

# PAVEMENT STRUCTURAL DESIGN GUIDELINE SUMMARY

**City of Toronto**



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**CITY OF TORONTO**  
**PAVEMENT STRUCTURAL DESIGN**  
**GUIDELINE SUMMARY**

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## GLOSSARY OF ABBREVIATIONS

AADT	- average annual daily traffic
AADTT	- average annual daily truck traffic
AASHO	- American Association of State Highway Officials
AASHTO	- American Association of State Highway and Transportation Officials
AC	- asphalt concrete
CRL	- crusher run limestone
DRIP	- drainage requirements in pavements software
EGT	- equivalent granular thickness
EICM	- enhanced integrated climate model
E*	- dynamic modulus
ESAL's	- equivalent single axle loads
FHWA	- Federal Highway Administration
HMA	- hot mix asphalt
IRI	- international roughness index
LCCA	- life cycle cost analysis
LSBC	- large stone binder course
LTPP	- long term pavement performance
M-E PDG	- mechanistic-empirical pavement design guide
MPMA	- municipal pavement management application
M <sub>r</sub>	- subgrade resilient modulus
NCHRP	- national cooperative highway research program
OPSS	- Ontario provincial standard specification
PCA	- Portland cement association
PCC	- Portland cement concrete
PGAC	- performance graded asphalt cement
PMS	- pavement management system
RCC	- recycled crushed concrete
SMA	- stone mastic asphalt
TS	- Toronto specification
VCI	- visual condition index

## 1.0 PROJECT BACKGROUND

The City of Toronto maintains a network of about 5,200 centreline-kilometres of roads and over 250 centreline-kilometres of laneways. It controls an extensive network of roadways that varies in function from low volume residential roadways to controlled access highways.

The City of Toronto pavement infrastructure has been constructed, maintained, and enhanced over more than 100 years. Roads have been constructed using a variety of pavement structural designs depending on the location within the City, soil conditions, and traffic characteristics. Many of the structural designs are empirical (based on past experience and observations) that have evolved and been modified over time.

Over the past several decades, fuelled by research and other technological advancements in the pavement engineering field, a gradual shift is being observed in terms of how pavements and pavement materials are designed, tested, evaluated, constructed, and managed. As part of this effort, pavement design is transitioning from an empirical to a mechanistic-empirical realm (based on the principals of engineering mechanics correlated to actual field performance). The U.S. National Cooperative Highway Research Program (NCHRP) Project 1-37A was initiated to develop the Mechanistic-Empirical Pavement Design Guide (M-E PDG) and associated evaluation version 0.704 software (1). The Guide has been delivered for stakeholder review.

The M-E PDG was developed as a major enhancement on the existing American Association of State Highway and Transportation Officials (AASHTO) 1993 Guide for Design of Pavement Structures (2). The AASHTO 1993 design procedure was based on empirical performance models that were developed from the AASHO Road Test of the late 1950's and early 1960's. The 1993 AASHTO procedure has been widely implemented and has been used extensively by North American agencies including the Provinces of British Columbia, Alberta, Manitoba, Ontario, Quebec, New Brunswick, and Nova Scotia. The Ministry of Transportation, Ontario has adapted and validated the procedure for Ontario conditions (3). Although widely used, the design procedure is based on an extrapolation of a limited data set generated from the original AASHO Road Test in the late 1950's.

One of the major recommendations to come out of the NCHRP 1-37A project was the need for local calibration of the models. The data used to calibrate the models presented in the M-E PDG is based on data collected as a part of the Long Term Pavement Performance (LTPP) program. Although the LTPP data was collected from locations across Canada and the United States, it was collected on provincially and state owned highways rather than municipal roadways. The outcome of this study will position the City of Toronto for ease of transition to the M-E PDG once adopted for use by AASHTO. When issued for use, the M-E PDG will allow the City to evaluate pavement requirements using mechanistic-empirical principals.

Of principal importance, this study reviews the various design guidelines used across the City and consolidates/integrates them based on mechanistic-empirical design principals and the past performance of roadways within the City of Toronto.

## 2.0 RECOMMENDED PAVEMENT DESIGN GUIDELINES

In the municipal environment it must be recognized that public roads serve a multitude of functions that can be drawn from the City of Toronto's Official Plan as follows:

- A high quality, safe and comfortable pedestrian environment
- Vehicular access including emergency vehicles, cars and bicycles
- Adequate emergency access
- Space for the local and system-wide (trunk) water supply and sanitary sewer utility infrastructure
- Space to accommodate telecommunications and energy infrastructure provided by utility companies
- Environmentally sustainable stormwater run-off
- Solid waste collection and waste diversion
- Improved access for persons with disabilities
- Increases to the City's tree canopy
- Maintenance and servicing efficiencies
- Urban design and civic improvements

In the context of the urban versus suburban municipal environments, the urban environment within the City of Toronto is typically associated with the downtown or inner-city core and portions of the arterial road system. The suburban residential and industrial areas (Etobicoke, North York and Scarborough) span a horseshoe type shape around the inner-city core. However, there are examples of both urban and suburban local streets across the City.

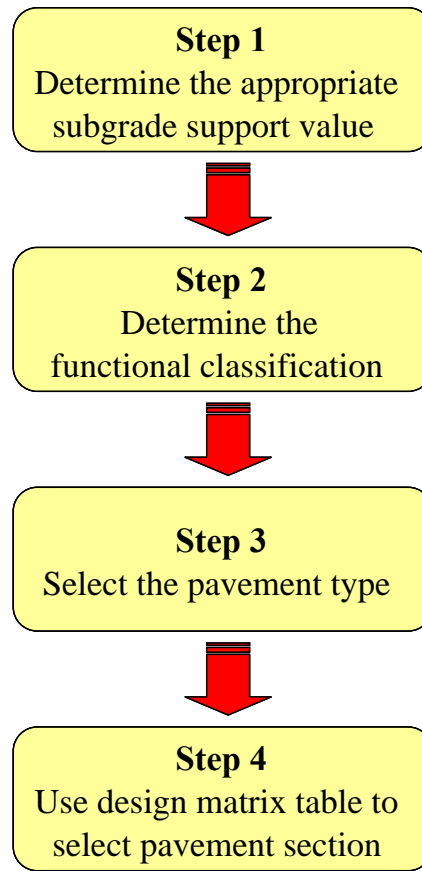
Within the urban environment the demands for space in the public road allowance, both horizontally and vertically, is highly competitive because there are significant needs and conflicting priorities. Building densities, sizes and the related utility needs are respectively greater. Extensive sub-surface utilities are placed directly beneath the pavement structure in urban areas. In the suburban setting most of the utilities are placed in the soft boulevard area. As a result, the utility intrusion of the pavement in urban situations has a much greater impact than on suburban pavements when all the needs are considered over the service life of the pavement.

