Public Works
Travaux publics

Pavement Design Guideline - DRAFT

City of Winnipeg

Pavement Management Branch

Public Works

1. General

The Pavement Design Guideline has been prepared by the Public Works Department, Pavement Management Branch to set out design requirements to promote uniformity of pavement design and to achieve long lasting quality pavements that will contribute to traffic safety and efficient roads for the well-being of the travelling public. This guideline is still under development and updates will be provided as new information becomes available. The City is still calibrating and validating the pavement design models using Winnipeg pavement performance data. The need for sound engineering judgment is still a crucial aspect in generating a pavement design (selection of realistic and representative input values) with reasonable initial cost and good long-term performance. Other design factors that affect the design, such as suitability of subgrade soils, extent of removal of unsuitable subgrade, and type of backfill materials shall be determined (or estimated) for each project.

The design procedure used in the development of the Guide is based on both scientific principles (mechanistic) and observed pavement performance (empirical). This methodology is referred to as mechanistic-empirical pavement design and represents one of the most up-to-date approaches in designing reliable and long-lasting pavements. However, both AASHTO 1993 and Mechanistic-Empirical Design Procedure (AASHTOWare Pavement ME Design) can be used based on their applicability to the road classification and traffic volumes. The AASHTOWare Pavement ME Design procedure is primarily for high traffic volume roads (heavily trafficked collectors and above) and is based on the ME Design Version 2.5.5 while AASHTO 1993 "Guide for Design of Pavement Structures" along with its software package titled Design Analysis and Rehabilitation for Windows (DARWin) or other software based on AASHTO design methods can be used for lower-volume facilities, with adjustments made to consider the City of Winnipeg's past experience and pavement materials. The designer should be familiar with the required inputs for the software programs, as well as the specific system defaults that cannot be changed or do not fit the project design criteria. If the program defaults do not match the project circumstances, the software program should not be used.

The guideline introduces customized default parameters for City of Winnipeg conditions for use with the AASHTO 1993 or AASHTO ME Design. It is a reference document to assist the designer in selecting default parameters. Where no guidance is provided in this interim document, engineering judgment will be used.

The information presented in this guideline was carefully researched and presented. However, no warranty, express or implied, is made on the accuracy of the contents or their extraction from referenced publications; nor shall the fact of distribution constitute responsibility by the City of Winnipeg for omissions, errors or possible misrepresentation, or financial loss that may result from use or interpretation of the material contained herein.

2. Definitions

Sub-grade	–	the natural in-situ material or imported material that has been used to build an embankment
Sub-base layer	–	the layer of material between the sub-grade and the base course
Base course layer	–	the layer of material between the sub-base and the pavement wearing surface
Granular A	–	open-graded virgin (not recycled) aggregates intended for use as free draining base and sub-base within the pavement structure of high traffic volume streets (i.e. expressways, major arterials, minor arterials, industrial/commercial collectors, residential major collectors, residential minor collectors, and industrial/commercial locals), including approaches
Granular B	–	well-graded virgin or recycled aggregates intended for use as base and sub-base within the pavement structure of low traffic volume streets (i.e. residential locals, public lanes, and asphalt pathways), including approaches. Granular A can be used instead of Granular B
Granular C	–	dense graded virgin or recycled aggregates intended for use as base and sub-base for street pavement rehabilitations and other applications

3. AASHTO 1993 Procedure

The design parameters required for rigid pavements differ from those for flexible pavements. Table 1 summarizes the parameters required for the design of each pavement structure.

Table 1: Summary of Design Parameters for each Pavement Type

Description	Flexible Pavement	Rigid Pavement
Performance Criteria		
Initial Serviceability Index	√	√
Terminal Serviceability Index	√	√
Design Variables		
Analysis Period	√	√
Reliability	√	√
Traffic	√	√
Overall Standard Deviation	√	√
Material Properties		
Soil Resilient Modulus	√	
Modulus of Subgrade Reaction		√
Concrete Properties		√
Layer Coefficients	√	
Pavement Structural Characteristics		
Coefficient of Drainage	√	√
Load Transfer Coefficients		√
Loss of Support		√

3.1. Performance Criteria

Condition of pavements are rated with a present serviceability index (PSI) ranging from 5 (perfect condition) to 0 (poor condition).

a. **Initial Serviceability Index (P_o):** The initial serviceability index (Po) is the PSI immediately after the pavement is open. Values of 4.5 for rigid pavement and 4.2 to 4.4 for flexible pavement (2 to 4 layers, respectively) are recommended.

b. **Terminal Serviceability Index (P_t):** The terminal serviceability index (Pt) is the PSI representing the lowest acceptable level before resurfacing or reconstruction becomes necessary. Recommended terminal serviceability indices are provided in Table 2.

Table 2: Recommended Levels of Terminal Serviceability

Street Classification		Terminal Serviceability Index
Locals	Residential	2.0 – 2.25
	Industrial / Commercial	2.25 – 2.35
Collectors	Residential Minor/Major	2.25 – 2.35
	Industrial / Commercial	2.4

c. **Serviceability Loss:** The predicted loss or drop in serviceability (ΔPSI) is the difference between initial and terminal serviceability (P_o - P_t). The ΔPSI is the basis for the pavement design.

