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, widening, reconstruction, and rehabilitation in California are rigid, flexible, and composite pavements. Rigid and flexible pavements are considered for all new and reconstructed pavements. For widening and rehabilitation projects, flexible or rigid pavements may be appropriate based on performance, maintainability, and constructability of new and/or existing pavement structure. Composite pavement consisting of a flexible layer placed over a rigid pavement has mostly been used to maintain and rehabilitate rigid pavements on State highway facilities.

Life-cycle cost analysis discussed in Topic 619 should be used as a decision-support tool when selecting optimal pavement structure type for a specific project.

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 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 with a systematic consideration of the following project specific conditions:

- Pavement design life
- Traffic considerations
- Soils characteristics
- Climate
- Existing pavement type and condition
- Existing drainage type and condition
- Availability of materials
- Recycling
- Maintainability
- Constructability
- Life-cycle cost analysis
- Life-cycle assessment

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) while accounting for the other considerations listed above. In addition, the Department is currently developing a tool based on the life-cycle assessment that can be valuable in supporting the selection of pavement type and rehabilitation strategies while assisting the Department in achieving its sustainability goal (see Topic 620).

The principal factors considered in selecting pavement structures are discussed in Topic 612 through Topic 619.

Topic 612 - Pavement Design Life

612.1 Definition

Pavement design life, also referred to as the performance period, is the period of time that a newly constructed or rehabilitated pavement is engineered to perform before reaching any of the performance thresholds in Table 622.2 for concrete pavements or those in Topic 633 for asphalt pavements. 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 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 Topic 612.

612.2 New Construction and Reconstruction

The pavement design life for new construction and reconstruction projects shall be no less than 40 years. For roadside facilities such as parking lots and rest areas, 20-year pavement design life may be used. Realignments or other new roadways that fit the definition of spot improvement in Design Information Bulletin 79 or current DIB are considered rehabilitation for determining pavement design life**.**

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 widening. **The pavement design life for the mainline traveled way, ramp traveled way, and intersection widening projects shall either be: (a) the remaining pavement service life of the adjacent roadway (but not less than the project design period as defined in Index 103.2), (b) 20 years, or (c) 40 years depending on which pavement design life produces the lowest life-cycle costs.** Design the first 2 feet of new shoulder pavement structure in conjunction with the lane widening, or if the shoulder is expected to be converted to a traffic lane within the pavement design life, it should be engineered to provide the same pavement design life as the adjacent traveled way. All other widening projects including shoulder widening and roadside facilities should be engineered to either match the adjacent existing pavement structure or provide a 20-year design life, depending on the design life that produces the lowest life-cycle cost. Life-cycle cost analysis is discussed in Topic 619.

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 and maintain ride quality of an existing pavement structure while it is in good condition. On average, the added service life can vary from a couple of years to over 7 years, depending on the strategy being used and the existing pavement condition. Effective timing of preventive maintenance is critical for it to be cost-effective. Preventive maintenance does not provide much value when placed on pavements with extensive cracking, or when placed too early.

(2) *Capital Preventive Maintenance.* The strategies used for CAPM projects have been engineered to extend the service life and maintain ride quality of a pavement that exhibits minor distress and/or triggered ride issues (Mean Roughness Index (MRI) greater than 170 inches per mile) by a minimum of 5 years. When properly engineered and placed on pavements that meet CAPM thresholds, CAPM strategies can last 5 to less than 20 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 12,000 vehicles, where the minimum pavement design life shall be either 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 12,000 using the Department's life-cycle cost analysis procedures.

612.6 Temporary Pavements and Detours

<u>Temporary pavements and detours should be engineered to accommodate the anticipated traffic loading that the pavement will experience during the construction period.</u> This period may range from a few months to several years depending on the type, size, and complexity of the project. Temporary pavement should not be designed to the same depth as the new traveled way and should not require a treated base.

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 and 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 or rehabilitated pavement should perform adequately for 10 or more years, and 5 or more years when placed on existing pavement as a part of pavement preservation.

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-trailer vehicles, 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 that damage the pavement.

For use in the pavement management system, and to provide a quick single measure of the intensity of traffic, a Traffic Index (TI) can be calculated as discussed in Index 613.2.

TI is no longer used directly for flexible pavement design calculations and rigid pavement design catalog tables due to the change to Mechanistic – Empirical (ME) pavement design and rehabilitation methods. Traffic information needed for flexible ME design using CalME are the number of all axle loads in the first year of the design period, the percentages of total axle loads for each load range on each axle configuration (single, tandem, tridem, and quad) which is referred to as the axle load spectrum, and the annual linear growth rate for the number of axle loads over the design life. CalME allows the user to input a TI, CalME then uses the TI along with traffic information for the project location in the Caltrans traffic databases to determine the number of axle loads, the axle load spectrum, and the annual linear growth rate. Traffic information needed for rigid pavement ME design is the Annual Average Daily Truck Traffic (AADTT) in the first year , the percentages of each truck class in the total number of trucks, the number of axles and axles types for each truck class, the percentages of axle loads for each load range on each axle configuration (single, tandem, tridem, and quad) within each truck class, the hourly distribution of truck traffic, and the annual linear growth rate for the number of axle loads over the design life.

All of these traffic input data are included in the traffic database in the CalME flexible ME design software. They are also included in the traffic database used in the Caltrans Pavement ME traffic input tool for use with the Pavement ME software for rigid pavement design, and they are used with Pavement ME when updating the Caltrans rigid pavement design catalog. These traffic data are updated periodically, and simultaneously with updates to the Caltrans pavement management software traffic database updates. All ME design programs and the PMS program use the same traffic data from the Caltrans traffic count systems and the Weigh-In-Motion (WIM) system.

For ME design, the percentages of each axle load range on each type of axle are collectively called an Axle Load Spectrum (ALS). Axle load spectra have been found to show distinct patterns based on analysis of Weight-In-Motion data on California state highways, and to be predictable based on several simple traffic variables. The appropriate axle load spectrum is identified for each segment of the State highway network with consistent traffic based on these variables, and is applied to the number of trucks in each lane on the highway segment for either flexible or rigid pavement design using the same approach and design lane distribution factors. The ME design program selects the specific ALS after the designer identifies the project location information (County, Route, Postmile, Lane, Direction). For the rigid pavement design catalog, the designer enters the tables using the AADTT in the first year and the appropriate ALS (one of five typical spectra) for the location on the state highway system. Further details on Axle Load Spectra are given in Index 613.3.

