City of Brandon

Municipal Servicing Standards

Section 7

Pavement Design Standard

Rev 00 (2025)

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PAVEMENT DESIGN STANDARD REVISION HISTORY

The Municipal Servicing Standards (MSS) may be reviewed, updated or otherwise modified at any time. The Proponent's Engineer shall ensure that the current version of the MSS is applied.

Where such alternative solutions, systems, or approaches are being considered, a written proposal outlining the benefits, limitations, and total cost of ownership of the proposed solution shall be submitted to the City of Brandon Engineering Department for formal approval.

Table 1-1 below summarizes the revision history.

Table 1-1 – Revisions to MSS

Date	Modification or Adjustment
July 2025	Pavement Design Standard (Section 7)

1.0 INTRODUCTION

1.1 Purpose

The purpose of the City of Brandon Pavement Design Standard (Design Standard) is to outline the pavement design methodology and process to be followed for all new flexible pavement designs within the City of Brandon. The Design Standard is based largely on the pavement design procedures described in the American Association of State Highway Transportation Officials 1993 (AASHTO, or AASHTO 1993) Guide for the Design of New Pavement Structures, with modifications to address conditions specific to the City of Brandon. The AASHTO 1993 guide provides a good reference for many of the pavement design terms and processes described in the Design Standard.

1.2 Engineering Submissions

For all submissions and approvals required as part of a Proponent's project refer to Section 2 – Engineering Submission Standards.

1.3 Pavement Design Overview

This Design Standard focusses on addressing key areas related to the design of new flexible pavement design structures, specifically:

- Cross-section type (e.g., urban vs. rural) and subdrain requirements,
- Subgrade support characterization,
- Traffic loading conditions,
- Ground water and drainage layer requirements,
- Pavement material characterization,
- Pertinent AASHTO design inputs, and
- Pavement design structural number.

The design procedures described in this Design Standard address the necessary steps and inputs the Pavement Designer must consider when completing a new flexible pavement design. These steps are further described in Section 2.1 of the Design Standard, "Overview of the Design Process".

2.0 PAVEMENT DESIGN PROCEDURE

Roadway classifications described in this Design Standard are defined as follows:

- Local Roads – Typically residential roadways with low volume traffic and occasional heavy loaded vehicles (e.g., garbage trucks).
- Collector Roads – Typically accumulation of residential roadway traffic, resulting in higher volumes. Two subsets of collector roads have been included: 1) with transit buses, and 2) without transit buses.
- Arterial Roads – Typically the highest volume of traffic within the roadway network. Can include multi-lane roadways.
- Industrial Roads – Typically the highest traffic loading condition (> 5% heavy loaded vehicles) within specific areas within the City's road network identified as industrial areas.

2.1 Overview of Design Process

There are two approaches to the design of flexible pavements based on assigned roadway classification:

- Local and Collector Roads – Prescribed Standard Pavement Design Structures, and
- AArterial and Industrial Roads – "Case-by-case" Project Specific Pavement Design, with Pre-determined Minimum Pavement Structures.

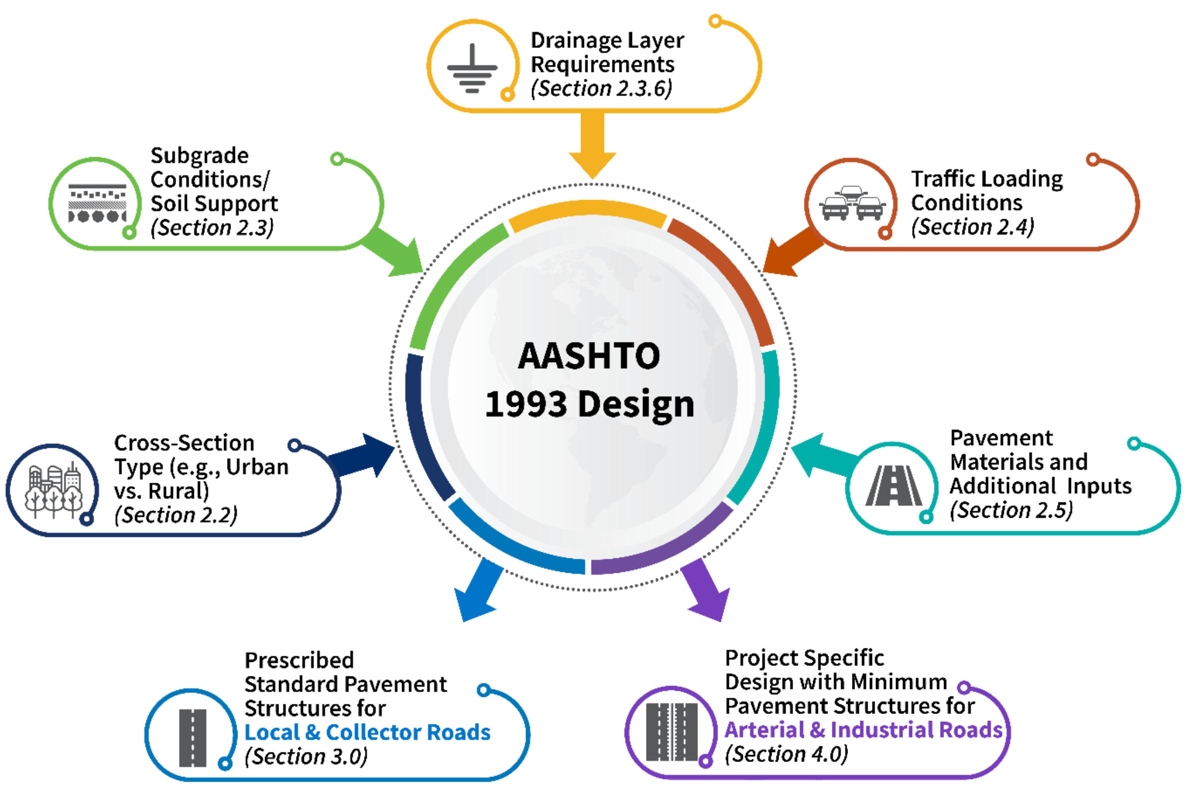


Figure 2-1 – General Overview of the Design Process

Figure 2-1 provides a schematic of the general pavement design procedure.

Further details on how to determine the required inputs for the pavement design of each group of roadway classes are described in subsequent sections of the Design Standard.

2.2 Cross-Section Type

The pavement design procedures consider two standard cross-section types:

- Urban cross-section – Roadways with surface drainage managed through curb and gutter, catch basins, and a storm sewer system. Subsurface lateral drainage is directed to the low point of the subgrade cross-section and collected and directed to the storm sewer system through subdrains.
- Rural cross-section – Roadways with surface drainage directed to open ditches located on one or both sides of the road. Subsurface lateral drainage of the pavement material layers extended through the roadway shoulder granular layers and released to the roadway side-slope.

2.3 Subgrade Conditions

2.3.1 Typical Soils in the City of Brandon

The near surface soils in the City of Brandon and surrounding areas consist of glaciolacustrine deposits of fine sand, clay, silt, and gravel. The three most common soil types are as follows:

- Gs: Consists of fine sand, minor gravel, silt, and clay.
- Lc: Consists of clay, silt, and minor sand.
- A: Consists of sand and gravel, silt, clay, and organic waste.

A map showing the typical soil types in the City of Brandon is provided in Appendix 7A. Further description and classification of these soils are discussed in the following sections.

2.3.2 Estimating Subgrade Support Conditions

Subgrade support condition is expressed in terms of resilient modulus (M_R).