The fundamental purpose of this study was to develop new consolidated design guidelines for the City of Toronto. The study was based, in part, on the M-E PDG modelling of the existing pavement design guidelines in use by the City of Toronto, supplemented with the pavement design successes and experiences of City staff. The study has resulted in a consolidated and more consistent in-place cross-section based on a range of traffic levels was developed.

This Guide will outline some information on the selection of an appropriate pavement type and structure for various road applications within the City of Toronto.

### 2.1 Use of the Guidelines

The process to select the appropriate pavement design has been broken down into four steps as shown in Figure 2.1. These steps help identify the design considerations necessary for selecting an appropriate structural design that will withstand the anticipated traffic loading. Sections 2.1.1 thru 2.1.4 describe the key input variables required for selection of an appropriate pavement section.



**Figure 2.1: Pavement design selection procedure**

#### *2.1.1 Subgrade Support Value*

The City of Toronto is located within the physiographic region of Southern Ontario mapped as the Iroquois Lake Plain and the Peel Plain (Chapman and Putnam, 1984). The bars, beaches, and boulder fields of the lower lying Iroquois Plain stand in stark contrast to the undulating Peel Plain found further north. The soils in the lower (southern) Iroquois Plain are characterised by lacustrine deposits of sandy alluvium and clays. The soils of the Peel Plain are typically characterised as silt till and clay till.

Within the Greater Toronto area, the cohesive soils (ie, tills, clays, silts, etc) of the Iroquois and Peel Plains are characterised as providing ‘fair’ subgrade support with frost susceptibility ranging from low to high depending on the actual soil matrix. These subsoil’s are expected to provide subgrade support values (resilient modulus) in the order of 30 MPa.

The sandy alluvium soils of the Iroquois Plain are characterised as providing ‘good’ subgrade support. Dependant on the actual soil matrix, these soils typically have low susceptibility to frost heave. These subsoil’s are expected to provide subgrade support values (resilient modulus) in the order of 50 MPa.



### 2.1.2 Functional Classification and Traffic

Roadways within the City of Toronto are generally characterized by functional classification, ie, arterial, collector, local residential, etc. Within each functional classification, however, there is a wide range of traffic volume, and hence, traffic loading, that was not clearly addressed by the old City standards. In consideration that pavement damage is largely a function of traffic loading, these guidelines have been developed based on inputs that reflect traffic loading rather than just functional classification.

Three specific inputs are required to define traffic loading conditions; functional classification, average annual daily traffic (AADT), and commercial vehicle percentage. The functional classification of individual roadways within the City have been predetermined. The AADT and commercial vehicle component can be obtained from project specific vehicle counts or from City estimates.

The City of Toronto's Traffic Management Centre (TMC) is an excellent resource for obtaining traffic data. City staff can access traffic data using the City of Toronto intranet site and the following link <http://insideto.toronto.ca/wes/transportation/tmc/tcdsb/volumes/index.htm>.

### 2.1.3 Pavement Type Selection

Pavement type selection is one of the more challenging engineering decisions that City staff face today. They must balance issues of both short- and long-term performance with initial and long-term costs. The stakeholders that staff answer to, the travelling public, generally do not express strong feelings on the type of pavement constructed, as long as reasonable levels of service, safety, and ride quality are provided.

The dilemma facing the staff can be summarized best by the following quote from the AASHTO Guide for Design of Pavement Structures (2):

The selection of pavement type is not an exact science but one in which the highway engineer or administrator must make a judgment on many varying factors such as traffic, soils, weather, construction, maintenance, and environment.

The selection process may be facilitated by comparison of alternative structural designs for one or more pavement types using theoretical or empirically derived methods. However, such methods are not so precise as to guarantee a certain level of performance from any one alternate or comparable service for all alternatives.

Also, comparative cost estimates can be applied to alternate pavement designs to aid in the decision-making process. The cost for the service of the pavement should include not only the initial cost but also subsequent cost to maintain the service level desired. It should be recognized that such procedures are not precise since reliable data for maintenance, subsequent stages of construction, or corrective work and salvage value are not always available, and it is usually necessary to project costs to some future point in time. Also, economic analyses are generally altruistic in that they do not consider the present or future capabilities of the contracting agency.

To further cloud the issue of pavement type selection, City staff involved with the design and selection of pavements face a high degree of uncertainty regarding the types of loadings a pavement will experience over the whole service life, which is anticipated to be in the range 65 to



100 years in the City of Toronto. Typical whole life maintenance plans are presented in the design considerations chapter.

The surface type selection process consists of two principal steps:

1. Alternatives are developed and life cycle cost analysis (LCCA) is performed. If the life cycle cost is within a set range, generally 10 percent, the life cycle costs are considered equivalent.
2. Alternatives with equivalent life cycle costs are evaluated subjectively. Factors that may be considered include adjoining pavement types, constructability, traffic control, subgrade support, traffic volumes, and other design considerations.

The range of  $\pm 10$  percent at which deterministic life cycle cost values are considered equal is based on the fact that all of the inputs used in the LCCA are estimates, with potential for significant variability.

Within the City of Toronto, composite pavement structures are the preferred design in the urban environment while flexible pavements are preferred for suburban roadways. Notwithstanding, pavement structure selection shall be based on a life cycle cost comparison considering the whole service life, operating costs, impact to the public and risk analysis. The primary advantages of a composite pavement structure over a flexible pavement structure are the abilities of the rigid concrete base to resist deformation that may be caused by:

1. very poor subgrade soils, considering the soil type and associated drainage conditions and frost impacts;
2. high density, location or incidence of utility intrusion, that typically results in settlements in and around the utilities; and,
3. repairs associated with these noted conditions, accounting for their frequency, density and severity.