Alternatively, if information indicates that prediction of future traffic based on current traffic information in the ME design traffic databases does not represent future traffic conditions well, traffic data can be input into CalME or the Pavement ME traffic input table. CalME can take a TI calculated externally to find the number of initial annual axle loadings (CalME), or an estimate of the annual axle loadings (all types summed together) can be directly input to the program. Manual calculation of TI is discussed in Indices 613.2. An initial AADTT can be estimated externally and input into the Pavement ME traffic input tool.

613.2 Manual Traffic Index Calculations

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

Current traffic volume or loading on State highways can be obtained from the following sources:

- Annual Average Daily Traffic (AADT) counts by axle classification,
- Weigh-In-Motion (WIM) station axle load data by axle classification, or
- Annual Average Daily Truck Traffic (AADTT) volume counts by axle classification.

Both AADT and AADTT on California State Highways are updated approximately annually by Headquarters Division of Traffic Operations and used to update ME and PMS traffic databases (*https://dot.ca.gov/programs/traffic-operations*).

Districts typically have established a unit within Traffic Operations or Planning specifically responsible for providing travel forecast information. The Project Engineer should coordinate with these units in their District early in the project development process to determine whether traffic data in the ME design databases for past traffic volumes should be used for future predictions, or whether local information indicates that a manual calculation of TI or initial annual axle loadings for CalME or AADTT for Pavement ME or the rigid design catalog should be done.

(2) *Design Year Annual Average Daily Truck Traffic (AADTT).* A traffic growth factor obtained from the traffic forecasting unit is used to project current AADTT to the design year AADTT for each axle classification. In its simplest form, a straight-line projection is used to project the current one-way AADTT data to the design year AADTT. When using the straight-line projection, the truck traffic data for each axle classification 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. When there is a difference between sources, Caltrans will determine which data and assumptions to use.

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

(3) *Determine the Projected Equivalent Single Axle Loads (ESAL*s). The information obtained from traffic projections and Truck Weight Studies is used to develop 18-kip Equivalent Single Axle Load (ESAL) constants (see Table 613.3A). The ESAL constants represent the estimated total cumulative traffic loading for each of the four vehicle types by axle classification during the pavement design life. Due to the relatively low number of buses in comparison to trucks, buses are typically included in the 2-axle and 3-axle truck counts. 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. For these facilities and in response to the passing of Assembly Bill 1250 which increases axle weight of transit buses procured through a solicitation process, new ESAL constants must be used for all two-axle and three-axle buses; as shown in Table 613.3A. In a facility where a significant number of buses exists beside trucks, counts for the two- and three-axle trucks must be separated from counts for the two- and three-axle buses. These distinct counts must be used with the corresponding ESAL constants to calculate the total ESALs during design life.

The ESAL constants in Table 613.3A are used as multipliers of the projected AADTT for each truck type (and bus type) by axle classification to determine the total cumulative ESALs for all truck types during the pavement design life. The total cumulative ESALs for all truck types during the design life for the pavement are in turn used to determine the Traffic Index (TI) as described in Index 613.3(5). Both the total cumulative ESALs and the resulting TI are the same magnitude when engineering flexible, rigid, and composite pavement structures.

The current 10, 20, 30, and 40-year ESAL constants are shown in Table 613.3A. Note that the constants for each axle classification are linearly proportional to design life.

(4) *Lane Distribution Factors.* Traffic on multilane highways normally varies by lane with passenger cars, vans, pickups, and buses generally in the median and HOV lanes, and heavy trucks in the outside 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. These factors are also used in the calculation of TI based on the selected design life.

(5) *Traffic Index (TI) Calculation.* 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: The TI is rounded up to the nearest 0.5.

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

Where:

TI = Traffic Index for a given design life

ESAL = Total number of cumulative 18-kip Equivalent Single Axle Loads for all truck/bus types over the design life of the pavement structure calculated using the ESAL constants given in Table 613.3A

LDF = Lane Distribution Factor (see Table 613.3B)

In lieu of using the above formula, Table 613.3C can be used to determine the TI depending on the total ESAL calculated for the design life. In Table 613.3C, the TI is given for a range of ESAL values. The total ESAL values given in Table 613.3C are already adjusted for LDF.

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 20-year design life. For this reason, the Project Engineer should involve District Transportation Planning and/or Traffic Operations in determining whether the information in the ME traffic databases should be used, or whether a more realistic and appropriate TI or initial axle loadings (CalME) or AADTT (Pavement ME or catalog) for each project should be calculated based on future projections that are different. This should be determined 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 30 and 40-year ESAL constants in Table 613.3A.

613.3 Axle Load Spectra

Each axle load spectrum includes the following data:

- 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 distribution of truck traffic for each axle type and axle load range combination throughout the day
- The distribution of truck traffic for each axle type and axle load range combination throughout the year if there is significant monthly variation

Table 613.3A
ESAL Constants

Vehicle Type (by Axle Classification)	10-Year Constants	20-Year Constants	30-Year Constants	40-Year Constants
Two-axle trucks or buses	690	1,380	2,070	2,760
Three-axle trucks or buses	1,840	3,680	5,520	7,360
Four-axle trucks	2,940	5,880	8,820	11,760
Five or more-axle trucks	6,890	13,780	20,670	27,560
Two-axle buses(1)	1,380	2,760	4,140	5,520
Three-axle buses(1)	6,808	13,616	20,424	27,232

Table 613.3B
Lane Distribution Factors

Number of Mixed Flow Lanes in One Direction (2)	Factors to be Applied to Projected One-Way Annual Average Daily Truck Traffic (AADTT) (3) — Mixed Flow Lanes (6), (7)			
	Lane 1 (1)	Lane 2	Lane 3	Lane 4
One	1.0	-	-	-
Two	1.0	1.0	-	-
Three	0.2 (4), (5)	0.8	0.8	-
Four	0.2 (4), (5)	0.2 (4), (5)	0.8	0.8

NOTES:
(1) Lane 1 is next to the centerline or median.
(2) For more than four lanes in one direction, use a factor of 0.8 for the outer two lanes plus any auxiliary/collector lanes and, a factor of 0.2 for other mixed flow through lanes, HOV lanes and other inside lanes (non-truck lanes).
(3) Projected one-way AADTT is the truck traffic volume expected to use the lane during the design life for the facility.
(4) TI for non-truck permitted lanes must not exceed 11 for 20-year pavement design life and 12 for 40-year pavement design life.
(5) If HOV or other inside lanes are designated (signage required) for truck use, they must be designed to the same standards as found in this table for the outside lanes.
(6) 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.
(7) The lane distribution factors in this table represent minimum factors and, based on knowledge of local traffic conditions and sound engineering judgment, higher values may be used for specific locations when warranted.

