BRITISH COLUMBIA

MINISTRY OF TRANSPORTATION
Geotechnical, Materials, & Pavement Engineering

PAVEMENT STRUCTURE DESIGN GUIDELINES

Technical Circular T-01/04

Geotechnical, Materials and Pavement Engineering

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PAVEMENT STRUCTURE DESIGN GUIDELINES

1.0 PURPOSE

The purpose of this draft Technical Circular is to define pavement design guidelines for new construction and rehabilitation in the Province of British Columbia.

This guidelines provide typical pavement structures to be considered in the design process by British Columbia Ministry of Transportation personnel, private consultants and contractors.

Four typical designs, based on general roadway classification, are used to categorize British Columbia's provincial road network. Twenty (20) year design Equivalent Single Axle Loads (ESAL's) are the primary criteria used for selection of the appropriate typical design with additional subgrade material criteria applied to low volume roads and subdivision roads. These are summarized as follows:

Standard Type	Roadway Designation	20 yr Design ESAL Criteria
Type "A"	High Volume Roads	> 1,000,000
Type "B"	Medium Volume Roads	100,000 to 1,000,000
Type "C"	Low Volume Roads	< 100,000
Type "D"	Subdivision Roads	< 100,000

The guidelines show the thicknesses of Asphalt Pavement (AP) and Crushed Base Course (CBC). The structural requirements for Select Granular Sub-base (SGSB) thickness are to be determined by the pavement designer based on traffic loading, subgrade type and local environmental conditions (drainage conditions and frost penetration). Minimum thicknesses of Select Granular Sub-base SGSB (Reference: Section 3.2) must be considered.

Where specific site conditions and economic benefits warrant departure from these pavement design guidelines, Crushed Granular Equivalency (CGE) factors can be used **as a guide** for development of alternative pavement designs.

These guidelines are reflected in the drawings currently in the BC Supplement to the TAC Geometric Design Guide

2.0 BACKGROUND

British Columbia pavement designs applied to primary highways have evolved from relatively thin pavement layers consisting of 75 mm of dense graded Asphalt Pavement (AP) placed on Crushed Base Course (CBC) and Select Granular Sub-base (SGSB) layers; to designs that incorporate a 50 mm dense graded Asphalt Pavement (AP) wearing course over 100 mm of Asphalt Base Course (ABC) over Crushed Base Course (CBC) and Select Granular Sub-base (SGSB) layers; to typical designs of 100 mm of Asphalt Pavement over Crushed Base Course and Select Granular Sub-base layers.

While use of ABC layers may be appropriate in specific circumstances, its use is discouraged as a result of problems that have arisen related to cracking and rehabilitation.

Current pavement design guidelines encourage the use of thinner, flexible asphalt pavements with associated saving in construction cost and ease of effective rehabilitation.

3.0 PROCEDURE

3.1 PAVEMENT STRUCTURE DESIGN GUIDELINES

Current pavement design guidelines replace those specified in the BC Supplement to the TAC Geometric Design Guide are summarized in Tables 1 and 2 and illustrated with typical cross-sections in Figures 1, 2, 3 and 4.

Pavement designs shall incorporate the use of the 1993 AASHTO Guide for the Design of Pavement Structures and design checks can be made as an option by using the Asphalt Institute's Thickness Design – Asphalt Pavements for Highways and Streets (MS-1) and Asphalt Institute's "Asphalt Overlay for Highway and Street Rehabilitation" (MS-17) and other methods such as ELMOD and the Shell method.

The analysis shall typically incorporate a twenty year analysis period.

Rehabilitation options with life cycle costing shall be considered in the design process.

One option shall be recommended.

Alternative designs shall be communicated to the Chief, Geotechnical, Materials and Pavement Engineer in Victoria for information.

3.2 SELECT GRANULAR SUB-BASE (SGSB) REQUIREMENTS

The structural requirements for Select Granular Sub-base (SGSB) thickness are to be determined by the pavement designer based on traffic loading, subgrade type and local environmental conditions (drainage conditions and frost penetration).

Dredged river sand, due to the susceptibility for rutting, should not be considered acceptable for use as SGSB in pavement structures. The angularity of the material and past performance of the particular source should be investigated.

The following specifications for minimum Select Granular Sub-base (SGSB) thicknesses shall be considered as a guide.

3.2.1 Rock Subgrades

A minimum thickness of 150mm Select Granular Sub Bases (SGSB) shall be applied over rock subgrades

All leveling materials applied directly to blasted rock cuts shall be of Select Granular Sub-base (SGSB) quality.

