.10 CRCP 0.25 HMA-A	
> 17	1.15 JPCP 0.35 LCB	1.15 JPCP 0.25 HMA-A	1.00 CRCP 0.25 HMA-A		1.30 JPCP 0.35 LCB	1.30 JPCP 0.25 HMA-A	1.10 CRCP 0.25 HMA-A	

NOTES:

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

Legend:

JPCP = Jointed Plain Concrete Pavement

CRCP = Continuously Reinforced Concrete Pavement

LCB = Lean Concrete Base

HMA-A = Hot Mix Asphalt (Type A)

ATPB = Asphalt Treated Permeable Base

AB = Class 2 Aggregate Base

TI = Traffic Index

Table 623.1G
Rigid Pavement Catalog (Inland Valley, Type II Subgrade Soil) ^{(1), (2), (3), (4), (5)}

TI	Rigid Pavement Structural Depth							
	With Lateral Support (ft)				Without Lateral Support (ft)			
< 9	0.70 JPCP	0.70 JPCP	0.75 JPCP	0.70 JPCP	0.75 JPCP	0.75 JPCP	0.80 JPCP	0.75 JPCP
	0.35 LCB	0.25 HMA-A	1.00 AB	0.35 ATPB	0.35 LCB	0.25 HMA-A	1.00 AB	0.35 ATPB
	0.50 AS	0.50 AS		0.80 AB	0.50 AS	0.50 AS		0.80 AB
9.5 to 10	0.70 JPCP	0.70 JPCP	0.80 JPCP	0.75 JPCP	0.80 JPCP	0.85 JPCP	0.90 JPCP	0.85 JPCP
	0.35 LCB	0.25 HMA-A	1.00 AB	0.35 ATPB	0.35 LCB	0.25 HMA-A	1.00 AB	0.35 ATPB
	0.50 AS	0.50 AS		0.80 AB	0.50 AS	0.50 AS		0.80 AB
10.5 to 11	0.75 JPCP	0.75 JPCP	0.85 JPCP		0.85 JPCP	0.90 JPCP	0.95 JPCP	
	0.35 LCB	0.25 HMA-A	1.30 AB		0.35 LCB	0.25 HMA-A	1.30 AB	
	0.60 AS	0.60 AS			0.60 AS	0.60 AS		
11.5 to 12	0.85 JPCP	0.85 JPCP	0.80 CRCP		0.95 JPCP	0.95 JPCP	0.85 CRCP	
	0.35 LCB	0.25 HMA-A	0.25 HMA-A		0.35 LCB	0.25 HMA-A	0.25 HMA-A	
	0.60 AS	0.60 AS	0.60 AS		0.60 AS	0.60 AS	0.60 AS	
12.5 to 13	0.85 JPCP	0.90 JPCP	0.80 CRCP		1.00 JPCP	1.00 JPCP	0.90 CRCP	
	0.35 LCB	0.25 HMA-A	0.25 HMA-A		0.35 LCB	0.25 HMA-A	0.25 HMA-A	
	0.70 AS	0.70 AS	0.70 AS		0.70 AS	0.70 AS	0.70 AS	
13.5 to 14	0.95 JPCP	0.95 JPCP	0.85 CRCP		1.05 JPCP	1.05 JPCP	0.95 CRCP	
	0.35 LCB	0.25 HMA-A	0.25 HMA-A		0.35 LCB	0.25 HMA-A	0.25 HMA-A	
	0.70 AS	0.70 AS	0.70 AS		0.70 AS	0.70 AS	0.70 AS	
14.5 to 15	1.00 JPCP	1.00 JPCP	0.90 CRCP		1.15 JPCP	1.15 JPCP	1.00 CRCP	
	0.35 LCB	0.25 HMA-A	0.25 HMA-A		0.35 LCB	0.25 HMA-A	0.25 HMA-A	
	0.70 AS	0.70 AS	0.70 AS		0.70 AS	0.70 AS	0.70 AS	
15.5 to 16	1.05 JPCP	1.05 JPCP	0.95 CRCP		1.20 JPCP	1.20 JPCP	1.05 CRCP	
	0.35 LCB	0.25 HMA-A	0.25 HMA-A		0.35 LCB	0.25 HMA-A	0.25 HMA-A	
	0.70 AS	0.70 AS	0.70 AS		0.70 AS	0.70 AS	0.70 AS	
16.5 to 17	1.10 JPCP	1.10 JPCP	0.95 CRCP		1.25 JPCP	1.25 JPCP	1.10 CRCP	
	0.35 LCB	0.25 HMA-A	0.25 HMA-A		0.35 LCB	0.25 HMA-A	0.25 HMA-A	
	0.70 AS	0.70 AS	0.70 AS		0.70 AS	0.70 AS	0.70 AS	
> 17	1.15 JPCP	1.15 JPCP	1.00 CRCP		1.30 JPCP	1.30 JPCP	1.10 CRCP	
	0.35 LCB	0.25 HMA-A	0.25 HMA-A		0.35 LCB	0.25 HMA-A	0.25 HMA-A	
	0.70 AS	0.70 AS	0.70 AS		0.70 AS	0.70 AS	0.70 AS	

NOTES:

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

Legend:

- | | | | |
|---------|---|--------|--------------------------------|
| JPCP = | Jointed Plain Concrete Pavement | ATPB = | Asphalt Treated Permeable Base |
| CRCP = | Continuously Reinforced Concrete Pavement | AB = | Class 2 Aggregate Base |
| LCB = | Lean Concrete Base | AS = | Class 2 Aggregate Subbase |
| HMA-A = | Hot Mix Asphalt (Type A) | TI = | Traffic Index |

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

TI	Rigid Pavement Structural Depth							
	With Lateral Support (ft)				Without Lateral Support (ft)			
< 9	0.70 JPCP 0.35 LCB	0.70 JPCP 0.25 HMA-A	0.75 JPCP 0.50 AB	0.70 JPCP 0.35 ATPB 0.40 AB	0.75 JPCP 0.35 LCB	0.75 JPCP 0.25 HMA-A	0.80 JPCP 0.50 AB	0.75 JPCP 0.35 ATPB 0.40 AB
9.5 to 10	0.75 JPCP 0.35 LCB	0.75 JPCP 0.25 HMA-A	0.80 JPCP 0.60 AB	0.80 JPCP 0.35 ATPB 0.40 AB	0.80 JPCP 0.35 LCB	0.85 JPCP 0.25 HMA-A	0.90 JPCP 0.60 AB	0.85 JPCP 0.35 ATPB 0.40 AB
10.5 to 11	0.80 JPCP 0.35 LCB	0.80 JPCP 0.25 HMA-A	0.85 JPCP 0.70 AB		0.85 JPCP 0.35 LCB	0.90 JPCP 0.25 HMA-A	0.95 JPCP 0.70 AB	
11.5 to 12	0.85 JPCP 0.35 LCB	0.85 JPCP 0.25 HMA-A	0.80 CRCP 0.25 HMA-A		0.90 JPCP 0.35 LCB	0.95 JPCP 0.25 HMA-A	0.85 CRCP 0.25 HMA-A	
12.5 to 13	0.95 JPCP 0.35 LCB	0.95 JPCP 0.25 HMA-A	0.85 CRCP 0.25 HMA-A		1.05 JPCP 0.35 LCB	1.05 JPCP 0.25 HMA-A	0.95 CRCP 0.25 HMA-A	
13.5 to 14	1.00 JPCP 0.35 LCB	1.00 JPCP 0.25 HMA-A	0.90 CRCP 0.25 HMA-A		1.15 JPCP 0.35 LCB	1.15 JPCP 0.25 HMA-A	1.05 CRCP 0.25 HMA-A	
14.5 to 15	1.05 JPCP 0.35 LCB	1.05 JPCP 0.25 HMA-A	0.95 CRCP 0.25 HMA-A		1.20 JPCP 0.35 LCB	1.20 JPCP 0.25 HMA-A	1.10 CRCP 0.25 HMA-A	
15.5 to 16	1.10 JPCP 0.35 LCB	1.10 JPCP 0.25 HMA-A	1.00 CRCP 0.25 HMA-A		1.25 JPCP 0.35 LCB	1.25 JPCP 0.25 HMA-A	1.10 CRCP 0.25 HMA-A	
16.5 to 17	1.15 JPCP 0.35 LCB	1.15 JPCP 0.25 HMA-A	1.05 CRCP 0.25 HMA-A		1.30 JPCP 0.35 LCB	1.30 JPCP 0.25 HMA-A	1.10 CRCP 0.25 HMA-A	
> 17	1.20 JPCP 0.35 LCB	1.20 JPCP 0.25 HMA-A	1.10 CRCP 0.25 HMA-A		1.30 JPCP 0.35 LCB	1.30 JPCP 0.25 HMA-A	1.10 CRCP 0.25 HMA-A	

NOTES:

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

Legend:

JPCP = Jointed Plain Concrete Pavement

CRCP = Continuously Reinforced Concrete Pavement

LCB = Lean Concrete Base

HMA-A = Hot Mix Asphalt (Type A)

ATPB = Asphalt Treated Permeable Base

AB = Class 2 Aggregate Base

TI = Traffic Index

Table 623.11
Rigid Pavement Catalog (Desert, Type II Subgrade Soil) (1), (2), (3), (4), (5)

TI	Rigid Pavement Structural Depth							
	With Lateral Support (ft)				Without Lateral Support (ft)			
< 9	0.70 JPCP	0.70 JPCP	0.75 JPCP	0.70 JPCP	0.75 JPCP	0.75 JPCP	0.80 JPCP	0.75 JPCP
	0.35 LCB	0.25 HMA-A	1.00 AB	0.35 ATPB	0.35 LCB	0.25 HMA-A	1.00 AB	0.35 ATPB
	0.50 AS	0.50 AS		0.80 AB	0.60 AS	0.60 AS		0.80 AB
9.5 to 10	0.75 JPCP	0.75 JPCP	0.80 JPCP	0.80 JPCP	0.80 JPCP	0.85 JPCP	0.90 JPCP	0.85 JPCP
	0.35 LCB	0.25 HMA-A	1.00 AB	0.35 ATPB	0.35 LCB	0.25 HMA-A	1.00 AB	0.35 ATPB
	0.50 AS	0.50 AS		0.80 AB	0.60 AS	0.60 AS		0.80 AB
10.5 to 11	0.80 JPCP	0.80 JPCP	0.85 JPCP		0.85 JPCP	0.90 JPCP	0.95 JPCP	
	0.35 LCB	0.25 HMA-A	1.30 AB		0.35 LCB	0.25 HMA-A	1.30 AB	
	0.60 AS	0.60 AS			0.60 AS	0.60 AS		
11.5 to 12	0.85 JPCP	0.85 JPCP	0.80 CRCP		0.90 JPCP	0.95 JPCP	0.85 CRCP	
	0.35 LCB	0.25 HMA-A	0.25 HMA-A		0.35 LCB	0.25 HMA-A	0.25 HMA-A	
	0.60 AS	0.60 AS	0.60 AS		0.60 AS	0.60 AS	0.60 AS	
12.5 to 13	0.95 JPCP	0.95 JPCP	0.85 CRCP		1.05 JPCP	1.05 JPCP	0.95 CRCP	
	0.35 LCB	0.25 HMA-A	0.25 HMA-A		0.35 LCB	0.25 HMA-A	0.25 HMA-A	
	0.70 AS	0.70 AS	0.70 AS		0.70 AS	0.70 AS	0.70 AS	
13.5 to 14	1.00 JPCP	1.00 JPCP	0.90 CRCP		1.15 JPCP	1.15 JPCP	1.05 CRCP	
	0.35 LCB	0.25 HMA-A	0.25 HMA-A		0.35 LCB	0.25 HMA-A	0.25 HMA-A	
	0.70 AS	0.70 AS	0.70 AS		0.70 AS	0.70 AS	0.70 AS	
14.5 to 15	1.05 JPCP	1.05 JPCP	0.95 CRCP		1.20 JPCP	1.20 JPCP	1.10 CRCP	
	0.35 LCB	0.25 HMA-A	0.25 HMA-A		0.35 LCB	0.25 HMA-A	0.25 HMA-A	
	0.70 AS	0.70 AS	0.70 AS		0.70 AS	0.70 AS	0.70 AS	
15.5 to 16	1.10 JPCP	1.10 JPCP	1.00 CRCP		1.25 JPCP	1.25 JPCP	1.10 CRCP	
	0.35 LCB	0.25 HMA-A	0.25 HMA-A		0.35 LCB	0.25 HMA-A	0.25 HMA-A	
	0.70 AS	0.70 AS	0.70 AS		0.70 AS	0.70 AS	0.70 AS	
16.5 to 17	1.15 JPCP	1.15 JPCP	1.05 CRCP		1.30 JPCP	1.30 JPCP	1.10 CRCP	
	0.35 LCB	0.25 HMA-A	0.25 HMA-A		0.35 LCB	0.25 HMA-A	0.25 HMA-A	
	0.70 AS	0.70 AS	0.70 AS		0.70 AS	0.70 AS	0.70 AS	
> 17	1.20 JPCP	1.20 JPCP	1.10 CRCP		1.30 JPCP	1.30 JPCP	1.10 CRCP	
	0.35 LCB	0.25 HMA-A	0.25 HMA-A		0.35 LCB	0.25 HMA-A	0.25 HMA-A	
	0.70 AS	0.70 AS	0.70 AS		0.70 AS	0.70 AS	0.70 AS	

NOTES:

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

Legend:

JPCP = Jointed Plain Concrete Pavement

CRCP = Continuously Reinforced Concrete Pavement

LCB = Lean Concrete Base

HMA-A = Hot Mix Asphalt (Type A)

ATPB = Asphalt Treated Permeable Base

AB = Class 2 Aggregate Base

AS = Class 2 Aggregate Subbase

TI = Traffic Index

Table 623.1J
Rigid Pavement Catalog
(Low Mountain/South Mountain, Type I Subgrade Soil) (1), (2), (3), (4), (5)

TI	Rigid Pavement Structural Depth							
	With Lateral Support (ft)				Without Lateral Support (ft)			
< 9	0.70 JPCP	0.70 JPCP	0.75 JPCP	0.70 JPCP	0.75 JPCP	0.75 JPCP	0.75 JPCP	0.75 JPCP
	0.35 LCB	0.25 HMA-A	0.50 AB	0.35 ATPB 0.40 AB	0.35 LCB	0.25 HMA-A	0.50 AB	0.35 ATPB 0.40 AB
9.5 to 10	0.70 JPCP	0.70 JPCP	0.75 JPCP	0.75 JPCP	0.80 JPCP	0.80 JPCP	0.85 JPCP	0.80 JPCP
	0.35 LCB	0.25 HMA-A	0.60 AB	0.35 ATPB 0.40 AB	0.35 LCB	0.25 HMA-A	0.60 AB	0.35 ATPB 0.40 AB
10.5 to 11	0.75 JPCP	0.75 JPCP	0.80 JPCP		0.85 JPCP	0.85 JPCP	0.90 JPCP	
	0.35 LCB	0.25 HMA-A	0.70 AB		0.35 LCB	0.25 HMA-A	0.70 AB	
11.5 to 12	0.80 JPCP	0.85 JPCP	0.80 CRCP		0.90 JPCP	0.95 JPCP	0.85 CRCP	
	0.35 LCB	0.25 HMA-A	0.25 HMA-A		0.35 LCB	0.25 HMA-A	0.25 HMA-A	
12.5 to 13	0.90 JPCP	0.95 JPCP	0.85 CRCP		1.00 JPCP	1.05 JPCP	0.90 CRCP	
	0.35 LCB	0.25 HMA-A	0.25 HMA-A		0.35 LCB	0.25 HMA-A	0.25 HMA-A	
13.5 to 14	0.95 JPCP	1.00 JPCP	0.85 CRCP		1.05 JPCP	1.10 JPCP	0.95 CRCP	
	0.35 LCB	0.25 HMA-A	0.25 HMA-A		0.35 LCB	0.25 HMA-A	0.25 HMA-A	
14.5 to 15	1.00 JPCP	1.05 JPCP	0.90 CRCP		1.15 JPCP	1.20 JPCP	1.05 CRCP	
	0.35 LCB	0.25 HMA-A	0.25 HMA-A		0.35 LCB	0.25 HMA-A	0.25 HMA-A	
15.5 to 16	1.05 JPCP	1.10 JPCP	0.95 CRCP		1.20 JPCP	1.25 JPCP	1.10 CRCP	
	0.35 LCB	0.25 HMA-A	0.25 HMA-A		0.35 LCB	0.25 HMA-A	0.25 HMA-A	
16.5 to 17	1.10 JPCP	1.15 JPCP	1.00 CRCP		1.25 JPCP	1.30 JPCP	1.10 CRCP	
	0.35 LCB	0.25 HMA-A	0.25 HMA-A		0.35 LCB	0.25 HMA-A	0.25 HMA-A	
> 17	1.15 JPCP	1.20 JPCP	1.00 CRCP		1.30 JPCP	1.35 JPCP	1.10 CRCP	
	0.35 LCB	0.25 HMA-A	0.25 HMA-A		0.35 LCB	0.25 HMA-A	0.25 HMA-A	

NOTES:

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

Legend:

JPCP =	Jointed Plain Concrete Pavement	ATPB =	Asphalt Treated Permeable Base
CRCP =	Continuously Reinforced Concrete Pavement	AB =	Class 2 Aggregate Base
LCB =	Lean Concrete Base	TI =	Traffic Index
HMA-A =	Hot Mix Asphalt (Type A)		

Table 623.1K
Rigid Pavement Catalog
(Low Mountain/South Mountain, Type II Subgrade Soil) ^{(1), (2), (3), (4), (5)}