3.2. Design Variables

a. **Analysis Period:** The analysis period is the period of time for which the analysis is to be conducted. Table 3 shows the recommended analysis period for both concrete and asphalt pavements.

b. **Reliability:** Reliability is the probability that the design will succeed for the life of the pavement. Because higher roadway classification facilities are considered more critical to a transportation network, a higher reliability is used for these facilities. The traffic volume, difficulty of diverting traffic, and public expectation of road availability shall be considered when selecting the levels of reliability. The reliability values in Table 3 are recommended for the design; however, they shall be adjusted based on the design Equivalent Single Axle Loads (ESALs). The designer shall consult with the City's Project Manager to confirm the site specific value for reliability.

Table 3: Recommended Analysis Period and Reliability

Street Classification		Analysis Period, year		Recommended Levels of Reliability, %
		Flexible Pavement	Rigid Pavement	
Locals	Residential	20	30	75
	Industrial / Commercial	20	30	80
Collectors	Residential Minor/Major	25	40	80/85
	Industrial / Commercial	30	40	90

c. **Traffic:** In the 1993 AASHTO Design Guide, traffic is described in terms of Equivalent Single Axle Loads (ESALs), which estimates the total damage caused by 18,000 lbf single axles. Since vehicle configurations and axle loads vary, AASHTO has established a method to convert different axle loads and configurations to ESALs. For example, a 34,000 pound tandem axle produces approximately 1.9 ESALs for rigid pavements or 1.1 ESALs for flexible pavements. Summing the different ESAL values for each axle combination on a vehicle provides a vehicle's Load Equivalency Factor (LEF) that can then be applied to the assumed vehicles and the annual average daily traffic volume (AADT) to determine ESALs.

To estimate the design ESALs, the procedures found in Appendix D of the 1993 AASHTO Design Guide should be performed or computer programs based on that procedure. The need for separate ESAL tables for flexible and rigid pavements is based on the inherent ability of each type of pavement to distribute point loading. Rigid pavements have the ability to distribute the load across the slab; point loading on a flexible pavement is more localized. This results in different ESAL factors for the two types of pavements.

An estimate of the number of Equivalent ESALs during the analysis can be estimated based on:

- average AADT;
- average percentage of trucks; and
- traffic growth factor (TGF).

Tables 4 and 5 provide typical AADT, growth rate and lane distribution factors (LDF). Traffic growth factor (TGF) can be determined using the following equation:

$$TGF = \frac{(1+G)^n - 1}{G}$$

Where: G and n are the growth rate and design period in years.

Where possible, traffic data should be project specific. The designer shall consult with the City's Transportation Division and Project Manager to confirm site specific traffic data.

Table 4: Recommended AADT, Growth Rate, Minimum Commercial Vehicles

Street Classification	Locals		Collectors	
	Residential	Industrial / Commercial	Residential Minor/Major	Industrial / Commercial
AADT (veh/day)	1,000	5,000	8,000/12,000	15,000
Growth Rate (%)*	1	1	1.5	1.5
Minimum Commercial Vehicles %	2	2	4/6	8

*Note: for new developments, growth rates shall be 0.5% more than the values in the above table and a minimum of 2%.

Table 5: Lane Distribution Factors (LDF)

Number of Lanes per Direction	Urban Cross Section	Rural Cross Section
1	Design ESALs to account for 100% commercial traffic and buses	Design ESALs to account for 100% commercial traffic and buses
2	Design ESALs to account for 80% commercial traffic and 100% buses	Design ESALs to account for 85% commercial traffic and 100% buses
3	Design ESALs to account for 75% commercial traffic and 100% buses	Design ESALs to account for 70% commercial traffic and 100% buses
4	Note1	Note1

These LDF factors are to be considered minimum values for design. Larger factors should be used when site and/or project specific data is available.
*Note 1: A traffic study should be completed to determine project specific LDF.

Where bus routes are anticipated but the number of buses is unknown, the recommended number of buses is listed in Table 6. Table 7 provides the recommended reliability based on the design ESALs.

Table 6: Recommended Number of Buses

Street Classification	Locals		Collectors	
	Residential	Industrial / Commercial	Residential Minor/Major	Industrial / Commercial
Number of Buses	16	32	32	64

Table 7: Recommended Reliability

Design ESALs	< 100,000	100,000-1,000,000	1,000,000-5,000,000	5,000,000-10,000,000	>10,000,000
Reliability %	75	80	85	90	ME Design Procedure

d. **Overall Standard Deviation (S_o):** The amount of statistical error in the design equations due to the variability of materials, construction, traffic, etc., shall be between 0.3 to 0.4 for rigid pavements and 0.4 to 0.5 for flexible pavements. Table 8 provides the recommended Standard Deviation for flexible and rigid pavements.

