The ABCs of PAVEMENT DESIGN

ohmpa

Ontario Hot Mix Producers Association

The ABC's OF PAVEMENT DESIGN

Anybody can design a road that can last for generations. You build it straight, build it flat and build it strong.

For many municipalities, however, that is no longer an option. Budget dollars are scarce (capital expenditure for upper tier municipal roads has decreased substantially since 1996) and road construction and rehabilitation has to compete with all the other infrastructure demands. At the same time, traffic volumes are steadily increasing and so too are the expectations of those using the roads.

The challenge is to design a road that operates efficiently for the least cost over a reasonable design life of twenty, thirty or forty years. And that is the art of pavement design.

Fortunately, high-performance, premium materials and new asphalt pavement construction technologies can provide significant benefits. Life cycles cost analyses, for example, have shown that asphalt technology improvements can increase the life of asphalt pavements by up to 30 percent.

This brochure introduces various concepts and design methods for asphalt pavements and asphalt overlays that can give municipalities the cost-effective solutions that they need.

Form Follows Function

A major freeway in Toronto is a far different road from a local suburban road in Timmins. The climate is different, the terrain is different, and the traffic is different. But there is one similarity. Both municipalities (in fact, every municipality in Ontario) are trying to do more with less, juggling infrastructure needs within budget constraints.

Roads are one of the biggest assets for any community and proper pavement design along with timely maintenance and rehabilitation are essential to ensure their durability and long-term service.

Pavement design is far more complex than most people realise. Roads have to withstand a combination of loads and stresses that depend not just on the type of traffic using the road but also the geometry of the road, the climactic conditions under which it operates and the geology of the ground that it crosses.

But regardless of the complexity or the conditions under which a road must operate, there are basic design requirements that every road needs. We call it the ABCs of pavement design: Asphalt, Base and Construction.

- **Asphalt** - the most cost-effective pavement surface
- **Base** – the solid foundation on which the road is built
- **Construction** – the craftsmanship that makes a good design a reality.

The Pavement Structure

The Components

Pavement design starts from the ground up:

The subgrade – the foundation layer, which normally consists of well-compacted existing subsoil

The sub-base and base – compacted granular material that provides drainage and a firm foundation

The pavement – usually two layers (or courses) of asphalt: a base course for structure and a surface course for wear.

Materials and Mixes

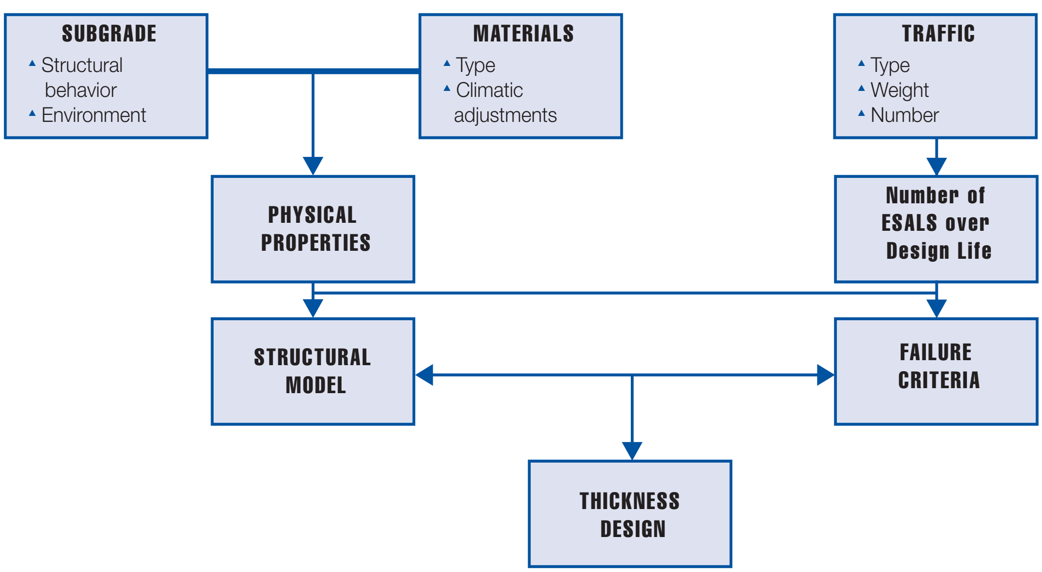
The Base: Granular unbound materials (aggregate) such as crushed stone, crushed or uncrushed gravel and sand, and suitable recycled materials are used to make the base and sub-base. Because of the environmental conditions in Ontario, these materials play an important role in pavement performance.