TI	Rigid Pavement Structural Depth							
	With Lateral Support (ft)				Without Lateral Support (ft)			
< 9	0.70 JPCP	0.70 JPCP	0.75 JPCP	0.70 JPCP	0.75 JPCP	0.75 JPCP	0.75 JPCP	0.75 JPCP
	0.35 LCB	0.25 HMA-A	1.00 AB	0.35 ATPB	0.35 LCB	0.25 HMA-A	1.00 AB	0.35 ATPB
	0.50 AS	0.50 AS		0.80 AB	0.50 AS	0.50 AS		0.80 AB
9.5 to 10	0.70 JPCP	0.70 JPCP	0.75 JPCP	0.75 JPCP	0.80 JPCP	0.80 JPCP	0.85 JPCP	0.80 JPCP
	0.35 LCB	0.25 HMA-A	1.00 AB	0.35 ATPB	0.35 LCB	0.25 HMA-A	1.00 AB	0.35 ATPB
	0.50 AS	0.50 AS		0.80 AB	0.50 AS	0.50 AS		0.80 AB
10.5 to 11	0.75 JPCP	0.75 JPCP	0.80 JPCP		0.85 JPCP	0.85 JPCP	0.90 JPCP	
	0.35 LCB	0.25 HMA-A	1.30 AB		0.35 LCB	0.25 HMA-A	1.30 AB	
	0.60 AS	0.60 AS			0.60 AS	0.60 AS		
11.5 to 12	0.80 JPCP	0.85 JPCP	0.80 CRCP		0.90 JPCP	0.95 JPCP	0.85 CRCP	
	0.35 LCB	0.25 HMA-A	0.25 HMA-A		0.35 LCB	0.25 HMA-A	0.25 HMA-A	
	0.60 AS	0.60 AS	0.60 AS		0.60 AS	0.60 AS	0.60 AS	
12.5 to 13	0.90 JPCP	0.95 JPCP	0.85 CRCP		1.00 JPCP	1.05 JPCP	0.90 CRCP	
	0.35 LCB	0.25 HMA-A	0.25 HMA-A		0.35 LCB	0.25 HMA-A	0.25 HMA-A	
	0.70 AS	0.70 AS	0.70 AS		0.70 AS	0.70 AS	0.70 AS	
13.5 to 14	0.95 JPCP	1.00 JPCP	0.85 CRCP		1.05 JPCP	1.10 JPCP	0.95 CRCP	
	0.35 LCB	0.25 HMA-A	0.25 HMA-A		0.35 LCB	0.25 HMA-A	0.25 HMA-A	
	0.70 AS	0.70 AS	0.70 AS		0.70 AS	0.70 AS	0.70 AS	
14.5 to 15	1.00 JPCP	1.05 JPCP	0.90 CRCP		1.15 JPCP	1.20 JPCP	1.05 CRCP	
	0.35 LCB	0.25 HMA-A	0.25 HMA-A		0.35 LCB	0.25 HMA-A	0.25 HMA-A	
	0.70 AS	0.70 AS	0.70 AS		0.70 AS	0.70 AS	0.70 AS	
15.5 to 16	1.05 JPCP	1.10 JPCP	0.95 CRCP		1.20 JPCP	1.25 JPCP	1.10 CRCP	
	0.35 LCB	0.25 HMA-A	0.25 HMA-A		0.35 LCB	0.25 HMA-A	0.25 HMA-A	
	0.70 AS	0.70 AS	0.70 AS		0.70 AS	0.70 AS	0.70 AS	
16.5 to 17	1.10 JPCP	1.15 JPCP	1.00 CRCP		1.25 JPCP	1.30 JPCP	1.10 CRCP	
	0.35 LCB	0.25 HMA-A	0.25 HMA-A		0.35 LCB	0.25 HMA-A	0.25 HMA-A	
	0.70 AS	0.70 AS	0.70 AS		0.70 AS	0.70 AS	0.70 AS	
> 17	1.15 JPCP	1.20 JPCP	1.00 CRCP		1.30 JPCP	1.35 JPCP	1.10 CRCP	
	0.35 LCB	0.25 HMA-A	0.25 HMA-A		0.35 LCB	0.25 HMA-A	0.25 HMA-A	
	0.70 AS	0.70 AS	0.70 AS		0.70 AS	0.70 AS	0.70 AS	

NOTES:

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

Legend:

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

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

Table 623.1L
Rigid Pavement Catalog
(High Mountain/High Desert, Type I Subgrade Soil) (1), (2), (3), (4), (5)

TI	Rigid Pavement Structural Depth							
	With Lateral Support (ft)				Without Lateral Support (ft)			
< 9	0.80 JPCP	0.85 JPCP	0.85 JPCP	0.80 JPCP	0.85 JPCP	0.90 JPCP	0.90 JPCP	0.90 JPCP
	0.35 LCB	0.25 HMA-A	0.50 AB	0.35 ATPB 0.40 AB	0.35 LCB	0.25 HMA-A	0.50 AB	0.35 ATPB 0.40 AB
9.5 to 10	0.85 JPCP	0.85 JPCP	0.90 JPCP	0.90 JPCP	0.90 JPCP	0.90 JPCP	0.95 JPCP	0.90 JPCP
	0.35 LCB	0.25 HMA-A	0.60 AB	0.35 ATPB 0.40 AB	0.35 LCB	0.25 HMA-A	0.60 AB	0.35 ATPB 0.40 AB
10.5 to 11	0.90 JPCP	0.90 JPCP	0.95 JPCP		0.95 JPCP	0.95 JPCP	1.00 JPCP	
	0.35 LCB	0.25 HMA-A	0.70 AB		0.35 LCB	0.25 HMA-A	0.70 AB	
11.5 to 12	0.95 JPCP	0.95 JPCP			1.05 JPCP	1.05 JPCP		
	0.35 LCB	0.25 HMA-A			0.35 LCB	0.25 HMA-A		
12.5 to 13	1.00 JPCP	1.05 JPCP			1.10 JPCP	1.15 JPCP		
	0.35 LCB	0.25 HMA-A			0.35 LCB	0.25 HMA-A		
13.5 to 14	1.05 JPCP	1.10 JPCP			1.15 JPCP	1.20 JPCP		
	0.35 LCB	0.25 HMA-A			0.35 LCB	0.25 HMA-A		
14.5 to 15	1.10 JPCP	1.15 JPCP			1.20 JPCP	1.25 JPCP		
	0.35 LCB	0.25 HMA-A			0.35 LCB	0.25 HMA-A		
15.5 to 16	1.15 JPCP	1.20 JPCP			1.25 JPCP	1.30 JPCP		
	0.35 LCB	0.25 HMA-A			0.35 LCB	0.25 HMA-A		
16.5 to 17	1.20 JPCP	1.25 JPCP			1.30 JPCP	1.35 JPCP		
	0.35 LCB	0.25 HMA-A			0.35 LCB	0.25 HMA-A		
> 17	1.25 JPCP	1.25 JPCP			1.35 JPCP	1.35 JPCP		
	0.35 LCB	0.25 HMA-A			0.35 LCB	0.25 HMA-A		

NOTES:

- (1) Thicknesses shown for JPCP are for doweled pavement only. The thickness shown in these tables are not valid for nondoweled JPCP.
- (2) Includes 0.15 ft sacrificial wearing course for future grinding of JPCP.
- (3) Portland cement concrete may be substituted for LCB when justified for constructibility or traffic handling. If Portland cement concrete is used in lieu of LCB, it must be placed in a separate lift than JPCP and must not be bonded to the JPCP.
- (4) If ATPB is needed for TIs > 10.0 to perpetuate an existing treated permeable layer, place the ATPB between the surface layer (JPCP or CRCP) and the base layer. No deduction is made to the thickness of the base and subbase layers on account of the ATPB.
- (5) Place a Bond Breaker between JPCP and LCB in all cases

Legend:

JPCP = Jointed Plain Concrete Pavement

ATPB = Asphalt Treated Permeable Base

CRCP = Continuously Reinforced Concrete Pavement

AB = Class 2 Aggregate Base

LCB = Lean Concrete Base

TI = Traffic Index

HMA-A = Hot Mix Asphalt (Type A)

Table 623.1M
Rigid Pavement Catalog
(High Mountain/High Desert, Type II Subgrade Soil) ^{(1), (2), (3), (4), (5)}

TI	Rigid Pavement Structural Depth							
	With Lateral Support (ft)				Without Lateral Support (ft)			
< 9	0.80 JPCP	0.85 JPCP	0.85 JPCP	0.80 JPCP	0.85 JPCP	0.90 JPCP	0.90 JPCP	0.90 JPCP
	0.35 LCB	0.25 HMA-A	1.00 AB	0.35 ATPB	0.35 LCB	0.25 HMA-A	1.00 AB	0.35 ATPB
	0.50 AS	0.50 AS		0.80 AB	0.50 AS	0.50 AS		0.80 AB
9.5 to 10	0.85 JPCP	0.85 JPCP	0.90 JPCP	0.90 JPCP	0.90 JPCP	0.90 JPCP	0.95 JPCP	0.90 JPCP
	0.35 LCB	0.25 HMA-A	1.00 AB	0.35 ATPB	0.35 LCB	0.25 HMA-A	1.00 AB	0.35 ATPB
	0.50 AS	0.50 AS		0.80 AB	0.50 AS	0.50 AS		0.80 AB
10.5 to 11	0.90 JPCP	0.90 JPCP	0.95 JPCP		0.95 JPCP	0.95 JPCP	1.00 JPCP	
	0.35 LCB	0.25 HMA-A	1.30 AB		0.35 LCB	0.25 HMA-A	1.30 AB	
	0.60 AS	0.60 AS			0.60 AS	0.60 AS		
11.5 to 12	0.95 JPCP	0.95 JPCP			1.05 JPCP	1.05 JPCP		
	0.35 LCB	0.25 HMA-A			0.35 LCB	0.25 HMA-A		
	0.60 AS	0.60 AS			0.60 AS	0.60 AS		
12.5 to 13	1.00 JPCP	1.05 JPCP			1.10 JPCP	1.15 JPCP		
	0.35 LCB	0.25 HMA-A			0.35 LCB	0.25 HMA-A		
	0.70 AS	0.70 AS			0.70 AS	0.70 AS		
13.5 to 14	1.05 JPCP	1.10 JPCP			1.15 JPCP	1.20 JPCP		
	0.35 LCB	0.25 HMA-A			0.35 LCB	0.25 HMA-A		
	0.70 AS	0.70 AS			0.70 AS	0.70 AS		
14.5 to 15	1.10 JPCP	1.15 JPCP			1.20 JPCP	1.25 JPCP		
	0.35 LCB	0.25 HMA-A			0.35 LCB	0.25 HMA-A		
	0.70 AS	0.70 AS			0.70 AS	0.70 AS		
15.5 to 16	1.15 JPCP	1.20 JPCP			1.25 JPCP	1.30 JPCP		
	0.35 LCB	0.25 HMA-A			0.35 LCB	0.23 HMA-A		
	0.70 AS	0.70 AS			0.70 AS	0.70 AS		
16.5 to 17	1.20 JPCP	1.25 JPCP			1.30 JPCP	1.35 JPCP		
	0.35 LCB	0.25 HMA-A			0.35 LCB	0.25 HMA-A		
	0.70 AS	0.70 AS			0.70 AS	0.70 AS		
> 17	1.25 JPCP	1.25 JPCP			1.35 JPCP	1.35 JPCP		
	0.35 LCB	0.25 HMA-A			0.35 LCB	0.25 HMA-A		
	0.70 AS	0.70 AS			0.70 AS	0.70 AS		

NOTES:

- (1) Thicknesses shown for JPCP are for doweled pavement only. The thickness shown in these tables are not valid for nondoweled JPCP.
- (2) Includes 0.15 ft sacrificial wearing course for future grinding of JPCP.
- (3) Portland cement concrete may be substituted for LCB when justified for constructibility or traffic handling. If Portland cement concrete is used in lieu of LCB, it must be placed in a separate lift than JPCP and must not be bonded to the JPCP.
- (4) If ATPB is needed for TIs > 10.0 to perpetuate an existing treated permeable layer, place the ATPB between the surface layer (JPCP or CRCP) and the base layer. No deduction is made to the thickness of the base and subbase layers on account of the ATPB.
- (5) Place a Bond Breaker between JPCP and LCB in all cases

Legend:

JPCP = Jointed Plain Concrete Pavement

CRCP = Continuously Reinforced Concrete Pavement

LCB = Lean Concrete Base

HMA-A = Hot Mix Asphalt (Type A)

ATPB = Asphalt Treated Permeable Base

AB = Class 2 Aggregate Base

AS = Class 2 Aggregate Subbase

TI = Traffic Index

Topic 624 – Engineering Procedures for Pavement Preservation

624.1 Preventive Maintenance

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

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

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

624.2 Capital Preventive Maintenance (CAPM)

CAPM strategies include the following or combinations of the following:

- (a) Slab replacement. The use of rapid strength concrete in the replacement of concrete slabs should be given consideration to minimize traffic impacts and open the facility to traffic in a minimal amount of time. Slab replacements may include replacing existing cement treated base or lean concrete base with rapid strength concrete. For further information (including information on rapid strength concrete) see the “Slab Replacement Guidelines” on the Department Pavement website.
- (b) Grinding to correct faulting.
- (c) Dowel bar retrofit. Guidelines for selecting and engineering dowel bar retrofit projects can be found on the Department Pavement website.

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

Topic 625 - Engineering Procedures for Pavement and Roadway Rehabilitation

625.1 Rigid Pavement Rehabilitation Strategies

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

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

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

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

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

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

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

625.2 Mechanistic-Empirical Method

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

Topic 626 - Other Considerations

626.1 Traveled Way

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

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

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

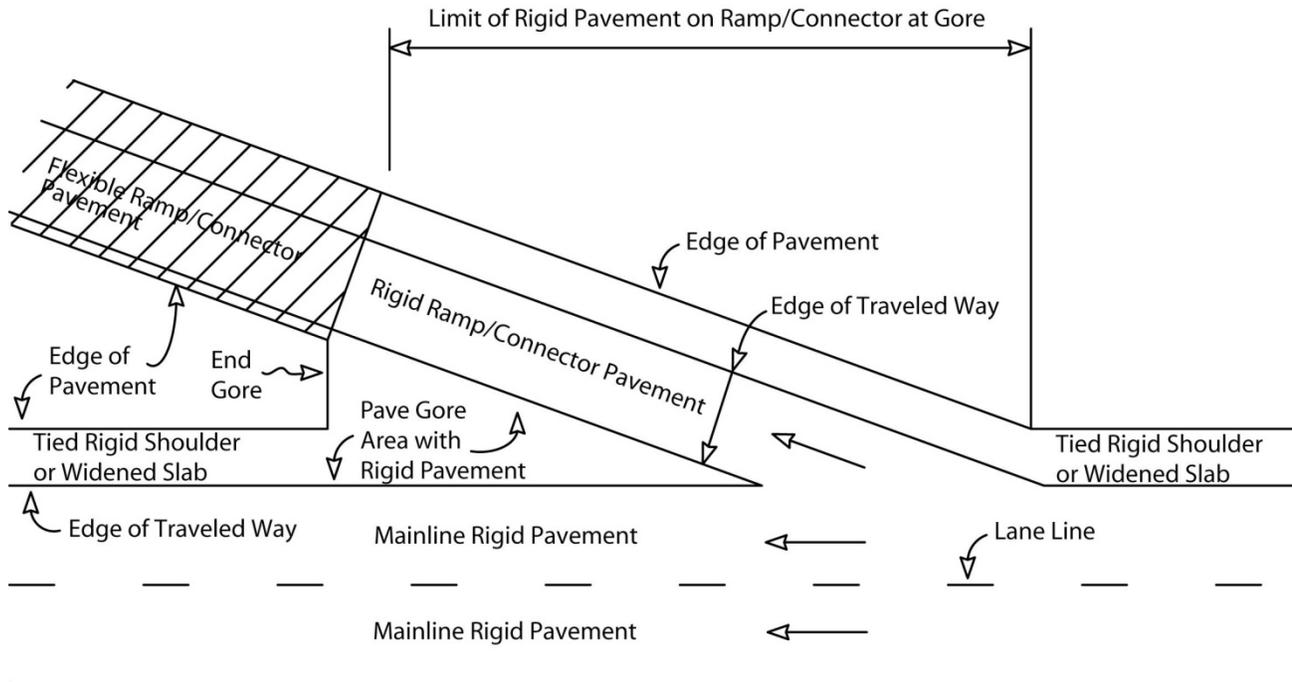
NOTE:

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

Legend:

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

Figure 626.1
Rigid Pavement at Ramp or Connector Gore Area



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

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

- (3) *Ramp Termini.* Rigid pavement is sometimes placed at ramp termini instead of flexible pavement where there is projected heavy truck traffic (as defined in Index 613.5(1)(c)) to preclude pavement failure such as rutting or shoving from vehicular braking, turning movements, and oil dripping from vehicles. Once a design TI is selected for the ramp in accordance with Index 613.5, follow the requirements in Index 623.1 to engineer the rigid pavement structure for the ramp termini. The length of rigid pavement to be placed at the termini will depend on the geometric alignment of the ramp, ramp grades, and the length of queues of stopped traffic. The rigid pavement should extend to the first set of signal loops on signalized intersections. A length of 150 feet should be considered the minimum on unsignalized intersections. Special care should be taken to assure skid resistance in conformance with current standard specifications in the braking area, especially where oil drippage is concentrated. End anchors or transitions should be used at flexible/rigid pavement joints. The Department Pavement website has additional information and training for engineering pavement for intersections and rigid ramp termini.

626.2 Shoulder

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

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

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

The pavement structure for the tied rigid shoulder should match the pavement structure of the adjacent traffic lane. Special delineation of concrete shoulders may be required to deter the use of the shoulder as a traveled lane. District Traffic Operations should be consulted to determine the potential need for anything more than the standard edge stripe.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

- Life-cycle cost of the shoulder.
- Ability and safety of maintenance crews to maintain the shoulder. In confined areas, such as in front of retaining walls or narrow shoulders, and on high volume roadways (AADT > 150,000) consideration should be given to engineering a shoulder that requires the least amount of maintenance, even if it is more expensive to construct.
- Future plans to widen the facility or convert the shoulder to a traffic lane.
- Width of shoulder. When shoulder widths are less than 5 feet, tied rigid shoulders are preferable to a widened rigid slab and narrow flexible shoulder, less than 3 feet, for both constructibility and maintainability.
- For projects where the tracking width lines are shown to encroach onto paved shoulders or any portion of the gutter pan, tied rigid shoulders and the gutter pan

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

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

626.3 Intersections

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

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

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

626.4 Roadside Facilities

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

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

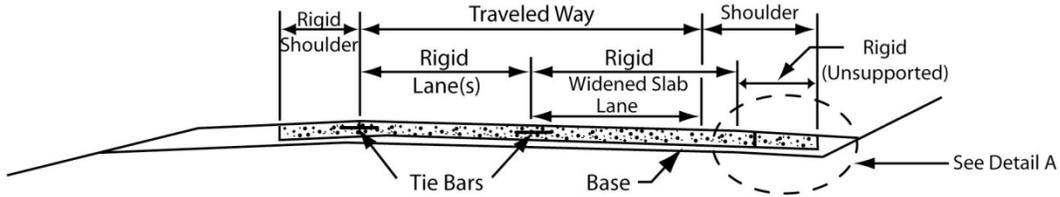
Use guidelines for intersections in Index 626.3 for further information.