Table 613.3C

Conversion of ESAL to Traffic Index

ESAL [1], [2]	TI [3]	ESAL [2], [3]	TI [3]
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 [4]
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) ESAL totals already adjusted for LDF.

(3) The determination of the TI closer than 0.5 is not justified. No interpolations should be made.

(4) For TI greater than 17.5, use the TI equation. See Index 613.3(5).

613.4 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 thicknesses for each individual lane would create complications for constructing the pavement. Therefore, use different lane distribution factors for pavement engineering of mainline lanes for a multilane highway with 3 or more lanes in each direction, based on thorough consideration of constructability issues discussed in Index 618.2, together with sound engineering judgment.

(b) Freeway and Expressway Lanes. Design traffic for all new freeway and expressway lanes, including widening and auxiliary lanes, must be the greater of either the calculated value, the generated TI of 12.0 for a 40-year pavement design life (flexible surface designed using CalME) or for an AADTT of 859 for a 40-year design life (rigid surface designed from the rigid design catalog or Pavement ME). For roadway rehabilitation projects, use the design traffic in the ME design software, or the calculated TI where called for by better information than that based on past and current traffic in the ME databases.

(c) Ramps and Connectors.

1. Connectors. AADTT and TIs for freeway-to-freeway connectors should be determined the same way as for mainline traffic.
2. Ramps to Weigh Stations. Pavement structures for ramps to weigh stations should be engineered using the mainline outside lane traffic data which has a 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 20-year, and 40-year TI or AADTT values given in Table 613.4A for light, medium, and heavy truck traffic ramp classifications, respectively. Design life TI or AADTT should be the greater of the calculated TI or AADTT, or the TI or AADTT values in Table 613.4A. Ramp TI or AADTT should never exceed mainline TI or AADTT.

The three ramp classifications are defined as follows:

- Light Traffic Ramps - Ramps serving undeveloped or residential suburban 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 613.4A
Traffic Index (TI) Values for Ramps and Connectors

(When reliable traffic forecasts are not available)

Ramp Truck Traffic Classification	Minimum Traffic Index (TI) for CalME		Minimum First Year AADTT(2) for Rigid Design Catalog or Pavement ME	
	20-Yr Design Life	40-Yr Design Life (1)	20-Yr Design Life	40-Yr Design Life (1)
Light	8.0	9.0	29	31
Medium	10.0	11.0	186	167
Heavy	12.0	14.0	859	1,272

NOTE:

(1)Based on straight line extrapolation of 20-year traffic.

(2)Based on 3% annual linear growth rate

(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.
- Current and future drainage requirements are not compromised.

- 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 designed to match the traffic data 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 where 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 design traffic 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 width and cross slope are designed to meet the geometric standards of a traveled lane following the following the guidance in Topic 301 and 302.
- 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 and its drainage should match the adjacent traffic lane for ease of construction. For asphalt pavements, the thickness of the shoulder surface course layer may be tapered from the lane surface course thickness to the shoulder pavement edge thickness of no less than 0.35 foot to address different cross slope conditions (see Figure 613.4A).

For all other cases, the following design standards shall apply:

The minimum design traffic data for the shoulder shall match the adjacent traffic lane for the first 2 feet of the outside shoulder width where the outside lane and shoulder have flexible surfaces, the first 1.0 foot of the outside shoulder as a widened slab in the outside lane where the outside lane has a rigid surface, and 1.0 foot of the inside shoulder measured from the edge of traveled way regardless of surface type. See Figure 613.4B.

For the remaining width of the shoulder, the design traffic data shall:

- **Be no less than 2 percent of the projected axle loads in the first year of the adjacent traffic lane or a TI of 5 for flexible surfaced shoulders designed using CalME, whichever is greater, and no less than 2 percent of the first year AADTT**

for rigid surfaced shoulders designed using the rigid design catalog or Pavement ME.

- **Not to exceed a TI of 9.0 for flexible surfaced shoulders, or a first year AADTT for rigid surfaces shoulders of 77 for 20-year designs and 31 for 40-year designs**.

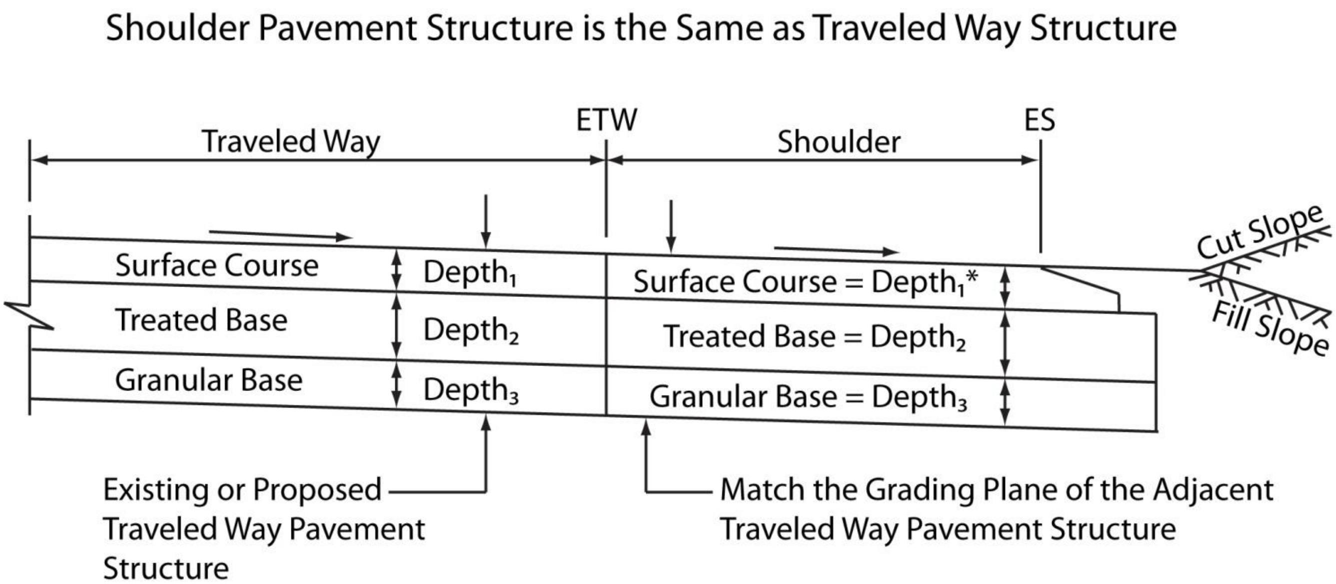
Do not use treated bases of any kind in the pavement, except when a treated permeable base is needed to provide continuity with existing treated permeable bases in the adjacent existing lane.