A geotechnical investigation and associated laboratory and/or field testing is required to characterize the subgrade. The specific procedure for completing the geotechnical investigation should be determined on a case-by-case basis by the geotechnical engineer, but should at minimum include the following components:

- Geotechnical drilling, soil classification, and sampling of in-situ soils.
- Installation and record of ground water monitoring (e.g., seasonal ground water elevations).
- Laboratory testing to determine soil properties (e.g., soil plasticity, grain size analysis, etc.).

- Identification of areas of problem/unacceptable soil conditions (e.g., silt, peat, organics, etc.).
- Determine appropriate un-soaked and soaked California Bearing Ratio (CBR) value(s) for estimating subgrade modulus (M_R).

In some cases, the design M_R determined from the geotechnical investigation can be supplemented using non-destructive Falling Weight Deflectometer (FWD) testing of existing prototype pavements.

For reference, a general guideline for corelating typical soils expected within and around the City with M_R are provided in Table 2-1.

Table 2-1 – Subgrade Soil Types and Corresponding Resilient Modulus Category

Information Source	Typical Range of Subgrade Modulus (MR)	
	< 30 MPa	**≥ 30 MPa**
Soil Type (from Local Surficial Geology Maps)	Lc	Gs and A
General Description	Fine-grained, low to high plastic, silty clay, clay, silt-clay	Coarse-grained, poorly graded, well-graded, sand, silty, clayey
Soil Classification (USCS)	CL, CH, MH	SP, SC, SW, SM, GM, GW1
AASHTO Soil Classification	A-4, A-5, A-6, A-7, A-7-5, A-7-6	A-2-4, A-2-5, A-2-6, A-2-7, A-1-6

2.3.2.1 Estimating Resilient Modulus from California Bearing Ratio

Laboratory CBR test results from field samples can be used to estimate an appropriate M_R condition. The correlation between soaked CBR condition and M_R for fine grained soils with a soaked CBR of 10 or less is:

$$M_R(MPa) = (10.3)(Soaked\ CBR)$$

An appropriate number of geotechnical test holes shall be performed to reflect the test repeatability, the range of soil types expected to be encountered on the project, and the size of the project. Geotechnical testing, including determination of CBR values, shall be completed once every 3,000 square metres of roadway area but not less than one test per street block.

2.3.2.2 Determining Resilient Modulus from Non-destructive Testing

When deemed appropriate by the geotechnical and/or pavement engineer, FWD testing can be used as a supplemental source of information for confirming/validating the M_R condition estimated from the geotechnical investigation. Examples of appropriate conditions include: infill developments, widening and/or twinning of existing roadways, higher vehicle loading roadways, etc.

Subgrade modulus can be back-calculated from deflections measured with an FWD testing completed on a prototype pavement at, or near the vicinity of the project. The back-calculated modulus is the field modulus of the subgrade soil. The prototype should preferably meet the following criteria:

- Be a minimum of three (3) years old;
- Be a minimum of 0.5 km in length;
- Be free of structural distress; and
- Have a similar pavement structure type as proposed for the new project being designed.

AASHTO 1993 requires the laboratory resilient modulus as an input, thus a conversion factor of 0.36 for adjusting the field modulus to its equivalent laboratory modulus should be multiplied to the back-calculated modulus. The design M_R can be determined using the following equation:

$$Design\ M_R(MPa) = (0.36)(Back\ calcuated\ M_R)$$

This conversion factor would apply to pavement tested by the FWD during the mid-summer through early fall months when the subgrade is in a relatively stable and unfrozen condition.

2.3.3 Problem / Unacceptable Soil Materials

Unacceptable soils include weak or soft soils that are prone to high compressibility and low strength. These soils usually consist of those that contain high quantities of peat and organic materials. These materials should be removed prior to further construction. Frost susceptible soils are typically classified as silt (ML) by the USCS soil classification system. These materials are highly susceptible to frost because it allows the formation of ice lenses when exposed to moisture and freezing temperatures.

When encountered, these problem/unacceptable soil types shall be removed to a depth of 1.0 m below top and subgrade elevation and replacement with non-frost susceptible materials such as Pit Run granular.

2.3.4 Requirements for Geotextile Separation

A non-woven geotextile separation layer installed at the subgrade / pavement granular Type C subbase layer (or drainage layer if present) interface is required for all new pavement structures.

2.3.5 Subdrain Requirements

Maintaining adequate subsurface drainage characteristics is an important geometric design component that can influence pavement performance. Suitable longitudinal grades and cross-sectional slopes at the top of the pavement subgrade are an important factor in managing subsurface drainage. These geometric considerations apply to both urban and rural cross-sections.

2.3.5.1 Rural Cross-Section Subdrain Requirements

Rural cross sections manage subsurface moisture by directing it through the daylighted granular layers to the ditch (sideslope), and therefore subdrains are not required for these roadway types.

2.3.5.2 Urban Cross-Section Subdrain Requirements

The nature of urban cross-sections can "trap" moisture within the pavement system, and therefore the installation of subsurface longitudinal subdrains is required for all urban cross-section roadways. Crowned roadways should have subdrains installed on both subgrade edge points. Constant-slope or superelevated roadways require subdrains on the low side of the subgrade edge point. Subdrains are typically corrugated flexible plastic pipes (100 or 150 mm in diameter) enveloped with filter sock.

Typical subdrain parameters used in Manitoba include dual wall High Density Polyethylene (HDPE) with a minimum stiffness of 320 kPa with perforated slots in compliance with AASHTO M252 Class 2. The selection of subdrain type should be selected by the geotechnical engineer, and accepted by the City.

Example roadway cross-section showing subdrain requirements for urban roadways are presented in Appendix 7C.

2.3.6 Drainage Layer Requirements

The incorporation of a pavement drainage layer is required when seasonal groundwater conditions encroach within 1.0 m of the top of subgrade elevation. Seasonal groundwater represents the shallowest groundwater condition anticipated and is ideally based on the hydrogeological study for the area.

Groundwater conditions should be determined as part of the geotechnical investigation (Section 2.3.2).

The following drainage layer requirements should be considered when designing new flexible pavement structures:

- Groundwater levels > 1.0 m from top of subgrade - no adjustment to the pavement structure is required.
- Groundwater levels < 1.0 m from top of subgrade, adjustments to the pavement structures will be required as follows:
  - For local and collector roads, increase Type C base by 200 mm.
  - For arterial and industrial roads, add 150 mm of drainage layer material.

Additional details on determining roadway classification are included in Section 2.4.5.

Material properties for acceptable drainage layer types are shown in Table 2-2.

Table 2-2 – Gradation Requirements of a Drainage Layer

Sieve Size	Percent Passing		
	Drainage Rock	Recycled Concrete	Bedding Sand
75 mm	100	100	-
25 mm	0 – 80	0 – 80	-
19 mm	-	-	-
12.5 mm	0 – 18	0 – 18	-
9.5 mm	-	-	100
4.75 mm	0 – 12	0 – 12	80 – 100
2.0 mm	-	-	40 – 100
425 µm	-	-	10 – 50
75 µm	0 – 5	0 – 5	0 – 5

The above gradations recommended for use in arterial and industrial roads have higher porosity and permeability making them more effective in draining the water out of the pavements quicker compared to the sub-base or base layers used in the City of Brandon.

Examples of roadway cross sections showing drainage layer requirements for urban and rural roadways are presented in Appendix 7C.