Drainage (both surface and subsurface drainage) is a critical pavement design consideration and essential for proper pavement performance.

Specifications for gradation and quality of the base and subbase materials used in Ontario are presented in Ontario Provincial Standard Specifications (OPSS).

Pavement Design Factors

(Asphalt Institute MS-17)



The Pavement: Hot mix asphalt (HMA) is a high-quality mixture of asphalt cement and well-graded, high-quality aggregate that has been thoroughly compacted to ensure long-term performance.

Asphalt concrete mixes are designed as either a base course or a surface course. The base course provides adequate load distribution properties. The surface or wearing course resists the polishing effects of heavy traffic and the effects of ageing or weathering and other environmental influences.

In some cases, a levelling (scratch or padding) course is necessary, during rehabilitation, to correct minor deviations in longitudinal and transverse profile of the existing pavement prior to overlay.

The Asphalt Cement: The performance-based specification for asphalt binders within the SHRP system is designed to reduce the occurrence of permanent deformation, fatigue cracking, and low-temperature cracking.

Performance graded asphalt cement binder specifications are based on climate and pavement temperatures and each binder is given a grade, for example PG 58-28.

The first number is the “high temperature grade”; the second number is the “low temperature grade”.

Consideration for additional performance requirements (heavy truck traffic, for example) is made by increasing the high temperature grade. Consideration is also made for incorporating recycled asphalt pavement (RAP).

The Ontario Hot Mix Producers Association’s “ABC of PGACs” *(Issue 2.0, April 1999)* is an excellent document that describes the PG system and its application in Ontario.

The Aggregates: The aggregates used in a dense-graded asphalt concrete mixture should meet the general requirements of OPSS 1003 for coarse and fine aggregates.

Both coarse and fine aggregates must meet standard materials quality specifications such as soundness, abrasion, and cleanliness. When selecting aggregates to be used in the asphalt concrete wearing surface, frictional characteristics need to be carefully considered.

Materials

Local jurisdictions may determine the use of each material (see Table 1 for general guidelines for materials used in dense-graded mixtures).

Use of Reclaimed Asphalt Pavement (RAP) in Marshall and Superpave mixtures is acceptable provided that the MTO Guidelines for Use of PGAC are followed.

Up to 15% RAP may be used in surface course mixtures but not in premium mixtures such as DFC, SMA, and OFC. Base course mixtures may use up to 30% RAP. In all cases, the recycled HMA mixture shall meet the gradation and volumetric requirements as specified by the local jurisdiction.

Mix Design

The mix design typically includes material proportions and characteristics as well as selected mixture properties such as volumetrics (e.g. percent air voids, VMA etc.) and strength.

In Ontario, there are two common procedures for designing HMA mixtures: the Marshall method (AI publication MS-2) and the new Superpave method (AI publication SP-2). While the move is to Superpave*, either mix designs procedure can be used to design quality mixtures.