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

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

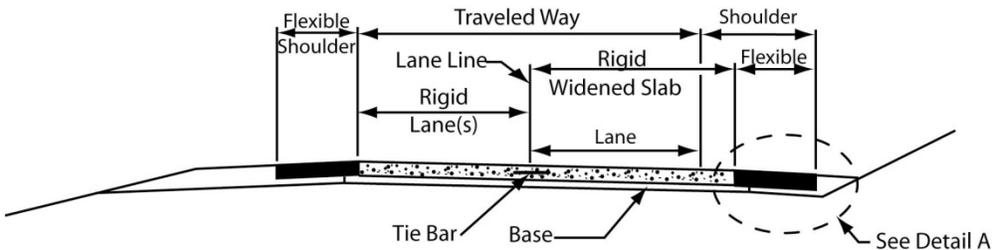
An end anchor may improve long-term performance at the flexible-to-rigid pavement transition. Doweled transverse joints should

Figure 626.2A
Rigid Pavement and Shoulder Details



RIGID SHOULDERS

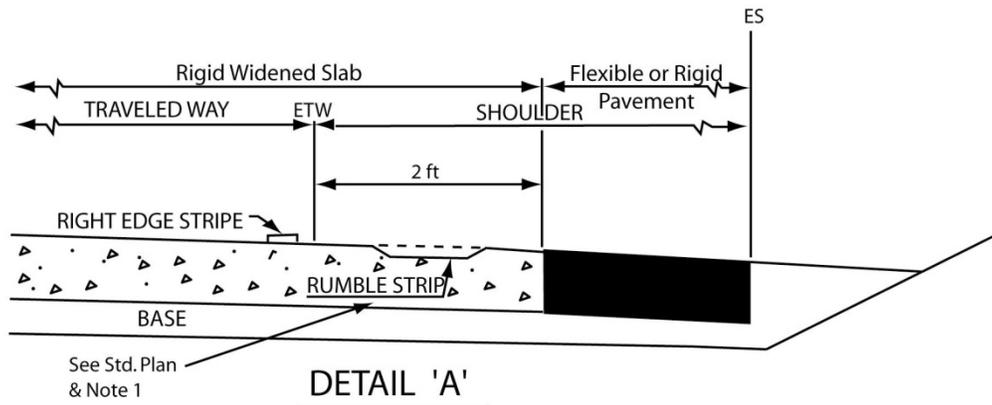
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FLEXIBLE SHOULDERS

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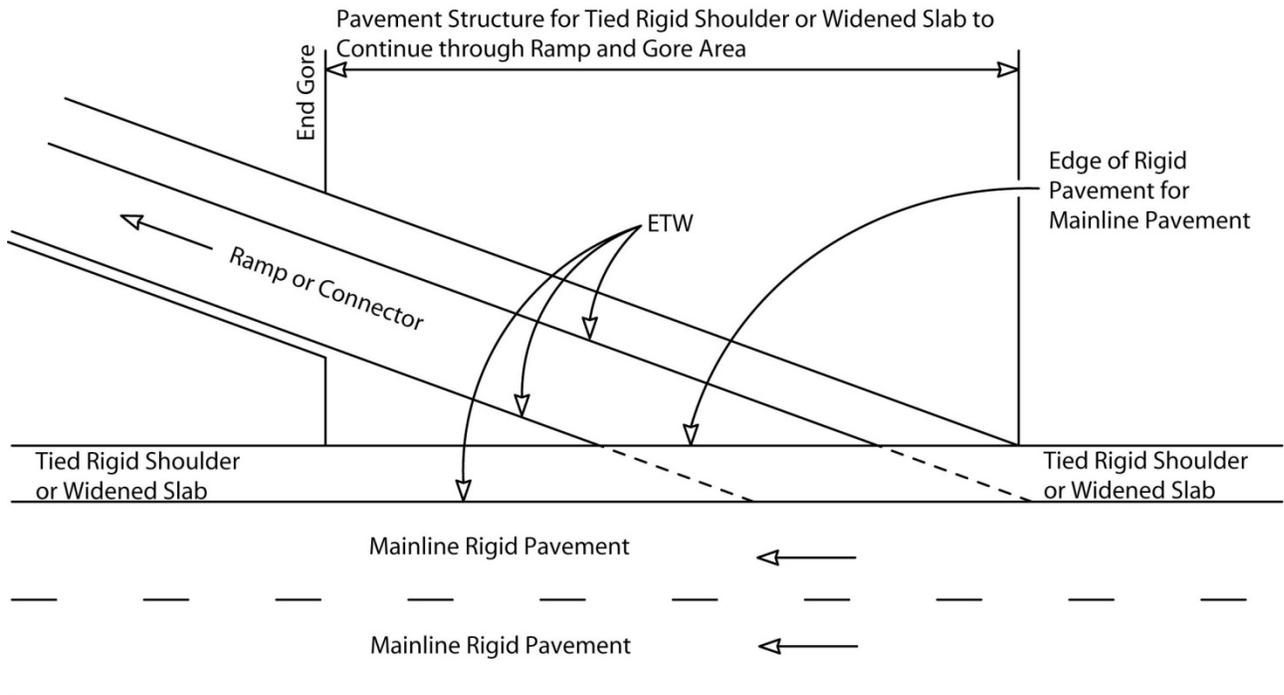
NOTE: These illustrations are only to show nomenclature and are not to be used for geometric cross section details.



DETAIL 'A'

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

Figure 626.2B
Rigid Shoulders Through Ramp and Gore Areas

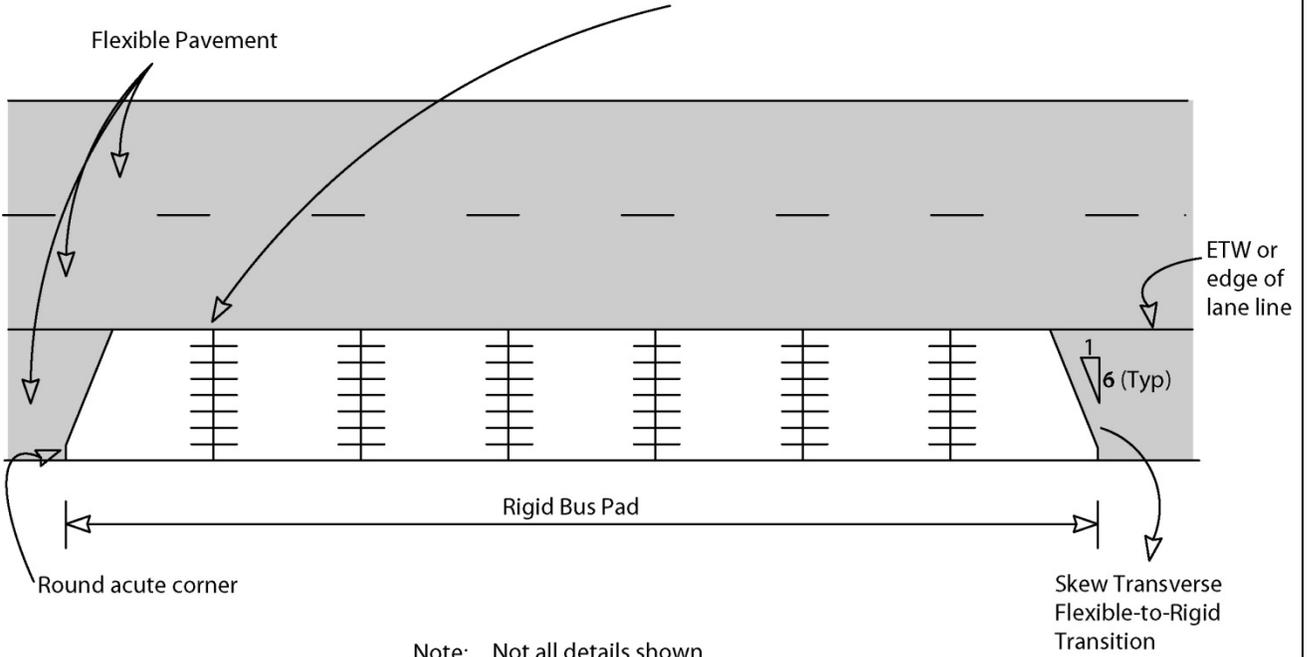


- Notes: 1) Not all details shown
2) Off ramp shown. Same conditions apply for on ramps.

be perpendicular to the longitudinal joint at maximum 15 feet spacing, but consider skewing (at 1:6 typical) entrance/exit transverse flexible-to-rigid transitions, note that since acute corners can fail prematurely, acute corners should be rounded (see Figure 626.4). Special care should be taken to assure skid resistance in conformance with current Standard Specifications in the braking area, especially where oil drippage is concentrated.

Figure 626.4
Rigid Bus Pad

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



CHAPTER 630 FLEXIBLE PAVEMENT

Topic 631 - Types of Flexible Pavements & Materials

Index 631.1 - Hot Mix Asphalt (HMA)

HMA consists of a mixture of asphalt binder and a graded aggregate ranging from coarse to very fine particles. The aggregate can be treated and the binder can be modified. HMA could be made from new or recycled material. Examples of recycled asphalt include, but are not limited to, hot and cold in-place recycling. HMA is classified by type depending on the specified aggregate quality and mix design criteria appropriate for the project conditions. HMA types are found in the Standard Specifications and Standard Special Provisions.

631.2 Open Graded Friction Course (OGFC)

OGFC (formerly known as open graded asphalt concrete (OGAC)) is a non-structural wearing course used primarily on HMA. It is occasionally used with modified binders on rigid pavements. The primary benefit of using OGFC is the improvement of wet weather skid resistance, reduced potential for hydroplaning, reduced water splash and spray, and reduced night time wet pavement glare. Secondary benefits include better wet-night visibility of traffic lane stripes and pavement markers, and better wet weather (day and night) delineation between the traveled way and shoulders.

For information and applicability of OGFC in new construction and rehabilitation projects refer to OGFC Guideline available on the Department Pavement website. Also, see Maintenance Technical Advisory Guide (MTAG) for additional information and use of OGFC in pavement preservation.

631.3 Rubberized Hot Mix Asphalt (RHMA)

Rubberized asphalt is formulated by mixing granulated (crumb) rubber with hot asphalt to form an elastic binder with less susceptibility to temperature changes. The rubberized asphalt is substituted for the regular asphalt as the binder for the flexible pavement. This is called the wet method. Other methods of using rubber in flexible pavements are available. See Asphalt Rubber Usages Guide (ARUG), available on the Department Pavement website, for further details.

RHMA is generally specified to retard reflection cracking, resist thermal stresses created by wide temperature variations and add flexibility to a structural overlay. At present, the Department uses gap-graded (RHMA-G) and open-graded (RHMA-O) rubberized asphalt. The difference between the two is in the gradation of the aggregate. RHMA-O is used only as a non-structural wearing course. RHMA-G can be used as either a surface course or a non-structural wearing course. RHMA should be considered the strategy of choice when evaluating alternatives for a project. If RHMA is found to be inappropriate due to availability, constructibility, environmental factors, or cost, it shall be documented in the scoping document, Project Initiation Document (PID), or Project Report (PR).

The minimum thickness for RHMA (any type) should be 0.10 foot for new construction and rehabilitation. For pavement preservation, RHMA may be placed as thin as 0.08 foot provided compaction requirements can be met. The maximum thickness for RHMA-G is 0.20 foot. The maximum thickness for RHMA-O is 0.15 foot. If a thicker surface layer or overlay is called for, then a HMA layer should be placed prior to placing the RHMA. RHMA should only be placed over a flexible or rigid surface course and not on a granular layer. RHMA-O may be placed on top of new RHMA-G. Do not place conventional HMA or OGFC over new RHMA pavement.

It is undesirable to place RHMA-G or RHMA-O in areas that will not allow surface water to drain. As an example, a surface that is milled only on the

traveled way and not on the shoulder forms a “bathtub” section that can trap water beneath the surface of the traveled way. To prevent this effect, RHMA-G should be placed over the whole cross section of the road (traveled way and shoulders).

For additional information and applicability of RHMA in new construction and rehabilitation projects refer to Asphalt Rubber Usage Guide available on the Department Pavement website.

631.4 Other Types of Flexible Pavement

There are other types of flexible pavements such as cold mix, Resin Pavement, and Sulphur Extended Hot Mix Asphalt. The other types of pavements are either used for maintenance treatments or not currently used on State highways. For pavement preservation and other maintenance treatments refer to the Department’s Maintenance Manual.

631.5 Stress Absorbing Membrane Interlayers (SAMI)

SAMI are used with flexible layer rehabilitation as a means to retard reflective cracks, prevent water intrusion, and (in the case of SAMI-R (rubberized)) enhance pavement structural strength. Two types of SAMI are:

- Rubberized (SAMI-R). SAMI-R is a rubberized chip seal.
- Geosynthetic Pavement Interlayer (GPI), consists of asphalt-imbued geotextile.

Sound engineering judgment is required when considering the use of a SAMI.

- Consideration should be given to areas that may prohibit surface water from draining out the sides of the overlay, thus forming a “bathtub” section.
- Since SAMI-R can act as a moisture barrier, it should be used with caution in hot environments where it could prevent underlying moisture from evaporating.
- When placed on an existing pavement, preparation is required to prevent excess stress on the membrane. This includes sealing cracks wider than ¼ inch and repairing potholes and localized failures.

A SAMI may be placed between layers of new flexible pavement, such as on a leveling course, or on the surface of an existing flexible pavement. A GPI should not be placed directly on coarse surfaces such as a chip seal, OGFC, areas of numerous rough patches, or on a pavement that has been cold planed. Coarse surfaces may penetrate the fabric and the paving asphalt binder used to saturate the fabric may collect in the voids or valleys leaving areas of the fabric dry. For the GPI to be effective in these areas, use a layer of HMA prior to the placement of the GPI.

GPI is ineffective in the following applications:

- When placed under rubberized hot mix asphalt (RHMA). This is due to the high placement temperature of the RHMA-G mix, which is close to the melting temperature of the GPI.
- For providing added structural strength when placed in combination with new flexible pavement.
- In the reduction of thermal cracking of the new flexible pavement overlay.

Topic 632 - Engineering Criteria

632.1 Engineering Properties

(1) *Smoothness*. The smoothness of a pavement impacts its ride quality, overall durability, and performance. Ride quality (which is measured by the smoothness of ride) is also the highest concern listed in public surveys on pavement condition. Smoothness specifications have been improved and incentive/disincentive specifications have been developed to assure designed smoothness values are achieved in construction. Incentive / disincentive specifications can be used where the project meets the warrants for the specification. For up to date and additional information on smoothness and the application of the smoothness specifications see the smoothness page on the Department Pavement website.

(2) *Asphalt Binder Type*. Asphalt binders are most commonly characterized by their physical properties. An asphalt binder’s physical properties directly relate to field

performance. Although asphalt binder viscosity grading is still common, new binder tests and specifications have been developed to more accurately characterize temperature extremes which pavements in the field are expected to withstand. These tests and specifications are specifically designed to address three specific pavement distress modes: permanent deformation (rutting), fatigue cracking, and low temperature cracking.

In the past, the Department has classified unmodified asphalt binder using viscosity grading based on the Aged Residue (AR) System and Performance Based Asphalt (PBA) binder system. Beginning January 1, 2006, the Department switched to the nationally recognized Performance Grade (PG) System for conventional binders. Effective from January 1, 2007, the Department has graded polymer-modified binders as Performance Graded-Polymer Modified (PG-PM) binder in lieu of PBA.

Performance grading is based on the concept that asphalt binder properties should be related to the conditions under which the binder is used. PG asphalt binders are selected to meet expected climatic conditions as well as traffic speed and volume adjustments. 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 must meet performance criteria at an average seven-day maximum pavement temperature of 64°C and also at a minimum pavement temperature of –10°C.

Although modified asphalt binder is more expensive than unmodified binder, in hot mix asphalt (HMA), 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 conventional

asphalt in many paving and maintenance applications.

Table 632.1 provides the binder grade 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.

Special conditions are defined as those roadways or portion of roadways that need additional attention due to conditions such as:

- Heavy truck/bus traffic (over 10 million ESALs for 20 years).
- Truck/bus stopping areas (parking area, rest area, loading area, etc.).
- Truck/bus stop and go areas (intersections, metered ramps, ramps to and from Truck Scales etc.).
- Truck/bus climbing and descending lanes.

The final decision as to whether a roadway meets the criteria for special conditions rests with the District. It should be noted that even though special binder grades help meet the flexible pavement requirements for high truck/bus use areas, they should not be considered as the only measure needed to meet these special conditions. The District Materials Engineer should be consulted for additional recommendations for these locations.

For more detailed information on PG binder selection, refer to the Department Pavement website.