Table 8: Recommended Levels of Standard Deviation (S_o)

Street Classification		Terminal Serviceability Index	
		Flexible Pavement	Rigid Pavement
Locals	Residential	0.45	0.35
	Industrial / Commercial	0.47	0.38
Collectors	Residential Minor/Major	0.45	0.35
	Industrial / Commercial	0.48	0.38

3.3. Material Properties

a. **Soil Resilient Modulus (M_R):** The soil resilient modulus measures the amount of recoverable deformation at any stress level under dynamic loading. A seasonal resilient modulus shall be used to cover the temperature and moisture changes that can have an effect on the strength, durability, and load-carrying capacity of the pavement during each season of the year and treat it as part of the overall design. An effective soil modulus is then established for the entire year, which is equivalent to the combined effects of all monthly seasonal modulus values.

Two acceptable methods for estimating M_R can be used:

1) Estimating the subgrade resilient modulus from California Bearing Ration (CBR – soaked condition):

$$M_R = 17.6 \times CBR^{0.64} \quad (MPa)$$

CBR shall be conducted in accordance with the Guideline for Site Investigation Requirements for Public Works Street Projects. It is critical to use subgrade support values higher than a CBR of 5 for thickness design with Winnipeg soils. Soils that have silt content less than 45%, plasticity indexes greater than 10, and are mechanically compacted may have a CBR of 5.

Due to the fine grained nature of some Winnipeg soils, it may be necessary to stabilize these soils through the use of agents such as lime, fly ash, cement, or asphalt to achieve a workable subgrade. Stabilization requires the agent to be thoroughly distributed into the soil matrix and the soil matrix must be well pulverized to prevent isolated clumps in the soil mass. It is critical that construction quality control verify that the increase in soil strength matches the value used in the design. If the designer confirms that a foundation has a high CBR, then a specific pavement design should be undertaken rather than using the standard designs presented in this section.

2) Determining the Resilient Modulus from Non-Destructive Testing:
The Resilient Modulus may be determined by testing a prototype pavement structure with a Falling Weight Deflectometer (FWD). This method requires a factor to adjust the value used to represent the subgrade conditions and regional climate effects. The City's Project Manager shall approve the use of this method to determine the M_R for pavement design on a project-by-project basis.

The design shall be based on the average M_R value for the site so as not to introduce increases in the thickness beyond those required by the reliability factor.

For flexible pavement design, 1993 AASHTO Guide, Part II, Tables 4.1 and 4.2 with AASHTO Wet-Freeze Zone III criteria are used to estimate the effective M_R value taking into account seasonal variability. Frozen conditions are half the month of December and the months of January and February. Due to spring thawing conditions, the M_R value for the month of March and half of April were assumed to be 30% of normal conditions. Half of April, and all of May, October, November, and half of December were assumed to be wet with the support value set at 67% of normal. The remaining months of June, July, August, and September were dry months.

Certain soils such as those that are excessively expansive, resilient, frost susceptible, or highly organic shall require remedial steps are taken to provide adequate support for the pavement section.

b. **Modulus of Subgrade Reaction:** For rigid pavement design, the strength of the soil is characterized by the modulus of subgrade reaction (k). M_R is used to calculate the modulus of subgrade reaction. Similar to the procedures used to estimate the effective M_R value for flexible pavement design, the AASHTO Design Guide provides procedures for estimating the k value taking into account potential seasonal variability, Part II, Chapter 3, Section 3.2.1, Develop Effective Modulus of Subgrade Reaction (k-value). The same seasonal variability assumptions used for flexible pavements should be used to calculate k values for rigid pavements.

c. **Concrete Properties:** The Modulus of Rupture used in the AASHTO Design Guide equations is represented by the average flexural strength of the pavement determined at 28 days using third-point loading (ASTM C 78). The approximate relation between modulus of rupture and compressive strength is:

$$\text{Modulus of Rupture} = 2.3 \times \text{compressive strength}^{\,0.667} \;\; (psi)$$

The Modulus of Elasticity for concrete depends largely on the strength of the concrete. The following equation can be used to estimate the Modulus of Elasticity:

$$\text{Modulus of Elasticity} \; = 6250 \times \text{Modulus of Rupture} \;\; (psi)$$

A value of 640 psi and 4,000,000 psi shall be used for normal concrete. The designer may adjust the values if high strength concrete will be used. Another material property that may be used in elastic analysis of pavement systems is Poisson's ratio. A value of 0.2 is recommended for normal concrete. This value shall be adjusted if high strength concrete is used.

d. **Layer Coefficients:** Structural layer coefficients (a_i values) are required for the structural design of flexible pavements. A coefficient is assigned to each material layer in the pavement structure in order to convert actual layer thickness into the structural number (SN). Table 9 provides typical values for layer coefficients.