A recent study completed by City staff, *Life-Cycle Cost Analysis of Composite and Flexible Pavement Structures*, concluded that composite pavement has much higher construction costs but also degrades much slower compared to flexible pavement. Composite pavement will be more economical than flexible pavement unless prices asphalt prices return to lower levels. The life-cycle cost analysis study focused mainly on the economics of composite and flexible pavement and from this point of view composite pavement currently provides a cost benefit for the City of Toronto.

#### 2.1.4 Pavement Section Selection

Having determined the appropriate subgrade support value, functional classification, AADT, and percent commercial vehicles, the Pavement Structural Design Matrix is used to select the appropriate pavement section.

The pavement sections presented in the Pavement Structural Design Matrix were based, in part, on the M-E PDG modelling of the existing pavement design guidelines in use by the City of Toronto, supplemented with the pavement design successes and experiences of City staff. The guide has resulted in a consolidated and more consistent in-place cross-section based on a range of traffic loadings as characterised by AADT and percent commercial vehicles. The designs were based on a 25 year design period assuming a 2 percent annual traffic volume growth rate.

Pavement Structural Design Matrix  
City of Toronto

		30,000		40,000		50,000		60,000		75,000	
		30 MPa	50 MPa	30 MPa	50 MPa	30 MPa	50 MPa	30 MPa	50 MPa	30 MPa	50 MPa
Major Arterial	Non-Truck Routes (5% Commercial Vehicles)	40 mm HL-1 110 mm HL8 (HS) 50 mm Granular A 300 mm Granular B * 500 mm Total	40 mm HL-1 90 mm HL-8 (HS) 50 mm Granular A 300 mm Granular B * 480 mm Total	40 mm HL-1 125 mm HL8 (HS) 50 mm Granular A 300 mm Granular B * 515 mm Total	40 mm HL-1 100 mm HL-8 (HS) 50 mm Granular A 300 mm Granular B * 490 mm Total	40 mm HL-1 135 mm HL8 (HS) 50 mm Granular A 300 mm Granular B * 525 mm Total	40 mm HL-1 110 mm HL-8 (HS) 50 mm Granular A 300 mm Granular B * 500 mm Total	40 mm HL-1 145 mm HL8 (HS) 50 mm Granular A 300 mm Granular B * 535 mm Total	40 mm HL-1 120 mm HL-8 (HS) 50 mm Granular A 300 mm Granular B * 510 mm Total	40 mm HL-1 155 mm HL8 (HS) 50 mm Granular A 300 mm Granular B * 545 mm Total	40 mm HL-1 125 mm HL-8 (HS) 50 mm Granular A 300 mm Granular B * 515 mm Total
	Truck Routes (7.5% Commercial Vehicles)	40 mm HL1 130 mm HL8 (HS) 50 mm Granular A 350 mm Granular B * 570 mm Total	40 mm HL1 110 mm HL8 (HS) 50 mm Granular A 350 mm Granular B * 550 mm Total	40 mm HL1 150 mm HL8 (HS) 50 mm Granular A 350 mm Granular B * 590 mm Total	40 mm HL1 130 mm HL8 (HS) 50 mm Granular A 350 mm Granular B * 570 mm Total	40 mm HL1 155 mm HL8 (HS) 50 mm Granular A 350 mm Granular B * 595 mm Total	40 mm HL1 135 mm HL8 (HS) 50 mm Granular A 350 mm Granular B * 575 mm Total	40 mm HL1 160 mm HL8 (HS) 50 mm Granular A 350 mm Granular B * 600 mm Total	40 mm HL1 145 mm HL8 (HS) 50 mm Granular A 350 mm Granular B * 585 mm Total	40 mm HL1 170 mm HL8 (HS) 50 mm Granular A 350 mm Granular B * 610 mm Total	40 mm HL1 150 mm HL8 (HS) 50 mm Granular A 350 mm Granular B * 590 mm Total
	Truck Routes (10% Commercial Vehicles)	40 mm HL-1 150 mm HL-8 (HS) 50 mm Granular A 350 mm Granular B * 590 mm Total	40 mm HL-1 125 mm HL-8 (HS) 50 mm Granular A 350 mm Granular B * 565 mm Total	40 mm HL-1 160 mm HL-8 (HS) 50 mm Granular A 350 mm Granular B * 600 mm Total	40 mm HL-1 135 mm HL-8 (HS) 50 mm Granular A 350 mm Granular B * 575 mm Total	40 mm HL-1 170 mm HL-8 (HS) 50 mm Granular A 350 mm Granular B * 610 mm Total	40 mm HL-1 145 mm HL-8 (HS) 50 mm Granular A 350 mm Granular B * 585 mm Total	40 mm HL-1 175 mm HL-8 (HS) 50 mm Granular A 350 mm Granular B * 615 mm Total	40 mm HL-1 155 mm HL-8 (HS) 50 mm Granular A 350 mm Granular B * 595 mm Total	40 mm HL-1 185 mm HL-8 (HS) 50 mm Granular A 350 mm Granular B * 625 mm Total	40 mm HL-1 165 mm HL-8 (HS) 50 mm Granular A 350 mm Granular B * 605 mm Total

		20,000		25,000	
		30 MPa	50 MPa	30 MPa	50 MPa
Minor Arterial	Non-Truck Routes (4% Commercial Vehicles)	40 mm HL-1 95 mm HL-8 (HS) 50 mm Granular A 250 mm Granular B * 435 mm Total	40 mm HL-1 80 mm HL-8 (HS) 50 mm Granular A 250 mm Granular B * 420 mm Total	40 mm HL-1 105 mm HL-8 (HS) 50 mm Granular A 250 mm Granular B * 445 mm Total	40 mm HL-1 85 mm HL-8 (HS) 50 mm Granular A 250 mm Granular B * 425 mm Total
	Truck Routes (7.5% Commercial Vehicles)	40 mm HL-1 135 mm HL-8 (HS) 50 mm Granular A 250 mm Granular B * 475 mm Total	40 mm HL-1 110 mm HL-8 (HS) 50 mm Granular A 250 mm Granular B * 450 mm Total	40 mm HL-1 140 mm HL-8 (HS) 50 mm Granular A 250 mm Granular B * 480 mm Total	40 mm HL-1 120 mm HL-8 (HS) 50 mm Granular A 250 mm Granular B * 460 mm Total