3.2.2 Soil Subgrades

PAVEMENT STRUCTURE DESIGN GUIDELINES - TYPES "A" & "B". (>100,000ESALs)

(1) A minimum thickness of 300 mm Select Granular Sub-base (SGSB) shall be applied over subgrade materials.

(2) Select Granular Sub-base (SGSB) may not be required in exceptional circumstances where the following criteria are met:

Structural Design Criteria is satisfied

and

Subgrade material consists of clean granular deposits that satisfy Select Granular Sub-base (SGSB) gradation and construction criteria in accordance with the latest version of British Columbia Ministry of Transportation Standard Specifications for Highway

Construction - Section 202 "GRANULAR SURFACING, BASE AND SUB-BASES".

PAVEMENT STRUCTURE DESIGN GUIDELINES - TYPES "C" & "D" (<100,000 ESALs)

(1) Thickness design for Select Granular Sub-base (SGSB) shall be based on subgrade material type as follows:

150 mm Select Granular Sub-base (SGSB) on Coarse Grained Subgrades (Unified Soils Classification System - GW/GP/GM/GC/SW/SP/SM/SC) where groundwater does not pose a drainage problem and frost penetration does not affect the structure.

300 mm Select Granular Sub-base (SGSB) on Fine Grained Subgrades (Unified Soils Classification System - ML/CL/OL//MH/CH/OH).

(2) Select Granular Sub-base (SGSB) may not be required in exceptional circumstances where the following criteria have been met:

Structural Design Criteria is satisfied

and

Subgrade material consists of clean granular deposits that satisfy Select Granular Sub-base (SGSB) gradation and construction criteria in accordance with the latest version of British Columbia Ministry of Transportation Standard Specifications for Highway Construction -Section 202 "GRANULAR SURFACING, BASE AND SUB-BASES".

3.2.3 TRAFFIC ANALYSIS

The recommended method for determination of 20 year design Equivalent Single Axle Loads (ESAL's) is the Modified Asphalt Institute Method specified in Table 3. Furthermore, it is recommended that in the application of this method, ESAL's for various truck axle configurations are determined based on the Transportation Association of Canada (TAC) Vehicle Weights and Dimensions Study, illustrated in Figure 5 (ESAL's vs Axle Group Load).

TABLE – 1

PAVEMENT DESIGN STANDARDS

Type "A" (Reference: Figure - 1)
> 1,000,000 ESAL's

100 mm AP
150 mm of 25mm CBC
150 mm of : 75mm CBC,
50mm CBC, or
25mm CBC
SGSB (Soil* 300 mm, Rock** 150 mm)

Type "B" (Reference: Figure – 2)
100,000 to 1,000,000 EASL's

75 mm AP [3]
150 mm of 25mm CBC
150 mm of : 75mm CBC,
50mm CBC, or
25mm CBC
SGSB: 300 mm over Soil sub-grade [1],
150 mm over Rock sub-grade [2]

Notes:

[3] 75 mm AP specified in Type "B" shall be constructed in 2 lifts of 19 mm MAXIMUM size aggregate or in a single lift of 25 mm MAXIMUM size aggregate (in accordance with the latest version of B.C. MOT Standard Specifications for Highway Construction - Section 502.

TABLE – 2

PAVEMENT DESIGN STANDARDS

Type "C" (Reference: Figure 3)
Low Volume Roads < 100,000 ESAL's

50 mm AP
225 mm of 25mm CBC
SGSB Soil [1, 2, 3] see notes below,
150 mm over Rock [4]

Type "D" (Reference: Figure 4)
Subdivision roads < 100,000 EASL's

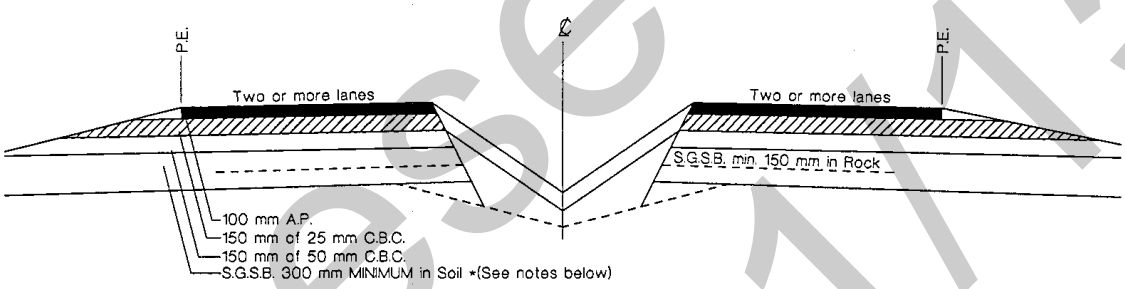
50 mm AP
225 mm of 25mm CBC
SGSB Soil [1, 2, 3] see notes below,
150 mm over Rock [4]