Table 1 Materials for Dense-graded Mixtures

LAYER	MATERIAL	LOW TRAFFIC TO MEDIUM TRAFFIC	HIGH TRAFFIC
surface	**Aggregate**	▲ Crushed gravel and quarried rock (stone and screenings) ▲ Manufactured sands and natural sands ▲ Typically 60% to 80% crushed coarse aggregate	▲ 100% crushed aggregate
	Asphalt Binder	▲ Typically unmodified ▲ Modification may be necessary for heavier traffic and at intersections	▲ Modification likely ▲ Unmodified asphalts used based on local experience
	Other	▲ RAP (Reclaimed Asphalt Pavement) ▲ Reclaimed materials (crumb rubber, glass) ▲ Fibres or reclaimed shingles ▲ Antistrip additive as required by testing	
base	**Aggregate**	▲ Crushed gravel & quarried rock (stone and screenings) ▲ Manufactured sands and natural sands ▲ Typically 60% to 80% crushed coarse aggregate	▲ 100% crushed aggregate
	Asphalt Binder	▲ Typically unmodified	▲ Unmodified except for very heavy loading or when traffic travels on the pavement for extended periods (e.g. for staged construction)
	Other	▲ RAP (Reclaimed Asphalt Pavement) ▲ Reclaimed materials (crumb rubber, glass) ▲ Fibres or reclaimed shingles ▲ Antistrip additive as required by testing	

Performance testing can be used before the mix is placed to ensure that a mix will perform as required.

*The Superpave (**Su**perior **Per**forming Asphalt **Pave**ments) system is a performance-based system for testing and evaluating asphalt binders and mixtures. It consists of a new asphalt binder specification; a volumetric mix design method using a gyratory compactor based on traffic and climatic conditions at the project site; and a mixture analysis protocol developed to predict mixture performance.

Basic Pavement Design

Design Criteria: Regardless of the design methodology used, there are a number of factors that must be considered in every pavement design:

- design life
- traffic
- subgrade type
- drainage
- environment
- materials
- performance criteria (e.g. rutting, aging, fatigue cracking and low temperature cracking)
- budget

Design Methodology: Pavements can be designed empirically (by using tables and charts), semi-empirically (incorporating material testing), or mechanistically (using more in depth analysis). Each method has its advantages and disadvantages but, if used appropriately, will provide a perfectly adequate design.

Empirical methods are usually based on experience with the long-term performance of pavements under different loading, climatic, and soil conditions. Empirical methods are also suitable for parking lots and low volume roads.

The MTO Routine Method of Pavement Design (as covered in the 1990 Pavement Design and Rehabilitation Manual), the Ontario Pavement Analysis of Costs (OPAC) and the AASHTO Method (as covered in the 1993 AASHTO Guide for Design of Pavement Structures) are empirical methods.

Mechanistic methods such as the Asphalt Institute's Multi-Layered Elastic System (MS-1) use basic engineering material properties to model stresses and strains from vehicular loading.

Failure is usually described in terms of unacceptable levels of cracking and surface roughness. (Remember that cracking and roughness can also be caused by climactic conditions).

For flexible pavements, limiting the horizontal (tensile) strain at the bottom of the hot mix asphalt pavement layer controls structural (fatigue) cracking. Limiting vertical strain in the subgrade can control pavement rutting.

Semi-empirical methods (the California Bearing Ratio [CBR] method for example) fall somewhere in-between using testing and design modified by experience.

The new AASHTO Guide under development (to be delivered in 2002) will provide a mechanistic-empirical method using the data from the Long Term Pavement Performance (LTPP) program and other accelerated loading test facilities.

Traffic and ESALs

Roadway Classification	Description
Freeway	Accommodates heavy volumes of traffic at high speed under free-flowing condition. Highly limited adjacent land access.
Arterial	Connects concentrations of industrial and commercial and residential neighbourhoods. Adjacent land access usually subject to stringent control.
Collector	Collect traffic from local roads and distribute it to other local roads, arterials and freeways. Access to adjacent land is usually permitted without as stringent control as arterial roads
Local	For local land access - the final link in the road network

Traffic volumes are usually measured in terms of ESALs (equivalent single axle loads). ESALs represent the number of axle loads, weighted by equivalency factors derived at the AASHO Road Test.