		5,000		7,500		10,000		15,000	
		30 MPa	50 MPa	30 MPa	50 MPa	30 MPa	50 MPa	30 MPa	50 MPa
Collector	Comm./Ind. (5% Commercial Vehicles)			40 mm HL3 105 mm HL-8 50 mm Granular A 250 mm Granular B * 445 mm Total	40 mm HL-3 75 mm HL-8 50 mm Granular A 250 mm Granular B * 415 mm Total	40 mm HL-3 115 mm HL-8 50 mm Granular A 250 mm Granular B * 455 mm Total	40 mm HL-3 85 mm HL-8 50 mm Granular A 250 mm Granular B * 425 mm Total	40 mm HL-3 125 mm HL-8 50 mm Granular A 250 mm Granular B * 465 mm Total	40 mm HL-3 95 mm HL-8 50 mm Granular A 250 mm Granular B * 435 mm Total
	Residential (3% Commercial Vehicles)	40 mm HL-3 70 mm HL-8 50 mm Granular A 250 mm Granular B * 410 mm Total	40 mm HL-3 60 mm HL-8 50 mm Granular A 250 mm Granular B * 400 mm Total	40 mm HL-3 85 mm HL-8 50 mm Granular A 250 mm Granular B * 425 mm Total	40 mm HL-3 60 mm HL-8 50 mm Granular A 250 mm Granular B * 400 mm Total	40 mm HL-3 95 mm HL-8 50 mm Granular A 250 mm Granular B * 435 mm Total	40 mm HL-3 60 mm HL-8 50 mm Granular A 250 mm Granular B * 400 mm Total		

		2,500		3,000		4,500	
		30 MPa	50 MPa	30 MPa	50 MPa	30 MPa	50 MPa
		Local Residential (3% Commercial Vehicles)		Local Industrial (10% Commercial Vehicles)		Local Throughway (3% Commercial Vehicles)	
Local		40 mm HL-3 60 mm HL-8 50 mm Granular A 250 mm Granular B * 400 mm Total	40 mm HL-3 60 mm HL8 50 mm Granular A 250 mm Granular B * 400 mm Total	40 mm HL-3 80 mm HL-8 50 mm Granular A 250 mm Granular B * 420 mm Total	40 mm HL-3 60 mm HL-8 50 mm Granular A 250 mm Granular B * 400 mm Total	40 mm HL-3 60 mm HL-8 50 mm Granular A 250 mm Granular B * 400 mm Total	40 mm HL-3 60 mm HL-8 50 mm Granular A 250 mm Granular B * 400 mm Total

Notes:

AADT

Subgrade

\* Subbase is Granular B - Type II as specified in OPSS 1010



### 3.0 DESIGN CONSIDERATIONS

There are many factors that influence the success of a pavement design. Notwithstanding the results of the design matrices presented herein, the selection of the most appropriate pavement for individual facilities will depend on a number of site specific factors including:

- Geographic and topographic conditions
- Physiographic setting and subgrade soil characteristics
- Groundwater conditions
- Projected traffic loading
- Availability of construction materials

Detailed geotechnical investigations and pavement design reports are recommended for all new and rehabilitated facilities.

The construction materials used and layer thickness is an important structural consideration, they are by no means the only factors that affect the performance of a pavement. Other important design considerations need to be addressed to maintain good performing roads and maintain consistency across the City of Toronto.

#### 3.1 Flexible Pavement Considerations

In general, pavements in Ontario are designed with sufficient total thickness so that subgrade overloading is typically not a problem. However, pavement surface distress in the form of rutting, transverse cracking, and fatigue cracking, is nevertheless a common flexible pavement problem in many locations across the Province. These problems are similar to those faced by the City of Toronto.

Often, fatigue cracking can be attributed to insufficient asphalt layer thickness for the projected traffic loading level. Mechanistic-empirical analysis methods, ie, the M-E PDG, have been found to better address the stress and strains at the bottom of the asphalt layer than the AASHTO 1993 method at higher traffic levels.

Plastic deformation of the asphalt layers has been found to be the most common cause of wheel track rutting in flexible pavements. Important considerations include careful attention to mix volumetrics, the aggregate skeleton, and selection of the appropriate performance grade asphalt binder (including high temperature bumps for heavy slow moving traffic).

The predominant asphalt mixes in use by the City are HL-1, HL-3, HL-8, and HL-8 (HS). These materials are specified in the City of Toronto Standard Construction Specifications as TS 11.50. The existing experience and availability from local mix producers makes them ideal choices for continued use. “Specialty” fine mixes such as HL-2 and HL-3(mod) have been found to exhibit stability issues and should be restricted to specific applications only.

Premium surface mixtures such as Stone Mastic Asphalt (SMA) can also be substituted for high priority roads where factors such as high traffic loading facilities, or where rut resistance and frictional properties are critical. Typically, SMA has been successfully used on the City’s freeway pavements (ie, the DVP), the Indy portion Lakeshore Boulevard, and other high traffic arterial routes.

The Superpave mix design methodology provides an alternative to the existing Hveem and Marshall methods for formulating asphalt mixes. The Superpave system is thought to be an improved method for

specifying the asphalt cement and component aggregates as well as developing the asphalt job mix formula. The Superpave binder selection has been used by MTO and the City of Toronto for a number of years. The Superpave mix design methodology has been recently adopted by MTO and we foresee that municipalities will follow. In general, MTO has found that existing HL mixes generally conform to the following Superpave designations:

**Table 3.1 . Superpave Mixtures that Correspond with HL Mixtures.**

<b>HL Designation</b>	<b>Comparable Superpave Designation</b>
SMA	SMA
DFC	Superpave 12.5FC2
HL-1	Superpave 12.5FC1
HL-3	Superpave 12.5
HL-8/HL-8(HS)	Superpave 19.0
LSBC	Superpave 37.5

#### *Asphalt Cement*

The City of Toronto currently uses performance graded asphalt cement (PGAC). PG 58-28 is the asphalt cement grade typically specified by the City for most applications. For surface courses in higher traffic areas, PG 64-28 is typically specified. For very high traffic applications and premium SMA mixes, PG 70-28 is specified. This practice should be maintained.