Notes:

1 SGSB 150 mm SGSB on Coarse Grained Subgrades (Unified Soils Classification System - GW/GP/GM/GC/SW/SP/SM/SC) where groundwater does not pose a drainage problem and frost penetration does not affect the structure.

2 SGSB 300 mm SGSB on Fine Grained Subgrades (Unified Soils Classification System - ML/CL/OL//MH/CH/OH).

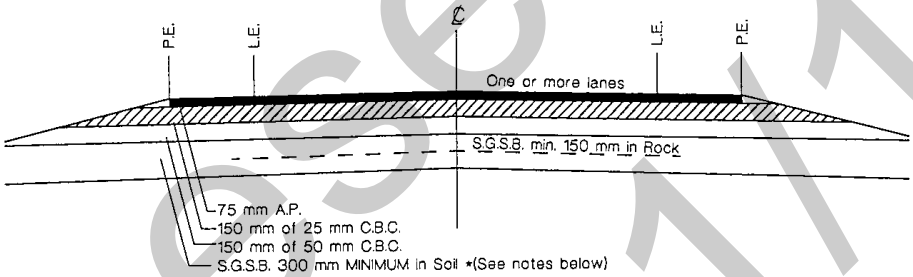
FIGURE - 1



TYPE "A"

HIGH VOLUME ROADS
> 1,000,000 ESAL's

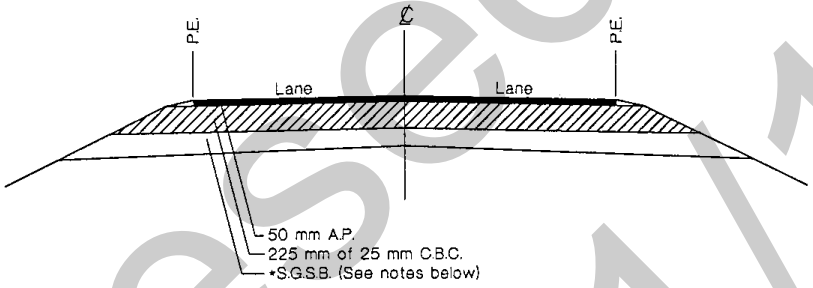
FIGURE - 2



TYPE "B"

MEDIUM VOLUME ROADS
100,000 to 1,000,000 ESAL's

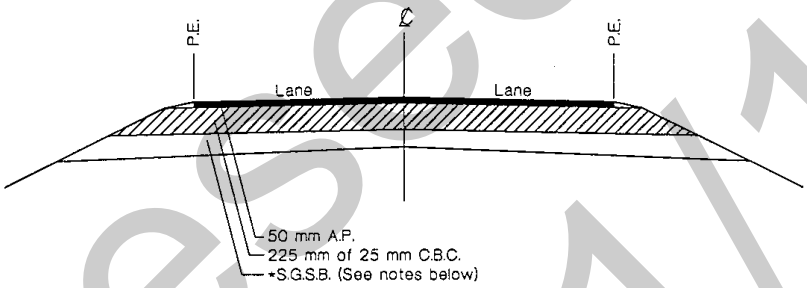
FIGURE - 3



TYPE "C"

LOW VOLUME ROADS
< 100,000 ESAL's

FIGURE - 4



TYPE "D"