632.2 Performance Factors

The procedures and practices found in this chapter are based on research and field experimentation undertaken by the Department and AASHTO. These procedures were calibrated for pavement design lives of 10 to 20 years and Traffic Index (TI) ranging from 5.0 to 12. Extrapolations and supplemental requirements were subsequently

Table 632.1

Asphalt Binder Grade

Binder Climatic Region	Binder Grades for Hot Mixed Asphalt (HMA) ^{(1), (2)}				Gap and Open Graded Rubberized Hot Mix Asphalt (RHMA)
	Dense Graded HMA		Open Graded HMA		
	Typical	Special ⁽³⁾	Placement Temperature		
			> 70°F	≤ 70°F	
South Coast	PG 64-10	PG 70-10	PG 64-10	PG 58-34 PM	PG 64-16
Central Coast		or			
Inland Valley		PG 64-28 PM			
North Coast	PG 64-16	PG 64-28 PM	PG 64-16	PG 58-34 PM	PG 64-16
Low Mountain	PG 64-16	PG 64-28 PM	PG 64-16	PG 58-34 PM	PG 64-16
South Mountain					
High Mountain	PG 64-28	PG 58-34 PM ⁽⁴⁾	PG 64-28	PG 58-34 PM	PG 58-22
High Desert					
Desert	PG 70-10	PG 64-28 PM	PG 70-10	PG 58-34 PM or PG 64-28 PM ⁽³⁾	PG 64-16

NOTES:

- (1) PG = Performance Graded
- (2) PM = Polymer Modified
- (3) PG 76-22 PM may be specified for conventional dense graded hot mix asphalt for special conditions in all climatic regions when specifically requested by the District Materials Engineer.
- (4) PG 64-28 may be specified when specifically requested by the District Materials Engineer.
- (5) Consult the District Materials Engineer for which binder grade to use.

developed to address longer pavement design lives and higher Traffic Indices. Details on mix design and other requirements for these procedures are provided in the Standard Specifications and Standard Special Provisions. Alterations to the requirements in these documents can impact the performance of the pavement structure and the performance values found in this chapter.

Topic 633 - Engineering Procedures for New and Reconstruction Projects

633.1 Empirical Method

The data needed to engineer a flexible pavement are California R-value of the subgrade and the TI for the pavement design life. Engineering of the flexible pavement is based on a relationship between the gravel equivalent (GE) of the pavement structural materials, the TI, and the California R-value of the underlying material. The relationship was developed by the Department through research and field experimentation.

The procedures and rules governing flexible pavement engineering are as follows, (Sample calculations are provided on the Department Pavement website.):

(1) *Procedures for Engineering Multiple Layered Flexible Pavement.*

The California Department of Transportation empirical method, commonly referred to as the Hveem method, for determining design thicknesses of the structural layers of flexible pavement structure involves the determination of the following design parameters:

- Traffic Index (TI)
- California R-value (R)
- Gravel Equivalent (GE), and
- Gravel Factor (G_f)

Once TI, R, GE, and G_f are determined, then the design thickness of each structural layer is determined using the Hveem method. These design parameters and the Hveem design method are discussed in the following sections:

- (a) As discussed in Index 613.3(3), the TI is a measure of the cumulative number of ESALs expected during the design life of the pavement structure. The TI is determined to the nearest 0.5 using the equation given in Index 613.3(3) or from Table 613.3C.
- (b) The California R-value is a measure of resistance of soils to deformation under wheel loading and saturated soils conditions. The California R-value is determined as discussed in Index 614.3.
- (c) The gravel equivalent (GE) of each layer or the entire flexible pavement structure is the thickness of gravel (aggregate subbase) that would be required to prevent permanent deformation in the underlying layer or layers due to cumulative traffic loads anticipated during the design life of the pavement structure. The GE requirement of the entire flexible pavement or each layer is calculated using the following equation:

$$GE = 0.0032(TI)(100 - R)$$

Where:

GE = Gravel Equivalent in feet

TI = Traffic Index

R = California R-value of the material below the layer or layers for which the GE is being calculated.

The GE requirement of each type of material used in the flexible pavement structure is determined for each structural layer, starting with the surface course and proceeding downward to base and subbase as needed. For pavements that include base and/or subbase, a safety factor of 0.20 foot is added to the GE requirement for the surface course to compensate for construction tolerances allowed by the contract specifications. Since the safety factor is not intended to increase the GE of the overall pavement, a compensating thickness is subtracted from the subbase layer (or base layer if there is no subbase). For pavements that are full depth asphalt,

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a safety factor of 0.10 foot is added to the required GE of the pavement structure. When determining the appropriate safety factor to be added, Hot Mix Asphalt Base (HMAB) and Asphalt Treated Permeable Base (ATPB) should be considered as part of the surface course.

- (d) The gravel factor (G_f) of pavement structural material is the relative strength of that material compared to gravel. Gravel factors for HMA decrease as TI increases, and also increase with HMA thickness greater than 0.5 foot; while G_f for base and subbase materials are only dependent on the material type.

The G_f of HMA varies with layer thickness (t) for any given TI as follows:

$t \leq 0.50$ ft:	$G_f = \frac{5.67}{(TI)^{1/2}}$
$t > 0.50$ ft:	$G_f = (7.00) \frac{(t)^{1/3}}{(TI)^{1/2}}$

These equations are valid for TIs ranging from 5 to 15. For TIs greater than 15, use a rigid or composite pavement or contact the Headquarters Division of Maintenance – Pavement Program for experimental options. For TIs less than 5, use a TI=5. Typical gravel factors for HMA of thickness equal to or less than 0.5 foot, and various types of base and subbase materials, are provided in table 633.1. Additional information on G_f for base and subbase materials are provided in Table 633.1B.

- (e) The design thickness of each structural layer of flexible pavement is obtained either by dividing the GE by the appropriate gravel factor for that layer material, or from Table 633.1. The layer thickness determined by dividing GE by G_f is rounded up to the next higher value in 0.05-foot increments.

$$\text{Thickness } (t) = \frac{GE}{G_f}$$

The minimum thickness of any asphalt layer should not be less than twice the maximum aggregate size, and the minimum thickness of the surface course should not be less than 0.15 foot. The limit thicknesses for placing HMA for each TI, and the limit thickness for each type of base and subbase materials, are shown in Table 633.1

Base and subbase materials, other than ATPB, should each have a minimum thickness of 0.35 foot. When the calculated thickness of base or subbase material is less than the desired 0.35 foot minimum thickness, either: (a) increase the thickness to the minimum without changing the thickness of the overlying layers or (b) eliminate the layer and increase the thickness of the overlying layers to compensate for the reduction in GE.

Generally, the layer thickness of Lime Treated Subbase (LTS) should be limited, with 0.65 foot as the minimum and 2 feet as the maximum. A surface layer placed directly on the LTS should have a thickness of at least 0.25 foot.

The thicknesses determined by the procedures outlined in this section are not intended to preclude other combinations and thicknesses of materials. Adjustments to the thickness of the various materials may be made to accommodate construction restrictions or practices, and minimize costs, provided the minimum thicknesses, maximum thicknesses, and minimum GE requirements (including safety factors) of the entire pavement structure and each layer are as specified.

- (2) *Procedures for Full Depth Hot Mix Asphalt.* Full depth hot mix asphalt applies when the pavement structure is comprised entirely of a flexible surface layer in lieu of base and subbase. The flexible surface layer may be comprised of a single or multiple types of

flexible pavements including HMA, RHMA, interlayers, special asphalt binders, or different mix designs. Considerations regarding worker safety, short construction windows, the amount of area to be paved, or temporary repairs may make it desirable in some instances to reduce the total thickness of the pavement by placing full depth hot mix asphalt. Full depth hot mix asphalt also is less affected by moisture or frost, does not let moisture build up in the subgrade, provides no permeable layers that entrap water, and is a more uniform pavement structure. Use the standard equation in Index 633.1(1) with the California R-value of the subgrade to calculate the initial GE for the entire pavement structure. Increase this by adding the safety factor of 0.10 foot to obtain the required GE for the flexible pavement. Then refer to Table 633.1, select the closest layer thickness for conventional hot mixed asphalt, and determine the adjusted GE that it provides. The GE of the safety factor is not removed in this design. Adjust the final thickness as needed when using other types of materials than hot mixed asphalt.

A Treated Permeable Base (TPB) layer may be placed below full depth hot mix asphalt on widening projects to perpetuate, or match, an existing treated permeable base layer for continuity of drainage. Reduce the GE of the surface layer by the amount of GE provided by the TPB. In no case should the initial GE of the surface layer over the TPB be less than 40 percent of the GE required over the subbase as calculated by the standard engineering equation. When there is no subbase, use 50 for the California R-value for this calculation. In cases where a working table will be used, the GE of the working table is subtracted from the GE of the surface layer as well. A working table is a minimum thickness of material, asphalt, cement, or granular based, used to place construction equipment and achieve compaction requirements when compaction is difficult or impossible to meet.

(3) *Modifications for Pavement Design Life Greater than 20 Years.* The above procedure

is based on an empirical method for a twenty-year pavement design life. For pavement design lives greater than twenty years, in addition to using a TI for that longer design life, provisions should be made to increase material durability and other appropriate measures to protect pavement layers from degradation.

The following enhancements shall be incorporated into all flexible pavements with a design life greater than twenty years:

- Use the procedures for full depth hot mix asphalt to determine the minimum thickness for flexible pavement. Cement treated base or lean concrete base can be used in lieu of hot mix asphalt but not in lieu of aggregate base, aggregate subbase, or a treated permeable base.
- Place a minimum 0.50 foot of Class 2 Aggregate base underneath the flexible pavement. This aggregate base layer is not considered part of the pavement structural design and cannot be used to reduce the thickness of the full depth hot mix asphalt layer.
- Use a non-structural wearing course (such as OGFC) above the surface layer (minimum 0.10 foot). See Index 602.1(5) for further details.
- Use rubberized hot mix asphalt (maximum 0.20 foot) or a PG-PM binder (minimum 0.20 foot) for the top of the surface layer.

The following enhancements should be incorporated into all flexible pavements with a pavement design life greater than twenty years when recommended by the District Materials Engineer:

- (a) Use higher asphalt binder content for bottom of the surface layer (rich-bottom concept) and using higher stiffness asphalt binder.
- (b) Utilize subgrade enhancement fabrics at the subgrade for California R-values less than 40.
- (c) Use SAMIs within the surface layer.

**Table 633.1
Gravel Equivalents (GE) and Thickness of Structural Layers (ft)**

Actual Layer Thickness (ft) ⁽⁵⁾	HMA ^{(1), (2)}											Base and Subbase ⁽³⁾					
	Traffic Index (TI)											TI is not a factor					
	5.0 & below	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5	CTPB;		CTB			
	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	LCB	(Cl. A)	ATPB	(Cl. B)	AB	AS	
	G _f (For HMA thickness equal to or less than 0.5 ft, G _f decreases with TI) ⁽⁴⁾											G _f (Constant for any base or subbase material irrespective of TI or thickness)					
2.54	2.32	2.14	2.01	1.89	1.79	1.71	1.64	1.57	1.52	1.46	1.9	1.7	1.4	1.2	1.1	1.0	
GE for HMA layer (ft)											GE for Base or Subbase layer (ft)						
0.10	0.25	0.23	0.21	0.20	0.19	0.18	0.17	0.16	0.16	0.15	0.15	--	--	--	--	--	
0.15	0.38	0.35	0.32	0.30	0.28	0.27	0.26	0.25	0.24	0.23	0.22	--	--	--	--	--	
0.20	0.51	0.46	0.43	0.40	0.38	0.36	0.34	0.33	0.31	0.30	0.29	--	--	--	--	--	
0.25	0.63	0.58	0.54	0.50	0.47	0.45	0.43	0.41	0.39	0.38	0.37	--	--	0.35	--	--	
0.30	0.76	0.69	0.64	0.60	0.57	0.54	0.51	0.49	0.47	0.45	0.44	--	--	0.42	--	--	
0.35	0.89	0.81	0.75	0.70	0.66	0.63	0.60	0.57	0.55	0.53	0.51	0.67	0.60	0.49	0.42	0.39	
0.40	1.01	0.93	0.86	0.80	0.76	0.72	0.68	0.65	0.63	0.61	0.59	0.76	0.68	0.56	0.48	0.44	
0.45	1.14	1.04	0.96	0.90	0.85	0.81	0.77	0.74	0.71	0.68	0.66	0.86	0.77	0.63	0.54	0.50	
0.50	1.27	1.16	1.07	1.00	0.94	0.90	0.85	0.82	0.79	0.76	0.73	0.95	0.85	0.70	0.60	0.55	
0.55	1.41	1.29	1.19	1.12	1.05	1.00	0.95	0.91	0.87	0.84	0.81	1.05	0.94	0.77	0.66	0.61	
0.60	1.58	1.45	1.34	1.25	1.18	1.12	1.07	1.02	0.98	0.95	0.91	1.14	1.02	0.84	0.72	0.66	
0.65	1.76	1.61	1.49	1.39	1.31	1.25	1.19	1.14	1.09	1.05	1.02	1.24	1.11	0.91	0.78	0.72	
0.70	--	1.78	1.64	1.54	1.45	1.38	1.31	1.26	1.21	1.16	1.12	1.33	1.19	--	0.84	0.77	
0.75	--	1.95	1.80	1.69	1.59	1.51	1.44	1.38	1.32	1.27	1.23	1.43	1.28	--	0.90	0.83	
0.80	--	2.12	1.96	1.84	1.73	1.64	1.57	1.50	1.44	1.39	1.34	1.52	1.36	--	0.96	0.88	
0.85	--	--	2.13	1.99	1.88	1.78	1.70	1.63	1.56	1.51	1.46	1.62	1.45	--	1.02	0.94	
0.90	--	--	2.30	2.15	2.03	1.92	1.83	1.76	1.69	1.63	1.57	1.71	1.53	--	1.08	0.99	
0.95	--	--	--	2.31	2.18	2.07	1.97	1.89	1.81	1.75	1.69	1.81	1.62	--	1.14	1.05	
1.00	--	--	--	2.47	2.33	2.21	2.11	2.02	1.94	1.87	1.81	1.90	1.70	--	1.20	1.10	
1.05	--	--	--	2.64	2.49	2.36	2.25	2.16	2.07	2.00	1.93	2.00	1.79	--	1.26	1.16	
1.10	--	--	--	--	2.65	2.51	2.40	2.29	2.20	2.12	2.05	--	--	--	--	1.10	
1.15	--	--	--	--	2.81	2.67	2.54	2.43	2.34	2.25	2.18	--	--	--	--	1.15	
1.20	--	--	--	--	2.98	2.82	2.69	2.58	2.48	2.39	2.30	--	--	--	--	1.20	
1.25	--	--	--	--	--	2.98	2.84	2.72	2.61	2.52	2.43	--	--	--	--	1.25	
1.30	--	--	--	--	--	3.14	2.99	2.87	2.75	2.65	2.56	--	--	--	--	1.30	
1.35	--	--	--	--	--	3.30	3.15	3.01	2.90	2.79	2.70	--	--	--	--	--	
1.40	--	--	--	--	--	--	3.31	3.16	3.04	2.93	2.83	--	--	--	--	--	
1.45	--	--	--	--	--	--	3.46	3.32	3.19	3.07	2.97	--	--	--	--	--	
1.50	--	--	--	--	--	--	3.62	3.47	3.33	3.21	3.10	--	--	--	--	--	
1.55	--	--	--	--	--	--	--	3.62	3.48	3.36	3.24	--	--	--	--	--	
1.60	--	--	--	--	--	--	--	3.78	3.63	3.50	3.38	--	--	--	--	--	
1.65	--	--	--	--	--	--	--	3.94	3.79	3.65	3.52	--	--	--	--	--	
1.70	--	--	--	--	--	--	--	--	3.94	3.80	3.67	--	--	--	--	--	
1.75	--	--	--	--	--	--	--	--	4.09	3.95	3.81	--	--	--	--	--	
1.80	--	--	--	--	--	--	--	--	4.25	4.10	3.96	--	--	--	--	--	
1.85	--	--	--	--	--	--	--	--	--	4.25	4.10	--	--	--	--	--	
1.90	--	--	--	--	--	--	--	--	--	4.40	4.25	--	--	--	--	--	
1.95	--	--	--	--	--	--	--	--	--	4.56	4.40	--	--	--	--	--	
2.00	--	--	--	--	--	--	--	--	--	--	4.55	--	--	--	--	--	

Notes:

- (1) Open Graded Friction Course (conventional and rubberized) is a non-structural wearing course and provides no structural value.
- (2) Top portion of HMA surface layer (maximum 0.20 ft.) may be replaced with equivalent RHMA-G thickness. See Topic 631.3 for additional details.
- (3) See Table 663.1B for additional information on Gravel Factors (G_f) and California R-values for base and subbase materials.
- (4) These G_f values are for TIs shown and HMA thickness equal to or less than 0.5 foot only. For HMA thickness greater than 0.5 foot, appropriate G_f should be determined using the equation in Index 633.1(1)(c).
- (5) For HMA layer, select TI range, then go down to the appropriate GE and across to the thickness column. For base and subbase layer, select material type, then go down to the appropriate GE and across to the thickness column.

- (d) Use a separation fabric above granular layers. Note that the fabric used needs to be able to resist construction loads or construction equipment must be able to keep off of the fabric.

(4) *Alternate Procedures and Materials.* At times, experimental procedures and/or alternative materials are proposed as part of the design or construction. See Topic 606 for further discussion.

633.2 Mechanistic-Empirical Method

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

Topic 634 - Engineering Procedures for Flexible Pavement Preservation

634.1 Preventive Maintenance

For details regarding preventive maintenance strategies for flexible pavement, see the “Maintenance Technical Advisory Guide” on the Department Pavement website. Deflection studies are not required for preventive maintenance projects.

634.2 Capital Preventive Maintenance (CAPM)

The standard design for a flexible pavement CAPM project with an International Roughness Index (IRI) less than 170 inches per mile at PS&E is an overlay of either 0.15 foot of rubberized hot mix asphalt or 0.20 foot of conventional asphalt binder or other approved modified asphalt binder mix. A 0.20-foot overlay of rubberized hot mix asphalt may be appropriate in certain circumstances and may be utilized with the concurrence of the Headquarters Program Advisor in the Headquarters Division of Maintenance – Pavement Program.

For flexible pavement CAPM projects with an IRI greater than 170 inches per mile, the standard design is to place a 0.25-foot hot mix asphalt overlay in two lifts. Existing pavement may be milled or cold planed down to the depth of the

overlay prior to placing the overlay. Situations where milling or cold planing may be beneficial or even necessary are to improve ride quality, maintain profile grade, maintain vertical clearance, or to taper (transition) to match an existing pavement or bridge surface.

If the necessary ride improvement cannot be adequately addressed with these CAPM treatments, the project should be developed as a roadway rehabilitation project.

A 0.06 foot – 0.10 foot non-structural wearing course (such as an open graded friction course) may be added, but is not to be considered part of the overlay requirements.