#### *Tack Coat*

A tack coat should be utilized between asphalt courses when construction is staged (or delayed) and at all tie-ins and vertical surfaces. The tack coat should meet the requirements outlined in City of Toronto Specification TS 3.20.

### **3.2 Rigid Pavement Considerations**

The current state of practice with rigid pavements includes the use of load transfer devices to reduce faulting, widened slabs to reduce edge stresses, and random perpendicular joint patterns. Further, to improve constructability, subgrade replacement should be considered for frost susceptible and subsoils with poor support characteristics.

PCC concrete road base should meet the requirements of the City of Toronto Specifications TS 3.40 and TS 13.00. Load transfer devices, in accordance with TS 3.40, should be considered for all PCC pavements with thickness greater than 200 mm. The use of load transfer devices has two principal benefits; they reduce differential deflection across joints, and they reduce tensile stresses on the top of the slab. For most applications, 32mm diameter by 450 mm long coated dowel bars are recommended. Larger diameter bar sizes can be considered for very heavy loading applications. Details for use of dowels in skewed joints can be obtained from OPSD 552.050 and OPSD 552.060. Matching details for perpendicular joints can be obtained from OPSD 552.051 and OPSD 552.061.

The M-E PDG design procedure shows a sensitivity to the slab length in the required design thickness of concrete pavement layers. The longer slab lengths (> 5 m) tend to show premature failure due to slab

cracking because of the a higher accumulation of thermal stresses in the form of curling and warping in combination with truck traffic loads. It is important for the city to monitor the deterioration of underlying concrete slabs to ensure that they are adequately dispersing the traffic loads to the granular materials and subgrade soils. If excessive slab cracking is found, shorter slab lengths may be considered.

### *Rigid Base Repair*

During the removal and replacement of the HMA layer on the surface of the composite pavements, detailed inspection of the exposed concrete road surface is recommended to identify maintenance and repair needs.

### **3.3 Granular Base Considerations**

The City of Toronto specifies Granular A and Granular B – type II for granular road base and sub-base. Crushed bedrock, typically crusher run limestone (CRL), has been the material of choice.

The use of Granular B – type I (ie, sand with gravel) may be warranted for some instances. Granular B – type II can be substituted with Granular B – type I on a 1:1.5 basis (ie, 100 mm of Granular B – type II equals 150 mm of Granular B – type I).

Acknowledging our finite mineral resources, the City of Toronto has been allowing the substitution of recycled crushed concrete (RCC) as granular base and subbase. RCC can be substituted for CRL on a 1:1 basis.

While RCC is specified to meet current TS and OPS specification requirements, field observations of materials with excessive fines have been reported. Granular materials with excessive fines have been shown to exhibit poor drainage characteristics, which in turn affects pavement performance. Materials suspected of excessive fines should be subjected to increased scrutiny. This may include confirmation of process control charts and/or increased quality assurance testing.

### **3.4 Pavement Drainage**

Pavement life is a function of a number of factors including drainage. Provision must be made to ensure that water drains out of the pavement structure. In urban cross sections, continuous longitudinal subdrains (minimum 150 mm diameter) should be installed at least 300 mm below subgrade under the curb line. The subdrains should be on a positive grade and connected to appropriate outlets.

Where continuous subdrains cannot be installed due to conflicts with underground utilities, or in areas with permeable sand subgrade soils, consideration should be given to the installation of stub drains. The stub drains should be a minimum of 10 m in length and extend longitudinally in either direction along the roadway from all catch basins.

### **3.5 Sensitive Subsoils**

Fine grained subgrade soils such as very fine sand and silt have a tendency to exhibit high capillarity and low cohesion. Soils exhibiting these properties have a tendency to be moisture sensitive and susceptible to frost heaving. The MTO Pavement Design and Rehabilitation Manual (4) identified the following susceptibility categories based on grain size analysis.

**Table 3.2 . Frost Susceptibility Based on Gradation**

<b>Grain Size (5-75 µm)</b>	<b>Susceptibility to Frost Heaving</b>
0-40%	Low
40-55%	Moderate
55-100%	High

Sensitive subsoils may require subgrade replacement in the form of additional granular base, or approved alternative, in addition to those values presented in the design matrices. The requirement for subgrade replacement can be evaluated through the geotechnical investigation phase of pavement design process (especially frost susceptibility), or through proof rolling during construction (moisture sensitivity and subgrade instability).

### **3.6 Geosynthetics**

The generic term geosynthetic is often used to cover a wide range of different materials, including geotextiles and geogrids. Geotextiles act as barriers that allow water to pass but retain the soil particles. Geotextiles are usually classified as either woven or non-woven. Geogrids consist of a regular grid of plastic with large openings between the elements. The function of the openings is to allow the surrounding soil materials to interlock across the plane of the geogrid. The selection of the opening size is partially dependent on the gradation of the material into which it will be placed.

Geosynthetics have successfully been used to improve soil conditions. The most common uses for roadway applications include; reinforcing subgrade soils and aggregate bases, layer separation, and for improving drainage. The separation function describes the maintenance of materials of different gradations as separate and distinct materials. In the specific case of the pavement application, separation relates to the maintenance of unbound granular base course materials as distinct from the subgrade. The reinforcement function is very similar to the reinforcement process in reinforced concrete elements. The geosynthetic is introduced to provide elements with tensile resistance into the unbound material, which on its own would exhibit very low tensile resistance.

The use of geosynthetics may be appropriate on a project specific basis.

### **3.7 Transition Treatments**

All widenings for bus bays, turn tapers, etc., must be constructed with tie-ins that ensure positive drainage from the base of the existing granular sub-base. This can be achieved by constructing the base of the new pavement granular at or below the base of the existing granular.

For instances where existing pavement sections differ from the pavement sections proposed in the new guidelines, the thicker of the two pavement sections should be used.



### **3.8 Perpetual Pavements**

Perpetual pavements are essentially a deep strength/full depth pavement that are designed for long life. Perpetual pavements are designed to limit the stress and strains at the bottom of the asphalt layer in an effort to eliminate fatigue cracking.

The perpetual pavement concept incorporates a premium wearing surface, a rut resistant interlayer, and a rich-fatigue resistant bottom layer. A properly designed and constructed perpetual pavement would only require rehabilitation/replacement of the wearing surface for an anticipated service life in excess of 50-years.