SUBDIVISION ROADS
< 100,000 ESAL's
&
INFREQUENT USE BY HEAVY COMMERCIAL VEHICLES

TABLE - 3

ESAL CALCULATIONS
MODIFIED ASPHALT INSTITUTE METHOD

$$ESAL = AADT * HVP * HVDF * NALV * TDY$$

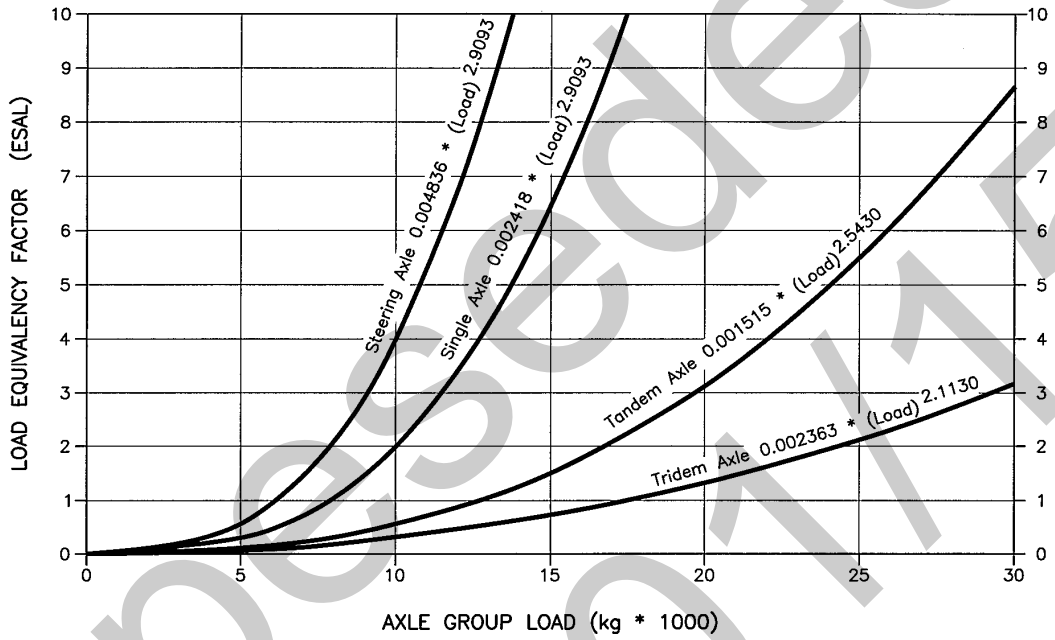
where:

ESAL	=	Equivalent single axle loads per lane per year (for the base year)
AADT	=	Average annual daily traffic (all lanes & both directions)
HVP	=	Heavy vehicle percentage (divided by 100, to express as a decimal)
HVDF	=	Heavy vehicle factor (% (as a decimal) of heavy vehicles in design lane)
NALV	=	Number of equivalent axle loads per vehicle (ESAL's per vehicle)
TDY	=	Traffic days per year

Note:
ESAL's (base year) x 20 yr. traffic growth rate factor = 20 year Design ESAL's.

FIGURE - 5

TAC VEHICLE WEIGHTS AND DIMENSIONS STUDY



3.4 AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS (AASHTO) PAVEMENT DESIGN CRITERIA

In order to ensure a consistent design approach using the American Association of State Highway and Transportation Officials (AASHTO) Pavement Design Method for new construction, the following criteria shall apply:

Analysis Period

= 20 Years

Reliability (R)

High volume & medium volume roads: R = 85%
Low volume & subdivision roads: R = 75%

Standard Deviation

(S_O): S_O = 0.45

Pavement Serviceability Index (PSI)

Initial Serviceability Index: (p_i) = 4.2
Terminal Serviceability Index: (p_t) = 2.5

Materials Characterization:

Material Description	**Resilient Modulus * (M_R) MPa (approx. psi)**	**Structural Layer Coefficient (a_i)**
Asphalt Pavement (AP)	2,750 (400,000)	0.40
Crushed Base Course (CBC) (25 mm, 50 mm & 75 mm)	200 (30,000)	0.14
Select Granular Sub-base (SGSB)	100 (15,000)	0.10

*If field or laboratory resilient modulus values (m_r) are available, they may be used.

Drainage Coefficients (m_i):

The following drainage coefficients (m_i) shall apply to untreated Crushed Base Course (CBC) and Select Granular Sub-base (SGSB) materials:

m_i	Crushed Base Course (CBC) Select Granular Sub-base (SGSB) Description
1.15	Open Graded Crushed Base Course (CBC.) & Select Granular Sub-base (SGSB)
0.95	High Quality Crushed Base Course (CBC) & Select Granular Sub-base (S.G.S.S.) (i.e. <5% fines passing .075 mm sieve)
0.80	Poor quality Crushed Base Course (CBC) & Select Granular Sub-base (SGSB) (i.e. >5% fines passing .075 mm sieve)

3.5 ALTERNATIVE PAVEMENT DESIGNS

Design options using life cycle costing are to be considered for presentation. One option shall be recommended.

Designs can be checked using Asphalt Institute methods, or others, (as a check only).