2.4 Traffic Loading Condition

2.4.1 Equivalent Single Axle Loads

The traffic loading condition used for pavement design is defined in terms of Equivalent Single Axle Loadings (ESALs), which represent the equivalent 80-kN standardized loads for a blend of commercial/truck vehicle types. The following sections of the Design Standard provide information on how to determine an appropriate design traffic loading condition in ESALs.

2.4.2 Annual Average Daily Traffic

Annual Average Daily Traffic (AADT) represents the average traffic per day on a roadway segment. It can be calculated based on a yearly count divided by 365 days, or on a daily or weekly count multiplied by a factor to convert it into an AADT value (for example, the average of the peak AM and PM counts multiplied by a factor of 10). AADT is mixed traffic consisting of small cars to heavy tractor trailer combinations and can be two-way count (combined traffic count in both direction) and one-way count (traffic count in one direction of travel).

2.4.3 Description of Vehicle Classes

The following vehicle classes should be considered when determining the design traffic loading condition:

- Class 1: Cars, SUVs, and pickup trucks consisting of two-axles and four tires.
- Class 2: Buses, generally consisting of vehicles manufactured as traditional passenger-carrying buses with two axles and six tires or three or more axles. Class 2 vehicles include school buses and passenger carrying buses.

- Class 3: Single Unit Trucks (SUT) are those with two to four axles on a single frame, including trucks, recreational vehicles, and motorhomes. Truck tractor units without a trailer are included in this category.
- Class 4: Tractor Trailer Combinations (TTC) are those with three or more axles consisting of a truck tractor unit pulling other units/trailers in a saddle mount configuration or a straight truck power unit.

2.4.4 Load Equivalency Factor and Equivalent Single Axle Load

The following Load Equivalency Factors (LEFs) should be used for each vehicle class:

- Class 1: Cars, SUV, pickup trucks, etc., where LEF is very low, and considered insignificant
- Class 2: Bus LEF = 3.000
- Class 3: SUT LEF = 0.881
- Class 4: TTC LEF = 2.078

For context, the impact of buses is three times the application of the standard 80-kN single axle load in the pavement. In short, one bus is equivalent to three 80-kN ESALs. Light vehicles such as cars, pick-up trucks and SUVs have insignificant impact on the pavements and were not considered in the calculation of Design ESALs.

2.4.5 Roadway Classification

Five unique roadway classes are considered when completing a pavement design:

- Local – residential roads in rural and urban areas where truck traffic consists of small delivery trucks, occasional garbage collection trucks, emergency vehicles, school buses, fire trucks, and recreational vehicles.
- Collector – Not a Bus Route – roads that collect and distribute traffic from local roads to arterial roads, with moderate traffic volumes, trip length and operating speeds.
- Collector – Bus Route – collector roads that are also designated as bus routes.
- Arterials – roadways that are either principal or minor roadways carrying longer-distance flows between important centers of activity or those that carry traffic from or to freeways or expressways and are designed with higher level of service due to higher traffic volumes and faster operational speeds.
- Industrial (5% or greater trucks) – roads primarily for transportation of industrial goods, and typically includes roadways with higher percentages of trucks.

2.4.6 Typical Truck Traffic Percent by Road Classification

In the absence of detailed traffic study inclusive of truck types and volumes, Table 2-3 provides typical values for each roadway class for both 1) percentage trucks (commercial) and 2) vehicle class proportions (SUT vs. TTC).

Table 2-3 – Heavy Vehicle Blend Bus Volumes for Each Road Classification

Road Class	Percentage of Heavy Vehicles (Class 3 and 4)	Heavy Vehicle Blend [1]	Class 2: Bus
Local	24/week	75% Class 3 / 25% Class 4	Occasional
Collector	3% of total AADT	75% Class 3 / 25% Class 4	Occasional
Collector – Bus Route	3% of total AADT	75% Class 3 / 25% Class 4	Typical
Arterial	3% of total AADT	75% Class 3 / 25% Class 4	Typical
Industrial	5% of total AADT	50% Class 3 / 50% Class 4	Typical

[1] Class 3 vehicles are Single Unit Trucks (SUT), Class 4 Vehicles are Tractor Trailer Combinations (TTC)

2.4.7 Directional Split for Two-way Roadways

For two-way roadways, a directional split of 50/50 in each direction should be used. This can be completed by dividing the two-directional AADT by 2.

2.4.8 Lane Distribution Factor

There are instances when vehicle loading may not be equally distributed between adjacent lanes of traffic following the same directional flow. Table 2-4 provides the Lane Distribution Factors (LDF) that should be used for multi-lane roadways.

Table 2-4 – Proposed Lane Distribution Factors Based on the Number of Lanes

<table>
<tr><th rowspan="2">Location</th><th rowspan="2">No. of Lanes Per Direction</th><th colspan="2">Load Distribution Factor (LDF)</th></tr>
<tr><th>Truck Percentages</th><th>Bus Percentages</th></tr>
<tr><td rowspan="2">Urban/ Rural</td><td>One lane</td><td>100%</td><td>100 %</td></tr>
<tr><td>Two or more lanes</td><td>50% Each Lane</td><td>100% Outer Lane
(0% in Inner Lane(s))</td></tr>
</table>

2.4.9 Growth Rate

Growth rate is the annual increase in traffic volumes, typically expressed as a percentage growth. A growth rate of 2.0% should be used for estimating the design period traffic loading condition. The calculation of the growth rate factor that will be used in estimating the total Design ESALs is provided below:

$$Growth\ Rate\ Factor = \frac{\left((1 + Growth\ Rate)^{(Design\ Period)} - 1\right)}{Growth\ Rate}$$

Growth rate in the above formula should be entered as a fraction (e.g., 0.02) not a percentage (e.g., 2.0%). For example, a 20-year design period and growth rate of 2% corresponds to a traffic growth factor of 24.3.

2.4.10 Design Period

A design period of 20 years should be used for all new flexible pavement designs.

2.4.11 Calculation of Design ESALs

The following equation can be used to determine the Design ESALs per day, per direction:

$$\frac{Design\ ESALs}{Day\ /\ Direction} = \left(\frac{\text{AADT}}{2}\right)((\%\text{SUT})(\text{LDF})(0.881) + (\%\text{TTC})(\text{LDF})(2.073) + (\%\text{Buses})(\text{LDF})(3.000))$$

Where:

AADT is a two-way count. If AADT is a one-way count, do not divide it in two.

LDF = Lane distribution factor (See Section 2.4.8)

SUT = Single Unit Trucks

TTC = Tractor Trailer Combination

If truck counts for SUT, TTC and buses are available, the above equation becomes:

$$\frac{Design\ ESALs}{Day\ /\ Direction} = (\text{SUT})(\text{LDF})(0.881) + (\text{TTC})(\text{LDF})(2.073) + (\text{Buses})(\text{LDF})(3.000)$$

The design period ESALs can be calculated using the following equation:

$$Design\ ESALs = \left(\frac{ESALS}{Day/Direction}\right)\ (Growth\ Rate\ Factor)(365\,\frac{days}{year})$$

2.5 Additional AASHTO 1993 Design Inputs

AASHTO 1993 design inputs used for completing new flexible pavement designs are presented in this section of the Design Standard.

2.5.1 Serviceability

Serviceability is defined as the ability of a pavement to serve traffic. The pavement structure should be able to serve traffic at a certain level of serviceability determined by the agency and is represented by the pavement serviceability index (PSI), which is based on a scale of “zero” for impassable to “five” for perfect pavements.

