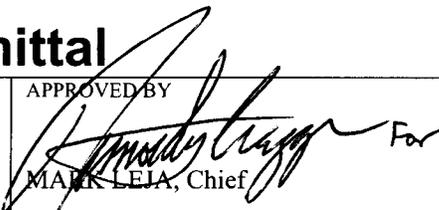


manual change transmittal

TITLE DIVISION OF DESIGN HIGHWAY DESIGN MANUAL FIFTH EDITION - ERRATA TO CHANGE # 6 and CHANGE #7		APPROVED BY  MARK LEJA, Chief	NO. Date Issued: 12/20/04 Page 1 of 2
SUBJECT AREA Table of Contents; List of Figures; List of Tables; Chapters: 100, 200, 300, 600, 820; and, Index	ISSUING UNIT DIVISION OF DESIGN		
SUPERCEDES Table of Contents; List of Figures; List of Tables; Chapters: 100, 200, 300, 600, 820; and, Index – 5 TH EDITION, JULY 1, 2004	DISTRIBUTION ALL HOLDERS OF THE 5TH EDITION, HIGHWAY DESIGN MANUAL		

The California Department of Transportation released Change Number 6 to the Highway Design Manual (HDM), Fifth Edition, on June 1, 2004. Since the release of Change Number 6, some corrections have been identified that need to be made; these errata are identified in the text below. In addition to the errata, a new Index 110.12, Tunnel Safety Orders, as well as extensive revisions to Topic 210, Reinforced Earth Slopes and Earth Retaining Systems, and minor revisions to Chapter 600, Pavement Structural Section, are included in this transmittal as HDM Change Number 7.

As a result of the errata and Change Number 7, the Table of Contents; List of Figures; List of Tables; Chapters: 100, 200, 300, 600, 820; and, the Index of the HDM, Fifth Edition, have been revised. Please replace the affected chapters and sheets in your HDM with the enclosed sheets. These revisions and changes are effective December 20, 2004, and shall be applied to on-going projects in accordance with HDM Index 82.5 – Effective Date for Implementing Revisions to Design Standards.

Please note that all revisions are indicated by a vertical line in the margin adjacent to the paragraph, table, or figure that contains a revision. A summary of the errata and revisions are as follows:

Chapter 100 Basic Design Policies

110.12 Added new index, Tunnel Safety Orders (TSO) to reflect current California Code of Regulations, Title 8, Subchapter 20 – Tunnel Safety Orders. Replaces existing Index 829.8. Figure 110.12 was added to show the boundaries of the three California Mining and Tunneling Districts and contact information for them.

Chapter 200 Geometric Design and Structure Standards

General Note on Chapter 200:

Topic 210, Reinforced Earth Slopes and Earth Retaining Systems was changed to reflect current state-of-the-practice.

Chapter 300 Geometric Cross Section

302.1 Errata: Table 302.1, paved left shoulder for conventional highways, 2-lane RRR, “See Table 307.3” was changed to “See Index 307.3”.

304.1 Relocated the advisory standard text to clarify the intent of the advisory standard.

309.1(3) Errata: Existing sentence of Index 309.1(3)(c) states, “For RRR projects, widths are shown in Table 307.3.”. Table 307.3 was replaced with Design Information Bulletin 79-02 during Change Number 6 and corrected here to indicate in the text.

Chapter 600 Pavement Structural Section

- 601.5(1) Last paragraph, omit the words “new construction”.
- 601.5(2) First sentence, omit the phrase “to satisfy unique project specific conditions or for research purposes”. Revised paragraph to clarify which “special” design projects should be submitted to DOD Office of Pavement Design for approval and what should be included in the submittal.
- 601.5(3) Second paragraph, add “including the Interstate Highway System” after “National Highway System (NHS),”. Minor revision to sub-Index(e). In sub-Index(f), replace “CTC Highway Appearances, Highway Encroachments” with “Resolution of Necessity, Encroachment Exceptions,” among other minor revisions.
- 602.1 Errata: Third paragraph, replace “(Topic 602.4)” with “(Index 602.4)”.
- 602.4 Errata: Correct the existing Traffic Index (TI) equation “ $TI = 9.0 \times (ESAL/106)^{0.119}$ ”, as follows, “ $TI = 9.0 \times (ESAL/10^6)^{0.119}$ ”. Table 602.4B, add note “Table 602.4B is an example only and should not be used for a specific design.”.
- 603.2 Errata: Table 603.2, for TI 8.5-10, change Aggregate Subbase (AS) 105 to 150. Change Note (3) from “place a minimum 25 mm AC” to “place a minimum of 30 mm of AC”. Figure 603.2, Detail ‘A’, change the word “Rumble Strip” to “Rumble Strip”.
- 604.2 Errata: First paragraph, first sentence, change the words “design period” to “pavement service life”.
- 604.2 Added definition for “soft areas”.
- 604.3(8) Errata: Second paragraph, added statement that “designs with a pavement service life greater than 20 years are to be submitted to the Division of Design, Office of Pavement Design for review.”.
- 604.4(1) First paragraph, first sentence, omit the phrases “Where possible” and “TI for the” and begin the sentence with the word “It”. Also replace the word “should” with “structural section”.
- 604.5(1) Mid-paragraph, replace “Such situations, where there may be no cost . . .” with “Situations where there may be no cost . . .”.
- 604.6 Extensive edits to clarify pavement design at various intersection situations.
- 605.3 Add information as to clarify the usefulness of life-cycle cost analysis (LCCA).
- 607.5 Errata: Figures 607.5A and 607.5B, notes corrected to correspond with figures.
- 607.5(3) Sub-index (c), first paragraph, change “Topic 606.3(3)” to “Index 606.3(3)”.
- 607.6 Errata: Figure 607.6A, arrows leading to all four lanes on right side of figure were corrected to point to each center of travel lane.

Chapter 820 Cross Drainage

- 829.8 This index has been completely omitted and replaced with new Index 110.12.

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

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

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

The reuse of AC pavement grindings will normally be consistent with the Fish and Game Code and not require a 1601 Agreement when these materials are placed where they

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

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

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

A Memorandum of Understanding (MOU) dated January 12, 1993, outlines the interim agreement between the DFG and Caltrans regarding the use of asphaltic materials. This MOU provides a working agreement to facilitate Caltrans' continued use of asphaltic materials and avoid potential conflicts with the Fish and Game Code by describing conditions where use of asphalt road

construction material by Caltrans would not conflict with the Fish and Game Code.

Specific Understandings contained in the MOU are:

- **Asphalt Use in Embankments**
Caltrans may use AC chunks and pieces in embankments when these materials are placed where they will not enter the Waters of the State.
- **Use of AC Pavement Grindings as Shoulder Backing**
Caltrans may use AC pavement grindings as shoulder backing when these materials are placed where they will not enter the Waters of the State.
- **Streambed Alteration Agreements**
Caltrans will notify the DFG pursuant to Section 1601 of the Fish and Game Code when a project involving the use of asphaltic materials or crumbled, flaked, or ground pavement will alter or result in the deposition of pavement material into a river, stream, or lake designated by the DFG. When the proposed activity incorporates the agreements reached under Section 1601 of the Fish and Game Code, and is consistent with Section 5650 of the Fish and Game Code and this MOU, the DFG will agree to the use of these materials.

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

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 750 mm or greater diameter or shaft excavations of six meters 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.

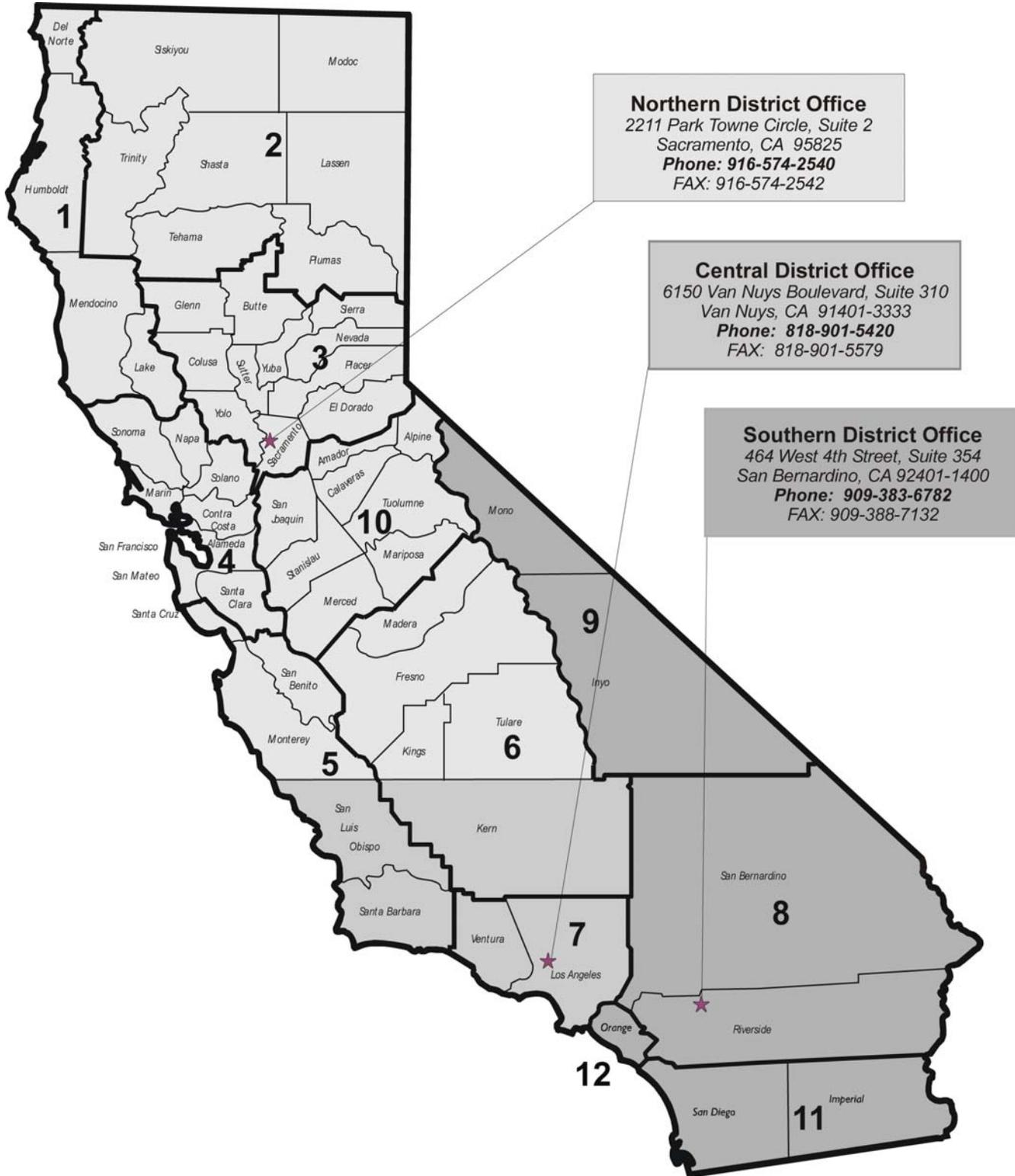
The request must include all pertinent and necessary data to allow the M&T Unit to classify the situation. The data specified under paragraph (a) of Section 8422 (complete text of Section 8422 reprinted below) is typical of new construction projects, however for culvert rehabilitation and other type 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;

Figure 110.12
California Mining and Tunneling Districts



-
- (4) Proximity and identity of existing utilities and abandoned underground tanks.
 - (5) Recommendation from owner, agency, lessee, or their agent relative to the possibility of encountering flammable gas or vapors;
 - (6) The Division may require additional drill hole or other geologic data prior to making gas classifications.
- (b) The Division shall classify all tunnels or portions of tunnels into one of the following classifications:
- (1) Nongassy, which classification shall be applied to tunnels where there is little likelihood of encountering gas during the construction of the tunnel.
 - (2) Potentially gassy, which classification shall be applied to tunnels where there is a possibility flammable gas or hydrocarbons will be encountered.
 - (3) Gassy, which classification shall be applied to tunnels where it is likely gas will be encountered or if a concentration greater than 5 percent of the LEL of:
 - (A) flammable gas has been detected not less than 12 inches (304.8 mm) 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 (304.8 mm) 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.

- (a) Materials investigations and environmental studies of local materials sources should be made to the extent necessary to provide a basis for study and design. Location and capacity of available disposal sites should be determined for all projects requiring disposal of more than 7500 m³ of clean material. Sites for disposal of any significant amount of material in sensitive areas should be considered only where there is no practical alternative.
- (b) Factual information obtained from such investigations should be made readily available to prospective bidders and contractors.
- (c) The responsibility for interpreting such information rests with the contractor and not with the State.
- (d) Generally, the designation of optional material sites or disposal sites will not be included in the special provisions. Mandatory sites must be designated in the special provisions. A disposal site within the highway right of way (not necessarily within the project limits) should be provided when deemed in the best interest of the Department as an alternative to an approved site for disposal of water bearing residues generated by grinding or grooving operations, after approval is obtained from the Regional Water Quality Control Board (RWQCB) having jurisdiction over the area.
- (e) Material agreements or other arrangements should be made with owners of material sites whenever the absence of such arrangements would result in restriction of competition in bidding, or in other instances where it is in the State's interest that such arrangements be made.
- (f) The general policy of Caltrans is to avoid specifying mandatory sources unless data in support of such sources shows certain and substantial savings to the State. Mandatory sources must not be specified on Federal-aid projects except under exceptional circumstances, and prior approval of the FHWA is required. Supporting data in such cases should be submitted as early as possible. This policy also applies to disposal sites.
- (g) It is the policy of Caltrans to cooperate with local authorities to the greatest practicable extent in complying with environmental requirements for all projects. Any corrective measures wanted by the local authorities should be provided through the permit process. Any unusual requirements, conditions, or situations should be submitted to the Division of Design for review (see Indexes 110.2 and 110.3).
- (h) The use of any materials site requires compliance with environmental laws and regulations, which is normally a part of the project environmental documentation. If the need for a site occurs after approval of the project environmental document, a separate determination of environmental requirements for the materials site may be required.
- (i) If the materials site is outside the project limits and exceeds 0.4 ha in size, or extraction will exceed 765 m³, it must comply with the Surface Mining and Reclamation Act of 1975 (SMARA) and be included on the current "AB 3098 List" published by the Department of Conservation before material from that site can be used on a State project. There

are limited exceptions to this requirement and the District Materials Engineer should be consulted.

111.2 Investigation of Local Materials

Sources

- (1) *Extent of Explorations.* Possible sources of materials should be investigated to the extent necessary to assure that the design of each project is based on the most economical use of available materials compatible with good environmental design practices. Where it can be reasonably assumed that all required materials can be most economically obtained from commercial sources on the current "AB 3098 List", it should be unnecessary to investigate other sites. In all other cases material sites should be investigated. Exploration of materials sources should not be restricted to those properties where the owner expresses willingness to enter into agreement with the State. Unless it is definitely known that the owner will under no circumstances permit removal of materials, the site should be considered as a possible source of local materials.
- (2) *Geotechnical Design Report or Materials Report.* The Geotechnical Design Report or Materials Report should include complete information on all sites investigated and should discuss the quality, cost, SMARA status, and availability of materials from commercial plants on the current "AB 3098 List". Sufficient sampling of sites must be performed to indicate the character of the material and the elevation of the ground water surface, and to determine changes in the character of the material, both laterally and vertically. Sampling must be done in such a manner that individual samples can be taken from each horizon or layer. Composite samples of two or more different types of material are unsatisfactory, as there is no assurance that the materials would be so combined if the materials source were actually used. Testing of blends of two or more types of materials is permissible, provided the test report clearly indicates the combination tested. The test report must clearly indicate the

location of the sample and the depth represented. The fact that materials sites are not designated in the Special Provisions does not reduce the importance of thorough exploration and testing.

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

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

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

It will be necessary for each District to maintain a filing system such that all preliminary test reports for potential materials sites are readily accessible. This will necessitate preparation of test reports covering

all preliminary tests of materials. It will also be essential to maintain some type of materials inventory system, whereby sites in the vicinity of any project can be readily identified and the test reports can be immediately accessible. Filing only by numerical or chronological order will not be permissible.

111.3 Materials Information Furnished to Prospective Bidders

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

- (a) A cover page entitled, "Materials Information", should show District, County, Route, kilometer post limits, and geographical limits. There should be a note stating where the records, from which the information was compiled, may be inspected. Also, an index, listing investigated material sites, and disposal sites, maps, test reports, tabulation sheets, SMARA status, and agreements is to be shown on the cover page.
- (b) A vicinity map showing the location of investigated materials sites and disposal sites in relation to the project.
- (c) A map of each material site showing the location and identification of boring or test pits.
- (d) A tabulation of the test data for each material site, showing complete information on the location, depth, and processing of each sample tested, together with all test results.
- (e) Copies of all options or agreements with owners of the material sites, if such arrangements have been made.
- (f) Soil survey sheets or suitable terrain maps showing borings and tests along the highway alignment.

- (g) A tabulation of which sites comply with environmental laws and regulations and are included on the current "AB 3098 List".
- (h) Material site grading and reclamation plan and disposal site grading plans, if they have been prepared.
- (i) Copies of local use permits and clearances (when they have been obtained by the State) such as environmental clearances, mining permits, Forest Service Fire Regulations, water quality control clearances, etc. If documents are of unusual length, a statement should be included that they have been obtained and are available for inspection at the District office or Sacramento Plans Counter.

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

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

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

111.4 Materials Arrangements

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

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

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

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

111.5 Procedures for Acquisition of Material Sites and Disposal Sites

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

(1) *General Procedure.*

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

- The project or projects on which the site is to be used and programming of proposed construction.
- The location and description of the property, zoning, and site restoration/reclamation proposals including necessary vicinity and site maps.
- The amount and quality of material estimated to be available in the site and amount needed for the project or projects, or amount of excess material to be disposed of and the capacity of the site or sites.
- An economic analysis using the estimated purchase price and value of land after removal of material or deposit of excess material. The total estimated savings over other possible alternatives must be clearly demonstrated. Alternatives must be shown from the standpoint of what would

have to be done if the site was not purchased. Alternatives could be changes in location or grade as well as alternative sources of material.

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

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

- (b) If the project or projects are to have Federal aid, the District will prepare a request, with supporting environmental clearance, for FHWA approval to specify the source as mandatory. One copy of this request should be sent to the Office Engineer and one copy to Division of Design.
- (c) If the estimated purchase price is over \$300,000, the District should include the item in the STIP and corresponding budget.
- (d) When the proposed purchase has been approved, the Project Engineer should notify the District Division of Right of Way, District Environmental Division and the District Materials Unit and request that Right of Way purchase the site (or obtain a Materials Agreement; the Materials Unit should assist in the development of the agreement) and the Environmental Division obtain environmental authorization to proceed.

- (e) The District must include the cost of purchase in the proper fiscal year program and/or budget as part of the District targets.
 - (f) After budgeting, the District must submit an expenditure authorization to cover purchase of the site. This could be concurrent if the project is added to the budget during a fiscal year. The expenditure authorization request should be processed through the District Project Management and Administration Units and obtain District Director approval.
 - (g) After issuance of an expenditure authorization, the District Division of Right of Way will complete purchase of the site.
- (2) *Material and Disposal Sites in Federal Lands.* The applicable sections of the Federal Highway Act of 1958 for procurement of borrow or disposal sites, Sections 107(d) and 317, are set forth in Section 8.18.02.00 of the Right of Way Manual; Section 107(d) applies to the Interstate System while Section 317 applies to other Federal-aid highways. Whenever Federal public lands are required for a material or a disposal site, and after preliminary negotiations at the local level with the Federal agency having jurisdiction, the District must submit a letter report to the FHWA. This report should observe the requirements of Index 111.5 of this manual and Section 8.18.02.03 of the Right of Way Manual.

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

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

The contract provisions must not specify a mandatory site for the disposal of surplus excavated materials unless a particular site is needed for environmental reasons or the site is found to be the most economical for one or more

Federal-aid projects. All points listed in Index 111.5(1)(a) and (b) must be covered and one copy of all attachments submitted. Supporting data must be submitted to the FHWA during the project planning phase or early in the project design phase as almost all cases of mandatory sites must go to the FHWA for decision.

Section 635.407 of 23 CFR 635D states in part:

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

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

Topic 112 - Contractor's Yard and Plant Sites

112.1 Policy

The Project Engineer should, during the design phase of a project, consider the need and availability of sites for the contractor's yards and materials plants. This is particularly important in areas where dust, noise, and access problems could limit the contractor in obtaining sites on their own in a timely manner. Asphalt concrete recycling projects pose special problems of material storage, access, and plant location; see Index 110.11. Temporary storage areas should be considered for grooving and grinding projects. As a general rule, the use of material sites designated in the Special Provisions should be optional. Should the materials site be desired, the contractor shall provide notice to the Resident Engineer within a designated time period after approval of the contract (30 days would be a minimum, but not

more than 60 days except in unusual situations). All environmental requirements must be satisfied and local permits must be obtained prior to submittal of the PS&E. Right of Way, Permits, and Environmental units must be informed early in the process. The contractor will be allowed to use these sites only for work on the designated project(s).