Deflection studies are not required for CAPM projects. The roadway rehabilitation requirements for overlays (see Index 635.1(1)) and preparation of existing pavement surface (Index 635.1(8)) apply to CAPM projects. Additional details and information regarding CAPM policies and strategies can be found in Design Information Bulletin 81 “Capital Preventive Maintenance Guidelines.”

Topic 635 - Engineering Procedures for Flexible Pavement and Roadway Rehabilitation

635.1 Empirical Method

- (1) *General.* The methods presented in this topic are based on studies for a ten-year pavement design life with extrapolations for twenty-year pavement design life. (For pavement design lives greater than twenty years, contact the Headquarters Office of Asphalt Pavement).

Because there are potential variations in materials and environment that could affect the performance of both the existing pavement and the rehabilitation strategy, it is difficult to develop precise and firm practices and procedures that cover all possibilities for the rehabilitation of pavements. Therefore, the pavement engineer should consult with the District Materials Engineer and other pertinent experts who are familiar with engineering,

construction, materials, and maintenance of pavements in the geographical area of the project for additional requirements or limitations than those listed in this manual.

Rehabilitation strategies are divided into three categories:

- Overlay
- Mill and Overlay
- Remove and Replace

Rehabilitation designs are governed by one of the following three criteria:

- Structural adequacy
- Reflective crack retardation
- Ride quality

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.

(2) *Data Collection.* Developing a rehabilitation strategy requires collecting background data as well as field data. The Pavement Condition Report (PCR), as-built plans, and traffic information are some of the sources used to prepare rehabilitation strategy recommendations. A thorough field investigation of the pavement surface condition, combined with a current deflection study and coring, knowledge of the subsurface conditions, thicknesses of existing flexible pavement layers, and a review of drainage conditions are all necessary for developing a set of appropriate rehabilitation strategies.

(3) *Deflection Studies.* Deflection studies along with coring data are used to measure the structural adequacy of the existing pavement. A deflection study is the process of selecting deflection test sections, measuring pavement surface deflection, and calculating statistical deflection values as described in California Test Method 356 for flexible pavement deflection measurements. A copy of the test method can be obtained and/or downloaded from the Department Pavement website.

To provide reliable rehabilitation strategies, deflection studies should be done no more than 18 months prior to the start of construction.

(a) Test Sections:

Test sections are portions of a roadway considered to be representative of roadway conditions being studied for rehabilitation. California Test Method 356 provides information on selecting test sections and different testing devices. Test sections should be determined in the field based on safe operation and true representation of pavement sections. Test sections can be determined either by the test operator or by the pavement engineer in the field.

Occasionally, a return to a project site may be required for additional testing after reviewing the initial deflection data in the office.

Individual deflection readings for each test section should be reviewed prior to determining statistical values. This review may locate possible areas that are not representative of the entire test section. An example would be a localized failure with a very high deflection. It may be more cost effective to repair the various failed sections prior to rehabilitation. Thus, the high deflection values in the repaired areas would not be included when calculating statistical values for the representative test sections.

(b) Mean and 80th Percentile Deflections:

The mean deflection level for a test section is determined by dividing the sum of individual deflection measurements by the number of the deflections:

$$\bar{x} = \frac{\sum D_i}{n}$$

Where:

\bar{x} = mean deflection for a test section, in inches

D_i = an individual measured surface deflection in the test section, in inches

n = number of measurements in the test section

The 80th percentile deflection value represents a deflection level at which approximately 80 percent of all deflections are less than the calculated value and 20 percent are greater than the value. Therefore, a strategy based on 80th percentile deflection will provide thicker rehabilitation than using the mean value.

For simplicity, a normal distribution has been used to find the 80th percentile deflection using the following equation:

$$D_{80} = \bar{x} + 0.84s$$

Where:

D_{80} = 80th percentile of the measured surface deflections for a test section, in inches

s = standard deviation of all test points for a test section, in inches

$$s = \sqrt{\frac{\sum (D_i - \bar{x})^2}{n - 1}}$$

D_{80} is typically calculated as part of the deflection study done by the test operator. The pavement engineer should verify that the D_{80} results provided by the operator are accurate.

(c) Grouping:

Adjacent test sections may be grouped and analyzed together. There may be one or several groups within the project.

A group is a collection of test sections that have similar engineering parameters. Test sections can be grouped if they have all of the following conditions:

- Average D_{80} that vary less than 0.01 inch.
- Average existing hot mix asphalt thickness that vary less than 0.10 foot.

- Similar base material.
- Similar TI

Once groups have been identified, D_{80} and existing surface layer thickness of each group can be found by averaging the respective values of test sections within that group.

An alternative to the grouping method outlined above is to analyze each test section individually and then group them based on the results of analysis. This way, all the test sections that have similar rehabilitation strategies would fall into the same group.

(4) *Procedures for Rigid Pavement Overlay on Existing Flexible Pavement (Concrete Overlay).* For concrete overlay (sometimes referred to as whitetopping) strategies, only structural adequacy needs to be addressed. To address structural adequacy, use the tables in Index 623.1 to determine the thickness of the rigid layer. The overlay should be thick enough to be considered a structural layer. Therefore, thin or ultra thin concrete layers (< 0.65 foot) are not qualified as concrete overlay. To provide a smooth and level grade for the rigid surface layer, place a 0.10 foot to 0.15 foot HMA on top of the existing flexible layer.

(5) *Procedures for Flexible Overlay on Existing Flexible Pavement.*

(a) Structural Adequacy. Pavement condition, thickness of surface layer, measured deflections, and the projected TI provide the majority of the information used for determining structural adequacy. Structural adequacy is determined using the following procedures and rules:

(b) Determine the Tolerable Deflection at the Surface (TDS). The term "Tolerable Deflection" refers to the level beyond which repeated deflections of that magnitude produce fatigue failure prior to the planned TI. TDS is obtained from Table 635.1A by knowing the existing thickness of the flexible layer and TI. For existing flexible pavement over a treated

Table 635.1A
Tolerable Deflections at the Surface (TDS) in 0.001 inches

Exist. HMA thick (ft)	Traffic Index (TI)											
	5	6	7	8	9	10	11	12	13	14	15	16
0.00	66	51	41	34	29	25	22	19	17	15	14	13
0.05	61	47	38	31	27	23	20	18	16	14	13	12
0.10	57	44	35	29	25	21	19	16	15	13	12	11
0.15	53	41	33	27	23	20	17	15	14	12	11	10
0.20	49	38	31	25	21	18	16	14	13	12	10	10
0.25	46	35	28	24	20	17	15	13	12	11	10	9
0.30	43	33	27	22	19	16	14	12	11	10	9	8
0.35	40	31	25	20	17	15	13	12	10	9	8	8
0.40	37	29	23	19	16	14	12	11	10	9	8	7
0.45	35	27	21	18	15	13	11	10	9	8	7	7
0.50 ⁽¹⁾	32	25	20	17	14	12	11	9	8	8	7	6
TB ⁽²⁾	27	21	17	14	12	10	9	8	7	6	6	5
	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5	15.5	16.5
0.00	58	45	37	31	27	23	20	18	16	15	13	12
0.05	53	42	34	29	25	21	19	17	15	14	12	11
0.10	50	39	32	27	23	20	18	16	14	13	11	11
0.15	46	36	30	25	21	19	16	14	13	12	11	10
0.20	43	34	28	23	20	17	15	14	12	11	10	9
0.25	40	32	26	22	19	16	14	13	11	10	9	8
0.30	37	29	24	20	17	15	13	12	11	9	9	8
0.35	35	27	22	19	16	14	12	11	10	9	8	7
0.40	32	26	21	18	15	13	11	10	9	8	8	7
0.45	30	24	20	16	14	12	11	9	9	8	7	6
0.50 ⁽¹⁾	28	22	18	15	13	11	10	9	8	7	7	6
TB ⁽²⁾	24	19	15	13	11	10	8	7	7	6	5	5

Notes:

- (1) For an HMA thickness greater than 0.50 ft use the 0.50 ft depth.
- (2) Use the TB (treated base) line to represent treated base materials, regardless of the thickness of HMA cover.

Table 635.1B
Gravel Equivalence Needed to Reduce Deflection

Percent Reduction In Deflection (PRD or PRM) ⁽¹⁾	GE (in feet) For HMA Overlay Design	Percent Reduction In Deflection (PRD or PRM) ⁽¹⁾	GE (in feet) For HMA Overlay Design
5	0.02	46	0.55
6	0.02	47	0.57
7	0.02	48	0.59
8	0.02	49	0.61
9	0.03	50	0.63
10	0.03	51	0.66
11	0.04	52	0.68
12	0.05	53	0.70
13	0.05	54	0.72
14	0.06	55	0.74
15	0.07	56	0.76
16	0.08	57	0.79
17	0.09	58	0.81
18	0.09	59	0.83
19	0.10	60	0.85
20	0.11	61	0.87
21	0.12	62	0.89
22	0.14	63	0.91
23	0.15	64	0.94
24	0.16	65	0.96
25	0.18	66	0.98
26	0.19	67	1.00
27	0.20	68	1.02
28	0.21	69	1.04
29	0.23	70	1.06
30	0.24	71	1.09
31	0.26	72	1.11
32	0.28	73	1.13
33	0.29	74	1.15
34	0.31	75	1.17
35	0.33	76	1.19
36	0.35	77	1.22
37	0.37	78	1.24
38	0.38	79	1.26
39	0.40	80	1.28
40	0.42	81	1.30
41	0.44	82	1.32
42	0.46	83	1.34
43	0.48	84	1.37
44	0.51	85	1.39
45	0.53	86	1.41

Note: (1) PRD is Percent Reduction in Deflection at the surface.
PRM is Percent Reduction in deflection at the Milled depth.

base, use TI and the TDS values in the row for Treated Base (TB) found in Table 635.1A

The existing base is considered treated if it meets all of the following conditions:

- Its depth is equal to or greater than 0.35 foot.
- The D_{80} is less than 0.015 inch.

(1) It is rigid pavement, Lean Concrete Base (LCB), or Class A Cement Treated Base (CTB-A). For each group compare the TDS to the average D_{80} . The D_{80} is the 80th percentile deflection value. It represents a deflection level at which approximately 80 percent of all deflections of a sample group are less than the calculated value and 20 percent are greater than the value. Therefore, a strategy based on the 80th percentile deflection will provide thicker rehabilitation than using the mean deflection.

If the average D_{80} is greater than the TDS, determine the required percent reduction in deflection at the surface (PRD) to restore structural adequacy as follows:

$$PRD = \frac{AverageD_{80} - TDS}{AverageD_{80}}(100)$$

Where:

PRD = Percent Reduction in Deflection required at the surface, as percent

TDS = Tolerable Deflection at the Surface, in inches

Average D_{80} = mean of the 80th percentile of the deflections for each group, in inches

(2) Using the calculated PRD and Table 635.1B, determine the GE

required to reduce the deflections to less than the tolerable level.

(3) Divide the GE obtained from Table 635.1B by the appropriate G_f for the overlay material to determine the required thickness of the overlay.

$$Thickness(t) = \frac{GE}{G_f}$$

Commonly used G_f for flexible pavement rehabilitation are presented in Table 635.1C.

**Table 635.1C
Commonly Used G_f for Flexible
Pavement Rehabilitation**

Material	$G_f^{(1)}$
Hot Mix Asphalt Overlay	1.9
Hot Recycled Asphalt	1.9
Cold in-Place Recycled Asphalt	1.5
HMA Below the Analytical Depth ⁽²⁾	1.4

NOTES:

(1) For G_f of bases and subbases see Table 663.1B.

(2) Analytical depth is defined in 635.1(6)(a).

(c) Reflective Cracking. The goal of these procedures is to keep cracks at the bottom of the surface course layer from propagating to the surface during the pavement design life. Retarding the propagation of cracks is an important factor to consider when engineering flexible pavement overlays. The procedures and rules for engineering for reflective cracking retardation are as follows:

(1) Determine the minimum thickness required for a 10-year pavement

design life. For flexible pavements over untreated bases, the minimum thickness of a HMA overlay with a ten-year design life should be half the thickness of the existing surface course layer but not to exceed 0.35 foot.

For flexible pavements over treated bases (as defined in the previous section on structural adequacy), a minimum HMA overlay of 0.35 foot should be used for a 20-year design life.

Exception: when the underlying material is a thick rigid layer (0.65 foot or more) such as an overlaid jointed plain concrete pavement that was not cracked and sealed, a minimum thickness of 0.45 foot should be used.

(2) Adjust thickness if the pavement design life is different than 10 years. For a twenty-year design life, experience has shown that the thickness should be 125 percent of the ten-year thickness for reflective cracking retardation.

(3) Adjust overlay thickness for alternative materials.

A thickness equivalency of not more than 1:2 is given to the RHMA-G when compared to the HMA for reflective crack retardation. The equivalencies are tabulated in Table 635.1D.

If a SAMI-R is placed under a non-rubberized hot mix asphalt that is engineered for reflective crack retardation, the equivalence of a SAMI-R depends upon the type of base material under the existing pavement. When the base is a treated material, a SAMI-R placed under HMA or OGFC is considered to be equivalent to 0.10 foot of HMA. When the base is an untreated material SAMI-R is equivalent to 0.15 foot of HMA.

**Table 635.1D
Reflective Crack Retardation
Equivalencies
(Thickness in feet)**

HMA (1)	RHMA-G	RHMA-G over SAMI-R
0.15	0.10	X
0.20	0.10	
0.25	0.15	
0.30	0.15	
0.35	<ul style="list-style-type: none"> • 0.15 if crack width < 1/8 inch • 0.20 if crack width ≥ 1/8 inch or underlying material CTB, LCB, or rigid pavement 	<ul style="list-style-type: none"> • N/A for crack width < 1/8 inch • 0.10 if crack width ≥ 1/8 inch and underlying material untreated • 0.15 if crack width ≥ 1/8 inch and underlying material CTB, LCB, or rigid pavement
0.45	0.15 over 0.15 HMA	0.20

NOTE:

(1) See Index 635.1(5)(b) for minimum and maximum HMA thicknesses recommended by the Department for reflective crack retardation on flexible pavements.

A Geosynthetic Pavement Interlay (GPI) placed under HMA that is engineered for reflective crack retardation provides the equivalent of 0.10 foot of HMA. This allows the engineer to decrease the new profile grade and also save on HMA materials.

Wearing courses are not included in the thickness used to address reflective cracking.

Thicker sections may be warranted. Factors to be considered that might necessitate a thicker overlay are:

- Type, sizes, and amounts of surface cracks.
- Extent of localized failures.
- Existing performance material and age.
- Thickness and performance of previous rehabilitation strategy.
- Environmental factors.
- Anticipated future traffic loads (Traffic Index).

As always, sound engineering judgment will be necessary for final decisions. Final decision for when to use more than the minimum requirements found in this manual rests with the District.

- (d) **Ride Quality.** Ride quality is evaluated based on the pavement's smoothness. The Department records smoothness as part of Pavement Condition Survey using the International Roughness Index (IRI). According to FHWA, the IRI value that most motorists consider uncomfortable for flexible pavement is 170 inches per mile. When IRI measurements are 170 inches per mile or greater, the engineer must address ride quality.
- (e) To improve ride quality, place a hot mix asphalt overlay thick enough (0.25 foot minimum) to be placed in two lifts. RHMA-G may be placed in two 0.10 foot lifts to meet the ride quality requirement. However, if a 0.10 foot layer cools prior to compaction, this strategy is inappropriate. A wearing course may be included in the ride quality thickness. SAMI's do not have any effect on ride quality.

Ride quality will ultimately govern the rehabilitation strategy if the requirements

for structural adequacy and reflective crack retardation are less than 0.25 foot.

Note that the Standard Specifications require the Contractor to place a 0.25 foot HMA in one layer. Projects with rehabilitation recommendations based on improving ride quality must specify in the Special Provisions that the overlay needs to be placed in two lifts. Examples of design calculations for flexible overlay thickness on existing flexible pavement are available on the Department Pavement website.

- (6) *Mill and Overlay Procedures.* Mill and Overlay is the removal of part of the surface course and placement of an overlay. Since existing pavement thicknesses will have slight variations throughout the project length, leave at least the bottom 0.15 foot of the existing surface course intact to ensure the milling machine does not loosen the base material or contaminate the recycled mix during the hot or cold in-place recycling. If removal of the entire surface course layer and any portion of the base are required, use the procedures for Remove and Replace in Index 635.1(7).

- a) **Structural Adequacy.** The engineering procedures for determining the structural adequacy for Mill and Overlay are the same as those for overlays found in Index 635.1(1), with the exception of the following:
- TDS is determined using the thickness of the existing pavement prior to milling.
 - Deflections are measured at the surface and adjusted to the milled depth.

The Engineer must consider milling down to the "analytical depth". As defined by the Department, the analytical depth is the least of:

- The milled depth where the Percent Reduction in deflection required at the Milled depth (PRM) reaches 70 percent.
- The milled depth equals 0.50 foot.

- The bottom of the existing HMA layer.

The percent reduction in deflection required at the milled depth is based on research that determined deflections increase by 12 percent for each additional 0.10 foot of milled depth up to the analytical depth. Once the analytical depth is reached, the existing HMA material below is considered to be of questionable structural integrity and hence is assigned a G_f of 1.4. Since it is not known at what milled depth the 70 percent PRM level or analytical depth will be reached, an iterative type of calculation is required.

Using the thickness of the existing HMA layer, the TI, and base material, determine the TDS from Table 635.1A. The deflection at the milled depth is found from the equation:

$$DM = D_{80} + \left[(12\%) \left(\frac{\text{MillDepth}}{0.10 \text{ ft}} \right) (D_{80}) \right]$$

Where

D_{80} = 80th Percentile deflections, in inches.

Mill Depth = the depth of the milling in feet.

DM = the calculated deflection at the Milled depth in inches.

Then:

$$PRM = \left(\frac{DM - TDS}{DM} \right) (100)$$

Where

PRM = Percent Reduction in deflection required at the Milled depth.

TDS = Tolerable Deflection at the Surface in inches.

Utilizing the calculated PRM value, go to Table 635.1B to get the total GE required to be placed on top of the milled pavement surface. The total GE required to reduce the measured deflection to the tolerable level is a combination of:

- The GE determined from the overlay calculations.
- The GE required to replace the material removed by the milling process.