The following values should be used for determining pavement serviceability:

- Initial Serviceability (p_i) = 4.2
- Terminal Serviceability (p_t) = 2.5
- Serviceability Loss (ΔPSI) = p_i - p_t = 4.2 – 2.5 = 1.7

2.5.2 Reliability

Reliability represents the probability that the predicted terminal serviceability discussed in Section 2.5.1 will not be exceeded within the design period. For example, a design reliability of 90% represents the probability (9 out of 10 projects) that the project will perform as expected over its design life.

The following values should be used for determining pavement design reliability:

- Local, Collector Roads Reliability (R) = 85%
- Arterial Roads Reliability (R) = 90%
- Industrial Roads Reliability (R) = 70%

2.5.3 Standard Deviation

The following value should be used for assigning a design standard deviation:

- Standard Deviation (σ) = 0.45

2.5.4 Pavement Layer Coefficients

Flexible pavement materials typically consist of the asphalt concrete pavement (ACP), granular base course (GBC), granular subbase course (GSC), and drainage layer (DL). The structural strength of each of these layers is expressed in terms of the pavement layer coefficient, estimated from the laboratory modulus of these materials. The AASHTO 1993 Guide provides guidance on how to estimate the layer coefficient for each of these materials.

The following pavement material layer coefficients should be used for determining pavement layer thicknesses:

- ACP layer coefficient (a_1) = 0.40
- Granular base layer coefficient (a_2) = 0.12 (City Type A Base)
- Granular subbase layer coefficient (a_3) = 0.09 (City Type C Base)
- Drainage layer coefficient (a_4) = 0.10 (see Table 2-2)

2.5.5 Drainage Coefficients

AASHTO drainage coefficients, m, are used for modifying the structural layer coefficients of the base and subbase materials in flexible pavements is based on the ability of the material to drain water and the percent of time that the pavement structure is exposed to moisture levels approaching saturation. Given that the assessment of groundwater, and consideration for the incorporation of subdrains (urban roadways) and drainage layers (all roadways) is integral to the pavement design, a "good" drainage quality of base and subbase materials should be considered appropriate.

A drainage layer coefficient of 1.0 should be used for the design of all pavement layer thicknesses.

3.0 PAVEMENT DESIGN STANDARD – LOCAL AND COLLECTOR ROADS

Following determining the roadway cross section type (rural or urban), pavement designs for local and collector roads shall comply with those provided in Table 3-1. The appropriate pavement design is selected by following these steps:

- *Step 1:* Determine the appropriate roadway classification (e.g., local or collector).
- *Step 2:* For collector roadways only – determine if the roadway is a bus route.
- *Step 3:* Determine which subgrade support condition applies (see Section 2.3 for more information on subgrade support characterization).
- *Step 4:* Determine which ground water condition applies (see Section 2.3.6 for more information on drainage layer requirements).
- *Step 5:* Select the corresponding pavement structure (consisting of ACP, Type A Base, and Type C base) based on steps 1 through 4.

Table 3-1 – Standard Pavement Design Structures for local and Collector Roads

Road Class	Subgrade Modulus MPa	Groundwater Level m	Layer Thickness, mm			
			ACP	Type A Base	Type C Base	Total
Local	All	> 1.0	100	200	200	500
		< 1.0	100	200	400	700
Collector	< 30	> 1.0	120	200	400	720
		< 1.0	120	200	600	920
	≥ 30	> 1.0	120	200	200	520
		< 1.0	120	200	400	720
Collector - Bus Route	< 30	> 1.0	160	200	500	860
		< 1.0	160	200	700	1060
	≥ 30	> 1.0	150	200	300	650
		< 1.0	150	200	500	850

4.0 PAVEMENT DESIGN PROCEDURE – ARTERIAL AND INDUSTRIAL ROADS

The following AASHTO 1993 design procedure should be followed for the flexible pavement design of arterial and industrial roads. Arterial and industrial roadways are major critical roadways/infrastructures that require project specific traffic consideration given their inherent highly variable traffic conditions and volumes.

4.1 AASHTO 1993 Design Procedure

The following steps should be followed for the flexible pavement design of arterial and industrial roads.

- *Step 1:* Establish Subgrade Support Condition (M_R) (see Section 2.3 for more information on subgrade support characterization).
- *Step 2:* Determine the design period ESALs (see Section 2.4 for more information on calculating ESALs).
- *Step 3:* Determine which ground water condition applies (see Section 2.3.6 for more information on drainage layer requirements).
- *Step 4:* Determine the Design Structural Number (SN) using the results of Steps 1 and 2 and the AASHTO 1993 design inputs provided in Section 2.5.
- The Design SN in Step 4 can be determined using one of the two methods.

4.1.1 *Method 1:* Determine Design SN from AASHTO SN Formula

Calculate the Design SN using the following equation:

$$\log_{10}(W_{18}) = Z_R \times S_o + 9.36 \times \log_{10}(SN+1) - 0.20 + \frac{\log_{10}\left(\frac{\Delta PSI}{4.2-1.5}\right)}{0.40 + \frac{1094}{(SN+1)^{5.19}}} + 2.32 \times \log_{10}(M_R) - 8.07$$

Where:

- M_R – Design Subgrade Resilient Modulus from design *Step 1.*
- W_{18} – the design period ESALs from design *Step 2*.
- Z_R – Standard Normal Deviate, based on assigned Reliability (Section 2.5.2):
  - R = 70%, Z_R = -0.524401
  - R = 85%, Z_R = -1.036433
  - R = 90%, Z_R = -1.281552
- S_O – Standard Deviation (Section 2.5.3)

- ΔPSI = Serviceability Loss = 1.7 (Section 2.5.1)

Note: There are many available computer programs and/or online applications that can be used to solve the AASHTO 1993 equation shown in Method 1.

4.1.2 *Method 2:* Determine the Design SN Using the AASHTO Nomograph

Determine the Design SN using the following nomograph:

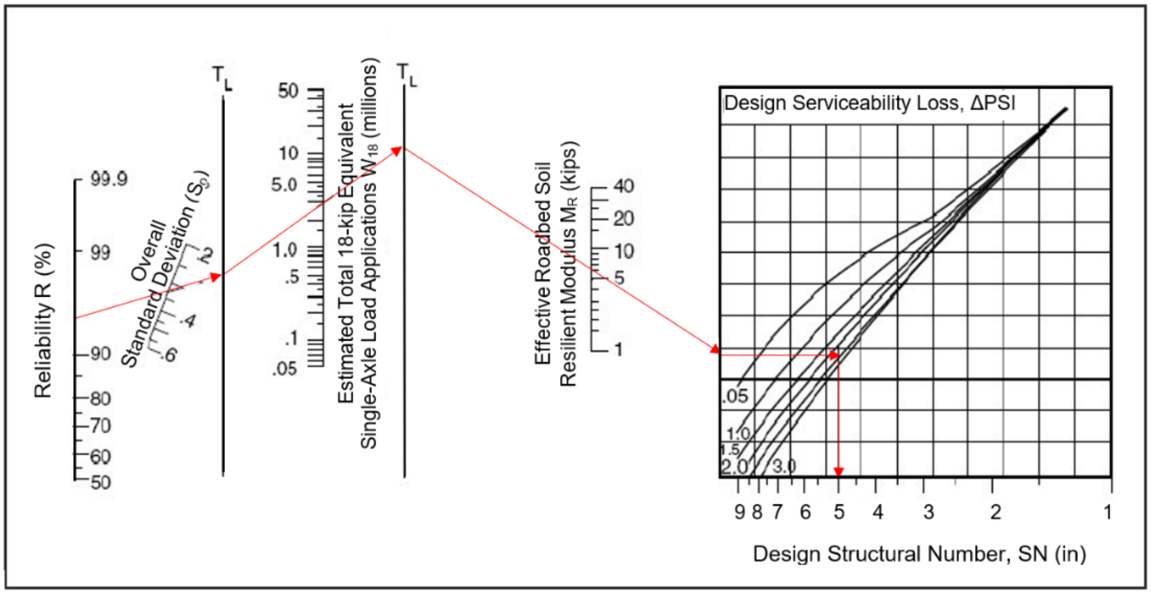


Figure 4-1– Equation and Nomograph for Estimating the Design Structural Number

- *Step 5:* Complete the AASHTO Pavement Layer Design using the following equation:

$$SN_{Design} = a_1 D_1 + a_2 D_2 m_2 + a_3 D_3 m_3 + a_4 D_4 m_4$$

Where:

- a_1 = ACP layer coefficient (0.40)
- a_2 = Type A Base layer coefficient (0.12)
- a_3 = Type C Base layer coefficient (0.09)
- a_4 = Drainage layer coefficient (0.10),

  and

- D_1 = ACP layer thickness (mm)
- D_2 = Type A Base layer thickness (mm)
- D_3 = Type C Base layer thickness (mm)
- D_4 = 150 mm (drainage layer thickness),

and

- $m_{2,3,4}$ = Drainage coefficient (use 1.0 for all layers)

The design structures should be verified by checking the following:

- The calculated SN of the recommended structure should be equal to or greater than the design SN.
- The thicknesses of the pavement layers should be greater than or equal to the minimum thickness requirements provided in Table 4-1.

4.2 Minimum Pavement Structures (Arterial and Industrial Roads)

The pavement design and layer thicknesses determined following the design procedure shown in Section 4.1 should also meet or exceed the minimum pavement layer thicknesses shown in Table 4-1.

Table 4-1 – Minimum Pavement Structure for Arterial and Industrial Roads

Road Class	Subgrade Condition, (MPa)	Ground Water Level (GWL) (m)	Minimum Pavement Thickness (mm)				
			ACP	Type A Base	Type C Base	Drainage Layer	Total
Arterial	< 30	>1.0	200	200	500	0	900
		<1.0	200	200	350	150	900
	≥30	>1.0	180	200	300	0	680
		<1.0	180	200	200	150	730
Industrial	< 30	>1.0	170	200	500	0	870
		<1.0	170	200	300	150	820
	≥30	>1.0	160	200	300	0	660
		<1.0	160	200	200	150	710

4.3 Design Examples

Typical design examples for arterial and industrial road classes are provided in Appendix 7B.

5.0 ACTIVE TRANSPORTATION

Active Transportation pavements are for uses such as walking, biking, and skateboarding, that seldom receive vehicular traffic. The following pavement section should be used for all Active Transportation pavements:

- 75 mm ACP
- 200 mm Type A Base

6.0 TYPICAL CROSS-SECTIONS

Typical cross-sections for urban and rural roadways are shown in Appendix 7C.

7.0 OTHER DESIGN CONSIDERATIONS

7.1 Subgrade Preparation

Subgrade preparation in road building provides two functions: providing an adequate platform for construction equipment and providing a uniform support condition on which the design pavement structure is founded. Adequate subgrade preparation typically involves three factors, thickness of lift, moisture content and compaction (typically expressed as a percent of Standard Proctor Density (SPD)).

Subgrade preparation depth typically varies between cut and fill conditions. For fills (typical of rural cross-sections) an appropriate subgrade preparation would be 300 mm in two lifts. For cut sections (typical for urban cross-sections) the preparation depth can be reduced to 150 mm or 200mm. Moisture content requirements for applications like utility installations typically favor slightly above optimum moisture content to mitigate further consolidation. In the upper layer of the subgrade a moisture content slightly below optimum is favored for stability. For compaction, 98% of Standard Proctor Maximum Dry Density (SPMDD) is generally considered adequate.

7.2 Geosynthetics

Geosynthetics can be defined as planar products manufactured from polymeric material, used together with soil, rock or other geotechnical engineering-related material as an integral part of a man-made project, structure, or system (Transportation Geotechnics, 2017). Seven categories of geosynthetic materials are manufactured: geocomposites, geogrids, geomembranes, geonets, geopipes, geotextiles, and geosynthetic clay liners. In the roadbuilding industry, generally three types of geosynthetics are typical: geotextiles (woven or non-woven), geogrids and geocomposites (combined geogrid and geotextile).

As previously noted, a non-woven geotextile is required at the subgrade granular interface for all roadways. The primary function is as a separator to mitigate subgrade materials from “pumping” into the pavement granular materials. Geocomposites (also referred to as “combi-grids”) can be used to assist in bridging problem soils. Geogrids are best placed within the granular layer to provide reinforcement much like rebar or mesh, are typically more effective in relatively weak pavement systems like gravel roads.