112.2 Locating a Site

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

Topic 113 - Geotechnical Design Report

113.1 Policy

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

113.2 Content

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

113.3 Submittal and Review

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

Topic 114 - Materials Report

114.1 Policy

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

114.2 Content

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

114.3 Submittal and Review

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

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

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

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

Topic 209 – (currently not in use)

Topic 210 - Reinforced Earth Slopes and Earth Retaining Systems

210.1 Introduction

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

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

210.2 Construction Methods and Types

(1) *Construction Methods.*

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

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

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

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

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

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

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

Reinforced earth slopes incorporate metallic or non-metallic reinforcement in construction of embankments and cut slopes with a slope angle flatter than 70 degrees from the horizontal plane. Reinforced earth slopes should be used in conjunction with erosion mitigation measures to minimize future maintenance costs. The slope face is typically

Table 210.2
Types of Reinforced Earth Slopes and Earth Retaining Systems⁽¹⁾

EARTH RETAINING SYSTEM	Construction Method ⁽²⁾	PS&E By	Typical Facing Material	Recommended Maximum Vertical Height, m	Ability to Tolerate Differential Settlement ⁽³⁾
Reinforced Earth Slopes					
Reinforced Embankments	BU	District PE	Vegetation/Soil	50.0	E
Rock/Soil Anchors	TD	District PE	Soil/Rock	40.0	E
State Designed Earth Retaining Systems with Standard Plans					
Concrete Cantilever Wall, Type 1, 1A & 2	BU	District PE	Concrete	10.9,3.6,6.7 ⁽⁴⁾	P
Concrete Counterfort Wall, Type 3 & 4	BU	District PE	Concrete	10.9,9.1 ⁽⁴⁾	P
Concrete L-Type Cantilever Wall, Type 5	BU	District PE	Concrete	3.6 ⁽⁴⁾	P
Concrete Masonry Wall, Type 6	BU	District PE	Masonry	1.8 ⁽⁴⁾	P
Crib Wall: Concrete, Steel or Timber	BU	District PE	Concrete, Steel, Timber	16.1,10.9,6.0 ⁽⁴⁾	P
State Designed Earth Retaining Systems Which Require Special Designs					
Standard Plan Walls with modified wall geometry, foundations or loading conditions	BU	Structure PE	Concrete, Steel, Timber	16.0	P-F
Non-Gravity Cantilevered Walls					
Sheet Pile Wall	TD	Structure PE	Steel	6.0	F
Soldier Pile Wall with Lagging	TD/BU	Structure PE	Concrete, Steel, Timber	6.0	F-G
Tangent Soldier Pile Wall	TD/BU	Structure PE	Concrete	9.0	F
Secant Soldier Pile Wall	TD	Structure PE	Concrete	9.0	F
Slurry Diaphragm Wall	TD	Structure PE	Concrete, Shotcrete	24 ⁽⁵⁾	F
Deep Soil Mixing Wall	TD	Structure PE	Shotcrete	24 ⁽⁵⁾	F-G
Anchored Wall (Structural or Ground Anchors)	TD	Structure PE	Concrete, Steel, Timber	24 ⁽⁶⁾	F-G
Gravity Walls					
Concrete Gravity Wall	BU	Structure PE	Concrete	1.8	P
Rock Gravity Wall	BU	District PE	Rock	4.0	E
Gabion Basket Wall	BU	District PE	Wire & Rock	8.0	E
Soil Reinforcement Systems					
Mechanically Stabilized Embankment	BU	Structure PE	Concrete	15.2	G
Salvaged Material Retaining Wall	BU	District PE	Steel, Timber	5.0	G
Soil Nail Wall	TD	Structure PE	Concrete, Shotcrete	25.0	F
Tire Anchored Timber Wall	BU	District PE	Timber	10.0	G
Proprietary Earth Retaining Systems (Pre-approved)					
The list of Pre-approved systems is available at the website shown in Index 210.2(3)(c).					
Proprietary Earth Retaining Systems (Pending)					
These systems are under review by DES-SD. For more information, see Index 210.2(3)(d).					
Experimental State Designed Earth Retaining Systems					
Geosynthetic Reinforced Walls	BU	Structure PE/ District PE	Concrete Blocks, Steel, Vegetation, Fabric	20.0	E
Mortarless Concrete Blocks Gravity Walls	BU	District PE	Concrete Blocks	2.5	P
Notes:	1. Comparative cost data is available from DES-SD.		4. Maximum Design Height		
	2. BU = Bottom Up; TD = Top Down		5. Anchors may be required		
	3. E = Excellent; G = Good; F = Fair; P = Poor		6. With lagging		

erosion protected with the use of systems such as geo-synthetics, bio-stabilization, rock slope protection, or reinforced concrete facing.

(3) *Earth Retaining Systems*

Earth retaining systems can be divided into five major categories depending upon the nature of the design and whether they are designed by the owner (State designed), a Proprietary vendor or a combination thereof. The term “State designed” as referenced herein is utilized to encompass earth retaining systems that are designed by the State or by Local or Private entities on behalf of the State. No assignment of roles and responsibilities is intended. The five categories are as follows:

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

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

- Retaining Wall Types 1, 1A and 2 (Concrete Cantilever). These walls have design heights up to 10.9 m, 3.6 m and 6.7 m, respectively, but are most economical below 6.0 m. Concrete cantilever walls can accommodate traffic barriers, and drainage facilities efficiently. See Standard Plans B3-1, B3-2, B3-3, B3-4, B3-8 and B3-9 for further details.
- Retaining Wall Types 3 and 4 (Concrete Counterfort). These walls have design heights up to 10.9 m and 9.1 m respectively. These walls may be used where minimum horizontal wall deflection is desired. When used in conjunction with concrete cantilever walls, there should be an offset in the plane of the wall faces to mask the difference in deflection between the two wall types. The cost of these walls is generally more than for concrete cantilever walls of similar height. See Standard Plans B3-5 and B3-6 for further details.
- Retaining Wall Type 5 (Concrete L-Type Cantilever). This wall has a design height up to 3.6 m. Although more costly than cantilever walls, these walls may be required where site restrictions do not allow for a footing projection beyond the face of the wall stem. See Standard Plan B3-7 for further details.
- Retaining Wall Type 6 (Concrete Masonry Walls). These walls may be used where the design height of the wall does not exceed 1.8 m. These walls are generally less costly than all other standard design walls or gravity walls. Where traffic is adjacent to the top of the wall, guardrail should be set back as noted in the Standard Plans. See Standard Plan B3-11 for further details.
- Crib Walls. The following types are available:
 - Concrete Crib Wall - This type of crib wall may be used for design heights up to 16.1 m. Concrete crib walls are suited to coastal areas and higher elevations where salt air and deicing salts may limit the service life of other types of crib walls. See Standard Plans C7A to C7G for further details.

Steel Crib Wall - This type of crib wall may be used for design heights up to 10.9 m. Steel crib walls are light in weight; easily transported and installed; and, therefore, suited for relatively inaccessible installations and for emergency repairs. See Standard Plans C8A to C8C for further details.

Timber Crib Wall - This type of crib wall may be used for design heights up to 6.0 m. Timber crib walls have a rustic appearance which makes them suitable for use in rural environments. When all of the wood members are pressure preservative treated, the service life of timber crib walls is comparable to that of concrete or steel crib walls. See Standard Plans C9A and C9B for further details.

Timber and concrete crib walls constructed on horizontal alignments with curves or angle points require special details, particularly when the wall face is battered. Because crib wall faces can be climbed, they are not recommended for use in urban locations where they may be accessible to the public.

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

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

Some special design earth retaining systems are as follows:

- Standard Plan Walls (PS&E by Structure PE). The design loadings, heights, and types of walls in the Standard Plans cover frequent applications for earth retaining systems. However, special designs are necessary if the imposed loading exceeds that shown on the Standard Plan. Railroad live loads; building surcharge; loads imposed by sign structures, electroliers, or noise barriers are examples of loading conditions that will require special designs. Foundation conditions that require pile support for the wall and angle points in the wall geometry necessitate a special design.
- Non-Gravity Cantilevered Walls (PS&E by Structure PE). These walls include sheet pile walls, soldier pile walls with lagging, tangent soldier pile walls, secant soldier pile walls, slurry diaphragm walls, and deep soil mixing walls. These walls are most practical in cut sections and are best suited for situations where excavation for a retaining wall with a footing is impractical because of traffic, utilities, existing buildings, or R/W restrictions. In embankment sections, a non-gravity cantilevered wall is a practical solution for a roadway widening where design heights are less than 4.6 m. They are also practical for slip-out corrections. Non-gravity cantilevered walls can consist of concrete, steel, timber, or cemented soil piles that may be either driven into place or placed in drilled holes and trenches.
- Anchored Walls (PS&E by Structure PE). These walls are typically composed of the same elements as non-gravity cantilevered walls, but derive additional lateral resistance from ground anchors (tiebacks), concrete anchors, or pile anchors. These anchors are located behind the potential failure surfaces in the retained soil and are connected to the wall structurally. The method of support and anchorage depends on site conditions, design height, and loading imposed. The cost of these walls is variable depending on earth retaining

requirements, site geology, aesthetic consideration, and site restraints, but is generally higher than “Standard Design Walls” for the same wall geometry and loading conditions. Anchored walls may be used to stabilize an unstable site provided that adequate material exists at the site for the anchors. Economical wall heights up to 24.0 m are feasible.

- Gravity Wall Systems that require special designs are Concrete Gravity, Rock Gravity, and Gabion Basket Walls.

Concrete Gravity Walls (PS&E by Structure PE). Concrete gravity walls are most economical at design heights below 1.2 m. However, they may be constructed at heights up to 1.8 m. These walls can be used in connection with a cantilever wall if long lengths of wall with design heights of less than 1.2 m are required. A Type 50C concrete barrier, see Standard Plans, can serve as a gravity retaining wall at locations where the differential height between the adjoining roadway grades is equal to or less than 0.9 m.

Rock Gravity Walls (PS&E by District PE). Rock gravity walls consist of rocks that are 50 to 1000 kg, stacked on top of each other at slight batter. These walls are typically used in areas where a rock appearance is desirable for aesthetic reasons. Wall heights range from 0.5 to 4.0 m, but are most economical for heights less than 3.0 m.

Gabion Basket Walls (PS&E by District PE). Gabion basket walls use compartmented units filled with stones and can be constructed up to 8.0 m in height. Each unit is a rectangular basket made of galvanized steel wire. The stone fill is 102 to 405 mm in size. Gabion basket walls are typically used for soil and stream bank stabilization. Service life of the gabion

basket wall is highly dependent on the environment in which they are placed. Corrosion, abrasion, rock impact, fire and vandalism are examples of site-specific factors that would influence the service life of the wall and should be taken into consideration by the District PE during the design of the project. See Standard Plans D100A and D100B for further details.

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

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

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

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

Special details are required when drainage structures, overhead sign supports or noise barriers on piles are within the reinforced soil mass. Concrete traffic barriers require a

special design support slab when used at the top of the facing of these systems. These systems cannot be used where site restrictions do not allow necessary excavation or placement of the soil reinforcing elements.

Soil reinforcement systems that require special design are as follows:

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

When the bottom-up construction method is possible and other conditions permit their use, these systems are generally the most economical choice for wall heights greater than 6.0 m. They may also be the most economical system for wall heights in the 3.0 m to 6.0 m range, depending on the specific project requirements.

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

Steel elements used in this method are sized to provide sacrificial steel to compensate for anticipated corrosion; and may be galvanized to provide additional protection.

- Salvaged Material Retaining Wall (PS&E by District PE). This system utilizes C-channel sections as soil reinforcement. Galvanized metal beam guardrail, timber posts or concrete panels are used as facing elements. Often these materials can be salvaged

from projects. The District Recycle Coordinator should be consulted as to the availability of salvaged materials.

- Soil Nail Wall (PS&E by Structure PE). This system reinforces either the original ground or an existing embankment during the excavation process. Soil nailing is always accomplished from the top-down in stages that are typically 1.2 m to 1.8 m in height. After each stage of excavation, corrosion protected soil reinforcing elements, "soil nails", are placed and grouted into holes which have been drilled at angles into the in situ material. The face of each stage of excavation is protected by a layer of reinforced shotcrete. After the full height of wall has been excavated and reinforced, a finish layer of concrete facing is placed either by the shotcreting method or by casting within a face form.

When top-down construction is possible and conditions permit its use, soil nail wall systems are generally the most economical choice for wall heights greater than 3.0 m. Wall heights in excess of 25.0 m are feasible in specific locations.

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

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

- Recycled Tire Anchor Timber (TAT) Walls (PS&E by District PE). This system utilizes steel bars with recycled tire sidewalls attached by cross bars as soil reinforcing elements. The facing elements are treated timber. TAT walls have a rustic appearance, which makes them suitable in rural environments. The length of commercially available timber post generally controls the height of wall but heights up to 10.0 m are feasible.

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

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

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

(d) Proprietary Earth Retaining Systems (Pending).

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

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

(e) Experimental State Designed Earth Retaining Systems.

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

Some earth retaining systems which are currently considered experimental follow:

- Geo-synthetic Reinforced Walls (PS&E by District PE). These systems utilize geo-synthetic material as the soil reinforcing elements. The face of these walls can be left exposed if the geo-synthetic material has been treated to prevent decay from ultra-violet rays. Concrete panels, mortarless masonry, tar emulsion, or air blown mortar may be used as facing materials or the face may be seeded if a more aesthetic

treatment is preferred. Design is by DES-GS.

- Mortarless Concrete Block Gravity Walls (PS&E by District PE). These wall types consist of vertically stacked, dry cast, concrete blocks. This system utilizes the friction and shear developed between the blocks and the combined weight of the blocks to retain the backfill. Some of these walls have been used as erosion protection at abutments and on embankments. They can be used as an aesthetic treatment for geo-synthetic material reinforced walls. All of these walls require a batter. Design is by the DES-GS.

210.3 Alternative Earth Retaining Systems (AERS)

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

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

The AERS procedure requires the involvement of the District PE, DES-SD, and the DES-GS. The District PE should submit pertinent site information (site plans, typical sections, etc.) to DES-GS for a

feasibility study as early as possible in the project development process.

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

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

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

210.4 Cost Reduction Incentive Proposals (CRIP)

Sometimes Contractors submit proposals for an earth retaining system under Section 5-1.14 of the Standard Specifications, “Cost Reduction Incentive.” The Contractor proposed system may modify or replace the earth retaining system permitted by the contract. The CRIP process allows vendors of proprietary earth retaining systems an alternative method for having their systems used prior to obtaining “pre-approval” (see Index 210.2(c)). CRIP submittals are administered

by the Resident Engineer. However, Contract Change Orders are not to be processed until the CRIP is approved by Headquarters Construction with review assistance provided by the District or Structure PE as appropriate.

210.5 Aesthetic Consideration

The profile of the top of wall should be designed to be as pleasing as the site conditions permit. All changes in the slope at the top of cast-in-place concrete walls should be rounded with vertical curves at least 6.0 m in length. Abrupt changes in the top of the wall profile should be avoided by using vertical curves, slopes, steps, or combinations thereof. Side slopes may be flattened or other adjustments made to provide a pleasing profile.

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

The wall area between the grade line and 1.8 m above it shall be free of any designed indentations or protrusions that may snag errant vehicles

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

210.6 Safety Railing, Fences, and Concrete Barriers

Cable railing shall be installed for employee protection in areas where employees may work adjacent to and above vertical faces of retaining walls, wingwalls, abutments, etc. where the vertical fall is 1.2 m or more.

If cable railing is required on a wall which is less than 1.4 m tall and that wall is located within the clear recovery zone, then the cable railing should be placed behind the wall. See Standard Plan B11-47 for details of cable railing.

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

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

Retaining walls joining right of way fences should be a minimum of 1.8 m clear height.

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

210.7 Design Responsibility

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

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

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

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

210.8 Guidelines for Type Selection and Plan Preparation

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

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

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

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

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

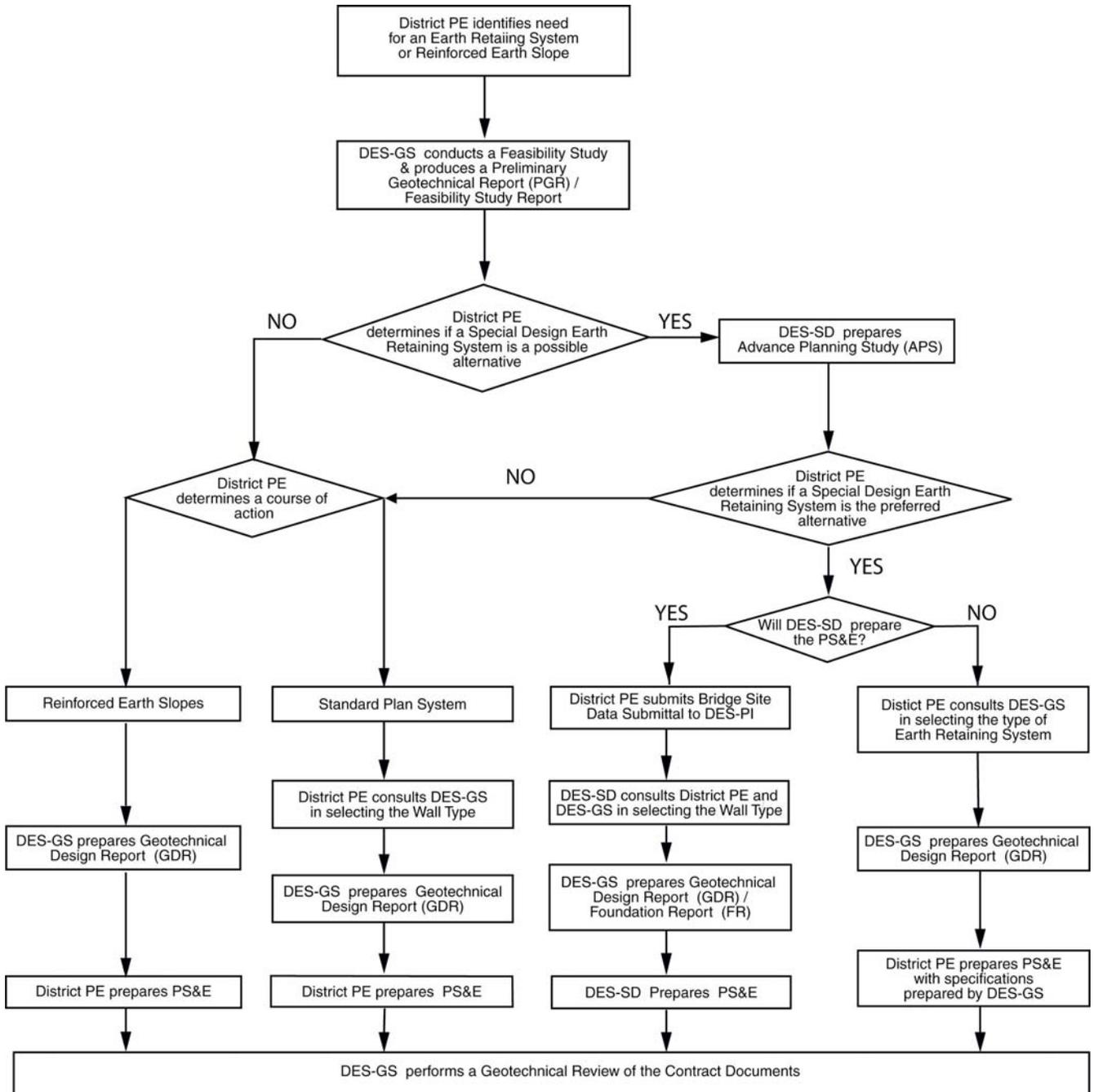
All appropriate State designed and proprietary earth retaining systems should be considered for inclusion in the contract documents to promote competitive bidding, which can result in cost savings.

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

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

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

Figure 210.8
Type Selection and PS&E Process for Reinforced Earth Slopes
and Earth Retaining Systems



- (b) Footing Steps. For economy and ease of construction of wall Types 1 through 6, the following criteria should be used for layout of footing steps.
- Distance between steps should be in multiples of 2.4 m.
 - A minimum number of steps should be used even if a slightly higher wall is necessary. Small steps, less than 0.3 m in height, should be avoided unless the distance between steps is 29.2 m or more. The maximum height of steps should be held to 1.2 m. If the footing thickness changes between steps, the bottom of footing elevation should be adjusted so that the top of footing remains at the same elevation.
- (c) Sloping Footings. The following criteria should be used for layout of sloping footings.
- The maximum permissible slope for reinforced concrete retaining walls is 3%. Maximum footing slope for masonry walls is 2%.
 - When sloping footings are used, form and joint lines are permitted to be perpendicular and parallel to the footing for ease of construction.
 - In cases where vertical electroliers or fence posts are required on top of a wall, the form and joint lines must also be vertical. A sloping footing should not be used in this situation since efficiency of construction would be lost.
 - Sloping footing grades should be constant for the entire length of the wall. Breaks in footing grade will complicate forming and result in loss of economy. If breaks in footing grade are necessary, a level stepped footing should be used for the entire wall.
- When the top of wall profile of crib walls is constant for the entire length, the bottom of wall profile may be sloped to avoid steps in the top of wall. In this case, all steps to compensate for changes of wall height and original ground profile would be made in the bottom of wall. The maximum permissible slope is 6%. If vertical electroliers or fence posts are required on top of the wall, the crib wall should not be sloped. Sloping crib walls are permissible with guard railing with vertical posts.
- (d) Wall Joints. General details for required wall joints on wall Types 1, 1A, 2, and 5 are shown on Standard Plan B0-3. Expansion joints, Bridge Detail 3-3, should be shown at maximum intervals of 29.2 m. Shorter spaces should be in multiples of 2.4 m. Expansion joints generally should be placed near angle points in the wall alignment. When concrete barriers are used on top of retaining walls, the waterstop in the expansion joint must be extended 150 mm into the barrier. This detail should be shown or noted on the wall plans. Weakened plane joints, Bridge Detail 3-2, should be shown at nearly equal spaces between joints.
- (e) Drainage. Gutters should be used behind walls in areas where it is necessary to carry off surface water or to prevent scour. Low points in wall vertical alignment or areas between return walls must be drained by downspouts passing through the walls. Standard Plan B3-9 shows typical drainage details. Special design of surface water drainage facilities may be necessary depending on the amount of surface water anticipated. Where ground water is likely to occur in any quantity, special provisions must be made to intercept the flow to prevent inundation of the backfill and unsightly continuous flow through weep holes.

- (f) Quantities. When the AERS procedure is not utilized, quantities for each wall item of work are usually developed for payment. The quantities for concrete, expansion joint waterstop, structure excavation, structure backfill, pervious backfill material, concrete barrier or railing, and gutter concrete must also be tabulated. Quantities should be tabulated on the plans for each wall.
- (4) *Soil Reinforcement Systems.* The following guidelines should be used to prepare the contract plans for soil reinforcement systems:
- (a) Leveling Pads. Most soil reinforcement systems do not require extensive foundation preparation. It may be necessary, however, to design a concrete leveling pad on which to construct the face elements. A reinforced concrete leveling pad will be required in areas prone to consolidation or frost disturbance.
- Steps in the leveling pad should be the same height as the height of the facing elements or thickness of the soil layer between the soil reinforcement.
 - Distance between steps in the leveling pad should be in increments equivalent to the length of individual facing elements.
 - A minimum number of steps should be used even if a slightly higher wall is necessary.
- (b) Drainage. Gutters should be used behind walls in areas where it is necessary to carry off surface water or to prevent scour. Low points in wall vertical alignment or areas between return walls must be drained by downspouts passing through the walls. Special design of surface water drainage facilities will be necessary and should be prepared by DES-SD. Where ground water is likely to occur in any quantity, special provisions must be made to intercept the flow to prevent inundation of the backfill.
- (c) Quantities. When the AERS procedure is not utilized, quantities for each item of work are usually developed for payment. Bid items must include, but not be limited to: excavation and backfill for the embedment depth, soil reinforcement, facing elements, and concrete for leveling pad construction. Additional bid items for inclusion are any drainage system, pervious backfill, concrete barrier, railings, and concrete gutters. Quantities should be tabulated on the plans for each wall.
- (5) *Earth Retaining Systems.* The following miscellaneous details are applicable to all earth retaining systems:
- (a) Utilities. Provisions must be made to relocate or otherwise accommodate utilities conflicting with the retaining wall. A utility opening for a Type 1 wall is shown on Standard Plan B3-9. Any other utility openings will require special design details and should be reviewed by DES-SD.
- (b) Electroliers and Signs. Details for mounting electroliers and signs on earth retaining systems are designed by DES-SD. Requests for preparation of details should be made at least 3 months in advance of the PS&E submittal to District Officer Engineer date. To accommodate the base plates for overhead signs, a local enlargement may affect the horizontal clearance to both the edge of pavement and the right of way line. This type of enlargement should be considered at the time of establishing the wall layout and a need for a Mandatory Design Exception determined. For mounting details, furnish DES-SD a complete cross section of the roadway at the sign and the layout and profile of the earth retaining system.
- (c) Fence and Railing Post Pockets. Post pocket details shown for cable railing in the Standard Plans may also be used for mounting chain link fence on top of retaining walls. Special details may be necessary to accommodate the reinforcement in soil reinforcement systems.