The Texas Department of Transportation has constructed perpetual pavements with HMA layers in the order of 500 mm thick. At traffic levels consistent with the minor arterial non-truck route classification, a designed perpetual pavement could have HMA layers in excess of 350 mm thick.

The consideration of the use of perpetual pavements should be on a project specific basis and in conjunction with a detailed LCCA.

### **3.9 Maintenance and Rehabilitation**

As the city and associated infrastructure ages, the need and occurrence for the maintenance, repairs, servicing, upgrades and replacement of utilities continues to grow. The timing and frequency of these various events fluctuates significantly. Consequently, pavements are disturbed at all times of year and sometimes different utilities may need access to their infrastructure over short-term periods (less than 5 years) resulting in pavements that have been cut into and repaired many times. Cuts made during winter months can exacerbate pavement damage because of infiltration of moisture and the resulting freeze/thaw action.

Annually, more than 30,000 utility cut permits are issued to utilities to allow them to cut City roads to access their infrastructure. The permits usually allow for multiple road cuts within one area or on one road. In 2006, the cost of the permanent repairs of these cuts amounted to about \$50 million. Put in context, these funds would enable the reconstruction of approximately 40 km of local 2-lane City roads.

Of a lesser impact are the annual repairs associated with potholes (\$3 million), general road maintenance to address settlements of utility frames and localized pavement degradation (\$4 million), major failures caused by long-term settlements of utility trenches (\$1 million) and natural storm damage (\$2 million). Combined, these items total \$10 million annually.

The key to long term cost effective pavement performance is the use of appropriate rehabilitation and maintenance options at the right time in the service life of the pavement. The benefits of timely rehabilitation and maintenance are important to ensure both low costs and adequate serviceability of all pavement sections.

An important component of the pavement rehabilitation process is estimating the remaining life of the in-service pavements. Remaining life should be defined in terms of both structural capacity and functional serviceability. The structural adequacy of the pavement designs put forth in this guide are based on the M-E PDG.

The functional component of the pavement, however, is no less important. The existing City of Toronto pavement sections, as well as the new design sections developed with the M-E PDG, have fatigue life



expectations in excess of 20 to 25 years. However, many of the Toronto pavement sections are being rehabilitated to address ride quality and safety issues rather than structural adequacy issues.

### *3.9.1 Pavement Preservation Strategies*

Pavement preservation strategies are used to increase the serviceability of pavement sections and hence, extend their service life. The AASHTO Standing Committee on Highways defines preventative pavement maintenance as “the planned strategy of cost-effective treatments to an existing roadway system and its appurtenances that preserves the system, retards future deterioration, and maintains or improves the functional condition of the system (without significantly increasing the structural capacity)” (5).

The selection of the most appropriate and cost effective maintenance and rehabilitation activity is not solely dependent on the pavement condition of the roadway, but also on the timing of its implementation. The appropriate rehabilitation or maintenance activity can mitigate existing pavement distress and allow the use of a cost effective activity before it deteriorates to a point where more costly repairs are necessary. The goal is to select the right treatment, for the right pavement, at the right time.

### *3.9.2 Whole Life Maintenance Plans*

The evaluation of a pavement over its entire life cycle will help ensure that an adequate level of serviceability is maintained and costs are kept to a minimum. The whole life maintenance plan not only considers the initial construction of each option, but also incorporates maintenance and rehabilitation costs that are incurred throughout the analysis period. Although one alternative may have a lower initial cost than another, maintenance and rehabilitation costs over the life of the pavement may make the initially less expensive option more costly over the analysis period. Therefore, it is necessary to account for future pavement repair requirements and the associated future costs.

In 2001, the City of Toronto created pavement performance models as part of the development of the City’s Municipal Pavement Management Application (MPMA). These models approximate the service life and year of rehabilitation of each road. The models were constructed using a series of pavement prediction curves which were chosen specifically to resemble the amount of traffic and pavement thickness of each road. For example, the curves which were used to construct local and collector roads had thin to average thicknesses and low to medium traffic levels.

Some models identify cold in-place rehabilitation rather than a resurfacing. A cold in-place rehabilitation is performed near a pavement quality index (PQI) of five and increases the PQI higher than the previous rehabilitation (other than reconstruction). When a resurfacing rehabilitation occurs, the PQI is, in most cases, lower than the previous rehabilitation. Although cold in-place rehabilitation is more expensive, the service life of a road is significantly increased.

Each model also contains points on the curve which indicate when maintenance is necessary. These maintenance activities do not increase the pavement quality index but they are preventive measures that have been proven to extend the life of the pavement. In all cases crack sealing is applicable. Slurry sealing is an optional preventive maintenance measure but is applicable to local residential streets only.

Pavement performance models are shown in Figure 3.1 and Figure 3.2. Figure 3.1 (a), (b), (c) and (d) apply to local and collector roads. Figure 3.2 (a), (b), (c) and (d) apply to minor and major arterial roads. The services lives presented in whole life maintenance plans are consistent with the outcome of both the MPMA performance models and the M-E PDG modelling. As with any pavement design, achieving the predicted service life is contingent on many factors including; traffic, soils, weather, construction, maintenance, and environment.

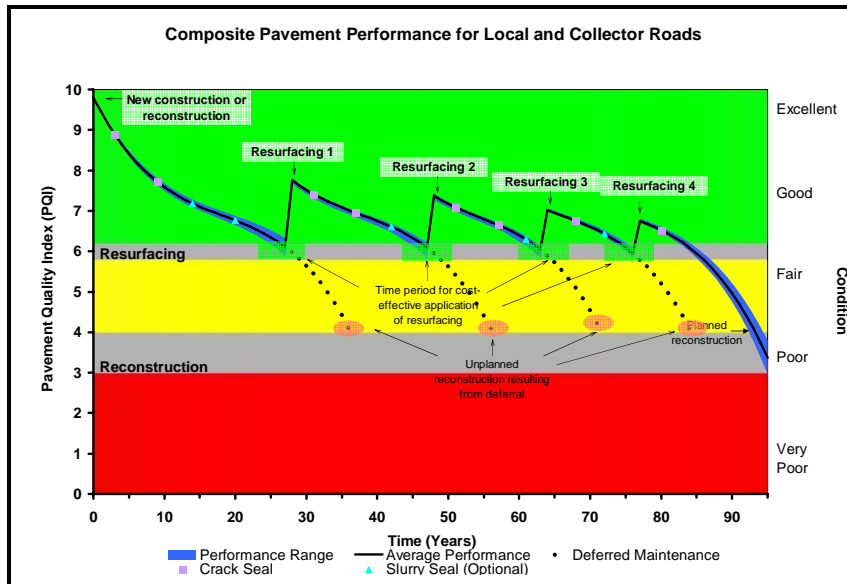


Figure 3.1(a)