If the milling goes below the analytical depth, the Additional GE that is required to replace the existing HMA below the analytical depth is calculated by multiplying the G_f of 1.4 by the milled depth below the analytical depth:

$$\text{Additional GE} = [(1.4)(\text{milled depth below the analytical depth})]$$

To determine the total GE for the overlay, the Additional GE below the analytical depth is added to the required GE above the analytical depth (found from Table 635.1B). As stated in Index 633.1(1)(d), the required minimum thickness of the overlay is determined by dividing the total GE by the G_f of the new overlay material.

$$\text{Thickness (t)} = \frac{\text{GE}}{G_f}$$

If milled material is to be replaced by Hot Recycled Asphalt (HRA), the overlay thickness is the same as that of HMA since both materials have a G_f of 1.9 (see Table 635.1C).

Since Cold In-Place Recycled Asphalt (CIR) has low resistance to abrasion, if the milled material is to be replaced with CIR, the CIR layer must be covered with a wearing surface shortly after the recycling process. To determine the required thickness of the cap layer, first determine the GE of the CIR layer:

$$GE_{\text{CIR}} = (\text{CIR thickness})(G_{f \text{ CIR}})$$

Where:

GE_{CIR} = Gravel Equivalence of the CIR

$G_{f \text{ CIR}}$ = Gravel Factor of CIR = 1.5 (see Table 635.1C)

The thickness of the cap layer is determined as follows:

$$\text{Cap Layer Thickness} = \frac{GE_{\text{TOTAL}} - GE_{\text{CIR}}}{G_f}$$

Where:

GE_{TOTAL} = Total GE requirement of CIR and cap layers.

G_f = Gravel Factor of the cap material.

If the cap layer is OGFC, its thickness should not be considered in pavement structure design. It is recommended to round up to get the CIR and cap layer thicknesses.

- (b) **Reflective Cracking.** The minimum thickness for reflective cracking is determined using the same procedures used for reflective cracking for overlays found in Index 635.1(5)(b) except that the thickness is determined based on the remaining surface layer rather than the initial surface layer.
- (c) **Ride Quality.** Milling the existing surface and overlaying with new surface course is considered sufficient to smooth a rough pavement.
- (7) **Remove and Replace.** The Remove and Replace operation consists of removing the entire surface layer and part or all of the base and subbase material. The entire removed depth is then replaced with a new flexible or rigid pavement structure. The Remove and Replace strategy is most often used when:
- It is not possible to maintain the existing profile grade using Mill and Overlay.
 - Existing base and or subbase material is failing and needs to be replaced.
 - It is the most cost effective strategy based on life cycle cost analysis.

Remove and Replace covers a variety of strategies. The discussion found here provides some general rules and minimum requirements for Remove and Replace strategies in general. For more specific information see the technical guidance on the Department Pavement website.

Because the existing surface layer is removed only structural adequacy needs to be addressed for Remove and Replace.

- (a) **Partial Depth Removal.** When only a portion of the existing depth is being removed, consideration needs to be given to the strength of the remaining pavement structure. Because the pavement has been stressed and has been subject to contamination from fines and other materials over time, it does not have the same strength (GE) as new material. Currently, for partial depth removals, the most effective engineering method is to determine the theoretical deflection of the remaining material otherwise known as DM. It should be noted that the greater the depth of removal, the less accurate the determination might be of the calculated deflections.

Also, using deflections for Remove and Replace strategies is also less accurate if a bulldozer or a scraper is used to remove the material under the pavement instead of a milling machine. This method of removing material disturbs the integrity of the in-place material from which the deflections were measured.

Because of these issues, the DME may require reduced GE from what is found in this manual or additional pavement thickness. Final determination of what GE is used rests with the District.

It is recommended that if the removal depth is more than 1 foot, determine the pavement thickness and layers use the method for new or reconstructed pavements discussed in Index 633.1. If the pavement structure is being replaced with rigid pavement, the resulting total pavement structure (including existing pavement left in place) cannot be less than the minimum values found in the rigid pavement catalog in Topic 623.

The analysis used for partial depth Remove and Replace with flexible pavement is similar to the Mill and

Overlay analysis. The procedures are as follows:

- (1) Consider milling down to what is called the analytical depth. This is an iterative type of calculation since it is not known at what milling depth the analytical depth will be reached.
- (2) Use the thickness of the existing HMA layer, the design TI and base material in Table 635.1A to determine the TDS. Then find the DM knowing D_{80} and the mill depth. Use DM and TDS to find the percent reduction in deflection at the milled depth (PRM).
- (3) Utilizing this calculated PRM value go to Table 635.1B to obtain the GE required to be placed on top of the milled surface. When the milled depth reaches the analytical depth, the analysis changes. The GE for the material milled below the analytical depth is added to the GE required at the analytical depth. The GE for each layer is calculated by multiplying G_f by the thickness of the layer milled.
- (4) Determine the required minimum thickness of HMA needed by dividing the sum of the GE's by the G_f of the new HMA (see equation below.)

$$\text{Thickness (t)} = \frac{\text{GE}}{G_f}$$

For the Remove and Replace method, use the G_f for the new HMA commensurate with the TI and HMA thickness found in Table 633.1. The total HMA thickness can be solved for each 0.05 foot of material milled until the desired profile is reached. Round the replacement thickness to the nearest 0.05 foot.
- (5) Adjust thicknesses as needed for alternate materials.
- (b) Full depth removal. When material is removed all the way to the subgrade, the Remove and Replace strategy should be engineered using the same procedures

used for new construction found in Index 633.1.

- (8) *Preparation of Existing Pavement.* Existing pavement distresses should be repaired before overlaying the pavement. Cracks wider than ¼ inch should be sealed; loose pavement removed/replaced; and potholes and localized failures repaired. Undesirable material such as bleeding seal coats or excessive crack sealant should be removed before paving. Existing thermoplastic traffic striping and raised pavement markers should also be removed. Routing cracks before applying crack sealant has been found to be beneficial. The width of the routing should be ¼ inch wider than the crack width. The depth should be equal to the width of the routing plus ¼ inch. In order to alleviate the potential bump in the overlay from the crack sealant, leave the crack sealant ¼ inch below grade to allow for expansion (i.e., recess fill). The Materials Report should include a reminder of these preparations. Additional discussion of repairing existing pavement can be found on the Department Pavement website.
- (9) *Choosing the Rehabilitation Strategy.* The final strategy should be chosen based on pavement life-cycle cost analysis (LCCA). The strategy should also meet other considerations such as constructibility, maintenance, and the other requirements found in Chapter 610.

635.2 Mechanistic-Empirical Method

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

Topic 636 - Other Considerations

636.1 Traveled Way

- (1) *Mainline.* No additional considerations.
- (2) *Ramps and Connectors.* Rigid pavement should be considered for freeway-to-freeway connectors and ramps near major commercial or industrial areas ($TI > 14.0$), truck terminals, and all truck weighing and inspection facilities.

(3) *Ramp Termini.* Distress is compounded on flexible pavement ramp termini by the dissolving action of oil drippings combined with the braking of trucks. Separate pavement strategies should be developed for these ramps that may include thicker pavement structures, special asphalt binders, aggregate sizes, or mix designs. Rigid pavement should be considered for exit ramp termini where there is a potential for shoving or rutting. At a minimum, rigid pavement should be used for exit ramp termini of flexible pavement ramps where a significant volume of trucks is anticipated ($TI > 12.0$). For the engineering of rigid pavement ramp termini, see Index 626.1(3).

636.2 Shoulders

The TI for shoulders is given in Index 613.5(2). See Index 1003.5(1) for surface quality guidance for bicyclists.

636.3 Intersections

Where intersections have “STOP” control or traffic signals, special attention is needed to the engineering of flexible pavements to minimize shoving and rutting of the surface caused by trucks braking, and early failure of detector loops. Separate pavement strategies should be developed for these intersections that may include thicker pavement structures, special asphalt binders, aggregate sizes, or mix designs. Rigid pavement is another alternative for these locations. For additional information see Index 626.3. For further assistance on this subject, the Design Engineer should contact the District Materials Engineer, or Headquarters Division of Maintenance – Pavement Program.

636.4 Roadside Facilities

(1) *Safety Roadside Rest Areas.* Safety factors for the empirical method should be applied to the ramp pavement but not for the other areas.

For truck parking areas, where pavement will be subjected to truck starting/stopping and oil drippings which can soften asphalt binders, separate flexible pavement structures which may include thicker structural sections, alternative asphalt binders, aggregate sizes, or

mix designs should be considered. Rigid pavement should also be considered.

(2) *Park & Ride Facilities.* To engineer a park and ride facility based on the standard traffic projections is not practicable because of the unpredictability of traffic. Therefore, standard structures, based on anticipated typical load, have been adopted. However, if project site-specific traffic information is available, it should be used with the standard engineering procedures.

The layer thicknesses shown in Table 636.4 are based on previous practices. These pavement structures are minimal, but are considered adequate since additional flexible surfacing can be added later, if needed, without the exposure to traffic or traffic-handling problems typically encountered on a roadway.

(3) *Bus pads.* Use rigid or composite pavement strategies for bus pads.

**Table 636.4
Pavement Structures for
Park and Ride Facilities**

California R-value for the Subgrade Soil	Thickness of Layers	
	HMA ⁽¹⁾ (ft)	AB (ft)
< 40	0.25	0
But < 60	0.15	0.35
≥ 40	0.15	0
≥ 60	Penetration Treatment ⁽²⁾	

NOTES:

- (1) Place in one lift.
- (2) Penetration Treatment is the application of a liquid asphalt or dust palliative on compacted roadbed material. See Standard Specifications.

Topic 637 - Engineering Analysis Software

Software programs for engineering flexible pavements using the procedures in this chapter can be found on the Department Pavement website. These programs employ the procedures and requirements for flexible pavement engineering enabling the engineer to compare numerous combinations of materials in seeking the most cost effective pavement structure.

CHAPTER 640 COMPOSITE PAVEMENTS

Topic 641 - Types of Composite Pavement

Index 641.1 - Flexible Over Rigid Layer

This configuration consists of a flexible layer on top of a rigid surface layer (typically jointed plain concrete pavement or continuous reinforced concrete pavement) where the flexible layer is used to increase the performance of the rigid layer. (Flexible layers over lean concrete base or cement treated base are considered to be flexible pavements for the purposes of this manual.) The function of the flexible layer is to act as a thermal and moisture blanket to reduce the vertical temperature and moisture gradient within the rigid surface layer and decrease the deformation (curling and warping) of concrete slabs. In addition, the flexible layer acts as a wearing course to reduce wearing effect of wheel loads on the rigid surface layer.

Flexible over rigid composite pavements are found most often on older pavements that have had a flexible pavement overlay such as hot mix asphalt, open graded friction course, or rubberized hot mix asphalt, placed over previously built jointed plain concrete pavement (JPCP) or continuously reinforced concrete pavement (CRCP.) New or reconstructed flexible pavements over JPCP or CRCP typically have not been built in the past on State highways because they have been viewed as combining the disadvantages of rigid pavements (higher initial cost) and flexible pavements (more frequent maintenance).

Thin flexible layers (i.e. sacrificial wearing course) have sometimes been placed over JPCP or CRCP to improve ride quality or friction of the rigid layer. Because ride quality and friction can also be improved by grooving or diamond grinding the existing rigid layer, the Engineer should perform a life-cycle cost analysis (LCCA) to determine if diamond grinding/grooving or a flexible sacrificial overlay is more cost effective before deciding which option to select.

In some cases such as matching the existing pavement structure when widening, adding truck lanes to an adjacent flexible pavement, or providing a new wearing surface to an old rigid surface layer that is still structurally sound, composite pavements may be an option.

641.2 Rigid Over Flexible Layer

Because of the minimum 0.70 foot thickness requirements for rigid surface layers, all pavements with a rigid surface are engineered according to the standards and procedures for rigid pavements in Chapter 620.

Topic 642 - Engineering Criteria

642.1 Engineering Properties

The engineering properties found in Index 622.1 for rigid pavement and Index 632.1 for flexible pavement apply to composite pavements. Care should be taken in selecting materials in the flexible layer to resist reflective crack propagation from the underlying rigid layer and facilitate construction of generally thin flexible layers.

642.2 Performance Factors

Flexible layers placed over rigid surface layers need to be engineered and use materials that will meet the following requirements:

- (1) *Reflective Cracking.* Joints or cracks from the underlying rigid surface layer should not reflect through the flexible layer for the service life of the flexible layer.
- (2) *Smoothness.* The flexible layer should be engineered to provide an initial IRI of 63 inches per mile and maintain an IRI that is less 170 inches per mile throughout its service life.
- (3) *Bonding.* A major factor in the effectiveness and service life of the flexible layer is the condition of the bond between the flexible and rigid layers. For a good bonding condition between flexible and rigid layer, the thickness of the flexible layer does not play an important role in its service life. Therefore, for practical purposes, if there is no thickness requirement from the structural/constructibility point of

view, the minimum thickness of the flexible layer should be based on material factors such as, gradation and aggregate structure, type of binder, etc. To achieve the maximum bond consult the District Materials Engineer or Headquarters Office of Concrete Pavement and Foundations for options on effective bonding between rigid and flexible layers.

For performance factors of rigid pavement, see Index 622.2.

Topic 643 - Engineering Procedures for New Construction and Reconstruction

643.1 Empirical Method

Before deciding to construct a new composite pavement, a LCCA should be completed to determine whether the composite pavement is more cost effective over the long term than flexible or rigid pavement alternatives.

At present, there is no comprehensive procedure to engineer a structural layer of flexible pavement over a rigid surface layer of JPCP or CRCP. Research is under way to provide guidelines for engineering and construction of composite pavements. When engineering composite pavements using JPCP or CRCP, the rigid layer with base and subbase is engineered as a rigid pavement using the procedures in Index 623.1. No reduction is made to the thickness of the rigid layer on account of the flexible overlay. The flexible pavement is treated as a sacrificial wearing course, and thus has no structural value.

When enough information is not available, the thickness requirement for placing a flexible pavement overlay over an old rigid pavement can be used as a conservative thickness for a new pavement.

643.2 Mechanistic-Empirical Method

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

Topic 644 - Engineering Procedures for Pavement Preservation

644.1 Preventive Maintenance

Preventive Maintenance is used to maintain the surface of the flexible layer or to replace thin flexible layers (i.e., non-structural wearing courses) placed over a rigid surface course layer. If work is needed to repair the underlying rigid layer, it should be developed as a CAPM (Index 644.2) or roadway rehabilitation (Topic 645) project. Additional information on preventive maintenance of the flexible layer can be found in the "Maintenance Technical Advisory Guide (MTAG)" available on the Department Pavement website.

644.2 Capital Preventive Maintenance (CAPM)

The procedures and designs for composite pavement CAPM projects are the same as those for flexible pavements (see Index 634.2). In the case of previously constructed crack, seat, and flexible overlay projects, it may be beneficial to mill a portion of the existing flexible layer prior to overlaying. Milling will reduce the thickness of the existing cracked pavement and therefore provide added life to the overlay.

The roadway rehabilitation requirements for overlays (see Index 645.1) and preparation of existing pavement surface (Index 645.1(3)) also apply to CAPM projects. Additional details and information regarding CAPM policies and strategies can be found in Design Information Bulletin 81 "Capital Preventive Maintenance Guidelines."

Topic 645 - Engineering Procedures for Pavement and Roadway Rehabilitation

645.1 Empirical Method

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.

Procedures for engineering rehabilitation projects for composite pavement are as follows:

Because the flexible surface layer is considered to have no structural value, only reflective cracking and ride quality need to be considered.

(1) *Reflective cracking.* If the flexible layer is placed over an existing (old) rigid pavement, the thickness is calculated based on the procedure outlined for rigid pavement rehabilitation, mainly for reflective crack retardation. The thickness depends on the design life of the flexible non-structural wearing course, as well as mix gradation, type and percentage of the binder.

For additional information on rehabilitation of rigid pavements refer to “Rigid Pavement Preservation and Rehabilitation Guidelines” available on the Department Pavement website.

(2) *Ride Quality.* When the smoothness of the existing roadway is 170 inches per mile or greater as measured by the International Ride Index (IRI), a minimum 0.25 foot flexible layer (0.20 foot rubberized hot mix asphalt) should be placed. The overall thickness can be a single material or a combination of open graded, dense/gap graded, or SAMI-R material. Note that in some cases, existing pavement will need to be repaired to assure the roadway smoothness will remain below 170 inches per mile throughout the life of the overlay.

(3) *Preparation of the Existing Pavement.* Existing pavement distresses should be repaired before overlaying the pavement. Cracks wider than ¼ inch should be sealed. Undesirable material such as bleeding seal coats or excessive crack sealant should be removed before paving. Existing thermoplastic traffic striping and raised pavement markers also should be removed. Spalls in rigid pavement should be repaired and broken slabs or punchouts replaced. Loose flexible pavement should be removed and replaced, and potholes and localized failures repaired. Ideally, existing non-structural wearing courses should be removed and, if needed, underlying pavement repaired prior to placing a new flexible wearing course. In some cases it may be more practical to overlay over the existing layer. (A LCCA of the two options will help determine which of these options is more cost effective. Note that when doing a LCCA, the need to ultimately remove all flexible layers in the future should be identified and included in the costs for the analysis.)

Routing cracks before applying crack sealant has been found to be beneficial. The width of the routing should be ¼ inch wider than the crack width. The depth should be equal to the width of the routing plus ¼ inch. In order to alleviate the potential bump in the overlay from the crack sealant, leave the crack sealant ¼ inch below grade to allow for expansion (i.e., recess fill). The Materials Report should include a reminder of these preparations. Additional discussion of repairing existing pavement can be found on the Department Pavement website.

645.2 Mechanistic-Empirical Method

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

CHAPTER 650 PAVEMENT DRAINAGE

Topic 651 - General Considerations

Index 651.1 Impacts of Drainage on Pavement

Saturation of the pavement or underlying subgrade, or both, generally results in a decrease in strength or ability to support heavy axle loads. Potential problems associated with saturation of the structural section and subgrade include:

- Pumping action.
- Differential expansion (swelling) of expansive subgrade.
- Frost damage in freeze-thaw areas.
- Erosion and piping of fine materials creating voids which result in the loss of subgrade support.
- Icing of pavement surface from upward seepage.
- Stripping of asphalt concrete aggregates.
- Accelerated oxidation of asphalt binder.