Table 9: Typical Values for Layer Coefficients

Layers	Thickness, mm		Coefficient	
	Minimum	Maximum	Urban Cross Section	Rural Cross Section
Asphalt layer				
Type 1A	35	50	0.42	0.42
Type III	50	75	0.38	0.38
Base layer				
Granular A	100	150	0.15	0.16
Granular B	100	125	0.11	0.12
Subbase layer				
50 mm Granular A	125	225	0.14	0.15
50 mm Granular B	125	200	0.11	0.12
50 mm Granular C	100	150	0.08	0.1
100 mm Granular A	250	350	0.14	0.15
100 mm Granular B	225	350	0.11	0.12
100 mm Granular C	225	300	0.08	0.1

The layer coefficients of granular base and subbase can be calculated using the following equation if the equivalent annual resilient modulus of base and subbase (psi) are available:

$$a_i = 0.25 \times \log M_R - 0.98$$

3.4. Pavement Structural Characteristics

a. **Coefficient of Drainage:** The coefficient of drainage (C_d) for rigid pavement design is used to account for the quality of drainage while the coefficient of drainage (m_i) for flexible pavement design is used to modify layer coefficients. In selecting the proper C_d or m_i value, consideration must be given to two factors:
   1) how effective is the drainage; and,
   2) how often is the subgrade and subbase expected to be saturated.

A value of 1.00 would have no impact on the design. Table 10 provides typical values for drainage coefficients. Where drainage is an issue, the designer shall consult with the City's Project Manager to confirm the coefficient of drainage.

Table 10: Typical Values for Drainage Coefficients

Layers	Urban Cross Section		Rural Cross Section	
	C_d	m_i	C_d	m_i
Asphalt layer				
Type 1A	-	1.00	-	1.00
Type III	-	1.00	-	1.00
Base layer				
Granular A	1.10	1.15	1.15	1.20
Granular B	1.00	1.00	1.10	1.10
Subbase layer				
50 mm Granular A	1.15	1.20	1.15	1.20
50 mm Granular B	1.00	1.00	1.10	1.10
50 mm Granular C	0.90	0.80	0.90	0.80
100 mm Granular A	1.15	1.20	1.15	1.20
100 mm Granular B	1.00	1.00	1.10	1.10
100 mm Granular C	0.90	0.80	0.90	0.80

b. **Load Transfer Coefficients for Jointed Concrete Pavements (J):** For jointed concrete pavements with load transfer devices (dowels), integral curb and gutter, tied concrete shoulder, or two lanes or more in one direction, a J-factor of 2.7 to 3.2 can be used with a recommended value of 2.8. A concrete shoulder of 1 m or greater may be considered a tied shoulder.

c. **Loss of Support:** According to the 1993 AASHTO Design Guide, Part II, Figure 3.6, with a value of 0, corresponding to cement treated granular material with no erosion and/or differential vertical movement, k does not change. With a value of 3, corresponding to fine grained subgrade soils; k of 100 becomes an effective k of 8. From a practical standpoint, a k value less than 50 represents conditions where a person's weight would produce noticeable deformations in the subgrade. Thus a subgrade with this level of support would never pass a proof roll test.

   The use of loss of support values has a very significant impact on the thickness design for rigid pavements. The 1993 AASHTO Design Guide, Part II, Section 2.4.3 states that experience should be the key element in the selection and use of an appropriate loss of support value.

3.5. Minimum Pavement Design

The AASHTO design is based on traffic-induced fatigue failures. There are other criteria which must be considered to avoid impractical designs such as:

- Ease of construction;
- Maintenance considerations; and,
- Engineering judgment and practice experience.

Taking these criteria into account, minimum designs for flexible and rigid pavements were developed. The minimum structure in Table 11 should be used to check the adequacy of a design. In addition, it can be used to estimate a design section in unusual circumstances. Note that these values should not be used to replace or circumvent the final design process.