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

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

CHAPTER 300 GEOMETRIC CROSS SECTION

Topic 301 - Traveled Way Standards

Index 301.1 - Traveled Way Width

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

301.2 Cross Slopes

- (1) *General.* The purpose of sloping on roadway cross sections is to provide a mechanism to direct water (usually from precipitation) off the traveled way. Undesirable accumulations of water can lead to hydroplaning or other problems which can increase accident potential. See Topics 831 and 833 for hydroplaning considerations.
- (2) *Standards.*
 - (a) **The standard cross slope to be used for new construction on the traveled way for all types of surfaces shall be 2%.**
 - (b) **For resurfacing or widening when necessary to match existing cross slopes, the minimum shall be 1.5% and the maximum shall be 3 percent.** However, the cross slope on 2-lane and multilane AC highways should be increased to 2% if the cost is reasonable.
 - (c) **On unpaved roadway surfaces, including gravel and penetration treated earth, the cross slope shall be 2.5% to 5.0%.**

On undivided highways with two or more lanes in a normal tangent section, the high point of the crown

should be centered on the pavement and the pavement sloped toward the edges on a uniform grade.

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

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

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

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

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

Topic 302 - Shoulder Standards

302.1 Width

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

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

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

Table 302.1
Standards for Paved
Shoulder Width

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

NOTES:

- (1) Total number of lanes in both directions including separate roadways (see Index 305.6). If a lane is added to one side of a 4-lane facility (such as a truck climbing lane) then that side shall have 3.0 m left and right shoulders. See Index 62.1.
- (2) May be reduced to 0.6 m. 1.2 m preferred in urban areas and/or when ramp is metered. See Index 504.3.
- (3) In restrictive situations, may be reduced to 0.6 m or 1.2 m (preferred in urban areas) in the 2-lane section of a non-metered ramp which transitions from a single lane. May be reduced to 0.6 m in ramp sections having 3 or more lanes. See Index 504.3.
- (4) For posted speeds less than 60 km/h, shoulder may be omitted (see Index 303.5(5)) except where drainage flows toward the curbed median.
- (5) On right side of climbing or passing lane section only. See Index 1003.2 if bike lanes are present.
- (6) 3.0 m shoulders preferred.
- (7) Where parking is allowed, 3.0 m to 3.6 m shoulders preferred.
- (8) Shoulders adjacent to abutment walls, retaining walls in cut locations, and noise barriers shall be 3.0 m.

shown on Figure 307.4. Local curb standards should be used when requested by local authorities for roads and streets that will be relinquished to them.

Topic 304 - Side Slopes

304.1 Side Slope Standards

Slopes should be designed as flat as is reasonable. For new construction, widening, or where slopes are otherwise being modified, embankment (fill) slopes should be 1:4 or flatter. Factors affecting slope design are as follows:

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

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

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

Embankment slopes steeper than 1:3 are considered non-recoverable and non-traversable. District Traffic, Chapter 7 of the Traffic Manual, and the AASHTO "Roadside Design Guide" should be consulted for methods of determining the preferred treatment.

Regardless of slope steepness, it is desirable to round the top of slopes so an encroaching vehicle remains in contact with the ground. Likewise, the toe of

slopes should be rounded to prevent vehicles from nosing into the ground.

- (b) *Erosion Control.* Slope designs steeper than 1:4 must be approved by the District Landscape Architect in order to assure compliance with the regulations affecting Stormwater Pollution contained in the Federal Clean Water Act (see Index 82.4). Slope steepness and length are two of the most important factors affecting the erodability of a slope. Slopes should be designed as flat as possible to prevent erosion. However, since there are other factors such as soil type, climate, and exposure to the sun, District Landscape Architecture and the District Stormwater Coordinator must be contacted for erosion control requirements.
- (c) *Structural Integrity.* Slopes steeper than 1:2 require approval of District Maintenance. The Geotechnical Design Report (See Topic 113) will recommend a minimum slope required to prevent slope failure due to soil cohesiveness, loading, slip planes and other global stability type failures. There are other important issues found in the Geotechnical Design Report affecting slope design such as the consistency of the soil likely to be exposed in cuts, identification of the presence of ground water, and recommendations for rock fall.
- (d) *Economics.* Economic factors such as purchasing right of way, imported borrow, and environmental impacts frequently play a role in the decision of slope length and steepness. In some cases, the cost of stabilizing, planting, and maintaining steep slopes may exceed the cost of additional grading and right of way to provide a flatter slope.
- (e) *Aesthetics.* Flat, smooth, well transitioned slopes are visually more satisfying than steep, obvious cuts and fills. In addition, flatter slopes are more easily revegetated, which provides for a more scenic landscape. Contact District Landscape

Architecture when preparing a contour grading plan.

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

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

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

304.2 Clearance From Slope to Right of Way Line

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

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

- (a) 6 m for cuts from 10 m to 15 m high.
- (b) 7.5 m for cuts from 15 m to 25 m high.
- (c) One-third the cut height for cuts above 25 m, but not to exceed a width of 15 m.

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

304.3 Slope Benches and Cut Widening

The necessity for benches, their width, and vertical spacing should be finalized only after an adequate materials investigation. Since greater traffic benefits are realized from widening a cut than from benching the slope, benches above grade should be used only where necessary. Benches above grade should be used for such purposes as installation of

horizontal drains, control of surface erosion, or intercepting falling rocks. Design of the bench should be compatible with the geotechnical features of the site.

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

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

Cut widening may be necessary:

- (a) To provide for drainage along the toe of the slope.
- (b) To intercept and store loose material resulting from slides, rock fall, and erosion.
- (c) For snow storage in special cases.
- (d) To allow for planting.

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

304.4 Contour Grading and Slope Rounding

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

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

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

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

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

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

- (a) Fixed objects should be eliminated or moved outside the clear recovery zone to a location where they are unlikely to be hit.
- (b) If sign posts 150 mm or more in any dimension or light standards cannot be eliminated or moved outside the clear recovery zone, they should be made yielding with a breakaway feature.
- (c) If a fixed object cannot be eliminated, moved outside the clear recovery zone, or modified to be made yielding, it should be shielded by guardrail or a crash cushion.

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

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

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

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

- (a) **The minimum horizontal clearance to fixed objects, such as bridge rails and safety-shaped concrete barriers, on all freeway and expressway facilities, including auxiliary lanes, ramps, and collector roads, shall be equal to the standard shoulder width of the highway facility as stated in Table 302.1. A minimum clearance of 1.2 m shall be provided where the standard shoulder width is less than 1.2 m.** Approach rail connections to bridge rail may require special treatment to maintain the standard shoulder width.
- (b) **The minimum horizontal clearance to walls, such as abutment walls, retaining walls in cut locations, and noise barriers on all freeway and expressway facilities, including auxiliary lanes, ramps and collector roads, shall not be less than 3.0 m.**
- (c) **On two-lane highways, frontage roads, city streets and county roads (all without curbs), the minimum horizontal clearance shall be the standard shoulder width as listed in Tables 302.1 and 307.2, except that a minimum clearance of 1.2 m shall be provided where the standard shoulder width is less than 1.2 m.** For RRR projects, widths are provided in DIB 79-02.

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

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

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

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

309.2 Vertical Clearances

(1) Major Structures.

- (a) Freeways and Expressways, All construction except overlay projects -- **5.1 m shall be the minimum vertical clearance over the roadbed of the State facility (e.g., main lanes, shoulders, ramps, collector-distributor roads, speed change lanes, etc.).**
- (b) Freeways and Expressways, Overlay Projects -- **4.9 m shall be the minimum vertical clearance over the roadbed of the State facility.**
- (c) Conventional Highways, Parkways, and Local Facilities, All Projects -- **4.6 m shall be the minimum vertical clearance over the traveled way and 4.5 m shall be the minimum vertical clearance over**

the shoulders of all portions of the roadbed.

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

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

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

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

structural section, final rehabilitation strategy, and pavement design details; and clearly conveys this information on the project plans and specifications for a Contractor to bid and build the project.

- (2) *District Materials Engineer (DME)* - Responsible for Materials information, when requested, for each project; prepares the Materials Report for each project; provides recommendations to and in continuous consultation with the Project Engineer and Resident Engineer throughout planning, design, and construction; coordinates Materials information with Caltrans functional units, Material Engineering and Testing Services (METS), Headquarters functional units, local agencies, industry, and consultants.
- (3) *Pavement Program Steering Committee (PPSC)* - Provides leadership and commitment to assure safe, effective, and environmentally sensitive highway pavement structural sections that improve mobility across California. Responsible for assuring structural section pavement initiatives, policies, and standards that reflect departmental goals; provides clear direction and priorities on pavement structural section initiatives; implements pavement structural section policies, standards, and specifications. Members include Headquarters Division Chiefs and some District Directors.
- (4) *Pavement Standards Team (PST)* - Multifunctional group consisting of METS, Design, Construction, Maintenance, Research and Innovation, Office Engineer, and selected District Materials Engineer representatives; provides structural section related policies, procedures, and practices to ensure quality of structural section features regarding design, construction, maintenance, and rehabilitation; develops and maintains structural section standards, specifications, and procedures; provides recommendations to the PPSC; approves nonstandard specifications. The chairperson of this team is the single focal point of contact for pavement related issues.

- (5) *Materials Engineering and Testing Services (METS)* - A subdivision of the Division of Engineering Services, METS is responsible for conducting standard and specialized laboratory and field testing, inspections, giving expert advice on all phases of transportation engineering involving materials and manufactured products; provides technical expertise for the development of statewide standards, guidelines, and procedure manuals; works closely with the District Materials Engineers and Resident Engineers to investigate ongoing field problems and/or disputes.
- (6) *Division of Design (DOD)* - Responsible for statewide consistency in the project design process. The Office of State Pavement Design (OSPD) is part of the DOD. OSPD is responsible for communicating and maintaining pavement structural section design standards, policies, procedures, and practices that are used statewide.

601.4 Research and Experimentation

Research and experimentation are continuing in order to provide improved design methods and standards, which take advantage of new technology, materials, and methods. Submittal of new ideas by Headquarters and District staff, especially those involved in the design, construction, maintenance, and materials engineering of the structural section, is encouraged. Suggested research should be sent to the Division of Research and Innovation in Sacramento. The Pavement Standards Team must approve experimental construction features before completing the final design phase of a project (refer to Index 601.5(2)). District Maintenance should also be engaged in the discussion involving experimental construction features.

Suggestions for research studies and changes in design standards may also be submitted to the Pavement Standards Team (PST).

601.5 Record Keeping

The following are instructions for the retention of pavement structural section design information:

(1) *Selection of Pavement Type.* One complete copy of the documentation for the type of pavement approved by the District Director should be retained in permanent District Project History files as well as subsequent updates of construction changes to the structural section. The documentation must contain the design period, R-values of the basement soil, the R-value(s) selected for the structural section(s) design, and the lane traffic index (TI) for each design. In addition, it must include the data required by the instructions set forth under Topic 605 for selection of pavement type, including a life-cycle cost analysis.

A life-cycle cost analysis should be completed for pavement type selection on projects with $TI \geq 10$ unless the pavement type is dictated by specific project conditions as discussed in Index 601.2.

(2) *“Special” Designs.* “Special” designs must be fully justified and submitted to DOD Office of Pavement Design for approval. “Special” designs are defined as those designs which involve products or strategies that meet any of the following:

- Reduce the structural sections to less than what is determined by the standards and procedures of this manual and the Flexible Rehabilitation Manual.
- Utilize experimental products or procedures (such as mechanistic-empirical design method) not covered in the design tables or methods found in this manual and accompanying technical guidance.

Submittals may be sent either electronically or with hard copies. Hard copy submittals must be in duplicate. Include the proposed structural section design(s) and a location strip map (project title sheet is acceptable). The letter of transmittal should include the design period (including both the construction year and design year), the R-value(s) of the basement soil(s), the R-value(s) selected for the structural section(s) design, the lane TI for

each structural section, and justification for the “special” design(s). DOD will act as the Headquarters focal point to obtain concurrence, as required, of PST representatives prior to DOD granting approval of the “special” designs.

(3) *Proprietary Items.* The use of new materials, methods, or products may involve specifying a patented or brand name method, material, or product. The use of proprietary items is discouraged in the interest of promoting competitive bidding.

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

- (a) There is no other known material of equal or better quality that will perform the same function, or
- (b) There are overwhelming reasons for using the material or product in the public’s interest, which may or may not include savings, or
- (c) It is essential for synchronization with existing highway or adjoining facilities, or

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

In addition to the RTL Guide requirements, the FHWA requires that the following information be documented when a proprietary item is specified in the design of a pavement structural section:

- (a) If it must be constructed on or immediately adjacent to an existing facility: year the existing facility was constructed and the original structural section details,
- (b) Traffic data (Average Daily Traffic (ADT), Peak Hour Flow, Annual Average Daily Truck Traffic (AADTT), TI),
- (c) Accident data,
- (d) Construction cost of the project,
- (e) When FHWA oversight is required per the stewardship agreement, name of FHWA representative who reviewed the proposed project, and
- (f) Tentative advertising schedule.

If the proprietary item is to be used experimentally and there is Federal participation, the request for FHWA approval must be submitted to the Chief, Office of 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.

Technical assistance is available from the Pavement Standards Team to assist with designs that utilize new materials, methods, and products. When no standard specification or standard special provision exists for the proprietary item, the Pavement Standards

Team must review and concur with the special provision. For further information see the Specifications section of the Pavement web site <http://www.dot.ca.gov/hq/oppd/pavement/specs.htm>

- (4) *Subsequent Revisions.* Any subsequent changes in structural sections must be documented and processed in accordance with the appropriate instructions stated above and with proper reference to the original design.

601.6 Other Resources

The following resources provide additional information on pavement design. Much of this information can be found on the Pavement website at <http://www.dot.ca.gov/hq/oppd/pavement/index.htm>.

- (1) *Standard Plans.* Generally, these are collections of commonly used design details intended to provide consistency for Contractors and designers in defining the scope of work for projects and assist in the biddability of the project contract plans.
- (2) *Standard Specifications and Standard Special Provisions.* The Standard Specifications provide material descriptions, materials quality and workmanship requirements, contract administration terms and definitions, and measurement and payment clauses for items entering the project. The Standard Special Provisions are additional specification standards used to modify the Standard Specifications for those items entering the project and include descriptions, quality requirements, and measurement and payment.
- (3) *Pavement Technical Guidance.* Pavement Technical Guidance is a collection of supplemental guidance and manuals regarding pavement design which is intended to assist designers, materials engineers, specialists, construction oversight personnel, and maintenance workers in making informed decisions on pavement structural section issues. Information includes, but is not limited to, aids for assistance in decision making, rigid and flexible pavement structural section rehabilitation strategies, and guidelines for the use of various products and materials. These Technical Guidance documents may be

accessed on the Pavement website at: <http://www.dot.ca.gov/hq/oppd/pavement/guidance.htm>.

- (4) *The AASHTO "Guide for Design of Pavement Structures."* The AASHTO "Guide for Design of Pavement Structures," although not adopted by Caltrans, is a comprehensive reference guide that provides background that is helpful to those involved in design of pavement structural sections. This reference is on file in the Division of Design and a copy should be available in each District. Design procedures included in the AASHTO Guide are used by FHWA to check the adequacy of the specific structural sections adopted for Caltrans projects, as well as the procedures and standards included in Chapter 600 of this manual. The AASHTO Guide was developed by a team of nationally recognized pavement structural section design experts with detailed input from several states, including California.
- (5) *Supplemental District Guidance.* Some Districts have developed additional structural section guidance to address local issues. Such guidance only supplements and does not replace the Headquarters guidance found in this manual, the Pavement Technical Guidance, the standard plans, specifications, and special provisions. Supplemental District Guidance can be obtained by contacting the District Materials Engineer.

Topic 602 – Pavement Service Life and Traffic Data

602.1 Introduction

This topic discusses the factors to be considered and procedures to be followed in developing an estimate of traffic loading for design of the "pavement structure" or the structural section for specific projects.

Pavement structural sections are designed to carry the projected truck traffic expected to occur during the pavement service life. This truck traffic is the primary factor affecting pavement life. Passenger cars, pickups, and two-axle trucks are considered to be negligible.

Truck traffic information that is required for structural section design includes axle loads, axle configurations, and number of applications. A mixed truck traffic stream of different axle loads and axle configurations are converted to an equivalent number of 80 kN axle loads for the design life. Finally, this sum is converted to a Traffic Index or TI (Index 602.4), which is used to select a standard portland cement concrete pavement structural section (Topic 603) or design an asphalt concrete pavement structural section (Topic 604).

Because of the complexity involved in developing travel forecasts, Districts typically have established a unit specifically responsible for providing travel forecasting information. These units are responsible for developing traffic projections (including trucks and equivalent single axle loads) for the planning and designing of State highways. The District Office Chief responsible for travel forecasting should notify the Headquarters Office of Travel Forecasting and Analysis (OTFA) in the Division of Transportation Systems Information if there is a significant difference between the traffic used to determine ESAL's and the traffic forecast by the regional agency in urban areas. The notification should include the reasons for the deviation so that OTFA may offer recommendations or provide consultation relative to the chosen methodology.

602.2 Pavement Service Life

Pavement Service Life is the period of time that a newly constructed or rehabilitated pavement structural section is designed to perform before reaching its terminal serviceability or a condition that requires major rehabilitation or reconstruction; this is also referred to as the performance period. The selected pavement service life varies depending on the characteristics of the highway facility, the objective of the project, and the severity of traffic. The strategy or structural section selected for any project needs to provide the minimum pavement service life that meets the objective of the project as described below.

On resurfacing projects, the entire paved shoulder and traveled way shall be resurfaced. Not only does this help provide a smoother finished surface, it also benefits bicyclists and pedestrians when they are allowed to use the shoulder.

- (1) *Capital Preventive Maintenance (CAP-M) Projects.* **The pavement service life for CAP-M projects shall be a minimum of 5 years to meet FHWA funding criteria.** CAP-M guidelines are available by contacting Headquarters Maintenance, Pavement Maintenance Managers. Additional information and guidance may be found in the Project Development Procedures Manual (PDPM) Appendix H at the following website address: <http://www.dot.ca.gov/hq/oppd/pdpm/pdpm.htm>.
- (2) *Pavement Rehabilitation Projects.* **The minimum pavement service life for rehabilitation projects shall be at least 10 years.** Longer service lives of 15, 20, and even 30 years may be more appropriate when the cost of the additional work is only incrementally higher. A Life-cycle Cost Analysis (LCCA) can be an effective tool in determining the most cost effective service life. LCCA is discussed further in Index 605.3. A pavement service life longer than 10 years needs concurrence from the District Maintenance Engineer and the Headquarters Rehabilitation Program Manager. For corridors with at least a current Annual Average Daily Traffic (AADT) of 150 000 or Annual Average Daily Truck Traffic (AADTT) of 15 000, it is recommended that a minimum pavement service life of 30-40 years be used.
- (3) *New Construction and Reconstruction.* **The minimum pavement service life must be no less than the project design period (see Index 103.2) or 20 years, whichever is greater. Where a project will meet either of the following criteria, the minimum pavement service life shall be 40 years:**
- The projected AADT 20 years after completion of construction equals or exceeds 150 000.
 - The projected AADTT will equal or exceed 15 000 trucks 20 years after the completion of construction.

The development of a 30 or 40 year TI may be difficult. District Transportation Planning and/or Traffic Operations should be involved

in determining a realistic and appropriate TI. Refer to Index 62.7 for the definition of new construction and reconstruction.

- (4) *Widening.* Additional consideration is needed when determining the service life for pavement widening. Factors to consider include the remaining service life of the existing pavement, planned future projects, and future corridor plans for any additional lane widening and shoulders. **At a minimum, the pavement service life for widenings shall match the adjacent roadway's pavement service life, but not be less than the pavement service life required for new construction and reconstruction as noted in Index 602.2(3).** See Index 604.4 for shoulder design considerations if future roadway widening is a potential. An economic analysis is recommended to assist in project decisions.

To minimize traffic handling, it may be advantageous to combine a widening project with needed rehabilitation. For example, grinding the adjoining PCC lane next to the proposed widening can improve constructability and provide a smoother pavement surface for the widening. The Project Development Procedures Manual Chapter 8, Section 7 provides additional guidance on widening adjacent to existing facilities.

- (5) *Temporary Pavements and Detours.* During construction, lane detours should be designed to accommodate the anticipated traffic during construction. This period of time may be several years and it is important to determine the traffic index based on the truck traffic the pavement will actually experience.

602.3 Truck Traffic Projection

- (1) *Mainline Traffic.* Considerable judgment is required to develop realistic traffic volume projections.

Truck traffic volume and loading projections on State Highways can come from weigh-in-motion (WIM) stations, the Vehicle Classification Program, and the Truck Weight Studies. Traffic and truck volume projections

and loading can be obtained from District Traffic or Planning.

The Division of Design uses information from the Truck Weight Study to develop 80 kilonewton (kN) Equivalent Single Axle Load (ESAL) constants that represent the estimated total accumulated ESAL, for each of the four axle configurations, during the design service life. The current 10-, 20-, and 40-year ESAL Constants are shown in Table 602.3A.

**Table 602.3A
ESAL Constants**

Vehicle Type	10-year Constants	20-year Constants	40-year + Constants
2-axle trucks	690	1380	2760
3-axle trucks	1840	3680	7360
4-axle trucks	2940	5880	11 760
5-axle trucks or more	6890	13 780	27 560

The ESAL constants are used as multipliers of the expanded AADTT to determine the total design period ESAL's and in turn the TI. The ESAL's and the resulting TI are the same magnitude for both AC and PCC pavement design alternatives.

The distribution of truck traffic by lanes must be considered in the structural section design for all multilane facilities. Truck traffic is generally lightest in the median lanes and heaviest in the outside lanes. Because of the uncertainties and the variability of lane distribution of trucks, lane distribution factors have been established for design purposes as shown in Table 602.3B.

**Table 602.3B
Lane Distribution Factors
for Multilane Roads**

Number of Lanes in One Direction	Factors to be Applied to Expanded Average Daily Trucks			
	Lane 1	Lane 2	Lane 3	Lane 4
One	1.0	-	-	-
Two	1.0	1.0	-	-
Three	0.2	0.8	0.8	-
Four	0.2	0.2	0.8	0.8

NOTES:

1. Lane 1 is next to the centerline or median.
2. For more than four lanes in one direction, use a factor of 0.8 for the outer two lanes and any auxiliary/collector lanes and a factor of 0.2 for all other lanes.