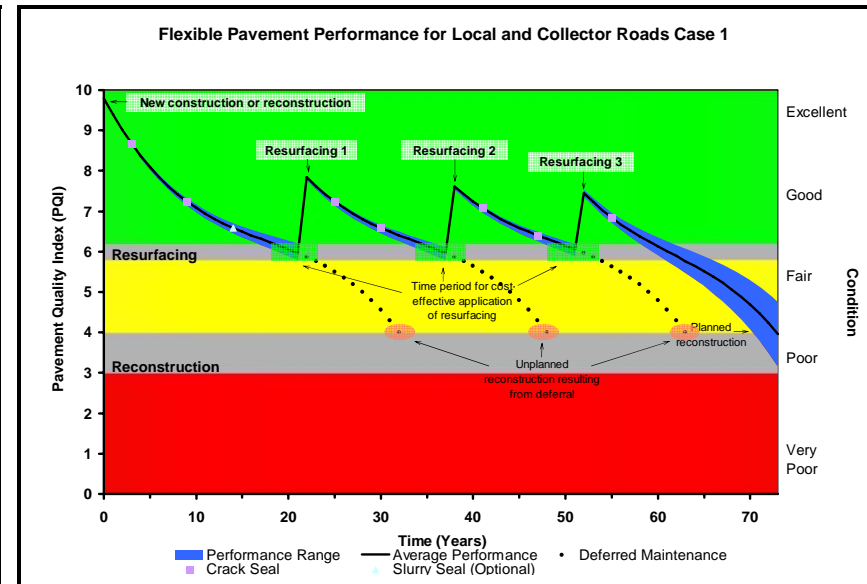


Figure 3.1(b)

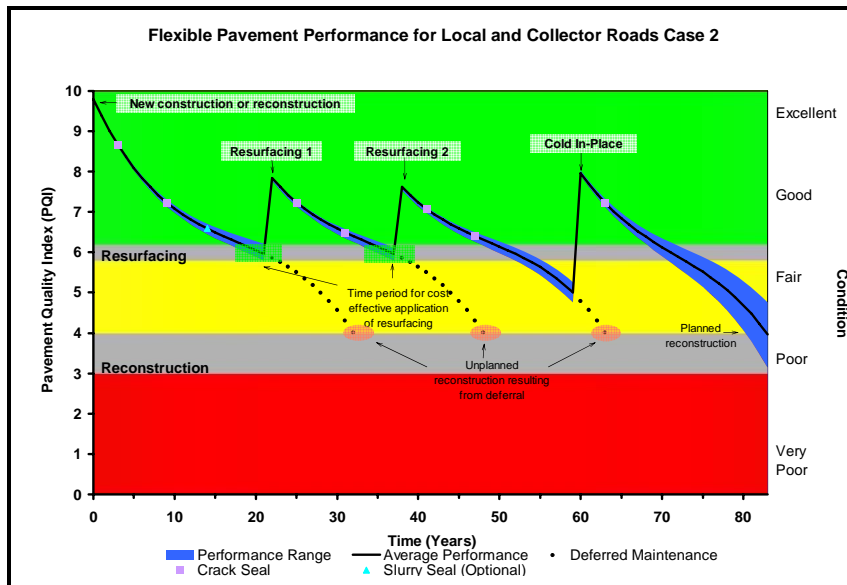


Figure 3.1(c)

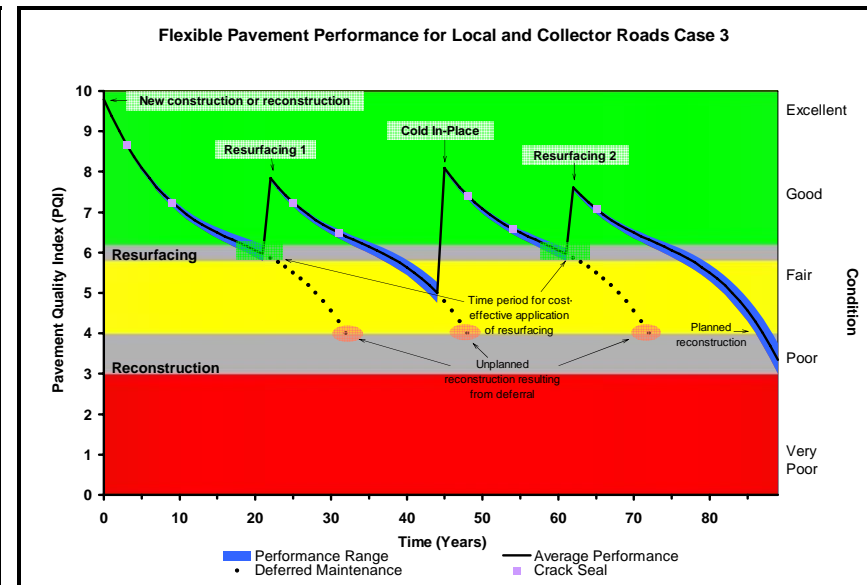


Figure 3.1(d)