Table 11: Minimum Pavement Designs

Material Types			Street Classification				
			Locals		**Collectors**		
			Residential	Industrial / Commercial	Residential Minor	Residential Major	Industrial / Commercial
Subgrade Strength	15 MPa (2.0 > CBR ≥ 1.3)	Rigid Pavement	150 mm Concrete 100 mm Base Granular B 300 mm - 100mm Granular B	200 mm Concrete 100 mm Base Granular A 325 mm - 50mm Granular A	200 mm Concrete 100 mm Base Granular A 325 mm - 50mm Granular A	200 mm Concrete 100 mm Base Granular A 150 mm - 50mm Granular A 250 mm - 100mm Granular A	200 mm Concrete 100 mm Base Granular A 150 mm - 50mm Granular A 250 mm - 100mm Granular A
		Flexible Pavement	50 mm Type IA 75 mm Type III 100 mm Base Granular B 125 mm - 50mm Granular B 225 mm - 100mm Granular B	40 mm Type IA 100 mm Type III 100 mm Base Granular A 325 mm - 50mm Granular A	40 mm Type IA 100 mm Type III 100 mm Base Granular A 325 mm - 50mm Granular A	50 mm Type IA 100 mm Type III 100 mm Base Granular A 150 mm - 50mm Granular A 250 mm - 100mm Granular A	50 mm Type IA 110 mm Type III 100 mm Base Granular A 150 mm - 50mm Granular A 300 mm - 100mm Granular A
	30 MPa (3.5 ≥ CBR ≥ 2.0)	Rigid Pavement	150 mm Concrete 100 mm Base Granular B 250 mm - 100mm Granular B	180 mm Concrete 100 mm Base Granular A 275 mm - 50mm Granular A	200 mm Concrete 100 mm Base Granular A 275 mm - 50mm Granular A	200 mm Concrete 100 mm Base Granular A 300 mm - 50mm Granular A	200 mm Concrete 100 mm Base Granular A 350 mm - 50mm Granular A
		Flexible Pavement	50 mm Type IA 70 mm Type III 100 mm Base Granular B 300 mm - 50mm Granular B	50 mm Type IA 75 mm Type III 100 mm Base Granular A 300 mm - 50mm Granular A	40 mm Type IA 100 mm Type III 100 mm Base Granular A 300 mm - 50mm Granular A	50 mm Type IA 100 mm Type III 100 mm Base Granular A 350 mm - 50mm Granular A	50 mm Type IA 110 mm Type III 100 mm Base Granular A 150 mm - 50mm Granular A 250 mm - 100mm Granular A
	45 MPa (5 ≥ CBR > 3.5)	Rigid Pavement	150 mm Concrete 100 mm Base Granular B 200 mm - 50mm Granular B	180 mm Concrete 100 mm Base Granular A 225 mm - 50mm Granular A	200 mm Concrete 100 mm Base Granular A 250 mm - 100mm Granular A	200 mm Concrete 100 mm Base Granular A 275 mm - 50mm Granular A	200 mm Concrete 100 mm Base Granular A 300 mm - 50mm Granular A
		Flexible Pavement	50 mm Type IA 60 mm Type III 100 mm Base Granular B 275 mm - 50mm Granular B	50 mm Type IA 75 mm Type III 100 mm Base Granular A 275 mm - 50mm Granular A	50 mm Type IA 75 mm Type III 100 mm Base Granular A 325 mm - 50mm Granular A	40 mm Type IA 100 mm Type III 100 mm Base Granular A 325 mm - 50mm Granular A	50 mm Type IA 100 mm Type III 100 mm Base Granular A 350 mm - 50mm Granular A

Note: Geotextile and Geogrid are mandatory for all structures as per CW3130 and CW3135. Any Collector streets with buses shall be considered as a Major collector.

4. AASHTOWare Pavement ME Design Procedure

4.1. General Information

- Design Type: Select 'New Pavement' when designing a new/reconstruction project;
- Pavement Type: Select either flexible pavement or jointed plain concrete pavement. The designer shall consult with the City's Project Manager to confirm the pavement type;
- Design Life: Design life will depend on the street classification and pavement type as shown in Table 12;
- Existing Construction: Month and year of the last construction (asphalt overlay, mill and resurfacing, etc.) of the existing structure;
- Base Construction: The anticipated month/year of base construction. Use May if the month is unknown;
- Pavement Construction: The anticipated month/year of surface construction. Use June if the month is unknown;
- Traffic Opening: The anticipated month/year for opening the project to traffic. Use July if the month is unknown;

Table 12: Recommended Levels of Analysis Period and Reliability

Street Classification		Design Life, year	
		Flexible Pavement	Rigid Pavement
Collectors	Residential Major	25	40
	Industrial / Commercial	30	40
Arterials	Minor	30	50
	Major	30	50

4.2. Performance Parameters

Tables 13 and 14 provide a list of performance criteria thresholds that need to be satisfied in order for the pavement design to meet City requirements.

The first criteria is smoothness which is measured using the International Roughness Index (IRI). The initial IRI is the expected smoothness of the pavement at the time it is opened to traffic. The terminal IRI is based on the predicted distresses and site factors. The site factors are site specific properties such as age, Plasticity Index of the subgrade, Freezing Index, Average Annual Precipitation, % of joints with spalls, etc. Designer judgement is required when using these values.

Fatigue cracking is the second criteria and includes Top-down and Bottom-up cracking. Bottom-up fatigue cracking is load related cracking in the wheel path initiating at the bottom of the asphalt layers. With continued loading, they ultimately progress to what is commonly referred to as alligator cracking. Top-down fatigue cracking is similar to bottom-up fatigue cracking in that they are both types of longitudinal cracking. It initiates at the surface of the asphalt layers and differs from bottom-up in the units used to describe it: lineal meters of cracking versus rather than surface area. The City will not consider top-down cracking performance criteria when reviewing a design; however, it is recommended that values in Table 13 are used.

Thermal cracking is transverse cracking that occurs due to temperature cycling. Low temperatures are typically what cause thermal cracking. Thermal cracking is measured in lineal meters of cracking per lane-kilometer. The software default of 190 m/km was adopted as the threshold.

Permanent deformation in the total structure is the vertical deformation found in the wheel paths. The amount of rutting for each layer (asphalt, unbound granular base and subbase, and subgrade layers) is summed to obtain the expected total rutting. It represents the average rut depth for both wheel paths. Permanent deformation in the asphalt layer is the portion of total rutting contributed by the asphalt layer(s) only. During the calibration process, the only rutting data available was for total rutting. Therefore, total rutting was calibrated while rutting in the asphalt, granular, and subgrade layers was not. Therefore, the City will not consider asphalt rutting performance criteria when reviewing a design; however, it is recommended that values in Table 13 are used.