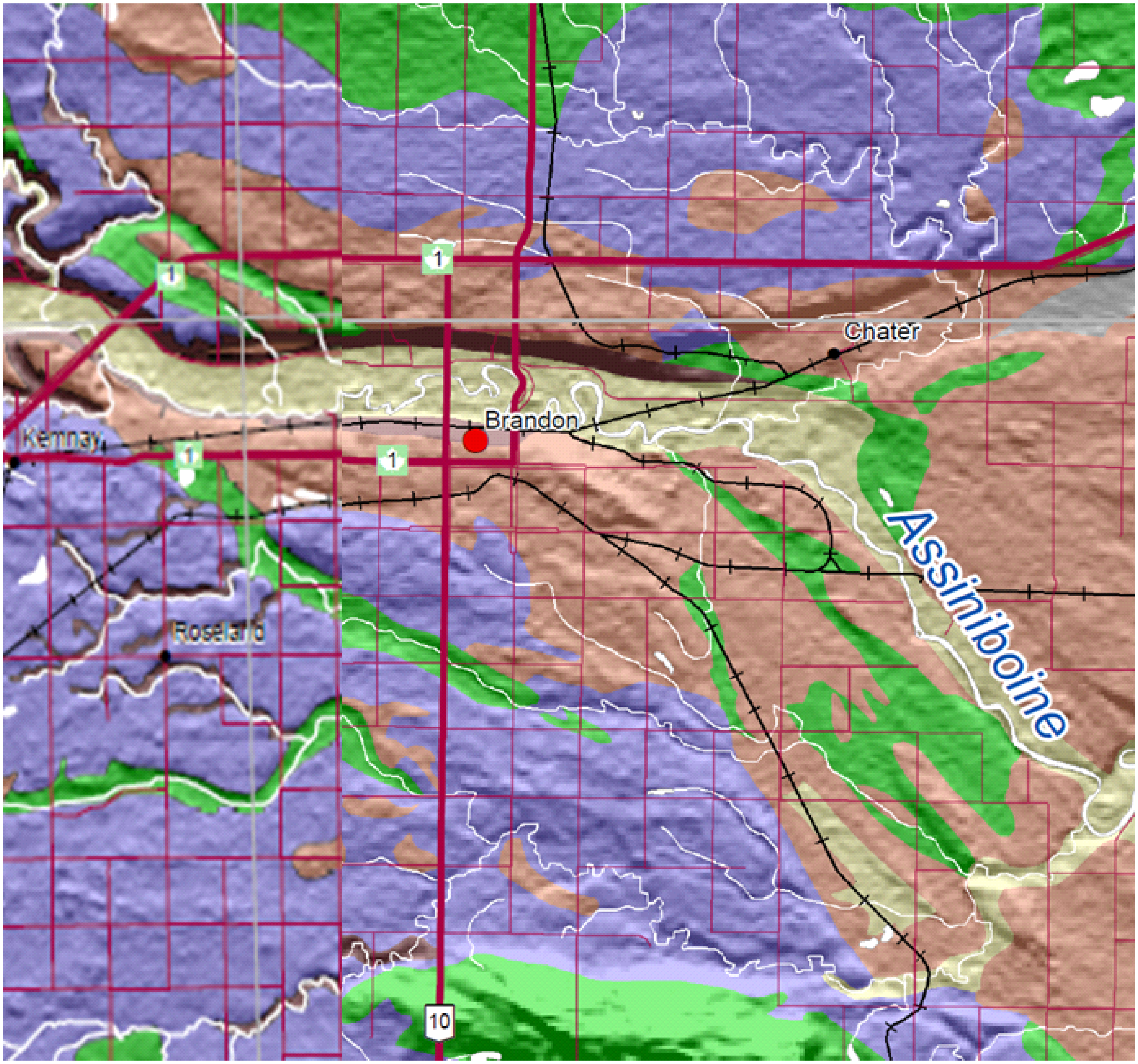
7.3 ACP Lift Thicknesses

Historically pavement practitioners used the rule-of-thumb that the minimum lift thickness should be 1.5 times the maximum aggregate size. Although this may have represented the minimum thickness for placement it was not appropriate for adequate compaction.

In the past several decades, and in part due to the advent of Superpave, the current guideline is three times the Nominal Maximum Size (NMS). The NMS is defined as the largest sieve size that the aggregate specification would allow material to be retained on. This guideline is considered as a minimum to promote adequate compaction. In the case of the City of Brandon current specifications for Class A and B mix aggregate the maximum size is 19 mm. The NMS is 12.5mm (i.e., the largest sieve size that the specification allows material to be retained). Therefore, the recommended minimum lift thickness is 12.5 mm X 3 = 37.5 mm or rounded to 40 mm.

Due to advances in compaction equipment (vibration, frequency, and amplitude controls, etc.), generally the maximum lift thickness is virtually unlimited to achieve adequate compaction. Therefore, a maximum recommended lift thickness is governed by two factors: the capability of the paver and smoothness. Most paving equipment is capable of lift thicknesses between 150 mm and 200 mm, so smoothness typically governs. Every time a roller stops and/or changes direction a depression or bump results. The thicker the lift the more pronounced and more difficult it is to remove the depression or bump. Therefore, the maximum lift thickness guideline is typically 4 times the maximum aggregate size. In the case of the City specification, the maximum lift thickness would be 19 mm X 4 = 76, or rounded to 80 mm. With smoothness being the governing factor, controlling the maximum lift thickness is more important for the upper lift than for lower lifts.

Appendix 7A Surficial Geology Map



LEGEND

- Gs = Distal Glaciofluvial Sediments (Subgrade Modulus, Mr > 30 MPa)
- Lc = Off Shore Glaciolacustrine (Mr < 30 MPa)
- Tc = Sediments Calcereous Silt Diamicton (Mr < 30 MPa)
- C = Colluvium or Landslide Debris, eroded slopes (Mr = N/A)
- E = Eolian (Mr < 30 MPa)
- A = Alluvial Sediments (Mr > 30 MPa)

TYPICAL SUBGRADE TYPE

SURFICAL GEOLOGY FOR CITY OF BRANDON

PROJECTION	DATUM	CLIENT
UTM Zone 14	NAD83	City of BRANDON

NOTES
Reference: Natural Resources and Northern Development, Government of Manitoba website: www.manitoba.ca/iem/geo/gis/surfgeomap.html

FILE NO.
704-TRN.PAVE03265-01_Fig_1.mxd

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Tt-VANC	AV	EO	BP	0

DATE	PROJECT NO.
January, 2023	TRN.PAVE03265-01

Appendix A

Appendix 7B Example Pavement Designs

Design Examples

The following are examples of new flexible pavement design using the Design Procedure presented Section 4.1 in this report.

Example 1: Industrial Roadway - Sample Project Description

Structural design is required for a new flexible pavement for a proposed two-lane (1-lane per travel direction) rural industrial roadway. The estimated AADT of the road is 5,000 vehicles/day with truck traffic consisting of 120 SUT, 130 TTC and 70 Transit Buses per day. Traffic growth rate is 2 percent. Based on the surficial geology map provided in Appendix A, the roadway will be in a soil type classified as "GS". The results of the geotechnical investigation revealed a subgrade soil consisting of fine-grained high plastic soil (CH based on USCS Soil Classification) and the groundwater level elevation is at 3 meters below the design subgrade elevation. Determine the required thicknesses of the ACP, base, and subbase layers.

Step 1 – Establish Subgrade Support: Based on geotechnical investigation, the resilient modulus, M_R, of the subgrade is less than 30 MPa. The design MR can also be confirmed from FWD testing of prototype roadways in the vicinity with seasonally adjusted resilient moduli. For this example, a seasonally adjusted back-calculated M_R of 20 MPa was determined from FWD testing.

Step 2 - Estimate Design ESALs: Use an annual growth rate of 2%. The LDF for SUT, TTC and Buses is 100% and the two-step calculation procedure of Design ESALs are as follows:

- Calculate the Design ESALs per day per direction:

Design ESALs/day/direction = SUT *x* LDF *x* 0.881 + TTC *x* LDF *x* 2.073 + Bus *x* LDF *x* 3.000

= (120 x 1.0 x 0.881) + (130 x 1.0 x 2.073) + (70 x 1.0 x 3.000)

= 585

- Calculate the 20-Year Design ESALs:

Design ESALs = ESALs/day/direction x Growth Rate Factor x 365 days per year

= (585)(24.3)(365)

= $\mathbf{5.2 \times 10^6}$

Step 3 - Establish Drainage Condition: The results of the geotechnical investigation indicated that GWL elevation was 3.0 m lower than the top of the design subgrade elevation, thus, a drainage layer is not required.

Step 4 - Determine AASHTO Structural Number (SN): Using the following Design Inputs from Steps 2 and 3 and the additional inputs from Section 2.5.2.

- From Step 1 Subgrade Soil Resilient Modulus (MR) = 20 MPa = 2.9 ksi

- From Step 2 Design ESALs (W18) = 5.2 million ESALs
- Following Design Method 1:
  - Design Reliability (R) = 70%
  - Initial Serviceability (P_I) = 4.2
  - Terminal Serviceability (P_T) = 2.5
  - Serviceability Loss: PSI_{LOSS} or ∆PSI = 4.2 – 2.5 = 1.7
- The SN can be calculated using the following equation:

$$\log_{10}(W_{18}) = Z_R \times S_o + 9.36 \times \log_{10}(SN+1) - 0.20 + \frac{\log_{10}\left(\frac{\Delta PSI}{4.2-1.5}\right)}{0.40 + \frac{1094}{(SN+1)^{5.19}}} + 2.32 \times \log_{10}(M_R) - 8.07$$

- Design Structural Number (SN) = 5.5 inch = 140 mm

Step 5: Complete AASHTO Layer Design: The following design alternatives have been generated based on the following Equation:

$$SN = a_1D_1 + a_2D_2m_2 + a_3D_3m_3 + a_4D_4m_4$$

Structural Layer Coefficients and Drainage Coefficients are obtained from Section 2.5.4. Note that a drainage layer will not be required for this roadway as the groundwater level (GWL) is >1.0 m below the top of the subgrade. Also, since the roadway will have a rural cross section, excess water in the granular base can be daylighted to the side slopes and subdrains will not be required. If GWL is less than 1 m from the top of the subgrade, the structural contribution of the drainage layer should be added in determining layer thicknesses.