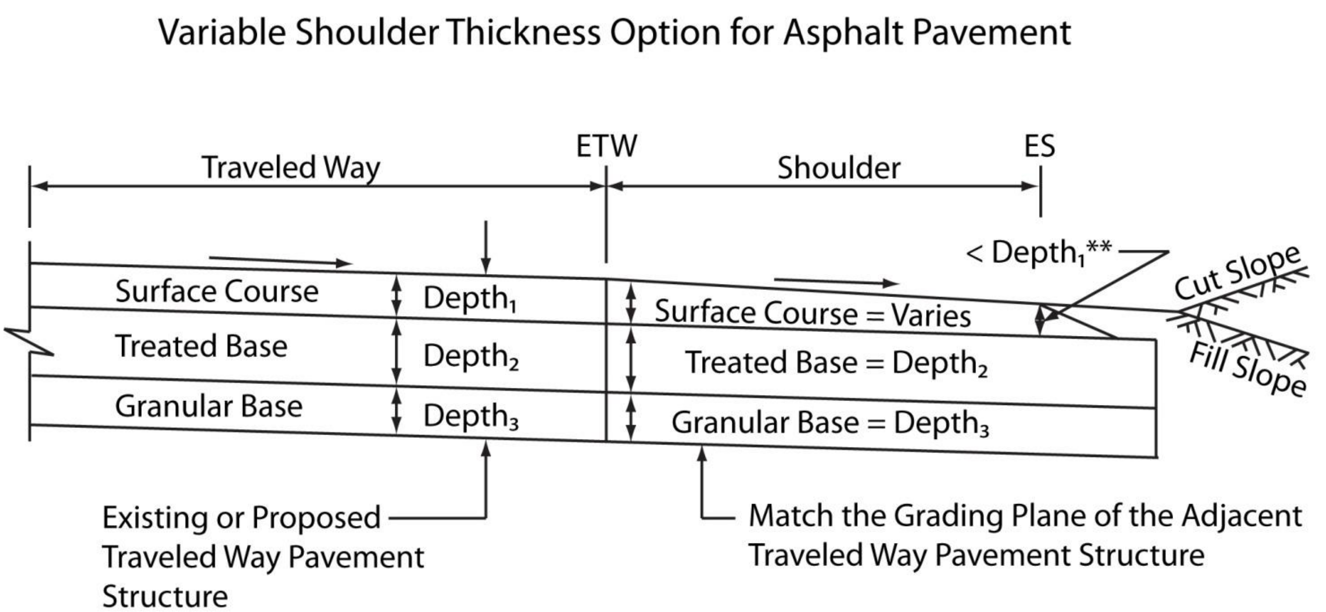
The total depth of the shoulder pavement structure (depth from the surface to the subgrade) shall match the pavement structure grading plane of the adjacent traffic lane.

Matching the total 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 613.4B). 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 traveled way and shoulder can offset any perceived savings from reduced materials.

Figure 613.4A

Shoulder Design for Design Traffic or TI Equal to Adjacent Lane Design Traffic or TI





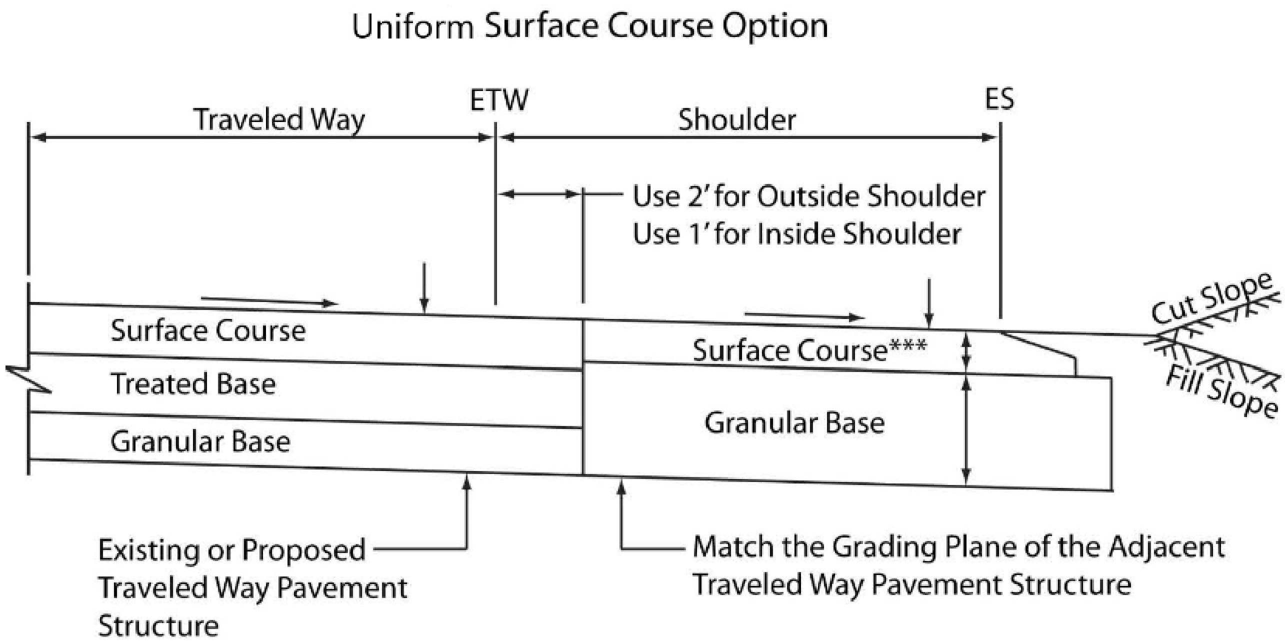
NOTES:

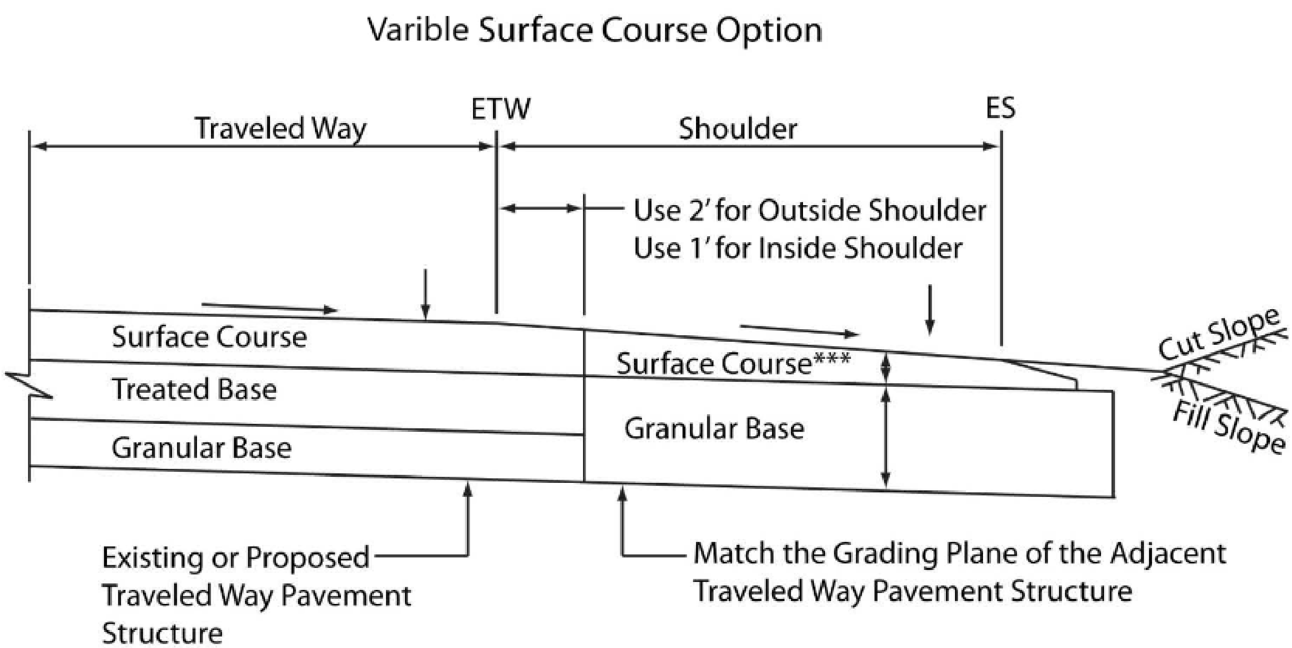
* Applies to concrete and asphalt pavements.

** For asphalt pavement, minimum thickness of surface course ≥ 0.35’.

Figure 613.4B

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





NOTES:

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

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

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

An alternate shoulder design is to taper the surface course from the surface course thickness of the adjacent traffic lane to no less than 0.60 foot (0.75 foot in High Mountain and High Desert climate regions) for concrete and 0.35 foot for asphalt at the edge of shoulder (see Figure 613.4B).

Bases and subbases for new or reconstructed shoulders should extend at least 1 foot from beyond the edge of shoulder as shown in Figures 613.5A 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 613.4(2)(f).

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

(d) Pavement Preservation.

Shoulder preservation should be done in conjunction with work on the adjacent traffic lanes to assure that the shoulder pavement structure will meet the performance requirements stated in Index 613.4(2)(a). Shoulders can be preserved by:

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

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

- Milling and replacing 0.15 foot of oxidized and cracked surfaces can also be considered either prior to an overlay or as a stand-alone action.

- 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 of roadway rehabilitation projects is to maintain existing shoulders wherever possible. The design truck traffic 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 (1.0 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 613.4(2)(b). For temporary traffic detours, see Index 613.4(2)(f) for further discussion.

Regardless of whether or not the design truck traffic 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 613.4(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 are 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 design traffic or 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 613.4(2)(b) except in this case 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 613.4(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 traffic . If curb and gutter are present and any portion of the gutter pan has 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 ME design traffic for intersections (TI or AADTT for flexible and rigid surfaced pavements, respectively) should be determined for each approach the same way 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 ME design traffic 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 613.4(1)(c).

In these cases, combine the traffic of the approaches to calculate the design axle loads in the first year or TI (flexible surfaced) or AADTT (rigid surfaced) for all approaches combined. If the resulting design traffic is greater than what is calculated for the mainline, then the intersection will need to be engineered using the combined design traffic and appropriate axle load spectrum.

(4) Roundabout.

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 ME design traffic estimatefor each quadrant. Choose the quadrant with the highest design traffic 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.
- 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.
- 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..

(5) Roadside Facilities.

The pavement for safety roadside rest areas, including parking lots, should meet or exceed the TI requirements found in Table 613.4B for a 20-year pavement design life for new/reconstructed or rehabilitated pavements.

Table 613.4B

Minimum TIs for Safety Roadside Rest Areas

Facility Usage	Minimum TI (20-Year) for CalME	Minimum First Year AADTT (20-Year) for Rigid Design Catalog or Pavement ME
Truck Ramps & Roads	8.0 (1)	2.9
Truck Parking Areas	6.0 (1)	2.5
Auto Roads	5.5	1.2
Auto Parking Areas	5.0	0.5

NOTE:

(1) For safety roadside rest areas next to all Interstates and those State Routes with AADTT greater than 12,000 use Table 613.4. A medium truck traffic for truck ramps, truck roads, and a minimum TI of 9.0 (CalME) or first year AADTT of 77 (rigid design catalog or Pavement ME) for 20 year designs 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. There can be considerable variation of soil types within project limits.