Finally, an expansion factor is developed for each axle classification. In its simplest form, the expansion is a straight-line projection of the AADTT data. When using the straight-line projection the data is projected to find the AADTT at the middle of the design period, thus representing the average AADTT for each axle classification for the design period. The expanded AADTT, for each axle classification, is multiplied by the appropriate lane distribution factor (fraction of the total AADTT) to arrive at the expanded AADTT for the lane. The lane AADTT is multiplied by the design period ESAL constant for each corresponding axle classification. Finally, the summation of these totals equals the total one-way ESAL's for the lane, which is converted into the TI for the lane (See Table 602.4B Example).

When other than a straight-line projection of available truck traffic data is used for design purposes, the procedure to be followed in developing traffic projections will vary. It will be dependent on a coordinated effort of the District's Planning and Traffic Divisions working closely with the Regional Agencies.

- (2) *Shoulder Traffic.* See Index 603.4 and 604.4 for PCC and AC shoulder design respectively.
- (3) *Ramp Traffic.* Estimating future truck traffic on ramps is more difficult than on through traffic lanes. The relative effect of the commercial and industrial development in an area is much greater on ramp truck traffic than it is on mainline truck traffic.

As an alternative to estimating and projecting an AADTT to determine the ramp TI, ramps may be classified and designed as follows:

- (a) *Light Traffic Ramps* - Ramps serving undeveloped and residential areas with light to no truck traffic should be designed for a TI of 8.0.
- (b) *Medium Traffic Ramps* - Ramps in metropolitan areas, business districts, or where increased truck traffic is quite likely to develop because of anticipated commercial development within the design period should be designed for a TI of 10.0.
- (c) *Heavy Traffic Ramps* - Ramps that serve weigh stations, industrial areas, truck terminals, and/or maritime shipping facilities should be designed for a TI of 12.0 for a pavement service life of 20 years or less and 14.0 for a pavement service life of greater than 20 years.

When ramps are widened to handle truck offtracking, the full structural section, based on the ramp TI, should be extended to the inner edge of the required widening, see 504.3(1)(b).

- (4) *Auxiliary Lane Traffic.* Because of structural section drainage considerations, the auxiliary lane structural section should perpetuate any drainage layer of the existing adjacent lane.
- (5) *Freeway-to-Freeway Connectors.* TI's for connectors should be determined the same way as for mainline traffic.

602.4 Traffic Index

The Traffic Index or TI is a measure of the number of ESAL's expected in the design lane over the design period. The TI does not vary linearly with the ESAL's but rather according to the following

exponential formula and as illustrated in Table 602.4A.

$$TI = 9.0 \times (ESAL/10^6)^{0.119}$$

Where:

TI = Traffic Index

ESAL = Total number of 80 kN Equivalent Single Axle Loads

Table 602.4B illustrates the determination of the TI for outside and median lanes of an 8-lane freeway. The expanded AADTT and the TI's shown in Table 602.4B are not intended to be used in the design for a specific project.

Topic 603 - Portland Cement Concrete Pavement Structural Section Design

603.1 Introduction

Portland cement concrete (PCC) pavement, or rigid pavement, should be considered as a potential alternative for all state highway facilities. PCC pavement should always be considered on Interstate and other interregional freeways. Standard structural sections are included herein for a range from very high to relatively low volumes of traffic. Truck traffic and soil conditions are the principal factors considered in selecting the structural section, however life-cycle economics and other pertinent or overriding factors may ultimately determine the pavement type to be used on any given project.

603.2 Design Procedure for Rigid Pavement

(1) Tie Bars and Dowel Bars.

New or reconstructed PCC pavements shall be doweled and tied except as noted below:

- Interior lane replacements (lanes not adjacent to a shoulder) should be undoweled if all adjacent lanes are undoweled.
- PCC shoulders being placed or reconstructed next to an undoweled PCC lane can be undoweled.
- PCC pavement should not be tied to adjacent PCC pavement with tie bars when the spacing of transverse joints of adjacent slabs is not the same.

Table 602.4A
Conversion of ESAL to Traffic Index

ESAL	TI*	ESAL	TI*	ESAL	TI*
48	3.0	164 000	7.5	9 490 000	12.0
194	3.5	288 000	8.0	13 500 000	12.5
646	4.0	487 000	8.5	18 900 000	13.0
1850	4.5	798 000	9.0	26 100 000	13.5
4710	5.0	1 270 000	9.5	35 600 000	14.0
10 900	5.5	1 980 000	10.0	48 100 000	14.5
23 500	6.0	3 020 000	10.5	64 300 000	15.0
47 300	6.5	4 500 000	11.0	84 700 000	15.5
89 800	7.0	6 600 000	11.5	112 000 000	
164 000		9 490 000			

*NOTE:

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

Table 602.4B
Example Determination of the 20 Year Traffic Index
for an 8-lane Freeway

(1) Vehicle Type	(2) ESAL 20 Year Constants	Outside Lanes		Median Lanes	
		(3) Expanded Annual Average Daily Truck Traffic	(4) Total 20 Year ESAL (Col.2 x Col.3)	(5) Expanded Annual Average Daily Truck Traffic	(6) Total 20 Year ESAL (Col.2 x Col.5)
2-axle trucks	1380	935	1 290 300	235	324 300
3-axle trucks	3680	550	2 024 000	140	515 200
4-axle trucks	5880	225	1 323 000	55	323 400
5-axle or more	13 780	1025	14 124 500	255	3 513 900
Totals	----	----	18 761 800	----	4 676 800
Traffic Index (TI) for 20 Year Design, From Table 602.4A = 12.5				11.0	

NOTE: Table 602.4B is an example only and should not be used for a specific design.

- No more than 15 m width of PCC should be tied together with tie bars to preclude random cracks from occurring due to the pavement acting as one large PCC slab.

For slab replacements, the placement of dowel bars and tie bars should be determined on a project by project basis based on proposed service life, construction work windows, existence of dowel bars and tie bars in adjacent slabs, condition of adjacent slabs, and other pertinent factors. Further information on slab replacement design, see “Slab Replacement Guides” and companion documents on the Pavement website <http://www.dot.ca.gov/hq/oppd/pavement/guidance.htm>.

Dowel bars are smooth round bars that act as a load transfer device across a pavement joint. Tie bars are deformed bars or connectors that are used to hold the faces of abutting PCC slabs in contact. PCC shoulders used with PCC pavement are to be tied to the adjacent lane with tie bars, see Figure 603.2. Further details regarding dowel bars and tie bars can be found in the Standard Plans and Pavement Technical Guidance on the Pavement website.

(2) *Structural Section Thickness.*

Standard structural section thicknesses shown in Table 603.2 should be used in the design for new, widening, and reconstruction projects. Structural section element thicknesses vary with Traffic Index (TI) and R-value of the basement soil material. Procedures for developing the TI are described in Topic 602. The R-Value for the basement soil to be used is contained in the project Materials Report or available from the District Materials Engineer. With an expansive basement soil (Plasticity Index > 12) and/or basement soil R-value < 10, an asphalt concrete, or flexible pavement, structural section should be specified. If based on engineering analysis, the R-value of the basement soil can be raised above 10 by treatment, to a minimum depth of 200 mm, with an approved stabilizing agent such as lime, cement, asphalt, or fly ash, PCC pavement can be specified.

The final selection of which of the five bases, as shown in Table 603.2, should be used on a given project depends on specific factors relative to the available materials, terrain, environmental conditions, and past performance of PCC pavement under similar project or area conditions. When the TI is greater than 10, only lean concrete base or asphalt concrete base is allowed, except on widening projects where existing pavement structural sections having treated permeable base, the treated permeable base should be perpetuated along the same plane. Questions on selection of base material for rehabilitation projects may be directed to the Office of Pavement Rehabilitation in METS. Questions concerning structural section features for new construction and reconstruction projects may be directed to the Division of Design. Consultation with the District Materials Engineer should be an ongoing process for the project. The Office of Rigid Pavement Materials and Structural Concrete is also available to provide forensic studies and project specific consultation.

(3) *Drainage.*

Structural sections should be designed to promote free drainage whenever possible. Alternative designs are provided, as shown in Figure 606.2. Incorporation of a treated permeable base daylighting to the edge of embankment may be considered; otherwise, an edge drain collector and outlet system may provide positive drainage of the structural section. The climatic region of the project site should be a factor in selection of a drainable or dense base layer under the PCC pavement. A dense non-erodible base (lean concrete base or asphalt concrete base) may also be considered with or without an edge drain collector and outlet system as discussed in Topic 606.

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

Table 603.2
PCC Pavement Structural Section Thickness Guidelines (mm)⁴

TI	Basement Soil R-value 10-40					
	PCC ¹ Pavement	Base ³ (LCB, ACB)	Aggregate Subbase (AS)	Treated Permeable Base (ATPB, CTPB)	Aggregate Base (AB)	Aggregate Subbase (AS)
8 or less	205	105	120	105	105	105
8.5-10	215	105	150	105	105	105
10.5-12	230	120	185	--	--	--
12.5-13.5	270 ²	150	215	--	--	--
14+	300 ²	150	215	--	--	--
TI	Basement Soil R-value > 40					
	PCC ¹ Pavement	Base ³ (LCB, ACB)	Aggregate Subbase (AS)	Treated Permeable Base (ATPB, CTPB)	Aggregate Base (AB)	Aggregate Subbase (AS)
8 or less	205	105	--	105	105	--
8.5-10	215	120	--	105	120	--
10.5-12	230	120	--	--	--	--
12.5-13.5	270 ²	150	--	--	--	--
14+	300 ²	150	--	--	--	--

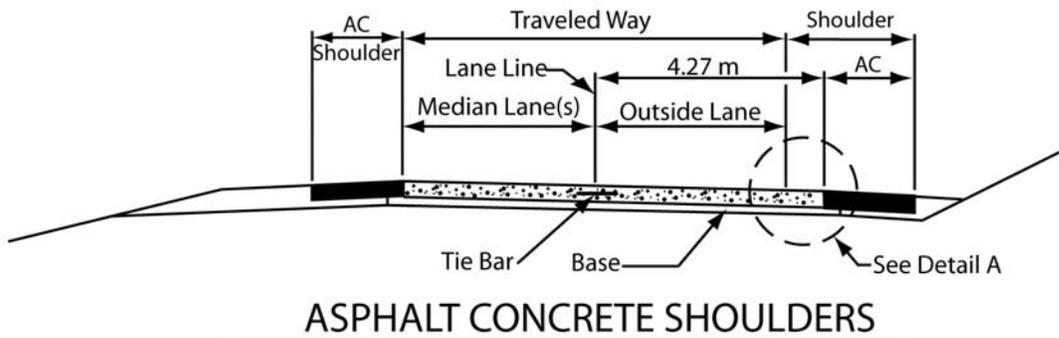
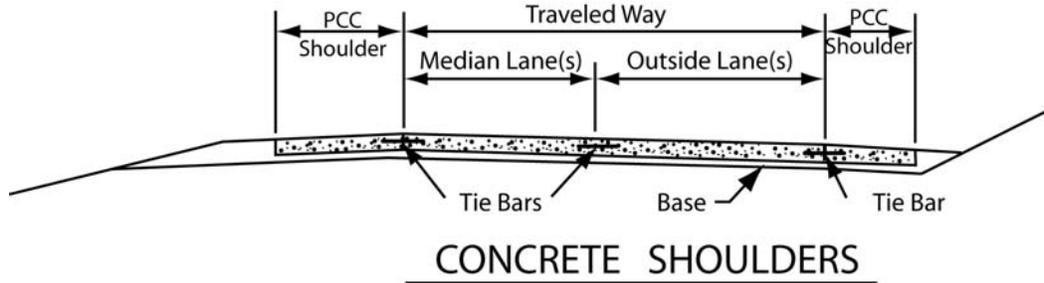
NOTES :

1. Additional thickness should be considered where chains are used for winter weather driving. Consult District Materials Engineer for recommendations.
2. Includes 10 mm of sacrificial thickness for future grinding.
3. In desert environment, where large temperature differentials occur, use ACB or, for LCB, place a minimum 30 mm AC between the LCB and PCC pavement layers.
4. The thicknesses shown in this table are only applicable for PCC pavement that includes either tied PCC shoulders or widened slab (see Index 603.4) and whose adjacent lanes are PCC pavement.

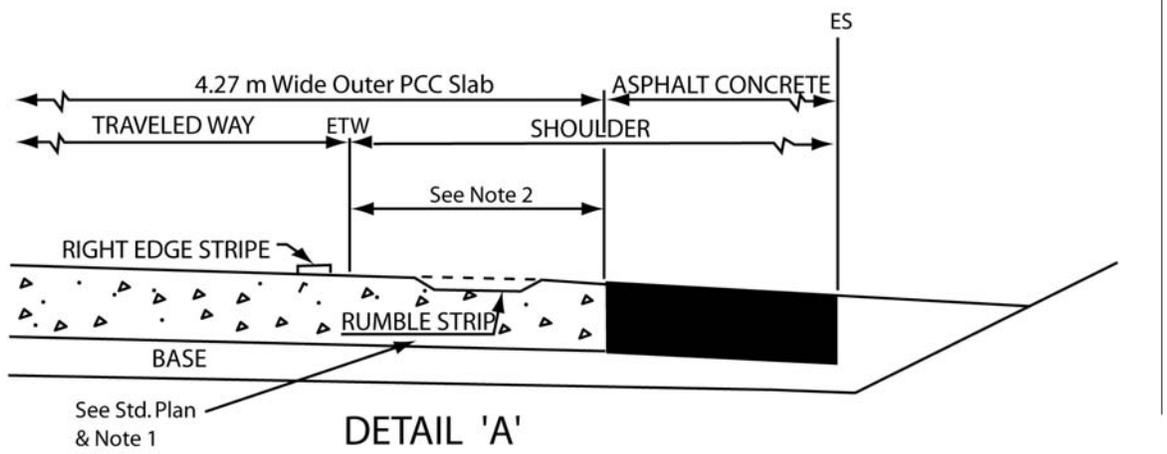
Legend

LCB	= Lean Concrete Base	PCC	= Portland Cement Concrete
ACB	= Asphalt Concrete Base	CTPB	= Cement Treated Permeable Base
ATPB	= Asphalt Treated Permeable Base	AS	= Aggregate Subbase
AB	= Aggregate Base		

**Figure 603.2
Portland Cement Concrete Pavement Details**



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



- NOTE: 1. Use of Rumble Strips is determined in consultation with District Traffic Operations.
2. 670 mm for 3.6 meter lane.
610 mm for 3.66 meter lane.

wax curing compound, slurry seals, or placing a 30 mm interlayer of AC. Application rates may be found in the Standard Specifications. For specific project recommendations on how to prevent bonding between PCC and lean concrete base, consult the District Materials Engineer.

Alternative combinations are diagramed in Table 603.2. Details of structural section drainage systems are provided in Topic 606 and the Standard Plans.

603.3 Structural Section Geometry

On projects with three or more lanes in one direction, the PCC pavement thickness should be constant for the median and outside lanes. When PCC shoulders are specified, a hinge point may be required at the median edge of the traveled way to minimize drainage across the pavement.

603.4 Shoulders

It is recommended that the shoulders be constructed of the same material as the mainline pavement in order to facilitate construction, improve pavement performance, and reduce maintenance cost. However, shoulders adjacent to PCC traffic lanes can be either PCC or AC with the following conditions:

- (a) **PCC shoulders shall be used for:**
- **PCC pavements constructed in mountainous areas that experience chain control (above 1300 m elevation)**
 - **Paved buffers between PCC High Occupancy Vehicle (HOV) lanes and PCC mixed flow lanes**
 - **PCC ramps to and from truck inspection stations**
- (b) **When AC shoulders are used, a widened concrete slab (4.27 m) shall be used in the outside lane, HOV lane(s), and truck bypass lanes (see Figure 603.2).** A rumble strip or a raised pavement marking is recommended next to the pavement edge line of widened concrete slabs to discourage trucks from driving on the outside 0.6 meters of the slab. The use of

rumble strips or raised markings requires approval from District Traffic Operations.

These conditions apply to all PCC paving projects including new construction, reconstruction, widening, adjacent lane replacements, and shoulder replacements. Typically existing AC shoulders next to PCC pavement are not replaced for rehabilitation projects that involve only grinding, dowel bar retrofits, and intermittent slab replacements unless the AC shoulder needs to be rehabilitated or replaced as part of the project.

Tied PCC shoulders or widened slabs increase the service life of PCC pavement by reducing edge stresses from trucks, buses, and other vehicles. PCC shoulders have the added benefit of reducing future maintenance costs and worker exposure.

The structural section selected must meet the pavement service life standards in Index 602.2. In selecting whether to construct PCC or AC shoulders the following factors should be considered:

- (a) Life-cycle cost of the shoulder
- (b) Construction cost of the shoulder
- (c) Ability and safety of maintenance crews to maintain the shoulder. In confined areas, such as in front of retaining walls or narrow shoulders, and on high volume roadways (AADT > 150,000) consideration should be given to providing a shoulder design that requires the least amount of maintenance, even if it is more expensive to construct.
- (d) Future plans to widen the facility or convert the shoulder to a traffic lane
- (e) Width of shoulder. When shoulder widths are less than 1.5 meters, tied PCC shoulders are preferable to a widened concrete slab and narrow AC shoulder (≤ 0.9 m).

The structural section for the PCC shoulder should match the structural section of the adjacent traffic lane. Cross slopes should meet the requirements found in Index 302.2. If the future conversion of the shoulder to a traffic lane is anticipated within the pavement service life of the pavement, it is preferred that the shoulder width match the width of

the future lane. Special delineation of concrete shoulders may be required to deter the use of the shoulder as a traveled lane. District Traffic Operations should be consulted to determine the potential need for anything more than the standard edge stripe.

In those instances where AC shoulders are used with PCC pavement, the minimum AC thickness should be determined in accordance with Index 604.4

603.5 Freeway-to-Freeway Connectors and Ramps

PCC should be considered for all freeway-to-freeway connectors and ramps near major commercial or industrial areas, truck terminals, and truck weighing and inspection facilities ($TI \geq 12.0$) Heavy trucks cause deterioration by repeated heavy loading on the outside edge of pavement, at the corners, or at the midpoint of the slab leading to flexure of the pavement. Distress is compounded on AC ramps by the dissolving action of oil drippings combined with the braking of trucks. At a minimum, PCC pavement should be used as exit ramp termini on AC ramps where a significant volume of trucks is anticipated (see Index 603.6).

When the entire new ramp is concrete, it is recommended to utilize the same base and thickness as that to be used under the traveled way, especially when concrete shoulders are utilized. If the base is Treated Permeable Base (TPB) under the traveled way and shoulder, TPB should be utilized in the ramp area.

For ramp reconstruction, consider recycling the existing base and subbase layers. In some situations, underground water from landscape irrigation or other sources may tend to saturate the existing slow-draining layers, thereby creating the potential for pumping and pavement damage. In this case, the design should provide for removal of such water by a TPB drainage layer when reconstruction is required or by using other positive drainage features which minimize maintenance (e.g., daylighting the structural section layers).

603.6 Ramp Termini

PCC pavement is placed at ramp termini instead of AC to preclude pavement failure due to high

truck traffic ($TI > 12$), vehicular braking, turning movements, and oil dripping from vehicles. The length of PCC pavement to be placed at the termini will depend on the geometric alignment of the ramp, ramp grades, and the length of queues of stopped traffic. The PCC pavement should extend to the first set of signal loops on signalized intersections. A length of 45 m should be considered the minimum on unsignalized intersections. Special care should be taken to assure skid resistance in conformance with current standard specifications in the braking area, especially where oil drippage is concentrated.

The PCC pavement for the termini of AC exit ramps should meet the minimum TI requirements found in Table 603.2 except that the minimum TI used should be 12.5. Special attention should be given to base type selection to assure continuity and adequacy of drainage. District Traffic Operations should be consulted for recommendations regarding construction windows to mitigate traffic impacts.

603.7 Pavement Joints

In Portland cement concrete pavement, there are longitudinal and transverse construction joints, longitudinal and transverse weakened plane joints, and transverse pressure relief joints. Required spacing for transverse joints is found in the Standard Plans and Standard Specifications. Dowel bars are required in all transverse joints along with tie bars for longitudinal joints as discussed in Index 603.2(1). Joints are sawed into the new pavement. Additional PCC pavement joint and slab saw cutting requirements are available on the Pavement Technical Guidance page of the Pavement website <http://www.dot.ca.gov/hq/oppd/pavement/guidance.htm>, Standard Specifications, Standard Special Provisions, and the Standard Plans.

Joints should be sealed to prevent incompressible materials from filling the joints and causing the concrete to spall. Seals also limit the entry of water that could otherwise degrade the underlying structural section layers. Various products or systems for sealing joints are available or are being developed. Each one differs in cost and service life. The need to specify the sealing of joints should be discussed in the Materials Report or by contacting the District Materials Engineer. For additional

information on various joint seal products, consult the Pavement Technical Guidance on the Pavement website <http://www.dot.ca.gov/hq/oppd/pavement/guidance.htm>, Standard Specifications, Standard Special Provisions, Standard Plans, or contact your District Materials Engineer or METS Office of Rigid Pavement Materials and Structural Concrete.

603.8 PCC Pavement Maintenance and Rehabilitation

Pavement maintenance and rehabilitation is the use of a single or combination of several preventive or corrective strategies, which will provide the best overall solution to extend the pavement service life for a predetermined number of years. The choice of strategies depends primarily on the pavement condition, traffic impacts, life-cycle cost considerations, and apparent rate of deterioration. The Materials Report should discuss any historical problems observed in the performance of PCC pavement constructed with aggregates found near the proposed project and subjected to similar physical and environmental conditions. The use of rapid strength concrete in the replacement of concrete slabs should be given consideration to minimize traffic impacts and open the facility to traffic in a minimal amount of time. The rate of deterioration is based on experience, field observation, and a review of successive annual Pavement Condition Survey Reports provided by Caltrans Division of Maintenance. The selection of the appropriate strategy may be based upon constructability, cost, deflection testing (if load transfer is a concern), materials testing, ride quality, safety, visual inspection of pavement distress, and other factors based upon project needs.

Pavement Scoping Team reviews are scheduled and coordinated by the District, with final approval by the District Director. See the Project Development Procedures Manual for further procedures and details.

PCC pavement structural section rehabilitation strategies may be found on the Design Pavement website under Technical Guidance at: <http://www.dot.ca.gov/hq/oppd/pavement/guidance.htm>.

Topic 604 - Asphalt Concrete Pavement Structural Section Design

604.1 Introduction

Asphalt concrete (AC) pavement should be considered as a potential alternative for all state highway facilities since it adjusts readily to differential settlement that is likely to occur where the roadway is constructed on relatively flexible or variable quality basement soil. Asphalt concrete is readily repaired or recycled and should be considered when traffic impacts must be minimized.