The last column below presents the product of structural layer coefficient and thickness. The sum of 141 is the calculated SN of the design structures and is used to verify the correctness of the layer thicknesses.

Pavement Layer	Layer Coefficient	Layer Thickness (mm)	a X D (mm)
ACP	0.40	180	0.40 X 180 X 1.0 = 72
Type A Base	0.12	200	0.12 X 200 X 1.0 = 24
Type C Base	0.09	500	0.09 X 500 X 1.0 = 45
		Calculated SN (mm)	141

Check the Design:

- Calculated SN is ≥ required SN or 141 > 140. ***Checked.***

- Layer thicknesses ≥ the provided minimum structures (Table 4-1 in Section 4.2). The table showed that the minimum layer thicknesses are 170 mm for ACP, 200 mm for Type A Base and 500 mm minimum for Type C Base. ***Checked.***

Example 2: Arterial Roadway - Sample Project Description

The City requires new pavement design for a 4-lane (2-lane per travel direction) Urban Arterial Roadway with an estimated two-way AADT of 14,000 vehicles/day, where truck traffic consists of 2.4% SUT, 1.6% TTC and 0.7% transit buses. The annual traffic growth rate is 2%. The proposed roadway will have an urban cross section with curbs and gutters. The geotechnical investigation indicated that the subgrade soil consists of coarse-grained, poorly graded sand or SP. Determine the required pavement layer thicknesses.

Step 1 – Establish Subgrade Support Conditions: The subgrade resilient modulus for SP is generally greater than 30 MPa. (See Table 2.1). Alternatively, this can be confirmed from FWD testing of prototype roadways in the vicinity. For this example, it is assumed that the seasonally adjusted back-calculated subgrade modulus is 35 MPa.

Step 2 - Estimate Design ESALs: The traffic annual growth rate is 2%. The following two-step procedures were used in calculating the Design ESALs:

- Calculate the Design ESALs per day per direction. Since there are two lanes per direction, the LDF used for trucks is 50% and the LDF used for buses is 100%.

Design ESALs/day/direction = AADT / 2 (%SUT x LDF x 0.881 + %TTC x LDF x 2.073 + %Bus x LDF x 3.000)

= (14,000/2)((0.024 x 0.5 x 0.881) + (0.016 x 0.5 x 2.073) + (0.007 x 1.0 x 3.000))

= 337

- Calculate the 20-Year Design ESALs

Design ESALs = ESALs/day/direction x Growth Rate Factor x 365 days per year

= (337)(24.3)(365)
= **3.0×10^6**

Step 3 - Establish Drainage Condition: The geotechnical investigation indicated that the groundwater level in the vicinity will be less than 1.0 m from the top of the subgrade. Based on discussion in Section 2.4, the roadway will require a drainage layer. Also, since this will have an urban cross-section, a subdrain will be required.

Step 4 - Determine AASHTO Structural Number (SN): Using the following Design Inputs from Steps 2 and 3 above:

- From Step 3 Design ESALs (W18) = 3.0M ESALs/direction
- From Section 2.5.2 of this report:
  - Design Reliability (R) = 90%
  - Initial Serviceability (P_I) = 4.2

   - Terminal Serviceability (P_T) = 2.5
   - Serviceability Loss Factor (ΔPSI) = 4.2 – 2.5 = 1.7

- From Step 3 Subgrade Soil Resilient Modulus (M_R) = 35 MPa = 5.1 ksi
- SN can be calculated using the following equation:

$$\log_{10}(W_{18}) = Z_R \times S_o + 9.36 \times \log_{10}(SN+1) - 0.20 + \frac{\log_{10}\left(\frac{\Delta PSI}{4.2-1.5}\right)}{0.40 + \frac{1094}{(SN+1)^{5.19}}} + 2.32 \times \log_{10}(M_R) - 8.07$$

- Design Structural Number (SN) = 4.7 inch = 121 mm

Step 5: Complete AASHTO Layer Design: The following design alternatives have been generated based on the following Equation:

$$SN = a_1 D_1 + a_2 D_2 m_2 + a_3 D_3 m_3 + a_4 D_4 m_4$$

Structural Layer Coefficients and Drainage Coefficients are obtained from Section 2.5.4. Note that a drainage layer will be required for this roadway as the groundwater level (GWL) is <1.0 m below the top of the subgrade, and the structural contribution of the drainage layer should be added in determining layer thicknesses.

The last column below presents the product of structural layer coefficient and thickness. The sum of 129 is the calculated SN of the design structures and is used to verify the correctness of the layer thicknesses.

Pavement Layer	Layer Coefficient	Layer Thickness (mm)	a X D (mm)
ACP	0.40	180	0.40 X 180 X 1.0 = 72
Type A Base	0.12	200	0.12 X 200 X 1.0 = 24
Type C Base	0.09	200	0.09 X 200 X 1.0 = 18
Drainage Layer	0.10	150	0.10 X 150 X 1.0 = 15
		The Calculated SN (mm) is	129

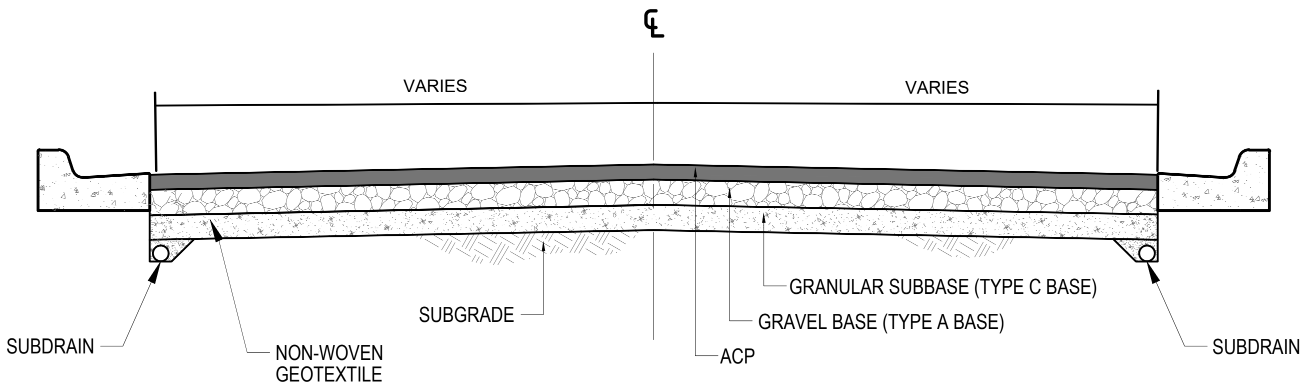
Check the Design:

- Calculated SN ≥ required SN or 129 mm > 121 mm. Checked!
- Layer thicknesses ≥ the minimum structure (Table 4-1 Section 4.2). The minimum pavement structures for arterials are 180 mm ACP, 200 mm Type A Base, 200 mm Type C Base, and 150 mm drainage layer. Checked!