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 the pavement design has adequate stiffness and strength to carry the predicted traffic loads during the design life. The expansion and/or contraction potential as well as drainage conditions of the subgrade soils should also be properly addressed before a pavement is designed.

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) and plasticity index. Gravels and sands with 5 to 12 percent fines are classified by dual soil properties or symbols. 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. Testing frequency will depend on the probability of soil types changing within the project limits. Consult the Site Investigation Guide for guidance on frequency of soils sampling and testing. The soils investigation includes sampling and testing for soil classification, testing with the dynamic cone penetrometer (DCP), and also includes resilient modulus testing. DCP testing is used to evaluate variability and should be done every 500 ft or more frequently depending on visual observation of variability. Soil sampling should be done every 1,000 ft, or less frequently (minimum of one per mile) based on the variability of soil stiffness and shear strength determined from the DCP results.

614.3 Resilient Modulus, M_r

Use. The mechanistic-empirical method for flexible pavement requires the soil stiffness (as well as other unbound materials such as aggregate bases and subbases) be represented using the resilient modulus (M_r) and rigid pavement requires subgrade reaction (k). The resilient modulus is an input in the Department's CalME flexible pavement design method. The resilient modulus is determined in a laboratory using the triaxial resilient modulus test (AASHTO T 307) or can be roughly estimated from USCS classification results or dynamic cone penetrometer testing using correlation charts in the Site Investigation Guide. Where there is an existing structure, resilient modulus can be determined from the backcalculation procedure using the software program CalBack. Refer to Index 635.3 (ME Method) for additional information. For rigid pavement design the modulus of subgrade reaction (k-value) should be estimated in the Pavement ME software by inputting the AASHTO classification of the soil, which can be determined using the same information (sieve size analysis, Atterberg limits) used to do a USCS classification. The default calculation of k for rigid pavement design based on the AASHTO soil classification should always be used. Resilient modulus data from laboratory testing, backcalculated moduli, or moduli estimated by other means should not be used to estimate k.

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%

CalME Design and Analysis. In the Caltrans ME design and analysis method for flexible pavements, the resilient modulus of subgrade materials must be determined either from soil classification, DCP, back calculation, and/or M_r testing in the laboratory on soil that is typical from each design sub-section within the project. Guidance on sampling and testing to determine resilient modulus is provided in the Site Investigation Guidance document.

Resilient modulus testing in the laboratory should be performed following the AASHTO T 307 test procedure (*Standard Method of Test for Determining the Resilient Modulus of Soils and Aggregate Materials*). Where there is more than one resilient modulus test within a sub-section, the lower value should be used from each design sub-section for input to ME design in addition to more frequent estimates of stiffness from the other methods. Sub-sections are determined from the DCP, classification and FWD data by grouping areas within the project into sub-sections with similar soils properties. Details about the selection of stiffnesses from triaxial testing, and stiffness estimates from USCS classification, DCP testing and back calculation using deflection data for design are described in the Site Investigation Guide. The resilient modulus of standard unbound engineered materials (aggregate bases, aggregate subbases) is obtained from the standard materials library available in CalME and Pavement ME. For subgrade soils, Table 614.3 lists typical resilient modulus ranges and values in pounds per square inch (psi) of subgrade soils based on their classification using the Unified Soils Classification System (see Table 614.2).

614.4 California R-Value

The R-value test used by Caltrans for flexible pavement design for more than 70 years does not give the required stiffness inputs needed for ME design and it is not the preferred method for estimation of stiffness.

Determination of R-value for subgrade is provided in California Test (CT) 301. Typical R-values used by the Department range from 5 for very soft material to 80 for unbound base material.

614.5 Expansive Soils

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

(1) Chemical treatment of expansive soil with lime or other chemical additives to reduce expansion in the presence of water. Lime is often used with highly plastic, fine-grained clay 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 subgrade strength. Selection of chemical treatment and mix design need to be determined based on laboratory testing of the soil and chemical, and not based on past experience on other projects. Swelling potential and the potential for sulfate reactions will also need to be considered during this testing. Further information on soil stabilization is available in the Soil Stabilization Guideline.

Lime stabilized soil is discussed further in Chapter 660.

Table 614.3

Typical Resilient Modulus and Poisson’s Ratios for Subgrade Soils

Subgrade Soil Classification	Resilient Modulus, M_r (ksi) (Range) Average value
CH	(3 to 13) 4
CL	(6 to 13) 9
GC	(13 to 26) 20
GW-GM	(24 to 40)
GP-GM	(19 to 37)
GW-GC	(16 to 37)
GP-GC	(16 to 35)
GM	(16 to 42) 30
GP	(18 to 35) 29
GW	(26 to 42) 38
MH	(3 to 9) 6
ML	(6 to 13) 11
SC	(6 to 16) 14
SW-SM	(13 to 27)
SP-SM	(13 to 27)
SW-SC	(11 to 25)
SP-SC	(11 to 25)
SM	(9 to 26) 21
SP	(9 to 26) 17
SW	(16 to 31) 21

(2) Replacing the expansive material with a non-expansive material (Fill) to a depth where the seasonal moisture content will remain nearly constant.

(3) Providing a pavement structure of sufficient thickness to counteract the expansion pressure. The expansion pressure is the uplift pressure that an expansive soil layer would exert upon swelling due to saturation. The expansion pressure may be determined experimentally in the laboratory or using correlation equations that relate the pressure to a number of geotechnical properties of the soil and other site conditions such as plasticity index, density, and moisture content.

(4) Utilizing two-stage construction by placing a base or subbase to permit the underlying material to consolidate and stabilize before placing leveling and surface courses.

(5) Stabilizing the moisture content by minimizing the access of water through surface and subsurface drainage through correction of inadequate drainage is important to maintain the designed properties of the subgrade. The use of a waterproof membrane (i.e., geomembrane, asphalt saturated fabric, or rubberized asphalt membrane) in addition to drainage improvement can also be considered but is not necessarily a reliable substitute for adequate drainage.

(6) Relocating the project alignment to a more suitable soil condition.