Asphalt concrete structural sections may be constructed from new or recycled materials including rubberized asphalt concrete (RAC), cold or hot recycling, cold foam in-place recycling, and pulverization, to name a few. Additionally, different asphalt binders have been developed to address different climatic and environmental constraints. The Pavement website includes discussions of the various asphalt pavement types and their applicability. The site may be found at: <http://www.dot.ca.gov/hq/oppd/pavement/guidance.htm>.

604.2 Design Data Requirements and Sources

The data needed to design a structural section are R-value of the basement soil and the Traffic Index (TI) for the pavement service life. The R-value is a measure of the resistance to deformation of the basement soil under saturated soil conditions and wheel loading. The R-value method of design is based on two separate measurements:

- (1) The R-value determines the thickness of cover or structural section required to prevent plastic deformation of the soil under imposed wheel loads.
- (2) The expansion pressure test determines the thickness or weight of cover required to maintain the compaction of the soil.

Fine grained and sandy soils may exhibit high R-values (greater than 50) and on occasion, the R-value test may not provide sufficient thickness of cover. Local experience with these soils should

govern in assigning a design R-value. The determination of R-Value for basement soils is provided under California Test Method (CTM) 301. Further discussion may be found on the Division of Design's Pavement website under Technical Guidance located at the following link: <http://www.dot.ca.gov/hq/oppd/pavement/guidance.htm>.

The R-Values of materials to be used on a project are contained in the Materials Report. The R-Value of basement soils within a project may vary substantially but cost and constructability should be considered in specifying one R-value for the project.

Judgment based on experience should still be exercised to assure a reasonably "balanced design" which will avoid excessive costs resulting from over conservatism.

If the range of R-value is small or if most of the values are in a narrow range with some scattered higher values, the lowest R-value should be selected for the structural section design. The lowest R-value should not, however, necessarily govern the structural section design throughout the length of long projects. If there are a few exceptionally low R-values and they represent a relatively small volume of basement soil or they are concentrated in a small area, it may be possible to specify placing this material in the bottom of an embankment or in the slope area outside the structural section limits. Occasionally lime treatment of a short length may be cost effective.

The placement of geotextiles below the structural section will provide subgrade enhancement by bridging soft areas and providing a separation between soft pumpable subgrade fines and high quality subbase or base materials. Soft areas are defined as:

- Poor 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 Caltrans R-value < 20).
- High water table, and high soil sensitivity.

Where changing geological formations and soil types are encountered along the length of a project, it may be cost-effective to design more than one structural section to accommodate major differences in R-value that extend over a considerable length. Care should be exercised, however, to avoid multiple variations in the structural section design that may actually result in increased construction costs that exceed potential materials cost savings.

Design of the flexible pavement structural section is based on a relationship between the "gravel equivalent" (GE) of the structural section materials, the Traffic Index (TI), and the R-value (R) of the underlying material. This relationship was developed by the Department through research and field experimentation and is represented by the following equation:

$$GE = 0.975 (TI)(100-R)$$

Gravel equivalency (GE) may be defined as the required gravel thickness needed to carry a load compared to a different material's ability to carry the same load. Gravel factor (G_f) is the relative strength of a material to gravel. Gravel factors for the various types of base materials are provided in Table 604.2. The relationship between the two is that the GE may be divided by the G_f to obtain the material's thickness as follows:

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

Structural section safety factors are utilized to compensate for construction tolerances allowed by the contract specifications. For structural sections that include base and/or subbase, a safety factor of 60 mm is added to the GE requirement for the AC layer. Since the safety factor is not intended to increase the GE of the structural section, a compensating thickness is subtracted from the subbase layer (or base layer if there is no subbase). For structural sections that are full depth AC, a safety factor of 30 mm is added to the required GE of the AC and is not removed. When determining the appropriate safety factor to be added, ACB and ATPB should be considered as part of the AC layer.

Table 604.2
Gravel Factor and R-Values for Subbases and Bases

Type of Material	Abbreviation	Gravel Factor (G_f)	Design R-Value
Aggregate Subbase	AS-Class 1	1.0	60
	AS-Class 2	1.0	50
	AS-Class 3	1.0	40
	AS-Class 4	1.0	specify
	AS-Class 5	1.0	specify
Aggregate Base	AB-Class 2	1.1	78
	AB-Class 3	1.1 ²	specify
Asphalt Treated Permeable Base	ATPB	1.4	NA
Cement Treated Base	CTB-Class A	1.7	NA
	CTB-Class B	1.2	80
Cement Treated Permeable Base	CTPB	1.7	NA
Lean Concrete Base	LCB	1.9	NA
Lime Treated Subbase	LTS	0.9 + $\frac{UCS}{6.9}$	NA

Notes:

- For Asphalt Concrete Base (ACB), see Pavement Technical Guidance at:
<http://www.dot.ca.gov/hq/oppd/pavement/guidance.htm>
- Must conform to the quality requirements of AB-Class 2.

Legend:

NA = Not Applicable
UCS = Unconfined Compressive Strength in MPa

604.3 Structural Section Design Procedures for New and Reconstruction Projects

A computer program for flexible pavement structural section design is available from METS' Office of Pavement Rehabilitation or the District Materials Engineer. The use of this program is recommended because it automatically employs the rules of the flexible pavement design procedure and enables the designer to compare numerous combinations of materials in seeking the most economical structural section. Numerous examples of flexible structural section design solutions are available on the Division of Design's Pavement website located at: <http://www.dot.ca.gov/hq/oppd/pavement/guidance.htm>.

The procedures and rules governing flexible structural section design are:

- (1) The TI is determined to the nearest 0.5.
- (2) The following standard design equation is applied to calculate the gravel equivalent (GE) requirement of the entire structural section or each layer:

$$GE = 0.975(TI)(100-R)$$

where:

- GE = gravel equivalent in mm
- TI = traffic index (See Index 602.4)
- R = R-value of the basement material. This may also be the R-value of the material below the layer for which the GE is being calculated.

- (3) GE values for each type of material are found in Table 604.3 by layer thicknesses. The G_f of asphalt concrete increases for any given TI as follows:

$t \leq 150 \text{ mm:}$	$G_f = \frac{5.67}{(TI)^{1/2}}$
$t > 150 \text{ mm:}$	$G_f = (1.04) \frac{(t)^{1/3}}{(TI)^{1/2}}$

- (4) Design – The GE to be provided by each type of material in the structural section is

determined for each layer, starting with the AC and proceeding downward. The thickness of each material layer is calculated by dividing the GE by the appropriate gravel factor from Table 604.3. When selecting the design layer thickness, the value is rounded to the nearest 15 mm. A value midway between 15 mm increments is rounded to the next higher value.

The following design example illustrates the general methodology to be followed.

- (a) AC/Untreated Base/Aggregate Subbase:

AC Layer: Calculate the initial $GE_{(AC)}$ from standard design equation using the R-value of the aggregate base material (AB) and add the safety factor to get the required $GE_{(AC)}$. Refer to Table 604.3 and select the closest GE layer thickness. A GE value midway between two GE values should be rounded to the next higher value. Finally, determine the $GE_{(AC)}$ value from Table 604.3 that the design layer thickness provides or corresponds to.

Untreated Base Layer: Calculate the initial $GE_{(AC+AB)}$ from the standard design equation using the R-value of the subbase material and add the safety factor. From this, subtract the $GE_{(AC)}$ taken from Table 604.3 to get the required $GE_{(AB)}$ (i.e., $GE_{(AB)} = GE_{(AC+AB)} - GE_{(AC)}$). Refer to Table 604.3 and select the closest layer thickness. Determine the adjusted $GE_{(AB)}$ that the design layer thickness provides.

Untreated Subbase Layer: Calculate the $GE_{(total)}$ (without the safety factor) for the entire structural section using the standard design equation with the R-value of the basement material. Then subtract the $GE_{(AC+AB)}$ as taken from Table 604.3, provided by the AC layer and AB layer ($GE_{(AS)} = GE_{(total)} - GE_{(AC+AB)}$). Finally, refer to Table 604.3 and select the closest layer thickness. (In this way, the GE of the subbase is decreased by the amount of the safety factor.) This thickness is also the adjusted $GE_{(AS)}$ that the subbase provides since the G_f for the subbase is 1.0.

Finally, summarize the structural layer thicknesses and adjusted GE's to easily check that all the requirements are satisfied.

(b) Full Depth AC:

Full depth AC (FDAC) is asphalt concrete used for the entire structural section in lieu of base and subbase. Considerations regarding worker safety, short construction windows, the amount of area to be paved, or temporary repairs may make it desirable to reduce the total thickness of the structural section by placing full depth AC. FDAC also is less affected by moisture or frost, provides no moisture build up in the subgrade, provides no permeable layers to entrap water, and is a more uniform structural section. Use the standard design equation with the R-value of the basement material to calculate the initial GE for the entire structural section. Increase this by adding the safety factor (indicated in Index 604.2) to obtain the required GE of the AC. Then refer to Table 604.3, select the closest layer thickness for AC, and determine the adjusted GE that it provides. The GE of the safety factor is not removed in this design.

An asphalt concrete base (ACB) may be utilized for part of the full depth AC pavement since ACB is considered part of the pavement design. The dense graded AC surface layer should have a minimum thickness of 45 mm.

A treated permeable base (TPB) layer may be placed below full depth AC or within the AC layer on widening projects to perpetuate, or match, an existing treated permeable base layer for continuity of drainage. Reduce the GE of the AC by the amount of GE provided by the TPB. In no case should the initial GE of the AC layer over the TPB be less than 40% of the GE required over the subbase as calculated by the standard design equation. When there is no subbase, use 50 for the R-value for this calculation. In cases where a working table will be used, the GE of the working

table is subtracted from the GE of the AC as well. A working table is a minimum thickness of material, asphalt, base, or subbase, used to place construction equipment and achieve compaction requirements when compaction is difficult or impossible to meet.

- (5) Base and subbase materials, other than ATPB, should each have a minimum thickness of 105 mm. When the calculated thickness of base or subbase material is less than the desired 105 mm minimum thickness, either (a) increase the thickness to the minimum without changing the thickness of the overlying layers or (b) eliminate the layer and increase the thickness of the overlying layers to compensate for the reduction in GE.
- (6) When Lime Treated Subbase (LTS) is used as a subbase it is substituted for all, or part, of the required AS layer. The design thickness of the base and AC surfacing layers are determined as though AS is the planned subbase material. The LTS is then substituted for the AS.

Since AS has a G_f of 1.0, the actual thickness and the GE are equal. When LTS is substituted for the AS, the actual thickness is determined by dividing the GE by the appropriate G_f based on unconfined compressive strength. The gravel factor for LTS is calculated from the Unconfined Compressive Strength (UCS) of the treated soil measured in MPa using the formula:

$$G_f = 0.9 + \frac{UCS}{6.9}$$

Generally, the layer thickness of LTS should be limited, with 200 mm as the minimum and 600 mm as the maximum thickness. An asphalt concrete layer placed directly on the LTS should have a thickness of at least 75mm.

Because the lime treatment of the basement soil may be less expensive than the base material, the calculated base thickness can be reduced and the LTS thickness increased because of cost considerations. The base layer thickness is reduced by the corresponding gravel equivalency provided by the lime treated basement soil or subbase.

**Table 604.3
Gravel Equivalents of Structural Layers (mm)**

	ASPHALT CONCRETE (DGAC)											BASE AND SUBBASE					
	Traffic Index (TI)																
	5 & below	5.5 6.0	6.5 7.0	7.5 8.0	8.5 9.0	9.5 10.0	10.5 11.0	11.5 12.0	12.5 13.0	13.5 14.0	14.5 & up	ACB; LCB	CTPB; CTB (Cl. A)	CTB (Cl. B)	ATPB	AB	AS
Actual Thickness of Layer (mm)	Gravel Factor (G _f)																
	G _f varies with TI ⁴											G _f constant					
	2.54	2.32	2.14	2.01	1.89	1.79	1.71	1.64	1.57	1.52	1.46	1.9	1.7	1.4	1.2	1.1	1.0
30	76	70	64	60	57	54	51	49	47	46	44	--	--	--	--	--	--
45	114	104	96	90	85	81	77	74	71	68	66	--	--	--	--	--	--
60	152	139	128	121	113	107	103	98	94	91	88	--	--	--	--	--	--
75	191	174	161	151	142	134	128	123	118	114	110	--	--	105 ²	--	--	--
90	229	209	193	181	170	161	154	148	141	137	131	--	--	126	--	--	--
105	267	244	225	211	198	188	180	172	165	160	153	200	180 ²	147	126	116	105
120	305	278	257	241	227	215	205	197	188	182	175	228	204	168	144	132	120
135	343	313	289	271	255	242	231	221	212	205	197	257	230	189	162	149	135
150	381	348	321	302	284	269	257	246	236	228	219	285	255	210	180	165	150
165	421	392	362	338	318	301	287	275	264	254	247	314	281	231	198	182	165
180	473	441	407	380	357	338	322	308	296	285	278	342	306	252	216	198	180
195	526	490	453	422	397	377	359	343	329	317	309	371	332	273	234	215	195
210	--	541	500	466	439	416	396	379	363	350	341	399	357	--	252	231	210
225	--	593	548	511	481	456	434	415	399	384	374	428	383	--	270	248	225
240	--	647	597	557	524	497	473	452	434	418	407	456	408	--	288	264	240
255	--	--	647	604	568	538	513	491	471	453	442	485	434	--	306	281	255
270	--	--	698	652	613	581	553	529	508	489	477	513	459	--	324	297	270
285	--	--	--	701	659	625	595	569	546	526	512	542	485	--	342	314	285
300	--	--	--	750	706	669	637	609	585	563	548	570	510	--	360	330	300
315	--	--	--	801	753	714	680	650	624	601	585	599	536	--	378	347	315
330	--	--	--	--	802	759	723	692	664	639	623	--	--	--	--	--	330
345	--	--	--	--	851	806	767	734	705	679	661	--	--	--	--	--	345
360	--	--	--	--	900	853	812	777	746	718	699	--	--	--	--	--	360
375	--	--	--	--	--	901	858	820	787	758	738	--	--	--	--	--	375
390	--	--	--	--	--	949	904	864	830	799	778	--	--	--	--	--	390
405	--	--	--	--	--	998	950	909	873	840	818	--	--	--	--	--	--
420	--	--	--	--	--	--	997	954	916	882	859	--	--	--	--	--	--
435	--	--	--	--	--	--	1045	1000	960	924	900	--	--	--	--	--	--
450	--	--	--	--	--	--	1094	1046	1004	967	942	--	--	--	--	--	--
465	--	--	--	--	--	--	--	1093	1049	1010	984	--	--	--	--	--	--
480	--	--	--	--	--	--	--	1140	1094	1054	1026	--	--	--	--	--	--
495	--	--	--	--	--	--	--	1188	1140	1098	1069	--	--	--	--	--	--
510	--	--	--	--	--	--	--	--	1187	1143	1113	--	--	--	--	--	--
525	--	--	--	--	--	--	--	--	1233	1188	1156	--	--	--	--	--	--
540	--	--	--	--	--	--	--	--	1280	1233	1201	--	--	--	--	--	--
555	--	--	--	--	--	--	--	--	--	1279	1245	--	--	--	--	--	--
570	--	--	--	--	--	--	--	--	--	1325	1290	--	--	--	--	--	--
585	--	--	--	--	--	--	--	--	--	1372	1336	--	--	--	--	--	--
600	--	--	--	--	--	--	--	--	--	--	1382	--	--	--	--	--	--

Notes:

- Standard layer thicknesses of 75 mm and 105 mm have been adopted respectively for ATPB and CTPB. These in turn correspond respectively to GEs of 105 mm and 180 mm. A thicker TPB drainage layer may be considered only under a unique combination of conditions.
- DGAC G_f also increases as the thickness increases, if the thickness is greater than 150mm - See Index 604.3(3).
- Rubberized layer thicknesses may be found in the Flexible Pavement Rehabilitation Manual, Table 3 and 4.
- Open Graded Asphalt Concrete is a surface wearing course and provides no structural value.

A subbase layer or even a base layer may be omitted if the R-value of the basement soil is relatively high. Lime treatment (or stabilization) may in some cases increase the R-value of a soil so that the subbase or even the base layer may be omitted.

- (7) The thickness of other structural section layers (other than AC, ATPB, and CTPB) determined by the procedures described herein may be adjusted to accommodate construction practice and to minimize cost provided the minimum GE and construction requirements are satisfied.
- (8) Alternate Designs. The design thickness determined by the procedures provided in Index 604.3(4) are not intended to prohibit other combinations and thickness of materials. Adjustments to the thickness of the various materials (other than AC, ATPB, and CTPB) may be made to accommodate construction restrictions or practices, and minimize costs, provided the minimum GE requirements, including safety factors, of the basement soil and each layer in the structural section are satisfied.

At times, experimental designs and/or alternative materials are proposed. These should be designed, constructed, and evaluated in cooperation with METS and the District Materials Engineer. In addition, designs with a pavement service life greater than 20 years are to be submitted to the Division of Design, Office of Pavement Design for review. Refer to Index 601.5(2) for further discussion.

Alternative design examples are provided in the Design Pavement website found at: <http://www.dot.ca.gov/hq/oppd/pavement/guidance.htm>

604.4 Shoulder Structural Section Design

The structural section design of median and outside shoulders is based on the same method described for the traveled way in Index 604.3.

(1) *Traffic Index (TI)*.

It is recommended that the shoulder structural section match that of the adjacent traffic lane except that the thickness of the base or AC

pavement may vary to account for the different cross slope between the shoulder and traffic lane. At a minimum the design for an AC shoulder is based on no less than 2% of the projected ESAL's in the adjacent lane; however, a TI less than 5.0 should not be used.

In an area where there are sustained steep grades (over 4%) without a truck climbing lane, the potential for slow moving trucks to encroach on the shoulder should be investigated. If said encroachment results in the ESAL's exceeding 2%, the shoulder structural section should be designed to accommodate the larger ESAL value.

(2) *Grading Plane*.

Normally, there is no break in the grading plane under the pavement shoulder contact joint. The shoulder structural section can be designed with or without an aggregate subbase (AS) layer, depending on the comparative initial cost of aggregate base (AB) versus AS.

The total GE of the shoulder section is usually more than required due to the thickness of AB and/or AS.

(3) *Future Conversion to Lane*.

On new facilities, if the future conversion of the shoulder to a traffic lane is within the pavement service life, the shoulder structural section should be equal to that of the adjacent traveled way.

If a decision has been made to convert an existing shoulder to a portion of a traffic lane, a deflection study must be made to determine the structural adequacy of the in-place material. The condition of the existing shoulder must also be evaluated for undulating grade, rolled-up AC at the PCC joint, surface cracking, raveling, brittleness, oxidation, etc.

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

(4) Medians.

In addition to the information in Index 305.5(2), when a median is 4.2 m wide or less on multi-lane undivided cross sections, the median structural section should be equivalent to the adjacent lanes.

604.5 Ramp Structural Section Design

Structural section design for AC ramps is based on the same method used for the traveled way, as described in Index 604.3. Refer to Index 602.3(3) for determination of design traffic for ramps.

(1) Structural Section Drainage. Provisions for positive, rapid drainage of the structural section is very important, as stated in Topic 606, on ramps as well as main lanes. However, including drainage systems in ramp structural sections can sometimes create drainage problems such as accumulation of water in the subgrade of descending ramps approaching local street intersections in flat terrain. Situations where there may be no cost effective way to provide positive drainage outlets call for careful evaluation of local conditions and judgment in determining whether a drainage system should be included or not in each AC ramp structural section.

(2) Shoulder Structural Section. Ramp shoulder structural sections are to be designed in accordance with Index 604.4 except where ramp widening is required to handle truck off-tracking, see Index 404.1. In such cases, the full ramp structural section should extend to the outer shoulder edge of the widened ramp, see Index 504.3(1)(b).

For the design of ramp termini, see Index 603.6.

604.6 Structural Section Design for Intersections, Roadside Rests, and Parking Lots

Following the standard pavement structural section design procedure for intersections, roadside rests, and park and ride lots is not practicable because of the unpredictability of traffic. This topic provides specialized guidance and/or standard sections for these cases.

(1) Intersection Design. Where intersections have stop control or traffic signals and where trucks are present, special attention is needed to the design of flexible pavement to minimize shoving and rutting of the surface caused by trucks braking, turning, and accelerating. Separate designs should be developed for these intersections which may include thicker structural sections, alternative asphalt binders, aggregate sizes, or mix designs. PCC pavement is another alternative for intersections. Attention is also needed in providing sufficient traffic windows and/or modifications for materials to make sure that the pavement structural section placed has adequate time to cure before placing traffic or the next layer of structural section.

The limits for the pavement design of an intersection should include the intersection, intersection approaches, and intersection departures, to the greater of the distances stated below:

- 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.
- 30 meters.
- 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, METS – Office of Flexible Pavement Materials, or Division of Design – Office of Pavement Design.

- (2) *Roadside Rest Pavement Design.* Table 604.6A gives recommended thicknesses for the elements of structural sections to be used on entrance and exit ramps, roads, truck parking areas - including maintenance stations, facilities, maintenance pull-out areas, and auto parking areas in safety roadside rests. These standard sections should be used unless project site specific traffic information is available, in which case, the standard design procedure should be used. The surface of the parking areas in safety roadside rests should be crowned or sloped to minimize the amount of surface water penetrating into the structural section. Drainage facilities for the surface runoff should be provided.

TI assumptions have been made which are the basis for Table 604.6A. The structural sections are minimal, to keep initial costs down, but are reasonable because additional AC surfacing can be added later, if needed, and generally without incurring exposure to traffic or traffic handling problems. When stage construction is used to minimize initial costs, the full subbase and base thicknesses should be placed in the initial construction. Table 604.6A considers R-value of the basement soil as the only variable under each traffic usage classification. Safety factors were applied in the ramp design but not for the other areas.

- (3) *Park and Ride Lot Pavement Design.* The layer thicknesses shown in Table 604.6B are based on successful practice. These designs are minimal to keep initial costs down, but are considered reasonable since additional AC surfacing can be added later, if needed, without the exposure to traffic or traffic-handling problems typically encountered on a roadway.

The surface of Park and Ride Lots should be crowned or sloped to minimize the amount of surface water penetrating into the structural section. Drainage facilities for the surface runoff should be provided. A 9.5 mm or 12.5 mm maximum AC mix is recommended to provide a relatively low permeability. The AC pavement should be placed in one lift to provide maximum density.

Table 604.6A, Structural Sections for Roadside Rests, should be used in designing the structural section for areas of park and ride lots that will be used by buses and/or trucks. Unique conditions may require other special considerations.

Coal tar pitch emulsion treatment should not be applied to park and ride lots. However, a fog seal coat may be required after placing the AC, particularly if the facility will not be used immediately after construction.