Where site-specific conditions warrant (i.e. granular quality, granular availability, etc.) alternative pavement designs may be generated using the Crushed Granular Equivalency (CGE) concept **as a guide**.

The economic benefit of any alternative design (minimum practical thicknesses are to be maintained) is to be determined on a project specific basis.

CGE factors for New Construction and Pavement Rehabilitation are provided in Tables 4 and 5 respectively.

Dynatest ELMOD software is acceptable for rehabilitation overlay design. However, ELMOD is not to be used for design of new construction.

TABLE – 4

CRUSHED GRANULAR EQUIVALENCY (CGE) FACTORS NEW CONSTRUCTION

PAVEMENT MATERIAL	CGE FACTOR
Bituminous Bound Layers	
Hot Mix Asphalt Pavement (AP)	2.0
B.C. Stabilizer	1.5
Open Graded Granular Base (Bituminous Bound)	1.5**
Asphalt Base Course (ABC)	1.7
Recycled Asphalt Pavement in Granular Base Course (min 50% Aggregate)	0.6*
Portland Cement Bound Layers	
Portland Cement Concrete	3.0
Roller Compacted Concrete	2.5
Cement Treated Base	1.8
Open Graded Granular Base (Cement Bound)	1.6
Unbound Crushed Base Course Layers (25 mm, 50 mm & 75 mm)	
Well Graded Crushed Unbound Granular Base	1.0
Intermediate Graded Crushed Unbound Granular Base	1.1**
Open Graded Crushed Unbound Granular Base	1.2**
Unbound Granular Sub-base Layers	
Well Graded Crushed Unbound Granular Sub-base	1.0
Intermediate Graded Crushed Unbound Granular Sub-base	1.1**
Open Graded Crushed Unbound Granular Sub-base	1.2**
Pit Run Granular Sub-base	0.7
Screened Granular Sub-base	0.7

* Based on British Columbia Ministry of Transportation experience.

** Based on British Columbia Ministry of Transportation experience and must be confined with a minimum of 75 mm of dense graded Asphalt Pavement (AP).

Notes:

1. **SURFACE TREATMENT:**
   For design, surface treatments are assumed to have no structural strength. Built-up layers of surface treatment (>75 mm thickness) could be assigned a CGE of 1.5.

2. **GEOTEXTILES AND GEOGRIDS:**

Geotextiles do not provide structural strength and are to be used only as separators. Geogrids can be used to provide structural equivalence if strength can be mobilized within the grid.

TABLE – 5

CRUSHED GRANULAR EQUIVALENCY (CGE) FACTORS
PAVEMENT REHABILITATION

PAVEMENT MATERIAL	CGE FACTOR
Bituminous Bound Layers	
Hot-Mix Asphalt Pavement (uncracked)	2.0
Hot-Mix Asphalt Pavement (cracked)	1.5
Hot-in-Place Recycled Asphalt Pavement	1.7
Cold-in-Place Recycled Asphalt Pavement	1.5
Recycled Asphalt Pavement in Granular Base Course (min 50% aggregate)	0.6**
Portland Cement Bound Layers	
Portland Cement Concrete (good condition)	3.0
Portland Cement Concrete (fair condition)	2.5
Portland Cement Concrete (poor condition)	2.0
Cement Treated Base	1.5
Unbound Crushed Base Course Layers(25 mm, 50 mm & 75 mm)	
Old Granular Base	0.7
Old Granular Sub-base (Crushed)	0.7

****** Based on British Columbia Ministry of Transportation experience.

Notes:

1. **SURFACE TREATMENT:**
   For design, surface treatments are assumed to have no structural strength. Built-up layers of surface treatment (>75 mm thickness) could be assigned a CGE of 1.5 (uncracked) and 1.1 (cracked).

2. **GEOTEXTILES AND GEOGRIDS:**
   Geotextiles do not provide structural strength and are to be used only as separators. Geogrids can be used to provide structural equivalence if strength can be mobilized within the grid.

3.6 RESPONSIBILITIES

In accordance with Section 3.5, Alternative Pavement Designs are to be communicated to the Chief, Geotechnical, Materials and Pavement Engineer.

Any future modifications to the PAVEMENT STRUCTURE DESIGN GUIDELINES shall be coordinated and issued by the Chief, Geotechnical, Materials and Pavement Engineer in Victoria.

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c.c. A.D.M. Planning & Major Projects
c.c. All Regional Directors
c.c. RGME's