Total cracking is the percentage of the overall lane surface that exhibits bottom-up and reflective cracking. Data to determine the amount of reflective cracking (rather than fatigue cracking) occurring in the top surface asphalt was not available, so this performance criteria was not calibrated. Therefore, the City will not consider reflecting or total cracking when reviewing a design.

Transverse Cracking is the amount of top-down and bottom-up transverse cracking in a concrete slab. These two predictions are combined into one value to arrive at a transverse cracking total. Transverse cracking is measured by the percentage of slabs that are cracked. Table 13 provides the recommended values for design.

Faulting is the vertical difference between the slabs on either side of a transverse joint in jointed plain concrete pavement. The predicted value represents the expected average per joint for the design.

Reliability is the probability that the predicted distress is less than the threshold value over the entire design life. AASHTOWare Pavement ME Design Procedure differs from the AASHTO 1993 design method in that reliabilities are considered for each performance criteria.

Table 13: Recommended Performance Parameter Inputs for Flexible Pavements

Street Classification	Collectors		Arterials	
	Residential Major	Industrial / Commercial	Minor	Major
Initial IRI (m/km)	1.0	1.0	0.9	0.9
Terminal IRI (m/km)	2.8	2.7	2.6	2.5
Top-down Fatigue cracking (m/km)	500	450	380	380
Bottom-up fatigue cracking (percent)	30	25	20	18
Thermal fracture (m/km)	190			
Permanent deformation – total structure (mm)	20	20	15	15
Permanent deformation – Asphalt layers only (mm)	12	12	10	8
Total Cracking (Reflective + Alligator; percent)	50			
Reliability%*	80	85	90	90

*50% reliability should be used for IRI

Table 14: Recommended Performance Parameter Inputs for Rigid Pavements

Street Classification	Collectors		Arterials	
	Residential Major	Industrial / Commercial	Minor	Major
Initial IRI (m/km)	1.8	1.6	1.5	1.2
Terminal IRI (m/km)	2.8	2.7	2.4	2.3
Transverse cracking (percent slabs)	20	20	15	15
Joint faulting (mm)	3	3	3	3
Reliability	80	85	90	90

4.3. Traffic

AASHTOWare Pavement ME Design requires the Annual Average Daily Truck Traffic (AADTT) as the major input in addition to vehicle class distribution, axle load spectrum, axle configuration and spacing, and monthly/hourly adjustment factors. Tables 15 and 16 provide typical AADT, growth rate and percentage of trucks in the design lane. Where possible, AADTT, number of lanes in design direction, vehicle class distribution, and operational speed should be project specific.

Table 15: Recommended AADT and Growth Rate

Street Classification	Collectors		Arterials	
	Residential Major	Industrial / Commercial	Minor	Major
AADT (veh/day)	12,000	15,000	<20,000	>20,000
Growth Rate (%)*	1	1.5	1.5	2

*Res: Residential; **Ind: Industrial; ***Com: Commercial. Note: for new developments, growth rate shall be 0.5% more than the values in the above table and a minimum of 2%.

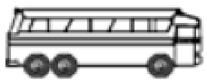
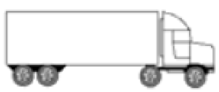
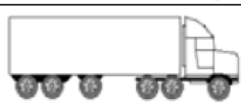
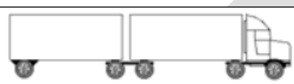
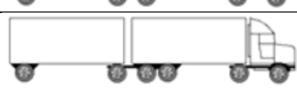
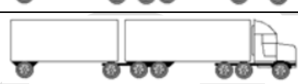
Table 16: Recommended Percentage of Trucks in Design Lane

Number of Lanes in One Direction	AADT	Percentage of Trucks in Design Lane (%)
1	-	100
2	<15,000 >15,000	90 80
3	<20,000 >20,000	80 75
4	<30,000 >30,000	70 70

For traffic capacity, axle configuration, lateral wander, wheel base, axles per truck, and axle load distribution, the designer should either select the default set that best describes the project or enter project-specific values if available. While conditions may vary locally, typical distributions for the three functional classifications being used are shown in Table 17 based on the 13 vehicle classes as established by the US Federal Highway Administration (FHWA).

Projects that have traffic or site conditions that differ significantly from the values assumed herein should be evaluated with a site specific pavement design.