604.7 Asphalt Concrete Pavement Maintenance and Rehabilitation

Policies and procedures governing AC pavement rehabilitation are contained in the Department's "Flexible Pavement Rehabilitation Manual," available from METS' Office of Pavement Rehabilitation or the District Materials Engineer. The "Flexible Pavement Rehabilitation Manual" may be accessed at: <http://www.dot.ca.gov/hq/oppd/pavement/guidance.htm>.

The Division of Maintenance has committed dedicated funding to pavement preservation. This pavement preservation funding implements a preventive maintenance program as a Departmental business practice. Preventive maintenance is applied to roadway surfaces in good condition. This effectively provides additional service life by minimizing the effects of weathering and reducing maintenance costs. For further information, contact the HQ Division of Maintenance.

Refer to the Maintenance Manual for preventive maintenance strategies and to the CAP-M guidelines for capital preventive maintenance strategies. CAP-M guidelines are available by contacting Headquarters Maintenance, Pavement Maintenance Managers.

Table 604.6A
Structural Sections for Roadside Rests
(Thickness of Layers¹ in mm)

Usage	TI	Material (Class) ³	R-value of Basement Soil									
			50 & Over	45-49	40-44	35-39	30-34	25-29	20-24	15-19-	10-14	5-9
Ramps & Truck Roads	8.0	AC	75	90	90	105	75	75	75	75	75	75
		CTB(A)	180	180	210	210	180	180	180	180	180	180
		AS(2)	0	0	0	0	105	120	165	195	240	270
		AC	105	105	105	105	105	105	105	105	105	105
		AB(2)	195	240	270	330	195	195	195	195	195	195
		AS(2)	0	0	0	0	105	150	195	225	270	300
		AC ²	195	210	225	240	255	270	285	285	285	300
Truck Parking Areas	6.0	AC	60	60	60	60	60	60	60	60	60	60
		AB(2)	135	165	195	210	135	135	135	135	135	135
		AS(2)	0	0	0	0	120	150	165	195	225	255
		AC ²	120	135	150	165	165	180	195	195	210	210
Auto Roads	5.5	AC	60	60	60	60	60	60	60	60	60	60
		AB(2)	120	135	165	180	210	120	120	120	120	120
		AS(2)	0	0	0	0	0	120	150	180	210	225
		AC ²	120	120	135	150	150	165	180	180	195	195
Auto Parking Areas	5.0	AC	45	45	45	45	45	45	45	45	45	45
		AB(2)	120	150	165	195	210	120	120	120	120	120
		AS(2)	0	0	0	0	0	105	135	165	180	210
		AC ²	90	105	120	120	135	135	150	165	165	180

Notes:

1. AC thicknesses of 75 mm or less must be placed in one lift.
2. Full Depth AC option (No base or subbase).
3. Structural section material options listed for each Usage, TI, and R-value are equivalent. The option chosen is the Project Engineer's decision based on recommendations from the District Materials Engineer, economics, and material availability.

**Table 604.6B
Structural Sections for
Park and Ride Lots**

R-Value Basement Soil	Thickness of Layers	
	AC* (mm)	AB (mm)
≥ 40	45	0
< 40	75	0
	45	105
≥ 40 and < 60	Penetration Treatment, using a liquid asphalt or dust palliative on compacted roadbed material. See Standard Specifications Section 93 or Section 18.	

* Place in one lift.

Topic 605 - Selection of Pavement Type

605.1 Introduction

The two types of pavement generally considered for new construction are rigid and flexible pavements as typified by Portland cement concrete (PCC) pavement and asphalt concrete (AC) pavement, respectively. There is no formula or clear-cut procedure which will produce a definite answer as to which pavement type is the most appropriate. In addition, because physical conditions are so variable and the influence of other factors differs significantly from location to location, projects must be studied individually. Therefore, the Project Engineer must consider the factors in Index 605.2, make certain assumptions, and use engineering judgment based on the best information available when determining which type or strategy to specify.

605.2 Pavement Type/Strategy Determination

The choice of pavement type or strategy should consider the following factors, which are listed and discussed in Appendix B of the 1993 AASHTO Guide for Design of Pavement Structures. These factors should be considered and addressed specifically in all project approval documents (PR, PSSR, etc.).

Primary factors listed are:

- Traffic,
- Soils characteristics,
- Weather,
- Construction considerations,
- Recycling, and
- Cost comparisons (initial and life-cycle).

No significance is attached to the order in which the factors are listed.

Secondary factors which may be pertinent, should also be considered and addressed. These factors include:

- Performance of similar pavements in the project area,
- Adjacent existing pavements,
- Conservation of materials and energy,
- Availability of local materials or contractor capabilities,
- Traffic and worker safety,
- Incorporation of experimental features,
- Stimulation of competition, and
- Municipal preference, participating local government preference, and recognition of local industry.

Pavement type selection may be dictated by specific project conditions such as:

- Predicted uneven foundation settlements or expansive soils dictate the use of AC,
- Groundwater or periodic inundation suggest the use of PCC pavement,
- Short freeway to freeway connections made between pavements of the same type,

- Existing pavement widening with a similar material,
- Traffic considerations,
- Stage construction, and
- Size of project less than 6.5 lane kilometers.

Another consideration that may have a possible effect on the final decision is the presence of grade controls, such as:

- Median barriers,
- Drainage facilities,
- Curbs and dikes
- Lateral and overhead clearances, and
- Structures which may limit the structural section design or rehabilitation strategies.

The pavement type selection should consider how these appurtenant features might affect the pavement structural section.

The new construction design and rehabilitation strategy should also minimize the exposure and maximize the safety of construction or maintenance forces and their equipment.

The final decision on pavement type should be the most economical design based on a life-cycle cost analysis (LCCA) which includes initial cost, maintenance cost, traffic delay cost and rehabilitation cost. At a minimum, a life-cycle cost analysis should be done for pavement type selection with $TI \geq 10$ unless the pavement type is dictated by specific project conditions (see Index 601.2 for examples).

After considering the various governing factors, alternative structural sections should be developed for economic analysis. If a detailed life-cycle cost analysis is not performed, a less comprehensive analysis must still be completed. This analysis is basically to determine the most economical structural section utilizing available structural section materials.

If a detailed LCCA is performed, it should follow the procedure in Index 605.3.

605.3 Life-Cycle Cost Analysis (LCCA)

LCCA is a useful tool for comparing the value of alternative structural sections and designs. It can be used both to compare the value of alternative designs for a given pavement service life and to compare alternative pavement service lives to determine which provides the optimum performance. LCCA comparisons must be made between properly designed, viable structural sections that would be approved for construction if selected. The structural section chosen in the economic comparison should be included in the final plans unless a revision is subsequently approved. In this event, a short memorandum is prepared referring to the original documentation, stating the details of the change, the reasons for the change, and the revised life-cycle costs. See Index 601.5 for documentation requirements.

(1) *General.* The economic comparison of structural sections should be based on total expected life-cycle cost. The following general guidelines should be used:

- (a) The structural sections to be compared should be shown by sketches so that quantities can be computed and checked.
- (b) A 35-year economic life-cycle period should be used for each project that is designed for a 20-year life. This assumes that the pavement structural section will be maintained and rehabilitated to carry the projected traffic over a 35-year period. The chart below provides for other analysis periods for different pavement service lives.

Pavement Service Life (years)	Economic Analysis Period (years)
10	20
20	35
30	45
40	50

- (c) A discount rate of 4% is used to convert costs to present worth.

- (d) Life-cycle costs are to be computed for the entire pavement structural section, including shoulders, for a length of one kilometer in one direction of travel on divided highways. The entire structural section is included for 2-lane roadways. Use one half of the normal maintenance cost per kilometer for divided highways.
- (2) *PCC Pavement Structural Section.* The life-cycle cost analysis for a PCC pavement structural section should include the following items as appropriate:
- (a) Initial Costs.
- PCC pavement,
 - Treated base (LCB, ACB, ATPB, CTPB)
 - Aggregate base (AB),
 - Aggregate subbase (AS),
 - PCC shoulders,
 - Shoulder base,
 - Shoulder subbase,
 - Structural section drainage system (TPB layer under PCC pavement and/or edge drains), and
 - Joint seals.
- (b) Maintenance Costs.
- Maintenance records should be obtained for cost data, including seal joints and cracks, undersealing to fill voids, repairing spalls, occasional slab replacement, etc., and
 - Traffic delay.
- (c) Rehabilitation Costs.
- Replacing slabs in truck lanes in year 15,
 - Placing AC overlay (preceded by slab cracking and seating) in year 25,
 - Engineering cost (preliminary and construction charges as percent of rehabilitation costs),
- Appurtenant and supplemental work (all work to be done to appurtenant drainage, safety, and other features made necessary by the rehabilitation work),
 - Traffic delay (obtain cost data from District Division of Planning),
 - Detours (may be included in appurtenant and supplemental work), and
 - Salvage value (estimated remaining service life of pavement or value of structural section materials).
- (3) *AC Pavement Structural Section.* The life-cycle cost analysis for an AC pavement structural section should include the following items:
- (a) Initial Cost.
- AC pavement,
 - Base (ACB, CTB, ATPB, CTPB, AB),
 - Aggregate subbase (AS),
 - AC shoulders,
 - Shoulder base,
 - Shoulder subbase, and
 - Structural section drainage system (TPB under AC pavement and/or edge drains)
- (b) Maintenance Cost.
- Maintenance records should be obtained for cost data, including thin AC blanket, chip seals, patching, sealing cracks, etc., and
 - Traffic delay.
- (c) Rehabilitation Cost.
- AC overlay for all lanes and shoulders once every 12 years,
 - Engineering cost (preliminary and construction charges as percent of rehabilitation costs determined from past district records),

- Appurtenant and supplemental work (all work to be done to appurtenant drainage, safety, and other features made necessary by the rehabilitation work),
- Traffic delay (obtain costs from District Division of Planning),
- Detours (may be included in appurtenant and supplemental work), and
- Salvage value (estimated remaining service life of pavement or value of structural section materials).

(4) *Present Worth Cost Calculation.*

$$PWC = IC + [(RC + EC + SC + DC) \times PWF \text{ No.1}] + (MC \times PWF \text{ No. 2}) - (SV \times PWF \text{ No. 3})$$

Where:

PWC	=	Present worth cost
IC	=	Initial costs
RC	=	Rehabilitation costs
EC	=	Engineering cost
SC	=	Supplemental work costs
DC	=	Traffic delay costs
PWF	=	Present worth factor
MC	=	Maintenance costs
SV	=	Salvage value

It is imperative that careful attention is given to the calculations involved and the data used in the calculations to ensure the most realistic and factual comparison between pavement types.

An economic life-cycle cost comparison outline for a 35-year period is presented in Table 605.3.

Topic 606 - Drainage of the Pavement Structural Section

606.1 Introduction

Distress in both flexible and rigid pavements is generally caused by exposure to heavy truck traffic when the pavement structural section is in a saturated condition. Saturation of the structural section or underlying foundation materials, or both, generally results in a decrease in strength or ability to support truck axle loads. Potential problems associated with saturation of the structural section and the subgrade foundation include:

- Pumping action,
- Differential expansion (swelling) of expansive subgrade soils,
- Frost damage in freeze-thaw areas,
- Erosion and piping of fine materials creating voids which result in the loss of subgrade support,
- Icing of pavement surface from upward seepage,
- Stripping of asphalt concrete aggregates, and
- Accelerated oxidation of asphalt binder.

Water can enter the structural section as surface water through cracks, joints, and pavement infiltration, and as groundwater from an intercepted aquifer, a high water table, or a localized spring. Both sources of water should be considered and provisions should be made to handle both. The structural section drainage system, which is designed to handle surface water inflow, is generally separate from the subsurface drainage system that is designed to accommodate encroaching sub-surface water. Local rainfall data should be used in the design of the roadway drainage system as discussed in Chapter 830 of this manual.

Table 605.3
Life-Cycle Economic Comparison of Pavement Types
(Variable-Year Analysis Period and 4% Discount Rate)

ALTERNATIVE 1	Cost Per Kilometer With Shoulders	
Initial Cost =		\$(_A_)
Rehabilitation Costs in Year ____:		
Repair Cost =	\$(_b_)	
Engineering \$(_b_)(0.1225) =	\$(_)	
Appurtenant and Supplemental Work \$(_b_)(0.1350) =	\$(_)	
Traffic Delay =	\$(_)	
	\$(_c_)	
Present Worth Cost of Rehabilitation Work in Year ____	\$(_c_) (PWF) =	\$(_C_)
Rehabilitation Costs in Year ____: ****		
Repair Cost =	\$(_d_)	
Engineering \$(_d_)(0.1225) =	\$(_)	
Appurtenant and Supplemental Work \$(_d_)(0.1350) =	\$(_)	
Traffic Delay =	\$(_)	
	\$(_e_)	
Present Worth Cost of Rehabilitation Work in Year ____	\$(_e_) (PWF) =	\$(_E_)
Annual/Average Maintenance over ____ years (See Index 605.3(2)(b))	\$(_*) (16.3742) =	\$(_F_)
Subtotal (A+C+E+F)		\$(_)
Less Salvage Value (of rehabilitation)** (Variable Ratio)	\$(_c_)(PWF) =	- \$(_)
PCC Pavement Net Present Worth Cost		\$(_)
ALTERNATIVE 2	Cost Per Kilometer With Shoulders	
Initial Cost =		\$(_G_)
Rehabilitation Costs in Year ____:		
Repair Cost =	\$(_h_)	
Engineering \$(_h_)(0.1225) =	\$(_)	
Appurtenant and Supplemental Work \$(_h_)(0.1350) =	\$(_)	
Traffic Delay =	\$(_)	
	\$(_i_)	
Present Worth Cost of Rehabilitation Work in Year ____	\$(_i_) (PWF) =	\$(_I_)
Present Worth Cost of Rehabilitation Work in Year ____	\$(_i_) (PWF) =	\$(_J_)
Annual/Average Maintenance over ____ years (See Index 605.3(3)(b))	\$(_*) (16.3742) =	\$(_K_)
Subtotal (G+I+J+K)		\$(_)
Less Salvage Value (of Resurfacing) ** (Variable Ratio)	\$(_i_)(PWF) =	- \$(_)
ALT2 Net Present Worth Cost		\$(_)
Savings Per Kilometer Using (ALT1/ALT2) [Circle appropriate alternative]		\$(_)

NOTES

- * As an initial estimate, use the average annual district maintenance cost for the respective type of pavement (use WIMS Data).
- ** Salvage Value Assumptions: **For purposes of this example**, the original PCC pavement is expected to require some type of rehabilitation work at 15 and 25 years. At the end of the 35-year comparison, the second rehabilitation is expected to serve 2 years longer. This provides a salvage value of 2/12 the cost of the second rehabilitation. The original AC pavement is expected to require resurfacing or recycling in 12 and 24 years, and the AC overlay or recycling is assumed to last 12 years for a total service of 36 years.
- *** The above format is an example of an outline for guidance only. Actual rehabilitation strategies for a specific project should be used. Refer to Pavement website – “LCCA” for further discussion.
- **** Repeat as necessary over pavement analysis period.

The estimated sub-surface water inflow can be determined by a combination of field investigations, analytical techniques, and graphical methods. "Subsurface Drainage" is discussed in Chapter 840. The Materials Report contains findings on subsurface conditions and recommendations for design. The District Materials Engineer and Division of Design can provide assistance in developing appropriate features in the plans and specifications to address the problem of water in the structural section.

606.2 Structural Section Drainage Practices

- (1) *New Construction Projects.* The structural section should include a layer of Treated Permeable Base (TPB) under the pavement except in areas where the mean annual rainfall is very low (less than 125 mm) or where the basement soil is free draining (a permeability greater than 3.53×10^{-4} m/s). The surface of the traveled way and shoulders should employ materials that will prevent surface water intrusion and any joints should be sealed. If sufficient right of way is available, it is desirable to grade the roadbed to allow for a free draining outlet for the structural section. The TPB, AB and AS layers of the structural section extend the full width of the roadbed (see Figure 606.2).
- (2) *Widening and Reconstruction Projects.* The widened structural section layers should conform to the existing structural section layers to perpetuate existing drainage. The widened layers should extend the full width of the roadbed to a free outlet, if feasible, as in new construction. (See Figure 606.2). Joints should be sealed as discussed in Index 603.7.
- (3) *Rehabilitation Projects.* The surface of the traveled way and shoulders should employ methods and materials that will help prevent surface water intrusion and any joints should be sealed. Existing structural section drainage should be perpetuated or restored, if feasible.

606.3 Drainage Components and Related Design Considerations

The basic components of a pavement structural section drainage system are:

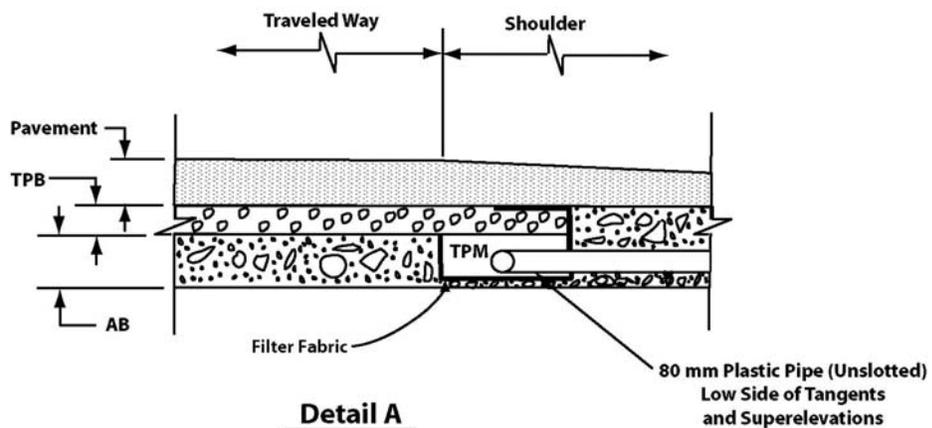
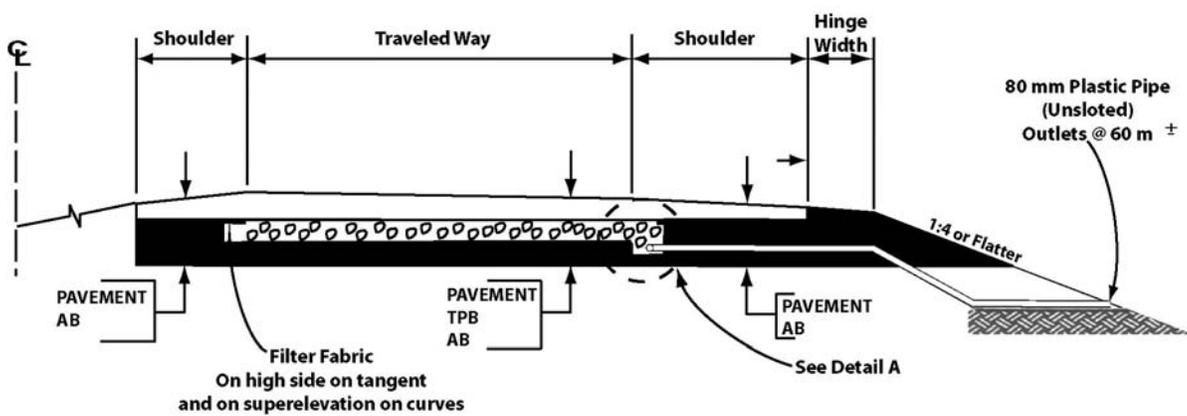
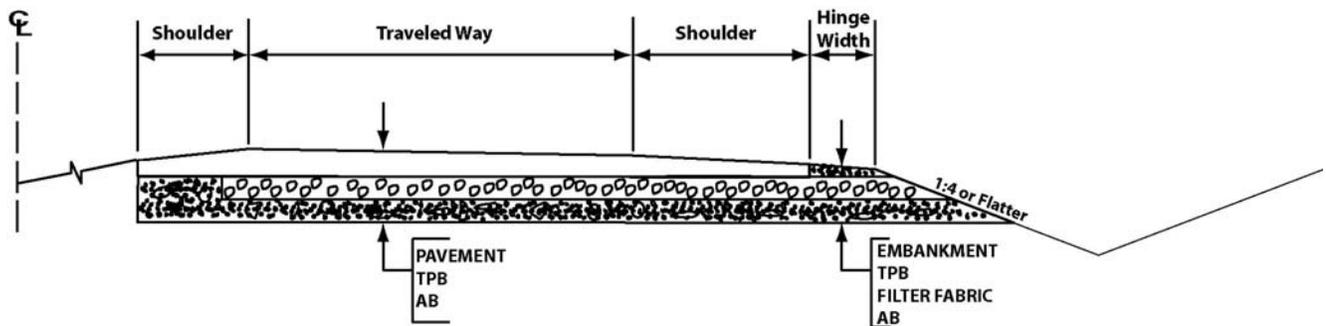
- Drainage layer.
- Collector system.
- Outlets, vents, and cleanouts.
- Filter Fabric (Selected for project specific soil conditions)
- Storm Water Management

- (1) *Drainage Layer.* A drainage layer consisting of either 75 mm of asphalt treated permeable base (ATPB) or 105 mm of cement treated permeable base (CTPB) should be placed immediately below the pavement for interception of surface water that enters the structural section. The drainage layer, base, and subbase should extend the full width of the roadbed (see Figure 606.2). If constraints exist, then the drainage layer should utilize a collector system of edge drains and collector pipes (see Figure 606.2).

When there is concern that the infiltrating surface water may saturate and soften the underlying subbase or subgrade (due either to exposure during construction operations or under service conditions) a filter fabric or other suitable membrane should be utilized. It should be applied to the base, subbase, or subgrade on which the TPB layer is placed to prevent migration of fines and contamination of the TPB layer by the underlying material.

Either of the standard ATPB or CTPB layers (75 mm or 105 mm respectively) will generally provide greater drainage capacity than is needed. The standard thicknesses are based primarily on constructability with an added allowance to compensate for construction tolerances. If material other than ATPB or CTPB with a different permeability is used, it is necessary to check the permeability and adequacy of the layer thickness.

Figure 606.2
Typical Section with Treated Permeable Base
Drainage Layer



See Std. Plans D99A-D99D
For Additional Information

- NOTES:
1. Section shown is a half-section of a divided highway. An edge drain collector and outlet system should be provided if insufficient Right of Way precludes a retention basin.
 2. This figure is only intended to show typical pavement structural section details, for geometric cross section details, see Chapter 300.

When using TPB, special attention should be given to drainage details wherever water flowing in the TPB encounters impermeable abutting structural section layers, a bridge approach slab, a sleeper slab, a pavement end anchor, or a pressure relief joint. In any of these cases, a cross drain interceptor should be provided.

Details of cross drain interceptors at various locations are shown in Figure 606.3A. The cross drain outlets should be tied into the longitudinal edge drain collector and outlet system with provision for maintenance access to allow cleaning.