**Figure 3.1. Pavement Performance Models for Local and Collector Roads**

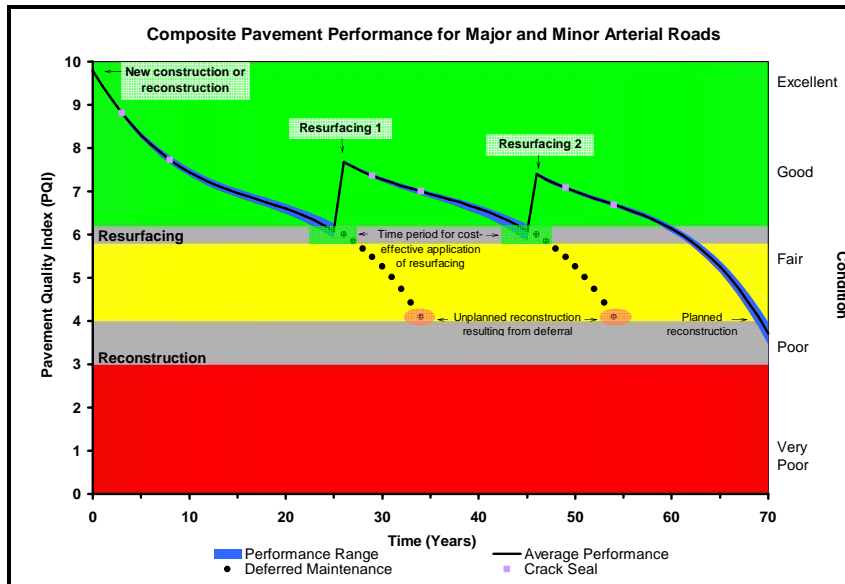


Figure 3.2(a)

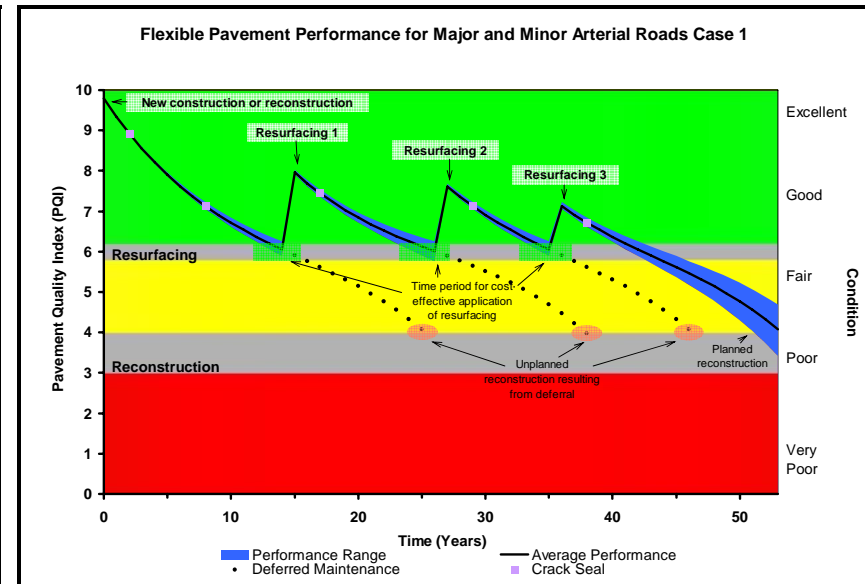


Figure 3.2(b)

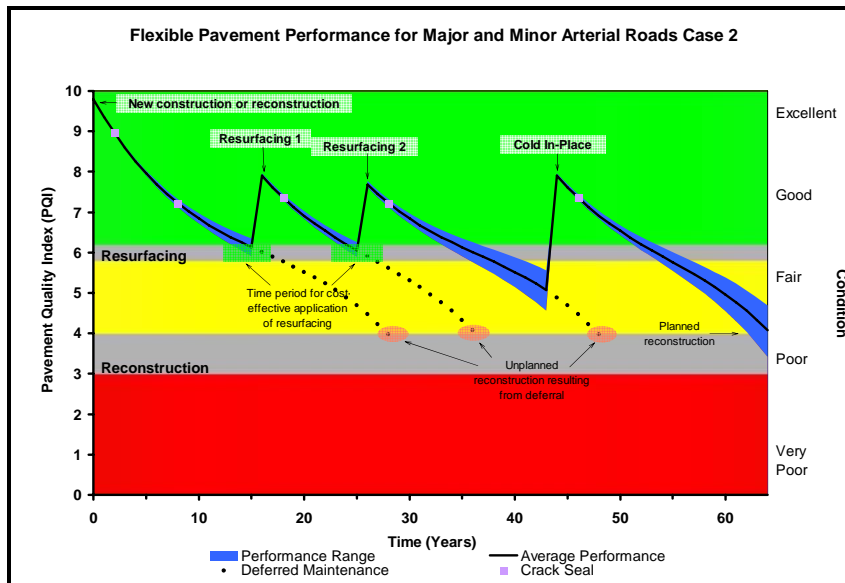


Figure 3.2(c)

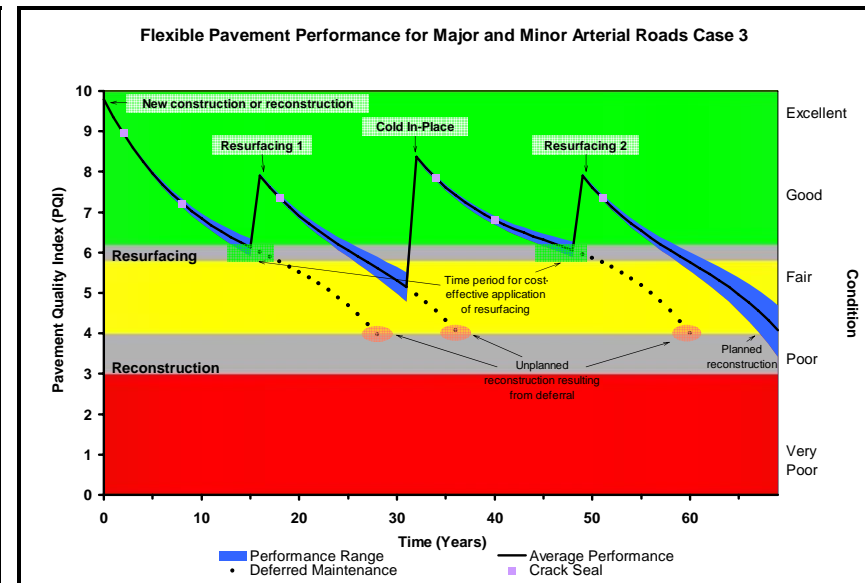


Figure 3.2(d)

**Figure 3.2. Pavement Performance Models for Major and Minor Arterial Roads**

#### 4.0 REFERENCES

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