Table 17: Expected Vehicle Distribution for Different Street Classification

FHWA Truck Class	Commercial Vehicle		Street Classification			
			Collectors		Arterials	
			Residential Major	Industrial / Commercial	Minor	Major
4		Two or Three Axle Buses	15	10	3.5	3
5		Two-Axle, Six-Tire, Single Unit Trucks	41	47	35	30
6		Three-Axle Single Unit Trucks	15	10	11	8
7		Four or More Axle Single Unit Trucks	9	6	5	5
8		Four or Less Axle Single Trailer Trucks	6	9	9	5
9		Five-Axle Single Trailer Trucks	12	14	32	30
10		Six or More Axle Single Trailer Trucks	2	2	3	8
11		Five or Less Axle Multi-Trailer Trucks	0	0.5	1	1
12		Six-Axle Multi-Trailer Trucks	0	0.3	0.3	3
13		Seven or More Axle Multi-Trailer Trucks	0	0.2	0.2	7

Note: Light vehicles, Class 1 through 3 (motorcycles and light passenger vehicles), are ignored and the remaining vehicle classes are the focus of the pavement structural design.

4.4. Climate

AASHTOWare Pavement ME Design software has a feature of map-based selection for the climate stations. The designer should select one or multiple stations adjacent to the site to download the climate file for the design. Modern-Era Retrospective analysis for Research and Applications (MERRA) and North American Regional Reanalysis (NARR) should be used for flexible and rigid pavements, respectively. Pavement ME Design comes with eight weather stations in the Winnipeg area. The designer can select either a single weather station or create a virtual weather station (i.e. an interpolation of the weather data from several weather stations).

4.5. Layers properties

4.5.1. Subgrade Properties

AASHTOWare Pavement ME Design default values for subgrade properties are based on the AASHTO soil classification system. The use of these values may result in a conservative design. Sound engineering judgment and testing (e.g. M_r, FWD) will provide more accurate values; concurrence from the City's Project Manager is required prior to proceeding with testing. Tables 18 and 19 provide a list of typical subgrade materials found in Winnipeg and their associated properties based on historical soils data. A value outside of the ranges provided in Table 18 may be used, but test verification should be available to support it.

Table 18: Typical Soil Properties in Winnipeg

Classification (AASHTO)	Brief Description	Drainage Characteristics	Frost Potential	Poisson's Ratio	Coefficient of Lateral Pressure (k_0)	CBR[1]	M_r[1] (MPa)
A-7-5	Medium to high plasticity clay	Very Low	Medium to High	0.45 (Saturated) 0.25 (Unsaturated)	0.52-0.60	<2	15-30
A-7-6/A-6	Low plasticity clays and compressible silts	Very Low	High to Very High	0.4 (Saturated) 0.2 (Unsaturated)	0.52-0.60	<3	20-40
A-5	Very fine silty sands	Low	High to Very High	0.4	0.47-0.58	4-7	25-50
A-4/A-3	Silty sand soils or silty clay	Fair to Low	Medium	0.35	0.47-0.58	6-9	35-60
Granular Fill	--	Fair	Medium to Low	0.3-0.35	0.5	30-60	65-100

[1]California Bearing Ratio (CBR) and Resilient Modulus (M_r) values are minimum values expected for each subgrade class.

Table 19: Gradation & other Engineering Properties for Typical Soils in Winnipeg

Classification (AASHTO)		A-7-5	A-7-6/A-6	A-5	A-4/A-3
Gradation	Sieve (mm)	Passing (%)			
	9.5	100	100	100	100
	4.75	100	100	100	100
	2.0	100	100	100	100
	1.18	95-100	95-100	90-100	90-100
	0.425	90-100	85-100	75-95	75-90
	0.18	85-100	80-95	70-90	60-85
	0.075	85-95	75-90	65-85	55-80
	0.042	70-85	60-80		
	0.03	65-80	55-75		
	0.02	55-75	50-65	40-60	35-55
	0.016	50-70	45-55		
	0.012	45-65	35-45		
	0.006	40-60	30-40		
	0.001	35-50	20-30		
Liquid Limit		60-80	50-70	45-65	25-45
Plasticity Index		30-45	20-40	15-30	10-25
Is layer Compacted		Yes*			
Maximum Dry Unit Weight (kg/m^3)		1450-1550	1450-1550	1500-1600	1500-1650
Saturated Hydraulic Conductivity (m/hr)		Calculated			
Specific Gravity of Solids		Calculated			
Optimum Gravimetric Water Content (T)		Calculated			

*The City requires the subgrade to be compacted to a certain density (95% Standard Proctor Maximum Dry Density); however, the designer may select "No" if the site conditions suggest that it will not be compacted.

Note: The distress outputs are sensitive to Gradation, Liquid Limit, Plasticity Index, and Degree of Compaction; therefore, it is recommended that sound engineering judgment and testing are used for more accurate values.

winnipeg.ca

4.5.2. Base and Sub-base Material Properties

The base and sub-base are granular layers that provide support, drainage, and frost-heave resistance for the paved surface layer. Section 2 provides direction on the type of granular material to be used depending on the street classification. Table 20 provides the typical properties for granular base and sub-base materials.