When TPB is encountered as a drainage layer in widening of a facility, the TPB should be perpetuated so water is not trapped within the structural section.

- (2) *Structural Section Design Considerations.* The standard flexible pavement design procedure, as covered under Index 604.4, is followed to develop AC pavement structural sections which incorporate a drainage layer to accommodate surface infiltration. A gravel factor (G_f) of 1.4 is used for ATPB with a standard thickness of 75 mm. A standard thickness of 105 mm is used for CTPB with a G_f of 1.7. Because of their relative rigidity, no R-value is assigned to either ATPB or CTPB and the design is handled in the same manner as Class A CTB. For design examples see Structural Section Design Examples on the Design Pavement website <http://www.dot.ca.gov/hq/oppd/pavement/guidance.htm>.
- (3) *Collector System.* Where it is not practical to drain water out of the structural section by other means, an 80 mm slotted plastic pipe edge drain should be installed in a longitudinal collector trench as shown in Figure 606.2. In areas where the profile grade is equal to or greater than 4%, intermediate cross drain interceptors, as shown in Figure 606.3B should be provided at an approximate spacing of 150 m. This will limit the longitudinal seepage distance in the drainage layer, minimizing the drainage time and preventing the buildup of a hydrostatic head under the

surface layer. Cross drain interceptor trenches must be sloped to drain.

In addition, cross drains need to be provided at the low-end terminal of TPB projects, as shown in Figure 606.3B. Care should be taken to coordinate the cross drains with the longitudinal structural section drainage system. Drainage layers in roadway intersections and interchanges may require additional collector trenches, pipes, and outlets to assure rapid drainage of the structural section.

A standard longitudinal collector trench width of 0.3 m has been adopted for new construction to accommodate compaction and consolidation of the TPB alongside and above the 80 mm slotted plastic pipe. The TPB type (cement or asphalt treated) for use in the collector trenches will be at the contractor's option.

Filter fabric should be placed as shown in Figures 606.2 and 606.3A, respectively, to provide protection against clogging of the TPM by intrusion of fines. Filter fabric should be selected based upon project specific materials conditions to ensure continuous flow of water and preclude clogging of the filter fabric openings. Consult with METS' Office of Pavement Rehabilitation to assist in selecting the most appropriate filter fabric for the project.

On curvilinear alignments, superelevation of the roadway may create depressions at the low side of pavement where the collected water cannot be drained away. An adjustment to the profile grade may be necessary to eliminate these depressions. Refer to Chapter 200 for superelevation design guidelines.

When a superelevation cross slope begins to drain the water through the TPB to the low side of pavement in cut sections, an edge drain system may be considered to direct water to an area where ponding will not occur.

- (4) *Outlet Pipes.* When edge drains are used, plastic pipe (unslotted) outlets should be provided at proper intervals for the pavement structural section drainage system to be free draining. The spacing of outlets (including

vents and cleanouts) should be approximately 60 m (75 m maximum). Outlets should be placed on the low side of superelevations or blockages such as bridge structures.

The trench for the outlet pipe must be backfilled with material of low permeability, or provided with a cut-off wall or diaphragm, to prevent piping.

The outlets must be daylighted, connected to culverts or drainage structures, or discharged into gutters or drainage ditches. The area under the exposed end of a daylighted outlet should have a splash block or be paved to prevent erosion and the growth of vegetation, which will impede flows from the outlet. Ready access to outlets, and the provision of intervening cleanouts when outlet spacing exceeds a maximum distance of 75 m, should be provided to facilitate cleaning of the structural section drainage system. Typical details are shown on the Standard Plans for Edge Drain Outlet and Vent Details.

The end of each outlet pipe should be indicated by an appropriate marker to facilitate location and identification for maintenance purposes and to reduce the likelihood of damage by vehicles and equipment. Consult the District Division of Maintenance for the preferred method of identification.

- (5) *Storm Water Management.* Drainage emanating from either the pavement surface or from subsurface drains (edge drains, underdrains, and daylighting of the structural section layers) is to be handled in accordance with the procedures provided in Chapter 800 of the HDM for conveyance and with the procedures in the Project Planning and Design Guide (PPDG) for treatment consideration. Storm water Best Management Practices (BMP's) are to be incorporated in the design of projects as prescribed in the PPDG.

Topic 607 - Structure Approach Pavement and Structure Abutment Embankment Design

607.1 Introduction

The ultimate goal of structure approach slab design is to provide a smooth transition between a pavement that is generally supported on a yielding medium (soil that is subject to consolidation and settlement) and a structure, which is supported on a relatively unyielding foundation (piling or spread footings).

The approaches to any structure, new or existing, often present unique geometric, drainage, structural section, and traffic situations that require special design considerations.

Adequate information must be available early in the project development process if all factors affecting the selection and design of a structure approach system are to be properly assessed. A field review will often reveal existing conditions, which must be taken into consideration during the design.

These design guidelines must be followed in the design of all projects involving new construction, reconstruction, or rehabilitation of structure approaches. They are not, however, a substitute for engineering knowledge, experience, or judgment.

607.2 Functional Area Responsibilities

- (1) *Project Engineer* - The Project Engineer (PE) is responsible for the Plans, Specifications, and Estimate (PS&E) of all structure approach contract items below the grading plane, except for the contiguous drainage system components placed within the abutments and wingwalls. The PE is responsible for PS&E of drainage outside the abutments and wingwalls. The PE is also responsible for coordinating and reviewing the adequacy of all drainage ties between the structure approach drainage features and other new or existing drainage facilities.

The PE should contact the Structures District Liaison Engineer as early as possible in the project development process to facilitate project scheduling. The PE must provide pertinent site information and traffic staging plans to DES and may submit recommendations concerning the need for concrete approach systems. Close coordination between the District staff and DES staff is necessary for the proper selection and design of a structure approach system.

- (2) *Division of Engineering Services* – The DES is responsible for the PS&E of all structure approach contract items above the grading plane and for the drainage system components placed within the abutments and wingwalls. Coordination between DES and the District should be as discussed in Index 607.2(1). Questions concerning approach slab design should be directed to DES. Figures 607.4, 607.5A and 607.5B show diagrammatically the structure approach features which are DES responsibilities. When the construction or rehabilitation of a concrete pavement approach is necessary, the DES is responsible for selecting the type of concrete approach system to be used. On new construction projects, the DES is responsible for determining whether or not a concrete pavement approach system is used at each bridge site. On rehabilitation projects, the Pavement Rehabilitation Scoping Team will recommend whether or not replacement or construction of a PCC approach slab(s) is necessary. The Pavement Rehabilitation Scoping Team is comprised of the Project Engineer, District Maintenance, other District functional unit representatives, Headquarters Program Advisors and others as needed.
- (3) *Office of Structural Foundations (OSF)* - Provides the Districts, Structures, and Headquarters with expertise in foundation investigations. Prepares Geotechnical Design Reports recommending estimates of settlement by areas, specific recommendations for foundation treatment, and a history of the performance of structure abutment foundations and embankments in the same area. The OSF Structure Foundation Branch on new construction projects should perform a foundation investigation and analysis. At the request of the DES, the OSF Roadway Geotechnical Engineering Branch will prepare a Geotechnical Design Report based upon its studies and information supplied by the District. The report should include a summary of field investigations, estimate of settlement by areas, specific recommendations for foundation treatment, and a history of the performance of structure abutment foundations and embankments in the same area. All foundation and embankment recommendations by the OSF Branches must be carefully followed in development of the project PS&E or documented as to why they were not followed.
- (4) *District Materials Engineer* - Responsible for materials information requested for each project from Planning through Maintenance. Prepares the District Materials Report for each project. Continuous consultation with the PE and Construction should take place. Coordinates Materials information with Caltrans functional units, METS, Headquarters functional units, local agencies, industry, and consultants. The District Materials Unit is responsible for conducting a preliminary soils investigation, which addresses the quality of the materials available in and under the roadway prism for constructing the project. Poor quality material, such as expansive soils, must be precluded from structure abutment embankments. If sufficient quality roadway excavation material is unavailable for constructing structure abutment embankments, the designer may specify select material, local borrow or imported borrow to satisfy the design requirements.
- (5) *Traffic Operations* - Recommends Traffic Management Plans (TMP's) and assists in the determination of construction windows. On approach slab rehabilitation projects, complete investigations by the District Division of Traffic Operations will be necessary to assess the impact of lane closures and detours on the traveling public.

607.3 Structure Approach Embankment

Structure approach embankment is that portion of the fill material within approximately 50 m longitudinally of the structure. Refer to Figure 607.3 for limits, the Standard Specifications, and other requirements.

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

607.4 Structure Approach Pavement Systems

Concrete pavement structure approach systems are used on all Portland cement concrete (PCC) pavements and on multilane asphalt concrete (AC) pavements located within currently designated urbanized areas. Urbanized areas are identified, by kilometer post, in the Route Segment Report, Project Management Control System (PMCS) Data Base and State Highway Inventory. The current boundaries of urbanized areas are also shown on the official State Highway Map.

There are several pavement slab alternatives that may be considered in the design of a structure approach pavement system. These alternatives are designated Types 14, 9, and 3 structure approach systems. Standard details and special provisions have been developed for each type of approach system. DES will select the appropriate alternate and provide applicable details, specifications, and an estimate of cost for inclusion in the PS&E package. It is recommended that dowel bars be placed at the transverse joint of PCC pavement where the pavement and approach slab meet to ensure load transfer at the joint. The thinner of either the pavement or the approach slab will govern placement of the dowel at half the thickness of the thinner slab.

On all new construction projects, regardless of the type of structure approach selected, provisions for positive drainage of the approach system are to be incorporated into the design. (See Structures Design Standard Details for requirements.)

On rehabilitation projects, provisions for positive drainage of the structural section must be incorporated into the structure approach design.

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

A brief discussion of the types of structure approach pavement systems follows:

(1) *Type 14 Structure Approach System (Approach and Sleeper Slabs/Drainage)*. The Type 14 system includes a 9 m long reinforced concrete pavement slab and a 4.5 m long structure approach sleeper slab (see Figure 607.4). The structure approach system extends laterally across all traffic lanes and shoulder areas. The approach slab is designed to either cantilever over (preferred) or extend to the inside faces of both abutment wingwalls.

The Type 14 approach system is used only on new construction with structures having diaphragm type abutments. It is primarily used on PCC pavement but may be used on AC pavement if warranted by special site conditions.

(2) *Type 9 Structure Approach Pavement System (Approach Slab/Drainage)*. This approach slab is a 9 m long reinforced concrete pavement slab which rests on and is tied to the structure abutment backwall or paving notch. The slab extends laterally across all traffic lanes and shoulder areas. The approach slab is designed to either cantilever over or extend to the inside faces of both abutment wingwalls.

Figure 607. 3
Limits of Structure Approach Embankment Material

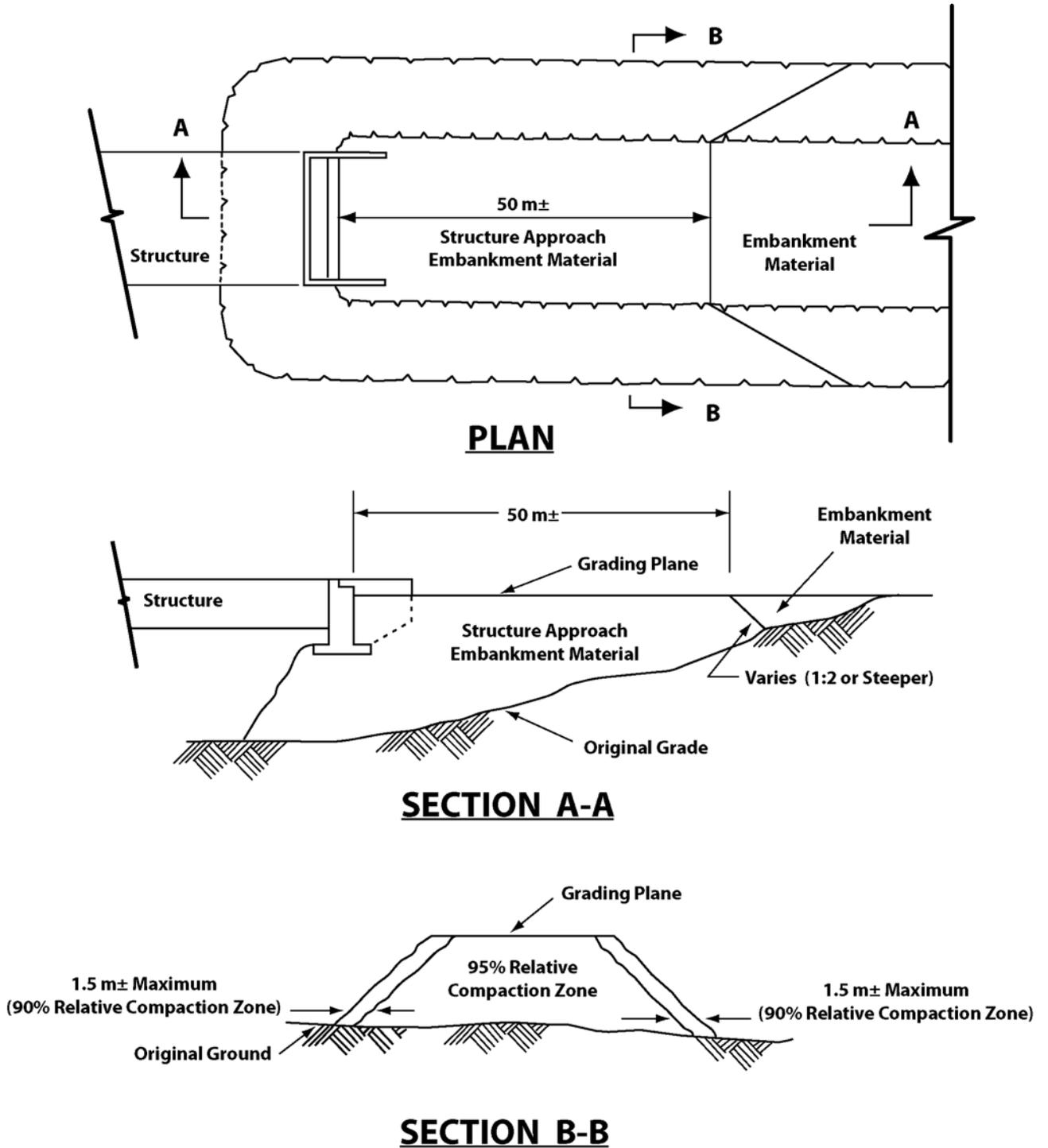
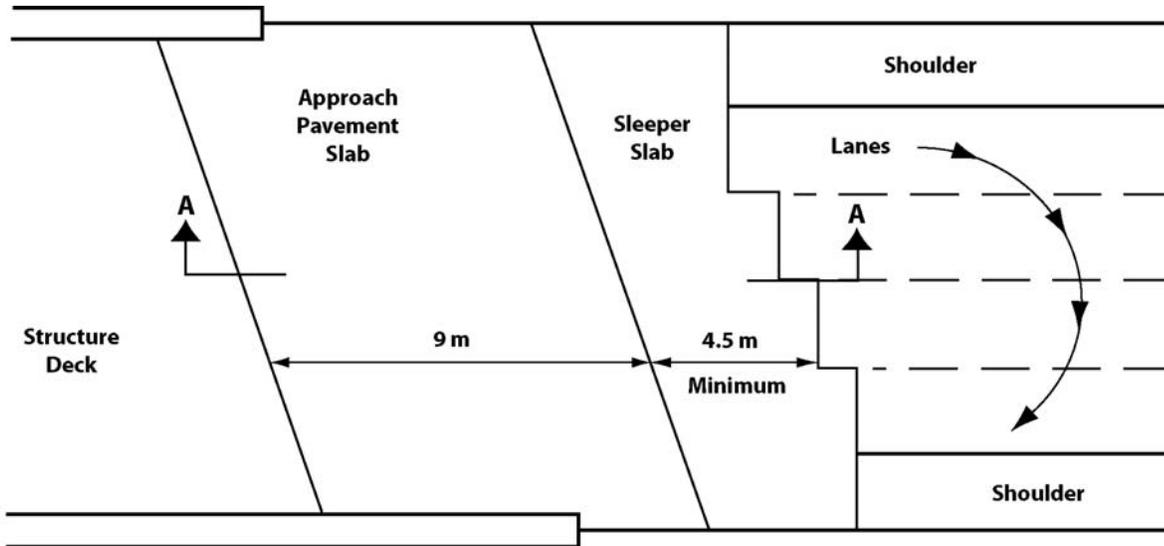
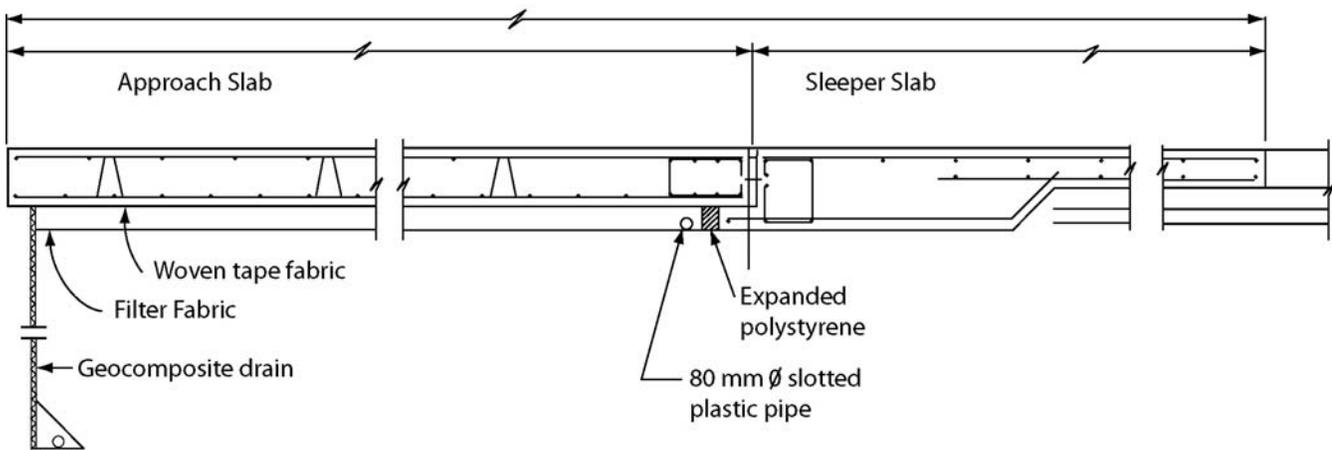


Figure 607.4
Type 14 Structure Approach Layout



Plan View



SECTION A-A

The Type 9 system is the design standard for new construction at structures with seat type abutments. The Type 9 system is also adaptable to diaphragm type abutments where the Type 14 approach system may be inappropriate. The Type 9 slab is the standard rehabilitation treatment at structures with either diaphragm or seat type abutments.

- (3) *Type 3 Structure Approach Pavement System - Earthquake Zones (Seismic Ramp Slab)*. The Type 3 structure approach slab, 3 m in length, is used only on AC pavement located within areas of high magnitude seismic activity. This approach slab is designed to provide a ramp to accommodate the passage of motor vehicles over the structure in the event that an earthquake creates settlement of the structure abutment embankment and approach pavement. The Type 3 seismic ramp slab is provided when both the following conditions (a) and (b) exist or when the following condition (c) exists:
- (a) Peak rock acceleration is estimated to be 0.6 x gravity or greater, as documented in the Geotechnical Design Report, District Materials Report or Foundation Report.
 - (b) Approach embankment or fill height exceeds 3 m.
 - (c) Geologic conditions, as documented in the Geotechnical Design Report, District Materials Report, or Foundation Report, indicate the need for a seismic approach ramp.

If an alternate and convenient route is available for use by emergency vehicles, the use of the Type - 3 structure approach system is not necessary.

607.5 Structure Approach Pavement System - New Construction

- (1) *Foundation and Embankment Design*. The structural stability and overall performance of the structure approach system depends, to a significant degree, upon the long-term settlement/consolidation of the approach foundation and structure abutment embankment. A design that minimizes this

post construction settlement/ consolidation is essential. Factors that influence settlement/ consolidation include soil types and depths, static and dynamic loads, ground water level, adjacent operations, and changes in any of the above. The PE must carefully follow all foundation and embankment recommendations by the OSF Branches and District Materials Unit, and any deviations from their recommendations must be approved by them.

The relative compaction of material within the embankment limits must not be less than 95%, except for the outer 1.5 m of embankment measured horizontally from the side slope. The District Materials Engineer or OSF may recommend using select material, local and/or imported borrow to assure that the compaction requirements are met and that shrink/swell problems are avoided. They may also recommend a height and duration of embankment surcharge to accelerate foundation consolidation.

- (2) *Abutment Details*. The Type 14 approach slab is rigidly tied to the structure abutment and acts as an extension of the structure. Any movement of the abutment will also occur in the approach slab. A sealed joint between the approach slab and the sleeper slab, parallel to and 9 m from the abutment wall, provides for this movement.

The Type 9 approach system is used at structures having either diaphragm or seat type abutments. At a diaphragm type abutment, structure movement is accommodated at the sealed joint between the approach slab and abutment. Structure movement at a seat type abutment will occur at the structure side of the abutment. The structure/abutment joint is designed to handle the movement.

The Type 3 approach system is also used at both seat and diaphragm type abutments. Various abutment/slab tie details are available to accommodate structure movement.

- (3) *Structure Approach Drainage*. Special attention must be given to providing a positive drainage system that minimizes the potential

for water damage to the structure approach embankment. The following features should be included:

(a) Abutment and Wingwall Drainage

A geocomposite drain covered with filter fabric is used behind both the abutment wall and wingwalls, as indicated in Figures 607.4, 607.5A and 607.5B.

A slotted plastic pipe drain, encapsulated with treated permeable material, is placed along the base of the inside face of the abutment wall as illustrated in Figure 607.5B. A pipe outlet system carries the collected water to a location where it will not cause erosion. Storm Water Best Practices should be incorporated. Coordination with DES is necessary for the exit location of the pipe system. The outlet type should be chosen from the standard edge drain outlet types shown in the Standard Plans. The PE must review the drainage design to insure the adequacy of the drainage ties between the abutment and wingwall drainage system and either new or existing drainage facilities.

(b) Structural Section Drainage

Figure 607.4 shows the components of the positive structural section drainage system. Filter fabric should be placed on the grading plane to minimize contamination of the TPB for all types of approach systems. For the Type 14 approach system, a transverse slotted plastic pipe is installed in the treated permeable layer under the approach slab and adjacent to the sleeper slab to intercept water that enters through this joint. The plastic pipe shall have a proper outlet to avoid erosion of the structure approach embankment. Storm Water Best Practices should be incorporated. The Districts are responsible for all drainage considerations of the roadway while DES Structures is responsible for structure related drainage.