Water can enter the pavement as surface water through cracks, joints, and pavement infiltration, and as groundwater from an intercepted aquifer, a high water table, or a localized spring. These sources of water should be considered and provisions should be made to handle both. The structural section drainage system, which is engineered to handle surface water inflow, is generally separated from the subsurface drainage system that is engineered to accommodate encroaching subsurface water. This chapter covers surface water drainage while the subsurface drainage system is covered in Chapter 840.

651.2 Drainage System Components and Requirements

The basic components of a pavement structural section drainage system are:

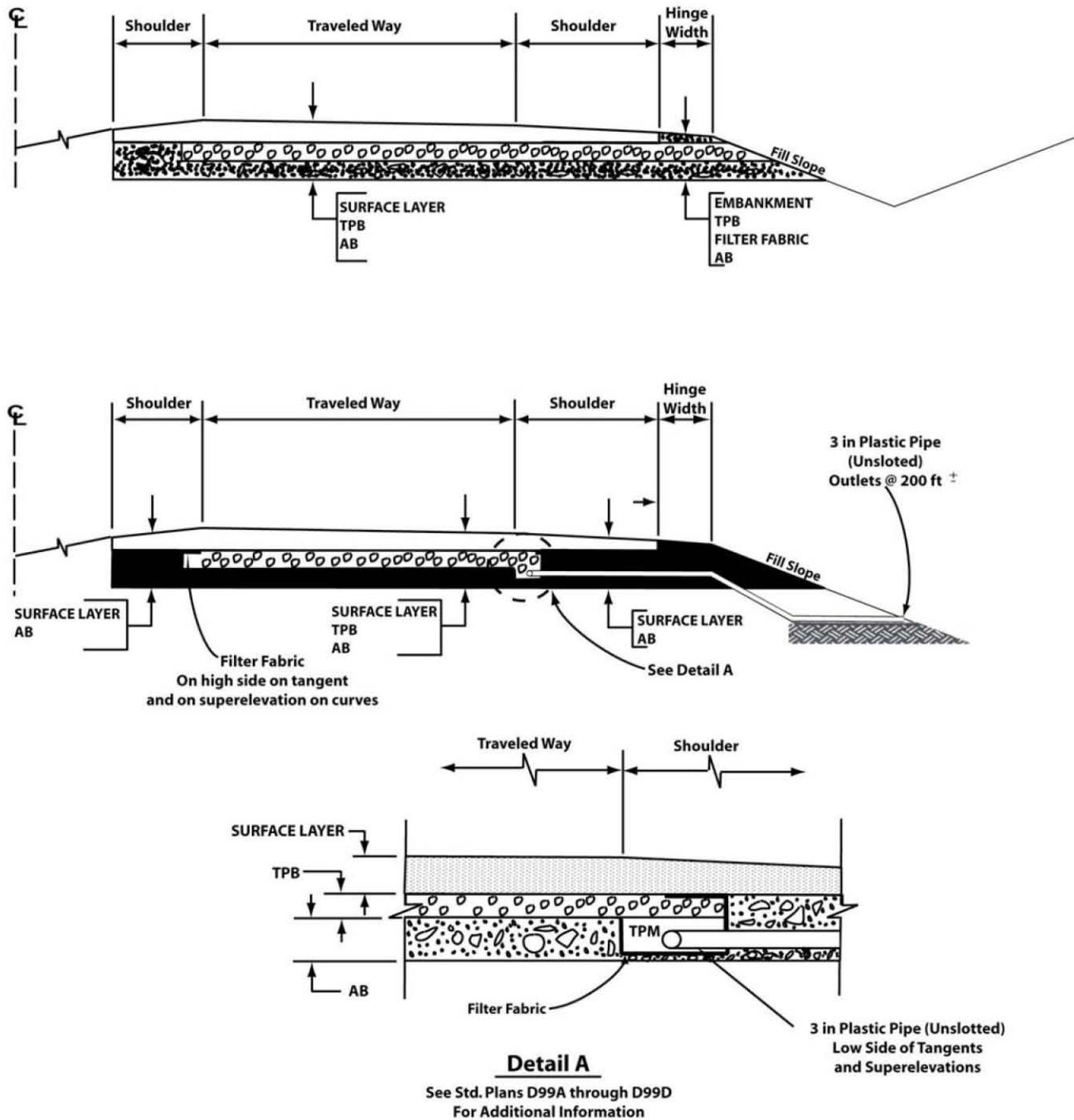
- (1) *Drainage Layer.* A treated permeable base (TPB) drainage layer may be useful where it is necessary to drain water beneath the pavement. A TPB requires the use of edge drains or some other method of draining water out and away from the pavement; otherwise the collected water will become trapped. If a TPB drainage layer is used, it should be placed immediately below the surface layer for interception of surface water that enters the pavement. The drainage layer limits are shown in Figure 651.2A. Further information for TPB can be found in Index 662.3.

When there is concern that the infiltrating surface water may saturate and soften the underlying subbase or subgrade (due either to exposure during construction operations or under service conditions), a filter fabric or other suitable membrane should be utilized and applied to the base, subbase, or subgrade on which the TPB layer is placed to prevent migration of fines and contamination of the TPB layer by the underlying material.

When using TPB, special attention should be given to drainage details wherever water flowing in the TPB encounters impermeable abutting pavement layers, a structure approach slab, a sleeper slab, a pavement end anchor/transition, or a pressure relief joint. In any of these cases, a cross drain interceptor should be provided. Details of cross drain interceptors at various locations are shown in Figure 651.2B. The cross drain outlets should be tied into the longitudinal edge drain collector and outlet system with provision for maintenance access to allow cleaning.

In some situations, underground water from landscape irrigation or other sources may tend to saturate the existing slow-draining layers, thereby creating the potential for pumping and pavement damage. In this case, the pavement

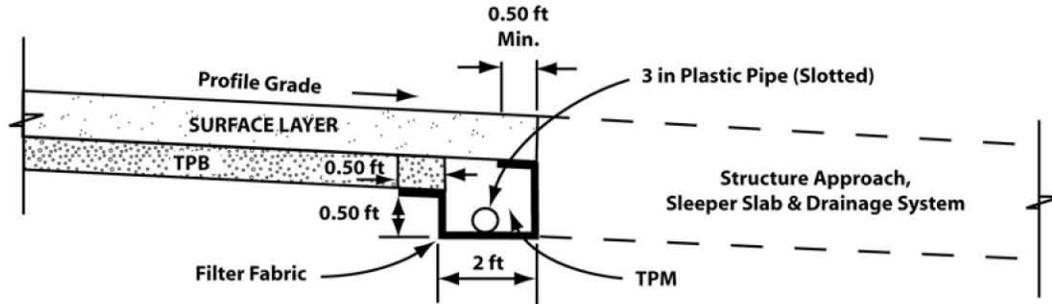
Figure 651.2A
Typical Section with Treated Permeable Base Drainage Layer



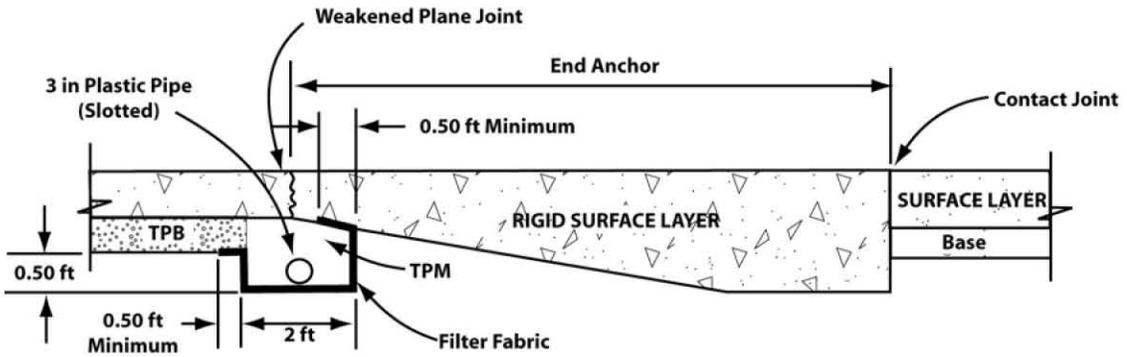
- NOTES:
1. Section shown is a half-section of a divided highway. An edge drain collector and outlet system should be provided if insufficient Right of Way precludes a retention basin.
 2. This figure is only intended to show typical pavement details, for geometric cross section details, see Chapter 300.

Figure 651.2B

Cross Drain Interceptor Details For Use with Treated Permeable Base



**AT STRUCTURE APPROACH
(LONGITUDINAL SECTION)**



**AT END ANCHOR
(LONGITUDINAL SECTION)**

should be engineered to provide for removal of such water when reconstruction is required.

- (2) *Collector System.* If constraints exist or where it is not practical to drain water out of the pavement by other means, a collector system should be provided to drain water from the drainage layer. Collector systems include a 3-inch slotted plastic pipe edge drain installed in a longitudinal collector trench as shown in Figure 651.2A. In areas where the profile grade is equal to or greater than 4 percent, intermediate cross drain interceptors, as shown in Figure 651.2C should be provided at an approximate spacing of 500 feet. This will limit the longitudinal seepage distance in the drainage layer, minimizing the drainage time and preventing the buildup of a hydrostatic head under the surface layer. Cross drain interceptor trenches must be sloped to drain.

In addition, cross drains need to be provided at the low-end terminal of TPB projects, as shown in Figure 651.2C. Care should be taken to coordinate the cross drains with the longitudinal structural section drainage system. Drainage layers in roadway intersections and interchanges may require additional collector trenches, pipes, and outlets to assure rapid drainage of the pavement.

A standard longitudinal collector trench width of 1 foot has been adopted for new construction to accommodate compaction and consolidation of the TPB alongside and above the 3-inch slotted plastic pipe.

When a superelevation cross slope begins to drain the water through the TPB to the low side of pavement in cut sections, an edge drain system may be considered to direct water to an area where ponding will not occur.

- (3) *Outlets, Vents, and Cleanouts.* Pavements should be engineered to promote free drainage whenever applicable. Alternative strategies are provided, as shown in Figure 651.2A. Incorporation of a TPB daylighting to the edge of embankment may be considered; otherwise, an edge drain collector and outlet system may provide positive drainage of the structural section.

When edge drains are used, plastic pipe (unslotted) outlets should be provided at proper intervals for the pavement drainage system to be free draining. The spacing of outlets (including vents and cleanouts) should be approximately 200 feet (250 feet maximum). Outlets should be placed on the low side of superelevations or blockages such as bridge structures.

The trench for the outlet pipe must be backfilled with material of low permeability, or provided with a cut-off wall or diaphragm, to prevent piping.

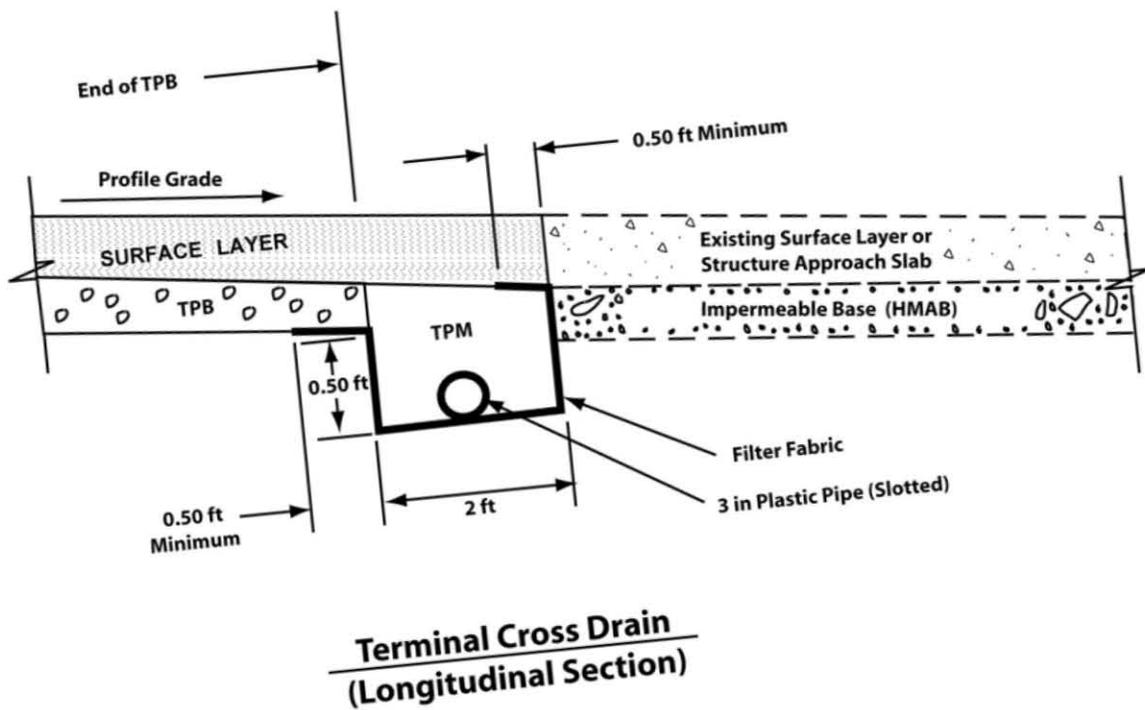
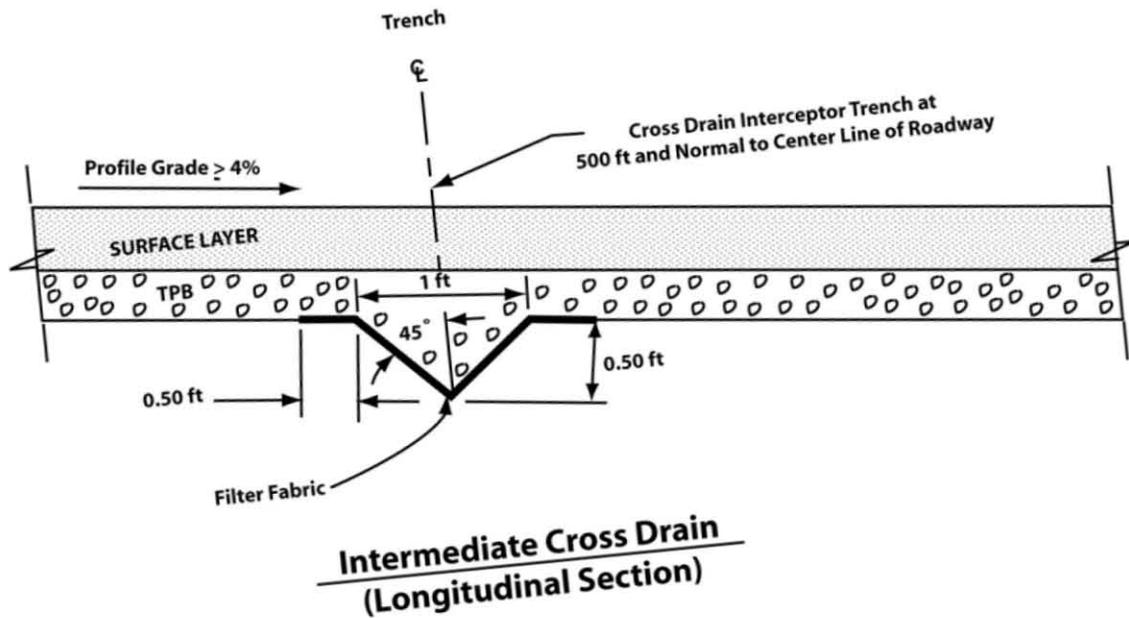
The outlets must be daylighted, connected to culverts or drainage structures, or discharged into gutters or drainage ditches. The area under the exposed end of a daylighted outlet should have a splash block or be paved to prevent erosion and the growth of vegetation, which will impede flows from the outlet. Ready access to outlets, and the provision of intervening cleanouts when outlet spacing exceeds a maximum distance of 250 feet, should be provided to facilitate cleaning of the pavement drainage system. Typical details are shown on the Standard Plans for Edge Drain Outlet and Vent Details.

The end of each outlet pipe should be indicated by an appropriate marker to facilitate location and identification for maintenance purposes and to reduce the likelihood of damage by vehicles and equipment. Consult the District Division of Maintenance for the preferred method of identification.

Filter Fabric. Filter fabric should be placed as shown in Figures 651.2A and B, respectively, to provide protection against clogging of the treated permeable material (TPM) by intrusion of fines. Filter fabric should be selected based upon project specific materials conditions to ensure continuous flow of water and preclude clogging of the filter fabric openings. Consult with the District Materials Engineer to assist in selecting the most appropriate filter fabric for the project.

Figure 651.2C

Cross Drain Interceptor Trenches



Topic 652 - Storm Water Management

Drainage emanating from either the pavement surface or from subsurface drains (edge drains, underdrains, and daylighting of the pavement drainage layers) is to be handled in accordance with the procedures provided in Chapter 890 of the HDM for conveyance and with the procedures in the Storm Water Quality Handbook - Project Planning and Design Guide (PPDG) for storm water compliance. Storm Water Best Management Practices (BMPs) are to be incorporated in the design of projects as prescribed in the PPDG. The PPDG and other information on storm water management can be found at Storm Water page of the Division of Design website.

Topic 653 – Other Considerations

653.1 New Construction Projects

The surface layer should employ materials that will minimize surface water intrusion and any joints should be sealed. If sufficient right of way is available, it is preferable to grade the roadbed to allow for a free draining outlet for the pavement rather than installing edge drain. When a free drainage outlet is used, the TPB and AB layers of the pavement must be daylighted on the low end of the section.

On curvilinear alignments, superelevation of the roadway may create depressions at the low side of pavement where the collected water cannot be drained away. An adjustment to the profile grade may be necessary to eliminate these depressions. Refer to Chapter 200 for superelevation guidelines.

653.2 Widening Projects

The widened pavement layers should be engineered to discharge any existing water collected by the pavement. This may be done by extending any drainage layer of the existing adjacent pavement while still providing sufficient pavement structure to meet the pavement design life requirements in Topic 612. The widened layers should extend the full width of the roadbed

to a free outlet, if feasible, as in new construction (See Figure 651.2A).