Alternative (5) 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 alternative(s) is/are practical. For further assurance, more than one alternative may be selected (e.g., alternative (1) and alternative (5)).

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 Unified Soil Classification, or M_r-value of the material that is to be excavated from the cut sections of the project. If there is any excavated material that should not be used, it should be identified in the Materials Report and noted in the PS&E.

(2) Imported Borrow. Imported borrow is used in the construction of embankments/fills when sufficient quantity of quality material (M_r >12 ksi or R-value > 20 and Platicity Index (PI) <12) is not available in the cut areas of the project. When imported borrow of desired quality is not economically available or when the entire earthwork consists of borrow, the M_r-value (or R-value) specified for the borrow material becomes the design M_r-value for the pavement project. The minimum M_r-value specified for borrow material should be at least 12 ksi (R-value of 20) and PI < 12 or the M_r for the native soil, whichever is greater. Since no minimum M_r-value is required by the Standard Specifications for imported borrow, a minimum $M_r$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 and specifications.

(3) Compaction. Compaction is densification of the soil by mechanical means. The Standard Specifications require a relative compaction of at least 95 percent per CT 216 or 231 to be obtained between the outer edges of shoulders for the greater depth of either 0.5 foot below the grading plane or 2.5 feet below finished grade. The 95 percent relative

compaction for the depth of 0.5 foot below the grading plane or 2.5 feet below the finished grade 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. Concrete temperature and drying shrinkage differences between the top and bottom of the slab cause stresses from slab curling and warping. 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 primarily based on air temperature and precipitation:

- 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. The 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

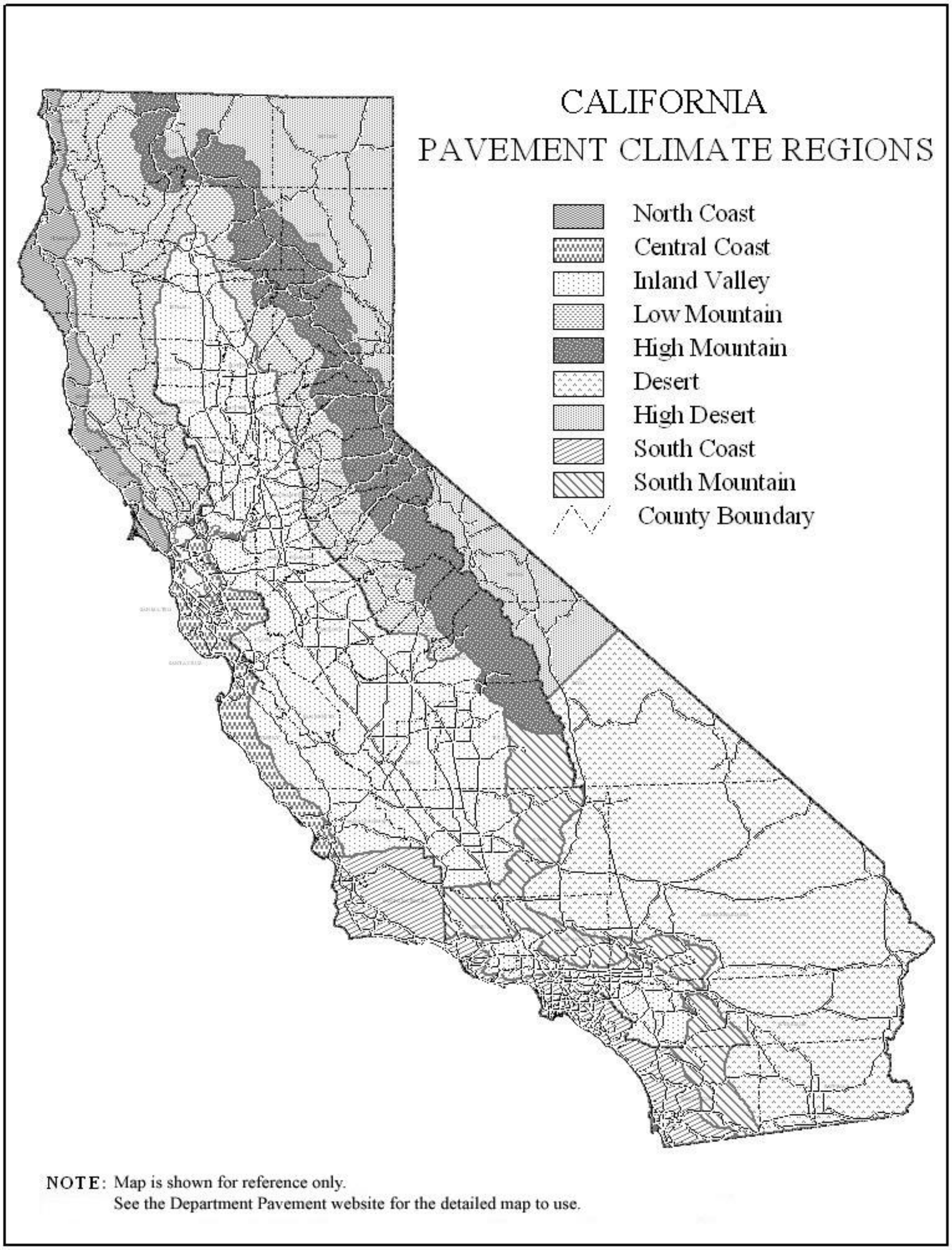
The type and condition of pavement on existing adjacent lanes or facilities should be considered when selecting new pavement structures or rehabilitation/preservation strategies. The selection process and choice made by the engineer is influenced by their experience and knowledge of existing facilities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

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 that may limit the new or rehabilitated pavement structure).