Table 20: Typical Granular Material Properties

Material Size	**Granular A**			**Granular B**			**Granular C**		
	Base Course	50 mm	100 mm	Base Course	50 mm	100 mm	Base Course	50 mm	100 mm
Layer Thickness (mm)	Project specific								
Minimum Placement Thickness (mm)	100	125	275	100	125	250	75	100	250
Maximum Placement Thickness (mm)	150	225	350	125	200	350	100	150	300
Poisson's Ratio	0.35								
Coefficient of Lateral Pressure (ko)	0.5								
Resilient Modulus (MPa)	220	220	200	150	140	130	110	110	100
Gradation	See CW 3110								
Liquid Limit	0	0	0	20	22	25	25	25	25
Plasticity Index	NP	NP	NP	NP	4	6	6	6	6
Maximum Dry Unit Weight (kg/m³)*	2100-2250			2150-2280 for VM/ 1990-2220 for RM			2150-2280 for VM/ 1990-2220 for RM		
Saturated Hydraulic Conductivity (m/hr)	Calculated								
Specific Gravity of Solids	Calculated								
Optimum Gravimetric Water Content (%)	Calculated								

*Maximum Dry Unit Weight shown is not corrected for oversize materials. VM: virgin material, RM: recycled material.

winnipeg.ca

4.5.3. Asphalt Properties

Asphalt properties and design parameters are provided in the Table 21. To establish the preliminary thicknesses used for mix selection, create the initial design using AASHTO's Guide for Design of Pavement Structures, 1993.

Table 21: Typical Asphalt Properties

Asphalt Type	Type 1A		Type II	Type III
	Top Layer	Other Layer		
Layer Thickness (mm)	Project specific			
Minimum Placement Thickness (mm)	40	30	30	50
Maximum Placement Thickness (mm)	50	50	40	70
Unit Weight (kg/m³)	2350-2400		--	2300-2350
Effective Binder Content (%)	11	11	--	9
Air Voids (%)	4.0		--	4.5
Poisson's Ratio	0.35	0.35	--	0.35
Dynamic Modulus	Input level: 3			
Aggregate Gradation	See CW 3410			
G Star Predictive Model	Use viscosity-based model			
Asphalt Binder	150-200(A) – PG 52-34			
Indirect Tensile Strength – 10 deg.C (MPa)	Calculated			
Creep Compliance (1/GPa)	Input level: 3			
Thermal Conductivity (watt/meter-Kelvin)	1.16			
Heat Capacity (joule/kg-Kelvin)	963			
Thermal Contraction	Calculated			

4.5.4. Concrete Properties

Jointed Plain Concrete Pavement (JPCP) with doweled joints is the typical concrete pavement design in Winnipeg. Concrete material properties and design parameters are provided in Table 22.

Table 22: Typical Concrete Properties

Concrete Properties		
Unit Weight (kg/m^3)		2300
PCC Coefficient of Thermal Expansion (mm/mm degC x 10^{-6})		7.8
PCC Thermal Conductivity (watt/meter-Kelvin)		2.16
PCC Heat Capacity (joule/kg-Kelvin)		1172
Cement Type		GU (Type 1)
Cementious Material Content (kg/m^3)		340
Water/Cement Ratio		0.42
Aggregate Type		Quartzite
PCC Set Temperature		Calculated
Ultimate Shrinkage (Microstrain)		Calculated
Reversible Shrinkage (% of Ultimate Shrinkage)		50
Time to Develop 50% of Ultimate Shrinkage (Days)		35
Curing Method		Curing Compound
Design requirements		
Layer Thickness (mm)		Project specific
Minimum Layer Thickness (mm)		150 mm
Concrete Strength (MPa)		32
Modulus of Rupture		4.4
Elastic Modulus (MPa)		28500
PCC Joint Spacing (m)		Project specific
Sealant Type		Other
Doweled	Spacing (mm)	300 – 450
	Diameter*	See Note[1]
Widened slab		Widened (4.25)
Tied Shoulders (see Note[2])		Tied with long term load transfer efficiency of 50
Erodibility Index		See Note[3]
PCC-Base Contact Friction		See Note[4]
Permanent Curl/Warp Effective Temperature Difference (deg C)		See Note[5]

Note 1: The City typically uses 19.1 mm for concrete thicknesses < 200 mm and 28.6 mm for concrete thicknesses ≥ 200 mm; however, the designer may increase the dowel diameter based on the concrete thickness to satisfy the required faulting.

Note 2: Use the software default “True” if concrete (including curb & gutter) shoulders are used or select “False” where asphalt shoulders are used.

Note 3: This input represents the resistance to erosion of the Base Layer under the concrete Layer, using an index on a scale of 1 (most resistant, least erodible) to 5 (least resistant, most erodible). It is recommended that 1 is used for cement stabilized base, 2 for Granular A materials, 3 for Granular B materials, and 5 for Granular C materials.

Note 4: This input allows the designer to indicate whether there is full friction at the interface of the underlying base and concrete slab. The designer shall use the software default “True” to indicate that there is full friction immediately after construction.

Note 5: This input indicates the equivalent temperature gradient difference between the top and bottom of the slab to describe the combined effect of the built-in curl and warp of the slab (at time of set), long-term creep of the slab, and settlement of the slab into the base. The designer shall use the software default unless further testing is done.