A simplified approach to determine the total design ESALs can be made by multiplying the total number of trucks over the design period by a mean truck equivalency factor (where 1 ESAL = 80 kilo Newtons or 18,000 lbs. single-axle load applications) that represents all the trucks for the highway class under consideration. For example, a roadway that carries 40 trucks per day (with a mean truck equivalency factor of 2.0) equates to approximately 300,000 ESALs (over a 20 year life with zero growth) whereas a roadway that carries 4,200 trucks per day is equal to about 30 million ESAL.

Mix Types

Mix Type

A dense-graded mix includes an even distribution of aggregate particles from coarse to fine. Properly designed and constructed mixtures are relatively impermeable.

Each agency may have their own unique HMA type description based on the Marshall mix design criteria. The general HMA type descriptions are based on OPSS for Marshall mixes. A definition of most mixtures used in Ontario is given in Table 2.

For Superpave (SP) mixes dense graded mixes are designated by the nominal maximum aggregate size (NMAS). The nominal maximum size is defined as "one sieve size larger than the first sieve to retain more than 10 percent." Dense graded mixtures can be further classified as fine graded or coarse graded mixtures (Table 3).

Table 2 Definition of Ontario HMA Mixtures

MIX TYPE	DESCRIPTION
HL 1	▲ HL 1 A dense-graded surface course mix with a premium quality coarse aggregate. It is used on high traffic volume highways and intersections and has a maximum aggregate size of 100% passing the 16.0 mm sieve size
HL 1 Modified	▲ A premium surface course with high frictional resistance that uses no more than 10% natural sand and has a maximum aggregate size of 16.0 mm.
HL 2	▲ A sand mix used primarily as a levelling course on existing pavements or as a surface course on low speed traffic areas requiring a thin overlay. It is also used to fill cracks and has 100% passing the 9.5 mm sieve size.
HL 2 Modified	▲ A fine mix used primarily as a surface course on low volume and low speed traffic areas. It has more coarse aggregate retained on the 4.75mm sieve size than conventional HL 2.
HL 2 High Stability	▲ A fine mix used as a surface course on low to medium traffic areas requiring a thin overlay. It uses aggregates with 100% crushed faces.
HL 3	▲ A surface course used on low to medium traffic areas and has a maximum aggregate size of 16.0 mm.
HL 3 High Stability	▲ A high quality mix used as a levelling or surface course. It generally uses aggregates with 100% crushed faces. It is designed to resist rutting and can be used in areas with heavy axle loadings.
HL 3 Fine	▲ Fine graded mix used as a surface course where handwork is necessary for placement. It is also used on roads, driveways, and boulevards where frictional resistance is not required.
HL 4	▲ Used as surface and binder courses. The maximum aggregate size is 19.0 mm. Used primarily in Northern Ontario.
HL 4 Modified	▲ Used as surface and binder courses. The coarse aggregate has 100% crushed faces and 50% of the fine aggregate has 100% crushed faces.
HL 4 Fine	▲ Fine graded mix used as a surface course where handwork is necessary for placement. It is also used on roads, driveways and boulevards where frictional resistance is not required.
HL 8	▲ A conventional low to medium traffic binder course and has 100% passing the 26.5 mm sieve size.
HL 8 High Stability/ Heavy Duty Binder	▲ A binder course designed to resist rutting used on high traffic or heavy axle loading areas. Both coarse and fine aggregate shall have 100% crushed faces.
Dense Friction Course	▲ A premium surface course with high frictional resistance. Typically, the coarse and fine aggregates are from the same source and have superior physical properties.
Stone Mastic Asphalt	▲ A premium surface course with excellent pavement performance characteristics. Provides frictional and rutting resistances and resistance to fatigue cracking.
Open Friction Course	▲ An open-graded mix with superior quality aggregates for use on urban highways or roadways with heavy traffic where low tire noise is desired. OFC is free draining and has good frictional resistance.
Large Stone Binder	▲ A binder course mix using a maximum stone size of 40 mm and typically used in the lower binder course for high traffic and/or heavy axle loadings.