Figure 615.1

Pavement Climate Regions



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. Suitable materials that 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 to be surfaced with a flexible structural surface course. See the In-Place Recycling Guidelines for further information for in-place recycling. The decision to use recycled materials should be made based on a thorough evaluation of material properties, performance experience, benefit/cost analysis, and engineering judgment. In general, recycling can be broadly classified as:

- In-Place Recycling (IPR), either
  - Partial Depth Recycling (PDR) and overlay, which involves recycling of all or part of the HMA
  - Full Depth Reclamation (FDR) (also called Full-Depth Recycling) and overlay, which involves recycling of all the HMA and part of the layers beneath the HMA,
  - Cold Central Plant Recycling (CCPR), which involves recycling all or part of the HMA and can also include recycling material from beneath the HMA in a mobile plant, and
- Reconstruction, either
  - Partial-Depth Reconstruction, where all of the HMA is removed, and part of the base and subbase layers,
  - Full-Depth Reconstruction, where all of the base and subbase layers are removed down to the subgrade; the materials removed can be recycled at the site using central plant recycling (CCPR); the subgrade may be stabilized if necessary

Additional information on use of recycled pavements is available in Index 110.11 and on the Department Pavement website (https://dot.ca.gov/programs/maintenance/pavement/local-agencies/in-place-recycling-main).

617.3 Milling for Structural Changes

The Department has established a minimum remaining HMA depth after milling 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 ensure that the milling machine does not loosen base material and possibly contaminate the recycled material. If the remaining flexible pavement surface course is badly cracked, has extensive moisture damage, or otherwise will not serve as a competent material after milling to 0.15 remaining thickness, it should be fully removed. 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. Inclusion of milled RHMA, open-graded materials and preservation treatments in recycled HMA used in new HMA is allowed and does not need to be separated for inclusion in new HMA.

Topic 618 – Maintainability and Constructability

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 constructability 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 Constructability

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, sufficient access during closures for construction hauling of material into and out of the work zone, construction windows when the project must be completed, adequate work area, and other constructability issues that have the potential of generating contract change orders.

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

- Clearance width of paving machines to barriers and hinge points should be provided for good control of paving operation and smoothness. A minimum of 2.5 feet from limits of paving to temporary K-rail for paving machine and survey control is to be provided Access for delivery trucks and construction equipment. Delivery of consistent material is important for the paving machine to operate at a constant rate to construct smooth and long lasting pavement.
- Public safety and convenience.
- Time and cost of placing multiple thin lifts of different materials as opposed to thicker lifts of a single material. For example, sometimes it is more efficient and less costly to place one thick lift of aggregate base rather than two thin lifts of aggregate base and subbase.
- The impact of combined lifts of different materials on long-term performance or maintenance of the pavement. For example, although it may seem to be a good idea to combine layers of Portland cement concrete and lean concrete base into a single layer to make it easier to construct, combining these layers has a negative impact on the pavement performance and will lead to untimely failure.
- Distance to material batch plant should be taken into consideration. If one is not accessible to the project site, a staging area of no less than 200 by 200 feet should be provided to produce consistent concrete or asphalt mixes and ensure proper moisture levels in aggregate mix as they are essential in creating sound and smooth pavement.
- Maximize lane closure times or utilize detours to provide consistent paving operations. Paving short sections causes more pavement tie-ins and more start-stop operations, both of which create greater potential for pavement roughness and lower durability. In lieu of short duration closures of less than 10 hours, the following traffic handling strategies should be considered for major pavement operations such as widening, rehabilitation, or reconstruction:
    - Extended weekend closures (55-hour, 48-hour, 24-hour, etc.).
    - Median widening to temporarily detour traffic.
    - Diverting some or all traffic to the opposite direction (split roadway) and using movable barriers, if needed, to maintain peak traffic flows.

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

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

Topic 619 – Pavement Life-Cycle

619.1 Life-Cycle Cost Analysis

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

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

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

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

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

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

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. LCCA must be performed and documented in the PID and PA&ED phases. If a change in pavement design is done after the PA&ED, the LCCA must be updated. The Project Engineer is responsible for coordinating all aspects of LCCA and utilizing the information to ensure the most efficient use of transportation funds. Information on how to perform and document LCCA can be found in the LCCA Procedures Manual (https://dot.ca.gov/programs/maintenance/pavement/concrete-pavement-and-pavement-foundations/life-cycle-cost-analysis).

619.2 Life-Cycle Assessment

Life Cycle Assessment (LCA) is an approach to quantify the environmental impacts of industrial products and processes, which has been applied to pavements. The Federal Highway Administration has developed a framework and Caltrans has developed a tool called eLCAP following this framework for LCA for pavements. Using this tool, it is possible to quantify the amount of greenhouse gases (GHGs) emission (in terms of tons of carbon dioxide equivalents) and other environmental impact indicators released during the production of the various materials to be used in pavement construction, transport to the job site, and use of these materials on the project, followed by the maintenance and rehabilitation of these materials, recycling, vehicle-pavement interaction considering the effects of the pavement on fuel use, and end-of-life (i.e., a cradle-to-grave analysis). The tool will be valuable in the decision-making process regarding the selection of pavement type, materials, and rehabilitation strategies and will help the Department achieve its sustainability goals. The tool will complement the LCCA tool RealCost in the final selection of pavement materials and strategies to minimize the greenhouse gas emissions and other environmental impacts associated with pavements.

619.3 Emission Savings Analysis and Table

The Department encourages the use of more sustainable materials and construction technologies. The Emissions Table is a method of quantifying and reporting any potential savings for the Department on a project level basis. Reporting savings will also aid the Department in being accountable for its sustainability goals. When possible, after performing the LCCA and the LCA, any additional savings may be reported in an emissions savings table. The recommended savings that may be reported are as follows:

- GHG Emissions Saved Through Material, Transport, and Construction: Savings would be calculated by comparing the current strategy with conventional materials and strategies. The calculated GHG Emissions may come from the eLCAP software or the GHG Reference Document.
- Material Diverted From Landfill: The amount of recycled material diverted from landfills may be the amount of recycled material used in the project.
- Truck Trips Saved: The eLCAP program assumes an End Dump Truck carrying material to and from the job site with a 34,760-pound capacity. The number of trucks required for the project would be the quantity of material divided by the capacity, rounded up to the

next whole number. The savings may be materials that are reused, such as using RAP or In-Place Recycling.

- Cost Savings: Monetary savings may come from alternate construction practices or materials compared with conventional techniques or from LCCA against the next best strategy.

EFFICIENCY PARAMETERS	
GHG EMISSIONS SAVED THROUGH MATERIAL, TRANSPORT, AND CONSTRUCTION (MT CO_2)	
MATERIAL DIVERTED FROM LANDFILL (TONS)	
TRUCK TRIPS SAVED	
COST SAVINGS ($)	