(c) Surface Drainage

Roadway surface drainage should be intercepted before reaching the approach/

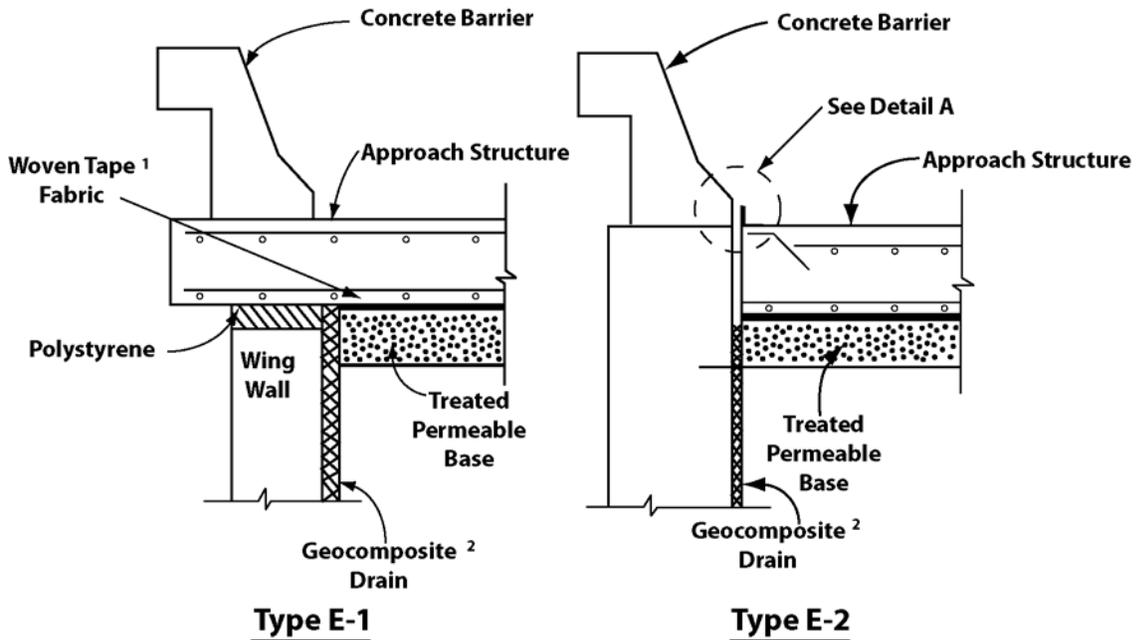
sleeper slab; likewise, structure deck drainage, when practicable, should be intercepted before reaching the abutment joint or paving notch. Cross drain interceptors are discussed in Index 606.3(3) and shown in Figures 606.2B and 606.3. The objective is to keep water away from the structure approach embankment. The surface water, once collected, should be discharged at locations where it will not create erosion.

Containment of surface drainage requires special treatment when the approach slab edge extends only to the inside faces of the abutment wingwalls. A 76 mm x 76 mm x 6.4 mm galvanized steel angle (see Figure 607.5A), pourable seal, and hardboard spacer prevent water from entering the structural section and embankment. On wingwalls longer than 9 m, the angle is terminated at the sealed joint between the approach slab and the sleeper slab. A 155 mm x 6.4 mm steel plate will be used instead of angle for the single slope barriers such as concrete barrier Type 732 or Type 736.

When a dike is required to protect the side slope from erosion, it should be placed on the approach and sleeper slabs and aligned to tie into the end of the structure railing. The guardrail alignment and edge of shoulder govern the positioning of the dike.

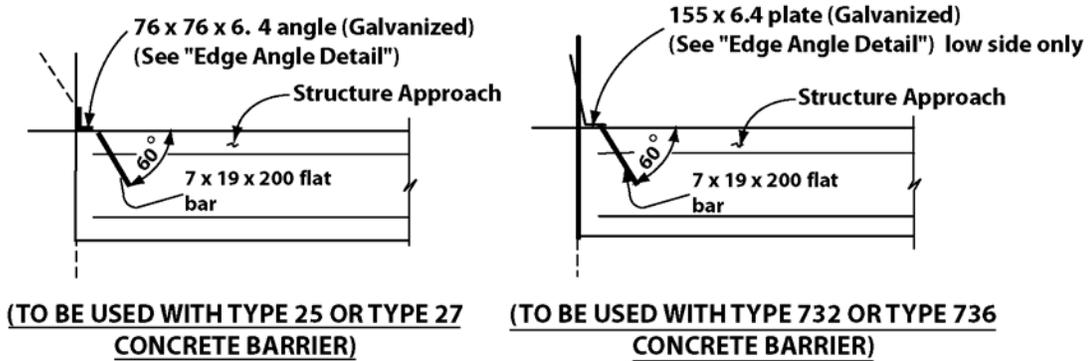
When the Type 14 approach system is used, an AC dike will inevitably crack due to expansion and contraction at the approach/sleeper slab joint. PCC dikes may be considered for this application. A metal dike insert is used to carry the flow across the sealed joint. The insert acts as a water barrier to minimize erosion of the fill slope. Details of the metal dike insert are shown in the structure approach plans provided by DES. Index 837.3(2) should be referenced when drainage inlets are to be placed at bridge approaches and departures.

Figure 607.5A
Approach Slab Edge Details



NOTES:

1. Applicable to Type 14 Structure Approach Systems only.
2. Applicable to new construction only.



DETAIL A

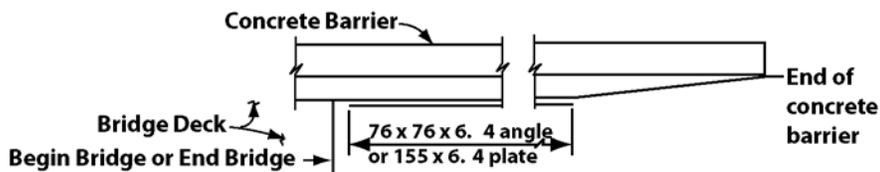
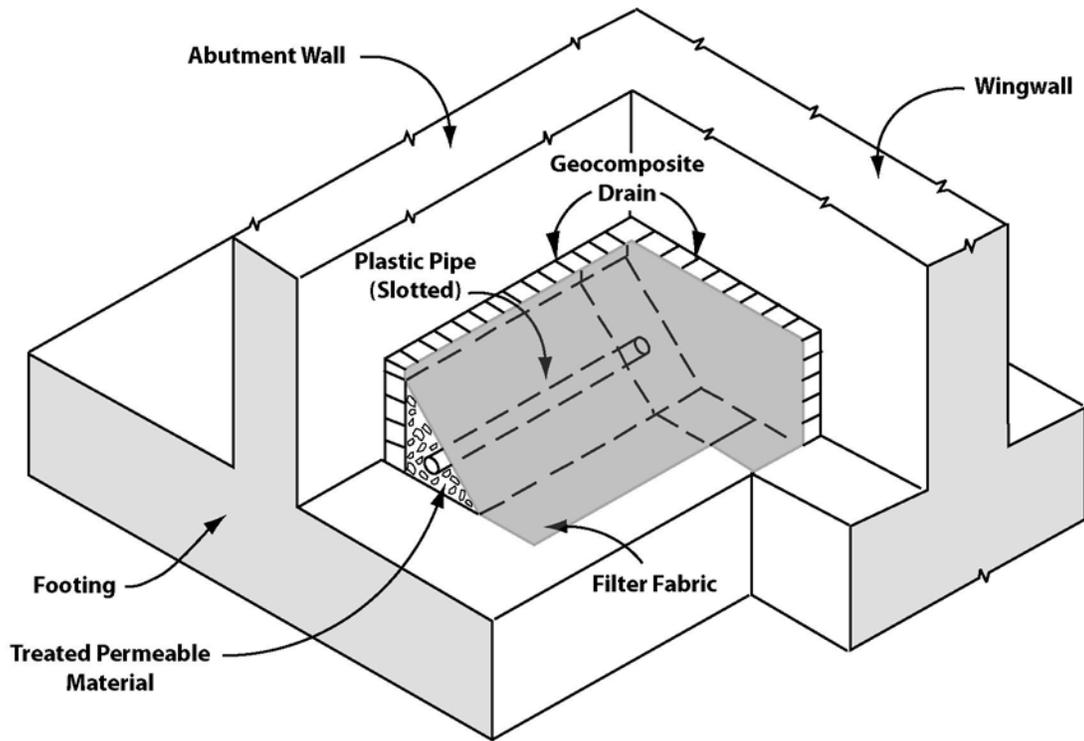


Figure 607.5B
Abutment Drainage Details*



***NOTE: Applicable to new construction only.**

- (4) *Pavement Details.* Approach/sleeper slabs extend the full width of the traveled way and shoulders. On new construction, or rehabilitation work where the structure railing will be replaced, the approach slab extends laterally to coincide with the edge of the structure superstructure. The slab extends over the wingwall, but is separated from the top of the wingwall by polystyrene fillers to preclude vertical loading of the wingwalls when settlement of the embankment occurs. The new structure railing is then attached to the approach slab.

The Type 14 approach slab system utilizes a woven tape fabric, which is used as an interlayer separator on top of the treated permeable base to reduce friction and accommodate movement of the approach slab. The sleeper slab functions as a bearing surface for the approach slab in the event that settlement/consolidation of the structure abutment foundation or embankment occurs. The sleeper slab also functions as a transition slab to the pavement structural section.

Any longitudinal construction joints (cold joints) required during construction of the structure approach or sleeper slabs should be placed on lane lines. The contact joint at the end of the sleeper slab is normal to the centerline. Transverse joints may be staggered at the lane lines at skewed structures; as illustrated in Figure 607.4. The stagger may occur 7.2 m or 10.8 m apart for skews of 20 to 45 degrees and at each lane line for skews greater than 45 degrees.

Structural adequacy must be met under the approach slabs.

- (5) *Guardrail.* The extension of the approach and sleeper slabs across the full width of the outside shoulder creates a conflict between the outside edge of these slabs and the standard horizontal positioning of some guardrail posts. Spacers are attached to the posts that conflict with the approach and sleeper slabs to move the postholes outside the edge of shoulder without changing the standard alignment of the guardrail. These details are covered by DES Standard Details and by Standard Plans.

607.6 Structure Approach Slab - Rehabilitation Projects

- (1) *Approach Slab Replacement.* The Type 9 approach slab is the primary rehabilitation standard for both PCC pavement and AC pavement. The Type 3 approach slab may be used on AC pavement only, if warranted by special site considerations (see Index 607.4(3)).

Replacement of a PCC approach slab consists of removing the existing pavement, approach slab, cement treated base and subsealing material (if applicable) and then replacing with an appropriate type of structure approach system. Depending on the thickness of the existing pavement and base materials to be removed, the minimum 300 mm approach slab thickness (Type 9 approach system) may have to be increased.

- (2) *Structure Approach Structure Section Drainage.* Typical details for positive drainage of a full-width structure approach system are shown in Figure 607.6A. Cross drains are placed at the abutment backwall and at the transverse joint between the existing pavement and the concrete approach slab. A collector/outlet system is placed adjacent to the wingwall at the low side of pavement. The collected water is carried away from the structure approach embankment to a location where it will not cause erosion. Storm Water Best Practices should be implemented.

The approach slab edge details to prevent entry of water at the barrier rail face (see Figure 607.5A- Type E2) apply when the wingwalls and/or bridge barrier railing are not being reconstructed.

- (3) *Pavement Details.* Special pavement details are necessary when PCC approach slabs will be replaced in conjunction with the crack, seat, and AC overlay pavement rehabilitation strategy for PCC pavement. Figure 607.6B, which is applicable to full-width slab replacement, illustrates a method of transitioning from the typical 105 mm AC overlay thickness to the minimum 45 mm final AC lift thickness. Care should be taken in

Figure 607.6A
Structure Approach Drainage Details
(Rehabilitation)

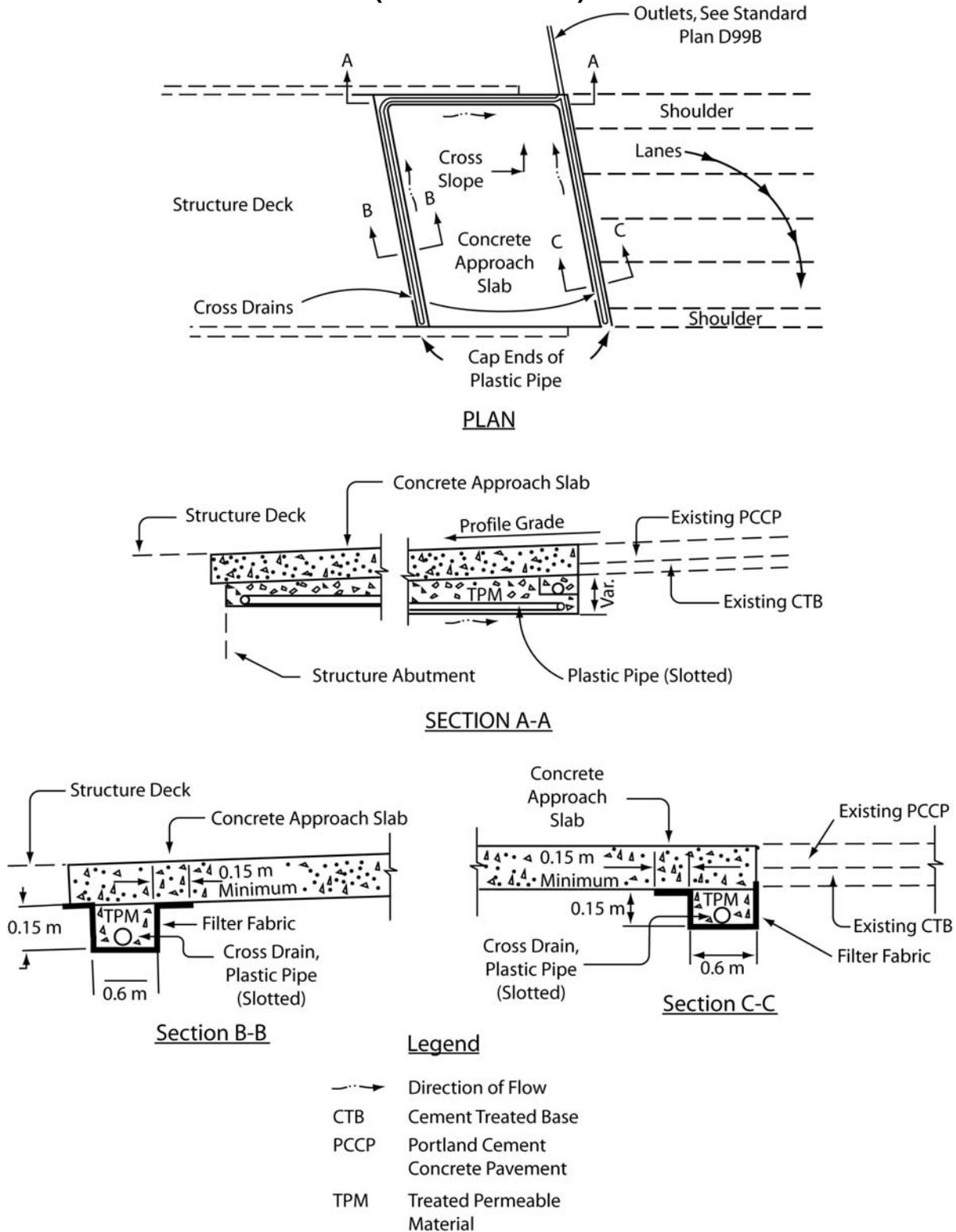
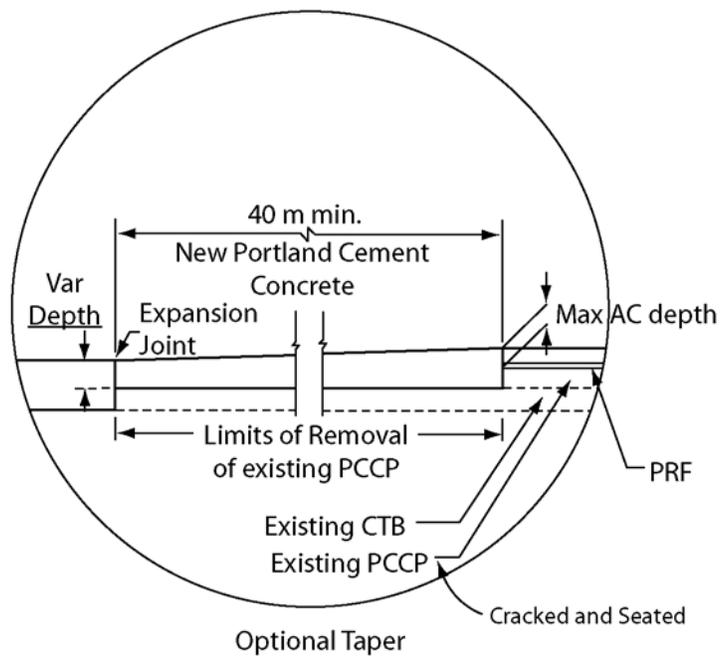
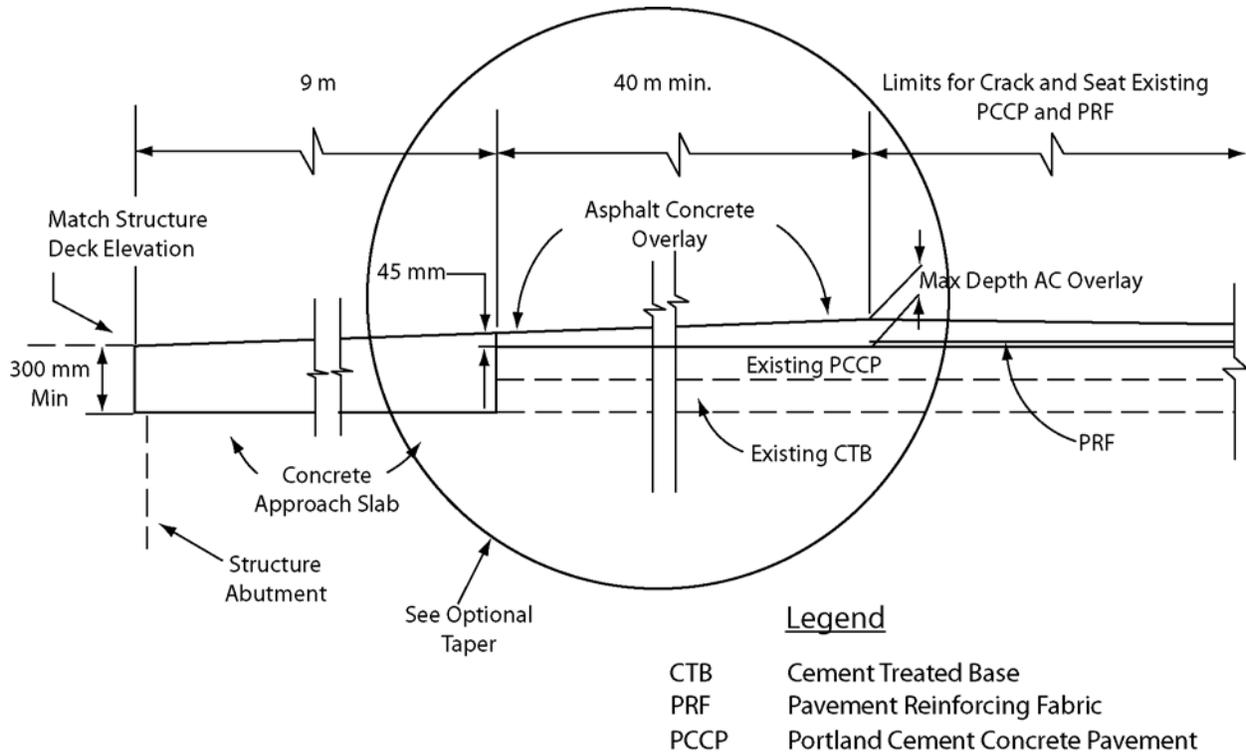


Figure 607.6B
Structure Approach Pavement Transition Details
(Rehabilitation)



areas with flat grades to avoid creating a ponding condition at the structure abutment.

Cracking and seating of the existing PCC pavement as well as the pavement reinforcement fabric (PRF) should be terminated at the start of the transition from the maximum AC overlay depth.

AC overlays should not be placed on structure decks without the concurrence of Structures Maintenance Investigations (SMI). The need for overlays on structure decks is the responsibility of the SMI. SMI is responsible for maintaining the structural adequacy of all State bridges. Some reasons for overlays include ride quality and/or deck protection. If an overlay is needed, SMI will provide the recommended strategy. If the recommended strategy is AC or slurry seal, the District will typically provide the details. If another strategy, such as polyester concrete, the details will be provided by either SMI or Office of Structure Design.

- (4) *Composite Pavements.* Flexible surfacing over rigid pavement is considered to be a rigid pavement for structure approach rehabilitation. The guidelines for rigid pavement apply to all composite pavement rehabilitation projects, which include structure approach slab replacements.
- (5) *Traffic Handling.* Traffic handling considerations generally preclude full-width construction procedures. Structure approach rehabilitation is therefore usually done under traffic control conditions, which require partial-width construction.

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

Pavement joint should not be located underneath the wheel paths.

829.8 – Currently Not In Use

829.9 Dams

Typically, proposed construction which is capable of impounding water to the extent that it meets the legal definition of a dam must be approved by the Department of Water Resource (DWR), Division of Safety of Dams. The legal definition is described in Sections 6002 and 6003 of the State Water Code. Generally, any facility 7.6 m or more in height or capable of impounding 61 700 m³ or more would be considered a dam. However, any facility 1.8 m or less in height, regardless of capacity, or with a storage capacity of not more than 18 500 m³, regardless of height, shall not be considered a dam. Additionally, Section 6004 of the State Water Code states "... and no road or highway fill or structure ... shall be considered a dam." Therefore, except for large retention or detention facilities there will rarely be the need for involvement by the DWR in approval of Caltrans designs.

Although most highway designs will be exempt from DWR approval, caution should always be exercised in the design of high fills that could impound large volumes of water. Even partial plugging of the cross drain could lead to high pressures on the upstream side of the fill, creating seepage through the fill and/or increased potential for piping.

The requirements for submitting information to the FHWA Division Office in Sacramento as described in Index 805.6 are not affected by the regulations mentioned above.

829.10 Reinforced Concrete Box Modifications

- (1) *Extensions.* Where an existing box culvert is to be lengthened, it is essential to perform an on-site investigation to verify the structural integrity of the box. If signs of distress are present, the Division of Structures must be contacted prior to proceeding with the design.
- (2) *Additional Loading.* When significant additional loading is proposed to be added to an existing reinforced concrete box culvert the Division of Structures must be contacted prior to proceeding with the design. Overlays of less

than 150 mm in depth, or widenings that do not increase the per unit loading on the box are not considered to be significant. Designers should also check the extent that previous projects might have increased loading on box culverts, even if the current project is not adding a significant amount of loading.

A

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