Table 3 Definition of Superpave Mixtures

SUPERPAVE DESIGNATION, mm	NOMINAL MINIMUM SIZE, mm	MAXMUM SIZE, mm
37.5	37.5	50.0
25.0	25.0	37.5
19.0	19.0	25.0
12.5	12.5	19.0
9.5	9.5	12.5

**Layer Thickness: The compacted thickness of the asphalt layer should be at least 3 times the NMAS of the aggregate to achieve adequate compaction, smoothness and durability.*

Table 4 Typical Municipal Pavement Mixes in Ontario

TRAFFIC CONDITIONS	SURFACE COURSE MIX TYPE	BINDER COURSE MIX TYPE
Low Traffic	▲ HL 3, HL 3 Fine, HL 2, HL 2 Modified, HL 4, HL 4 Fine ▲ SP 9.5, SP 12.5 ▲ Compacted lift thickness usually from 12.5 mm to 50 mm.	▲ HL 4, HL 4 Modified, HL 8 ▲ SP 19 ▲ Minimum compacted lift thickness usually 50 mm.
Medium Traffic	▲ HL 1, HL 3, HL 3 HS, HL 4, HL 4 Modified ▲ SP 9.5, SP 12.5, SP 19.0 ▲ Typical lift thickness from 40 mm to 50mm.	▲ HL 4, HL 8, HL 8 HS/HDBC ▲ SP 19 ▲ Typically two lifts on granular base.
High Traffic	▲ HL 1, HL 1 Modified, HL 3 HS, DFC, SMA, OFC ▲ SP 12.5, SP 19	▲ HL 4 Modified, HL 8 HS/HDBC, LSBC ▲ SP 19, SP 25, SP 37.5

Parking Lot and Driveway Mixtures

While using a fine surface mixture with natural sand is desirable for appearance, an increased use of 100% crushed fine aggregate will provide a surface mixture with the best performance. As well, it is recommended that engineering judgement be used in selecting the PGAC for these HMA surface mixtures. For example, PG 58-22 and PG 64-22 have been used in Zone's 2 and 3 and PG 58-28 and PG 58-22 have been used in Zone 1.

Designing Flexible Pavements

1. Municipal Pavement Design Guidelines

An example of a simple, effective pavement design procedure is presented in Table 4 based on the Minimum Pavement and Road Design Requirements developed by the City of Mississauga. It provides consideration for the class of road, subgrade frost susceptibility and drainage. Conventional designs for a typical Ontario subgrade soils are shown below in this example.

Example 1 Municipal Pavement Design Guidelines (thicknesses in mm)

CLASS OF ROAD	FROST SUSCEPTIBILITY FACTOR	1 80% SAND/GRAVEL	3 5 MAX 30% SILT	7 MIN. 30% SAND	11 MAX 55% SILT	15 + 55% SILT
Arterial / Industrial	▲ HL8 HMA (BASE) ▲ Granular A crushed ▲ Minimum total road structural depth	60 150 350		85 150 610	100 150 700	100 150 775
Collectors	▲ HL8 ▲ Granular A ▲ Minimum total road structural depth	50 150 350		85 150 540	100 150 625	100 150 660
Residential	▲ HL8 ▲ Granular A Minimum ▲ Minimum total road structural depth	50 150 350		85 150 460	100 150 520	100 150 550

Notes for Municipal Pavement Design Guidelines:

1. *HMA may be reduced by 35 mm to a minimum of 50 mm if:*
   a) Additional 70 mm of total road structural depth is added; or
   b) Granular A is used to make up the remaining minimum total road structural depth.
2. *Top 300 mm of the subgrade shall be compacted to a minimum of 98% SPD.*
3. *Minimum of 40 mm HL 3 surface course HMA shall be added to the road after adjacent buildings have been constructed.*
4. *Subbase shall be Granular B or equivalent, or additional Granular A (crushed)*
5. *Additional 150 mm thickness of Granular B shall be added at arterial or industrial road intersections. This extra depth shall extend for a minimum of 15 m from the property line of the intersecting street.*
6. *Full length subdrains shall be installed where the subgrade is silt or clay, or where the water table is within 1.3 m of the finished road surface.*
7. *These are minimum pavement and road base design requirements. The consultant bears the ultimate responsibility for the project.*

2. The AASHTO Method

The AASHTO method of pavement design is the most widely used method in North America.