653.3 Rehabilitation and Reconstruction Projects

The surface of the traveled way and shoulders should employ methods and materials that will help minimize surface water intrusion and any joints should be sealed. Saturation or soft spots should be identified and drainage system should be incorporated to restore or repair the existing pavement, if applicable.

653.4 Ramps

Provisions for positive, rapid drainage of the structural section is very important on ramps as much as main lanes. However, including drainage systems in ramp pavements can sometimes create drainage problems such as accumulation of water in the subgrade of descending ramps approaching local street intersections in flat terrain. Such situations, where there may be no cost effective way to provide positive drainage outlets, call for careful evaluation of local conditions and judgment in determining whether a drainage system should be included or not in each ramp pavement structure.

653.5 Roadside Facilities

The surface of parking areas should be crowned or sloped to minimize the amount of surface water penetrating into the pavement. Drainage facilities for the surface runoff should be provided if flexible pavement is used. A mix using $\frac{3}{8}$ inch or $\frac{1}{2}$ inch maximum aggregate is recommended to provide a relatively low permeability. The flexible pavement should be placed in one lift to provide maximum density.

CHAPTER 660 BASE AND SUBBASE

Topic 661 - Engineering Considerations

Bases and subbases serve as a support for the surface layer and distribute the wheel load to subgrade material.

In addition to functioning as part of the pavement structure, bases and subbases serve the following functions:

- Slow down the intrusion of fines from the subgrade soil into pavement structural layers.
- Minimize the damage of frost action.
- Prevent the accumulation of free water within or below the pavement structure.
- Provide a working platform for construction equipment.

Topic 662 - Base and Subbase Categories

Index 662.1 - Aggregate Base and Subbase

Aggregate bases and subbases consist of a combination of sand, gravel, crushed stone and recycled material. They are classified in accordance with their gradation and the amount of fines. The gradation of the aggregates can affect structural capacity, drainage, and frost susceptibility. The quality of aggregate base and subbase material affects the rate of load distribution and drainage.

662.2 Treated Base and Subbase

(1) *Hot Mix Asphalt Base (HMAB)*. Depending on the quality of aggregate, HMAB is classified as dense graded Type A or Type B Hot Mix Asphalt, (HMA). Type A is primarily a crushed aggregate, which provides greater stability than Type B. When used with HMA pavement, the HMAB is to be considered as part of the pavement layer. The HMAB will be assigned the same gravel

factor, G_r , as the remainder of the HMA in the pavement structure.

(2) *Other Treated Bases and Subbases*. Treated bases and subbases are materials mixed with asphalt, portland cement, or other stabilizing agents to improve the strength or stiffness of granular material. These materials include lean concrete base (LCB), cement treated base (CTB), asphalt treated base (ATB) and lime treated subbase (LTS). CTB has shown poor performance under rigid pavement in the past. CTB exhibit excessive pumping, faulting, and cracking. This is most likely due to impervious nature of the base, which traps moisture and yet can break down and contribute to the movement of fines beneath the slab.

662.3 Treated Permeable Base and Subbase

Treated permeable bases (TPB) provide a strong, highly permeable drainage layer within the pavement structure. The binder material may be either asphalt (ATPB) or portland cement (CTPB). Either of these TPB layers will generally provide greater drainage capacity than is needed. The standard thickness is based primarily on constructability with an added allowance to compensate for construction tolerances. If material other than ATPB and CTPB with a different permeability, it is necessary to check the permeability and adequacy of the layer thickness. TPB must be used in accordance with a positive sub-drainage system per Index 651.2.

Erosion and stripping (water washing away cement paste, binders, and fines) can be an issue for TPB. Research conducted in the 1990s at the University of California Pavement Research Center (UCPRC) indicates that the use of ATPB is highly susceptible to stripping. Because of this, the Department recommends use of standard aggregate base (AB), with a compaction of the HMA layer of at least 93 percent of theoretical Rice maximum, instead of ATPB for new pavement structures. When ATPB is needed, such as to ensure continuity of existing ATPB/CTPB layer and/or provide drainage through the pavement structure, special provisions should be

made to ensure that it is not subjected to conditions that will lead to premature structural failure. The following guidelines should be followed when using ATPB on State highway pavement projects.

(1) *Considerations for using ATPB.* The following two conditions warrant consideration to use ATPB layer in the pavement structure:

- (a) When widening or adding lanes adjacent to an existing ATPB layer to ensure continuity of existing ATPB layer.
- (b) Where there is need to drain excess water through the pavement, such as when the uphill side of pavement does not allow for drainage. However, when practical, it is better in such cases to use sub-surface drainage to carry water to the other side of the roadway rather than drain excess water through an ATPB layer just below the HMA.

(2) *Added features when using ATPB.* The following features are recommended when using ATPB:

- (a) Use edge drains or daylight the edges (see Figure 651.2A in Chapter 650).
- (b) If using edge drains, be sure that Maintenance is informed and can budget funds for maintaining edge drains. Developing an estimate of maintenance costs to maintain edge drains and Budget Change Proposals may be required to assure edge drains can be maintained.
- (c) Try to use permeable backfill in shoulders on sides of edge drain to avoid bathtub effect if edge drain becomes clogged.
- (d) Increase binder content to 3 percent (maybe higher)
- (e) Tack coat each layer.
- (f) Perform moisture sensitivity testing on ATPB.
- (g) Compaction of the HMA layer should be at least 93 percent of theoretical Rice maximum.

Topic 663 - Engineering Criteria

Because different types of treated and untreated aggregates have different capacities for resisting the forces imposed by traffic loads, this factor must be considered when determining the thickness of the pavement elements. For rigid pavement, this is considered in the design catalogs found in Topic 623. Table 663.1A provides the base and subbase material properties used for the Rigid Pavement Catalog. For flexible pavement, it is accomplished with California R-value and the gravel factor, G_f , which expresses the relative stiffness of various materials when compared to gravel. Table 663.1B provides the California R-values and G_f used for engineering flexible pavements.

The final selection of the bases and subbases for a given project depends on specific factors relative to the available materials, terrain, climate, economics, and past performance of the pavement under similar project or climatic conditions and travel patterns.

Since pavement engineering is a continually evolving field, the District Materials Engineer should be contacted for the latest guidance in base and subbase materials among other related engineering considerations.

Table 663.1A

Base and Subbase Material Properties for Rigid Pavement Catalog

HMA Type A Properties	
Aggregate gradation	0% retained on 3/4 inch sieve 32% retained on 3/8 inch sieve 52% retained on No. 4 sieve 5.5% passing No. 200 sieve
Asphalt binder type	See Index 632.1(2) and Table 632.1
Reference temperature	70 °F
Poisson's ratio	0.35
Effective binder content	11.662%
Air voids	8%
Total unit weight	149 lb/ft ³
Thermal conductivity	0.657 Btu/hr ft °F
Heat capacity	0.23 Btu/lbm-°F
Base erodibility index ⁽¹⁾	2
LCB Properties	
Unit weight	150 lb/ft ³
Poisson's ratio	0.20
Elastic modulus	2.00 x 10 ⁶ psi
Thermal conductivity	15 Btu-in/h-ft ² -°F
Heat capacity	0.28 Btu/lbm-°F
Base erodibility index ⁽¹⁾	1
AB / AS Properties	
Poisson's ratio	0.40
Coefficient of lateral pressure, K ₀	0.5
Resilient modulus for AB	43,500 psi
Resilient modulus for AS	29,000 psi
Plasticity Index	1
Passing No. 200	3%
Passing No. 4	20%
D ₆₀	0.315 inch
Base erodibility index ⁽¹⁾	4

Note:

- (1) D₆₀ = Particle diameter at which 60 percent of the material sample is finer than or would pass a sieve size of that diameter.
- (2) Base erodibility index is classified as a number from 1 to 5 as follows:
 - 1 = Extremely erosion resistant material
 - 2 = Very erosion resistant material
 - 3 = Erosion resistant material
 - 4 = Fairly erodible material
 - 5 = Very erodible material

Table 663.1B
Gravel Factor and California R-values for Bases and Subbases

Type of Material	Abbreviation	California R-value	Gravel Factor (G_f)
Aggregate Subbase	AS-Class 1	60	1.0
	AS-Class 2	50	1.0
	AS-Class 3	40	1.0
	AS-Class 4	specify	1.0
	AS-Class 5	specify	1.0
Aggregate Base	AB-Class 2	78	1.1
	AB-Class 3	specify	1.1 ⁽¹⁾
Asphalt Treated Permeable Base	ATPB	NA	1.4
Cement Treated Base	CTB-Class A	NA	1.7
	CTB-Class B	80	1.2
Cement Treated Permeable Base	CTPB	NA	1.7
Lean Concrete Base	LCB	NA	1.9
Hot Mix Asphalt Base	HMAB	NA	⁽²⁾
Lime Treated Subbase	LTS	NA	0.9+(UCS/1,000)

Notes:

- (1) Must conform to the quality requirements of AB-Class 2.
- (2) When used with HMA, the HMAB is to be considered as part of the pavement layer. The HMAB will be assigned the same G_f as the remainder of the HMA in the pavement structure.

Legend:

NA = Not Applicable

UCS = Unconfined Compressive Strength in psi (minimum 300 psi per California Test 373)

CHAPTER 670 STRUCTURE APPROACH SLABS

Topic 671 – Application

Index 671.1 - 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 structural approach slab projects involving new construction, reconstruction, or rehabilitation of structure approaches. They are not, however, a substitute for engineering knowledge, experience, or sound judgment.

671.2 Application

There are several alternatives that may be considered in the design of a structure approach slab system. These alternatives are designated as Types 45, 30, and 10 structure approach slab systems. Standard details and special provisions for each type of approach system can be found on the Structure Design page of the Division of Engineering Services (DES) website. Figure 671.1 shows a generic structure approach slab system layout. Structure Design Bridge Memo 5-3 provides the criteria for the selection and design of structure approach slabs. In the event of discrepancies between this manual and Structure Design Bridge Memo 5-3, Memo 5-3 shall govern.

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 Plans Specifications and Estimates (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.

Structure approach slabs are used on all rigid pavements and on multilane flexible pavements located within designated urbanized areas. Urbanized areas are identified, by postmile, in the Route Segment Report, Project Management Control System (PMCS) Database and State Highway Inventory.

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

Topic 672 - General Considerations

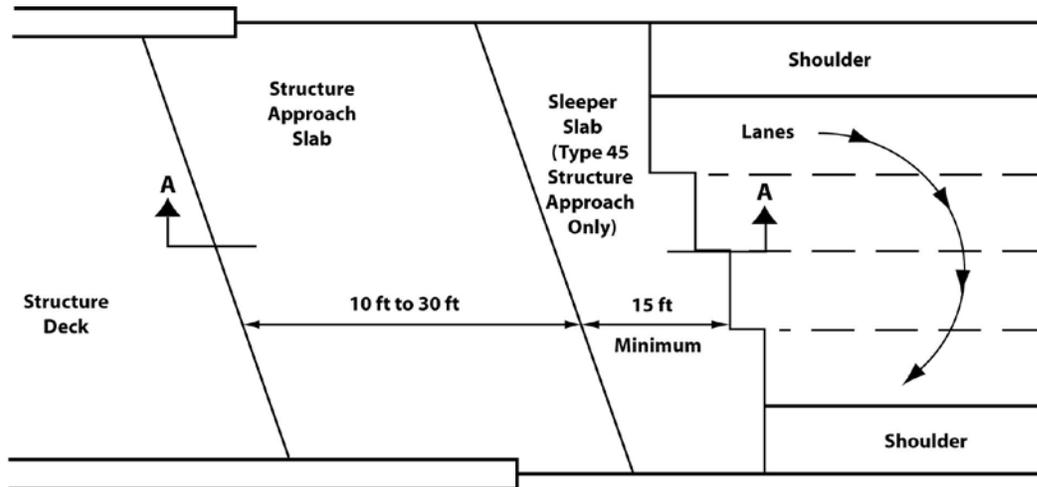
672.1 Field Investigations

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.

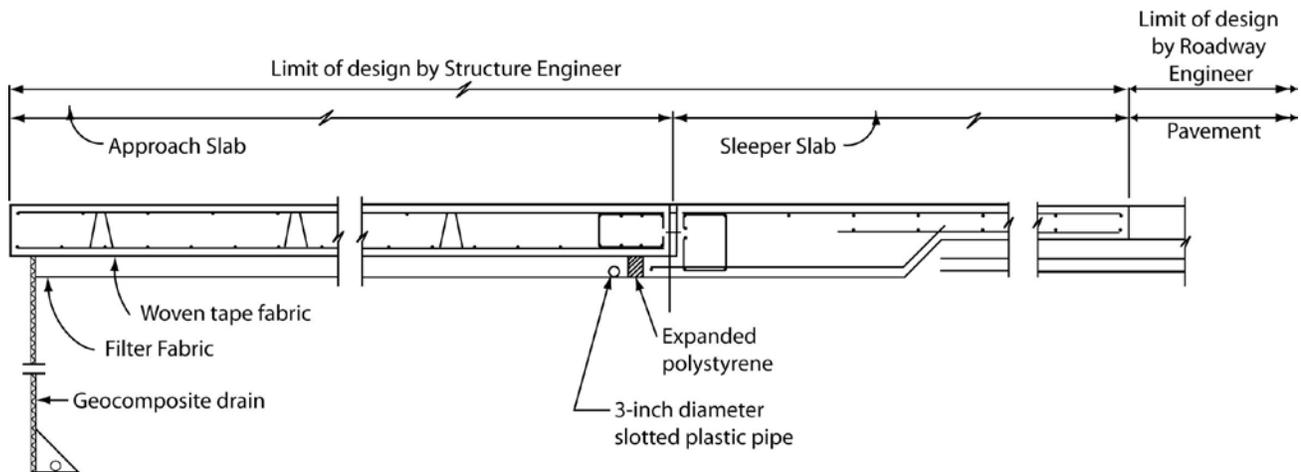
672.2 Load Transfer at Approach Slab/Concrete Pavement Joint

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 671.1
Structure Approach Slab Layout



Plan View



SECTION A-A

672.3 Guardrails

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

672.4 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 and part of the responsibilities of the structures engineer. The PE should coordinate with structure engineers to coordinate the limits and responsibility for barriers.

672.5 Structural Approach System Drainage

(1) *Pavement Drainage.* Figure 671.1 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 Structures Design Standard Details for requirements. The PE or the District Hydraulics Engineer are responsible for all drainage considerations of the roadway while DES, Structures Design (DES-SD) is responsible for structure related drainage. DES-SD is responsible for engineering of both the approach slab and the drainage system, which normally exits through the wingwall. The highway engineer designs 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.

Topic 673 - Structure Approach Slab Rehabilitation Considerations

673.1 Approach Slab Replacement

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. PE needs to make sure the structure engineer addresses this in their reports, plans, and specifications.

673.2 Structure Approach Slab Drainage

Typical details for providing positive drainage of a full-width structure approach system are shown in Figure 673.2. 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.

673.3 Pavement Details

Special pavement details are necessary when structure approach slabs will be replaced in conjunction with the crack, seat, and overlay pavement rehabilitation strategy for rigid pavement. Figure 673.3, which is applicable to full-width slab replacement, illustrates a method of transitioning from a 0.35 foot flexible pavement overlay thickness to a minimum 0.15 foot final flexible overlay thickness. Care should be taken in areas with flat grades to avoid creating a ponding condition at the structure abutment.

Cracking and seating of the existing rigid pavement as well as the geotextile reinforcement fabric should be terminated at the start of the transition from the maximum flexible pavement overlay depth.

Flexible pavement overlays should not be placed on structure decks and approach slabs without the concurrence of Structures Maintenance and Investigations (SMI). If an overlay is needed, SMI will provide the recommended strategy. If another strategy, such as polyester concrete is used, the details will be provided by either SMI or Office of Structure Design (OSD).

673.4 Traffic Handling

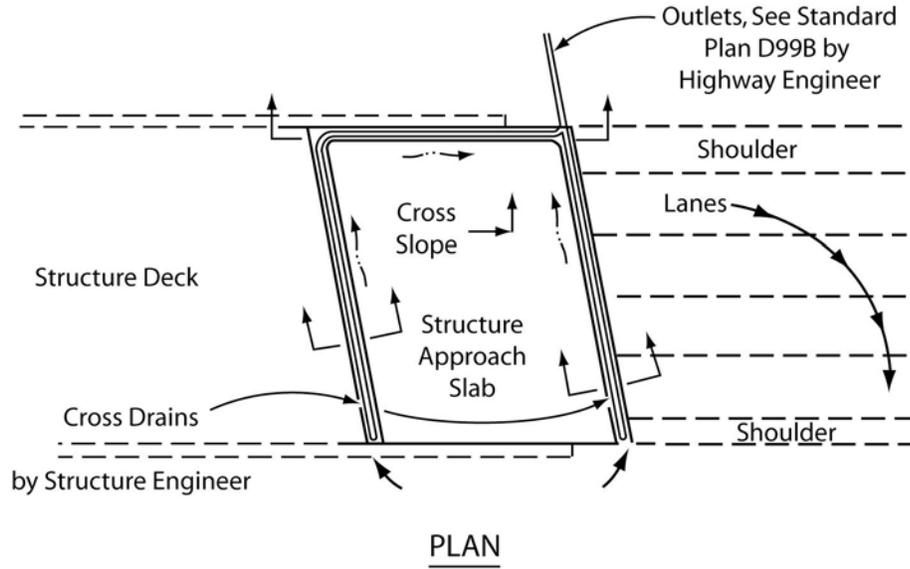
Traffic handling considerations typically preclude full-width construction procedures. Structure approach rehabilitation is therefore usually done under traffic control conditions, which require partial-width construction.

District Division of Traffic Operations should be consulted for guidance on lane closures and traffic handling. Also see Index 110.7 for additional information.

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 joint should not be located underneath any of the wheel paths.

Figure 673.2

**Structure Approach Drainage Details
(Rehabilitation)**



Legend

- Direction of Flow
- CTB Cement Treated Base
- PCCP Portland Cement Concrete Pavement
- TPM Treated Permeable Material

Figure 673.3

Structure Approach Pavement Transition Details
(Rehabilitation)