Appendix 7C Typical Pavement Sections

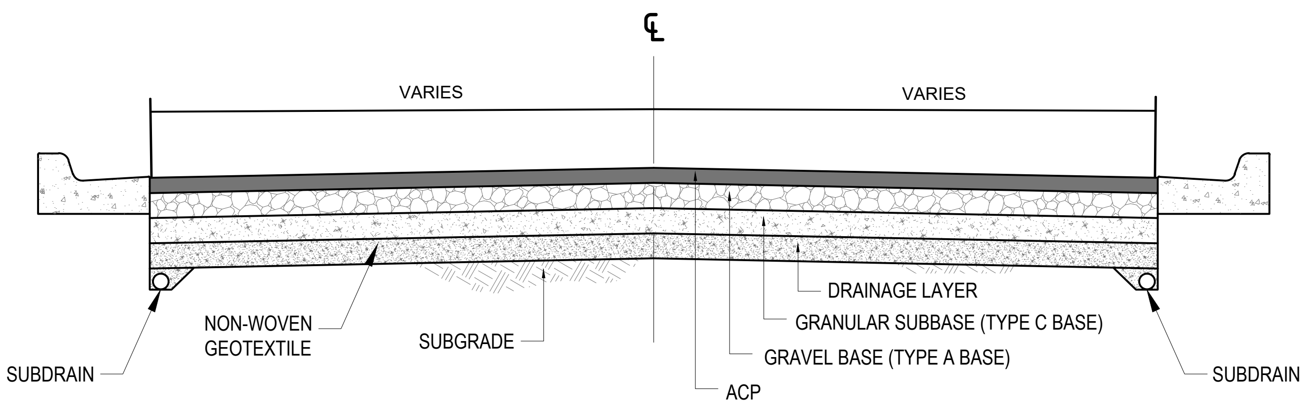
URBAN SECTION

GOOD DRAINAGE CONDITION



SEASONAL GROUNDWATER >1.0 m FROM SUBGRADE

POOR DRAINAGE CONDITION



SEASONAL GROUNDWATER <1.0 m FROM SUBGRADE

ISSUED FOR USE

NOTES

ALL DIMENSIONS ARE SHOWN IN METRES, UNLESS OTHERWISE INDICATED. TYPICAL SECTIONS & DETAILS ARE NOT TO SCALE.

ACTUAL PAVEMENT WIDTH SHOULD BE CONFIRMED WITH FIELD MEASUREMENTS AND TYPICAL CROSS SECTIONS UPDATED AS REQUIRED PRIOR TO TENDER.

CLIENT

City of BRANDON

CITY OF BRANDON

TYPICAL URBAN CROSS SECTION

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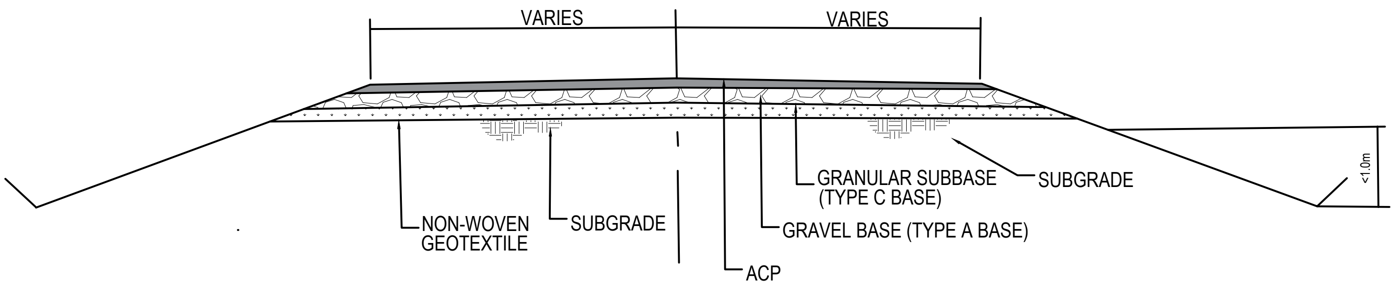
OFFICE	DATE		
EDM	April 2023		

Figure C-1

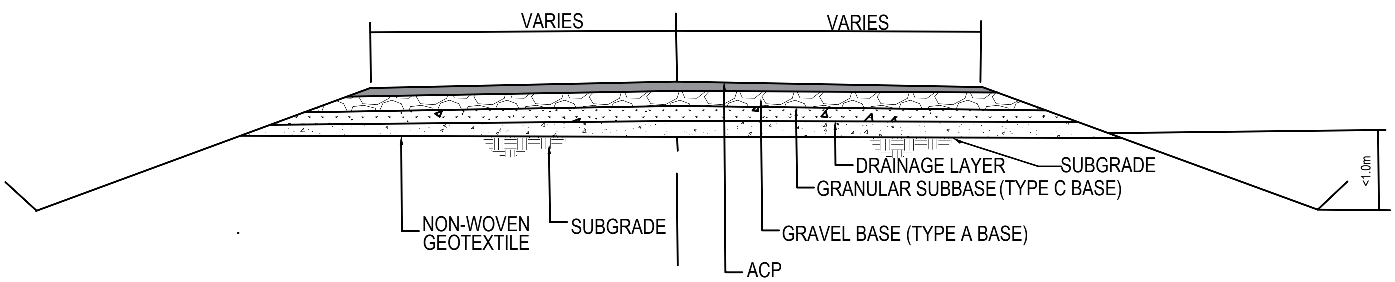
RURAL SECTION

GOOD DRAINAGE CONDITION



SEASONAL GROUNDWATER > 1.0M FROM SUBGRADE

POOR DRAINAGE CONDITION



SEASONAL GROUNDWATER < 1.0M FROM SUBGRADE

ISSUED FOR USE

NOTES

ALL DIMENSIONS ARE SHOWN IN METRES, UNLESS OTHERWISE INDICATED. TYPICAL SECTIONS & DETAILS ARE NOT TO SCALE.

ACTUAL PAVEMENT WIDTH SHOULD BE CONFIRMED WITH FIELD MEASUREMENTS AND TYPICAL CROSS SECTIONS UPDATED AS REQUIRED PRIOR TO TENDER.

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CITY OF BRANDON

TYPICAL RURAL CROSS SECTION

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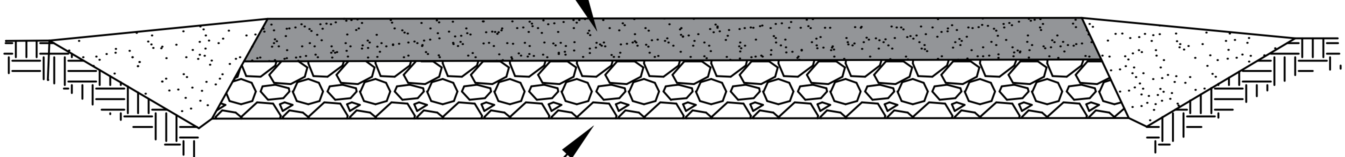
EDM	April 2023

Figure C-2

ACTIVE TRANSPORTATION



ISSUED FOR USE

NOTES

ALL DIMENSIONS ARE SHOWN IN METRES, UNLESS OTHERWISE INDICATED. TYPICAL SECTIONS & DETAILS ARE NOT TO SCALE.

ACTUAL PAVEMENT WIDTH SHOULD BE CONFIRMED WITH FIELD MEASUREMENTS AND TYPICAL CROSS SECTIONS UPDATED AS REQUIRED PRIOR TO TENDER.

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CITY OF BRANDON

TYPICAL ACTIVE TRANSPORTATION CROSS SECTION

PROJECT NO.	DWN	CKD	REV
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Figure C-3

C:\Users\akansha.vaish\Desktop\City Of Brandon\PAVE03256-01.dwg [FIGURE 2-TYPE 3] January 25, 2023 - 2:49:54 pm (BY: VAISH, AKANSHA)