From its empirical background from the AASHO Road Test carried out in the U.S. in the early Sixties, the AASHTO 93 method is now evolving into the mechanistic-empirical AASHTO 2002 method.

The AASHTOWare DARWin program is a simplified computerized version of the AASHTO 93 method. The following input parameters are required:

- **traffic loading** in terms of ESALs.
- **reliability level** for various road functional classifications ranging from 85 to 90 for urban highways to 50 to 80 for local rural roads
- **subgrade soil characterization** in terms of laboratory-determined subgrade resilient modulus for spring conditions.
- **expected drainage conditions** in terms of pavement materials drainage coefficients (mi), based on the percent of time the pavement structure is exposed to moisture saturation.
- **environmental conditions**, with a particular emphasis in Ontario on pavement frost susceptibility (frost susceptible soils, presence of water, and depth of frost penetration).
- **design serviceability loss**, as the difference between the pavement initial and terminal serviceability.
- **pavement layer coefficients** (ai) used to characterize the structural capacity of pavement materials.

The pavement thickness is designed by calculating the Structural Number (SN) and then selecting the pavement that meets the required SN. The AASHTO 93 method also requires that the thickness of the asphalt layers be checked for overstressing.

Designing Pavement Overlays

1. AI Design Methods:

The Asphalt Institute provides two design methods for overlays:

(i) Deflection Procedure

(ii) Effective Thickness Procedure

Both methods should be used to design the overlay, the results compared and engineering judgement used to select an appropriate overlay thickness. These methods are described in AI's Manual Series 17 along with a computer program (CP-4).

(i) Deflection Procedure

The Asphalt Institute's deflection based design method for flexible pavements is an empirical method that has been used successfully for many years.

The deflection procedure for flexible pavements uses an actual Representative Rebound Deflection (RRD) from the Benkelman Beam device, or an equivalent RRD from dynamic or impulse non-destructive tests such as the Dynaflect and FWD.

The magnitude of the deflection is an indicator of the structural capacity of the existing pavement and its ability to accommodate future traffic loading.

Based on the deflection data, a strengthening overlay is designed to reduce pavement deflections from a measured to a limiting design RRD for varying traffic conditions.

(ii) Effective Thickness Method

The Effective Thickness Method is another empirical design procedure can be used for flexible pavements.

As pavements deteriorate due to traffic loading and exposure to the environment, their physical characteristics may not change but because their performance has deteriorated they behave as if they are thinner than they really are. The effective thickness of this "thinner" pavement is the thickness of a full depth asphalt pavement with equivalent physical properties.

The overlay thickness is the difference between the full depth asphalt pavement thickness required for future traffic and the effective thickness of the existing pavement.

2. The MTO Method

The Ministry of Transportation of Ontario has a detailed design procedure for pavement overlays similar to the AI method.

The MTO method starts with a determination of the traffic loading in terms of daily ESALs (referred to as Daily Traffic Number (DTN)). The next step is to determine the actual deflection of the road using the Benkelman Beam, Falling Weight Deflectometer or other devices. These numbers are then used to determine either maximum traffic loading or thickness requirements using the Granular Base Equivalency (GBE).

3. AASHTO Method

The AASHTO Method for asphalt overlay design requires the following inputs:

- existing pavement design and construction data
- material types and thickness
- subgrade information
- traffic analysis
- pavement condition survey
- deflection testing, coring and material testing are recommended to investigate the existing conditions.

If the overlay is being placed for the purpose of structural improvement, the required thickness in terms of Structural Number for the overlay is calculated as the difference between the SN required to carry the future traffic and the SN of the existing pavement. The AASHTO Guide gives the range of layer coefficients for the materials in the existing pavement depending on the pavement condition.

Additional Design and Management Considerations

Life-cycle costing: Life-cycle cost analysis is the economic assessment of competing, technically suitable systems over their design life.

A life cycle cost analysis will consider initial construction costs, maintenance costs, rehabilitation costs and salvage and residual costs. It can also include user costs such as delay time costs. The net present worth method of analysis is most commonly used for pavements.

Life-cycle economic comparisons can only be made between properly designed, structurally equivalent pavement sections that meet the project functional requirements.

New asphalt technologies: The use of high-performance, premium materials and new technologies in asphalt pavement construction provide significant life-cycle cost benefits.

Life-cycle cost analyses indicate that improvements in pavement smoothness, enhanced quality control through end-result specifications, and the use of high quality materials such as performance graded asphalt cement, heavy duty binder course (HDBC) and stone mastic asphalt (SMA) mixes substantially reduce the overall life-cycle cost of an asphalt pavement.

Implementation of the Superpave mix design methodology, changes in aggregate quality characteristics, introduction of quality plans and use of large stone binder course mix are also expected to further improve asphalt pavement cost effectiveness.

Life-cycle cost analyses indicate that such asphalt technology improvements increase the life of asphalt pavements by about 20 percent and in the case of SMA, by more than 30 percent.

Perpetual pavements: Perpetual asphalt pavements have three distinct features: a rut-resistant and wear-resistant renewable surface course; a rut-resistant, durable intermediate layer; and a combination of adequate asphalt thickness and flexibility to resist deep fatigue cracking. They also have lower life-cycle cost than conventional pavements.

Perpetual asphalt pavements do not require costly reconstruction. Periodic replacement of the pavement surface and recycling the old pavement material can extend the life of a pavement to more than fifty years.

Asphalt recycling: Asphalt is 100 percent recyclable. Reclaimed Asphalt Pavement (RAP) material is routinely used in both binder and surface courses mixes.

Asphalt pavement can be recovered by cold milling machines or by full depth removal and crushing at the plant. The material can be further proportioned, heated and blended with new material to produce 'recycled' HMA that is equivalent to the performance of HMA without RAP.

Pavement maintenance, preservation and management: Pavement management is a proactive approach that includes systematic and timely maintenance and rehabilitation to extend pavement life. The key is to apply the most appropriate maintenance and rehabilitation treatment while the pavement is still in relatively good condition and has no structural damage.

Pavement maintenance and rehabilitation should be integrated into a Pavement Management System to maintain the condition of the pavement network within budget constraints.

Pavement Design CHECKLIST

Did you consider the following?

- Traffic
- Subgrade
- Drainage
- Environment (Frost Action)
- Materials Including Asphalt New Technologies
- Life-Cycle Cost
- Recycling
- Maintenance
- Pavement Preservation
- Existing Pavement Condition For Overlay Design.

GLOSSARY

AASHTO: American Association of State Highway and Transportation Officials

ADT: Average Daily Traffic

ADTT: Average Daily Truck Traffic

AI: Asphalt Institute

CBR: California Bearing Ratio

DTN: Daily Traffic Number

ESALs: Equivalent Single Axle Loads

FWD: Falling Weight Deflectometer

GBE: Granular Base Equivalency

HMA: Hot Mix Asphalt

LTPP: Long Term Pavement Performance

NMAS: Nominal Maximum Aggregate Size

OFC: Open Graded Friction Course

OPAC: Ontario Pavement Analysis of Costs

OPSS: Ontario Provincial Standard Specifications

PGAC: Performance Graded Asphalt Cement

RAP: Reclaimed Asphalt Pavement.

RRD: Representative Rebound Deflection

SHRP: Strategic Highway Research Program

SMA: Stone Mastic Asphalt

SN: Structural Number

ohmpa

The Ontario Hot Mix Producers Association

365 Brunel Road, Unit 4, Mississauga, ON L4Z 1Z5

Phone: 905.507.3707 • Fax: 905.507.3709
web site: www.ohmpa.org • email: info@ohmpa.org