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ONTARIO ASPHALT PAVEMENT COUNCIL

The ABCs of Stone Mastic Asphalt (SMA)

Design & Construction

INTRODUCTION

Originally developed in Germany in the late sixties, Stone Mastic/Matrix Asphalt (SMA), primarily used for surface courses in North America - is a durable, rut resistant mix that incorporates stone-on-stone contact to provide strength while utilizing a rich mortar binder to provide durability. It has a high proportion of coarse aggregate that interlock to form the strong stone skeleton, and a binder mastic composed of a high asphalt cement content (typically 6 to 7% in Europe), a cellulose or mineral fiber and high percentage of mineral filler. SMA has been used in Canada since the 1990's[1]. Figure 1 shows a cross section of SMA compared with Dense Graded Asphalt (DGA):

Figure 1 Cross Section of SMA (top) and Dense Graded Asphalt (bottom)

SMA ADVANTAGES – Some key benefits of using SMA are summarized below[2]:

- **Excellent rut resistant properties;**
- **Excellent durability** – *(slow ageing) compared to conventional hot mix asphalt mixtures in Europe and U.S;*
- **Good flexibility and resistance to fatigue** – *(performs well during low temperature conditions);*
- **High skid resistance – due to its rough texture;**
- **Reduced tire splash in wet conditions;**
- **Reduced tire noise;**
- **Additional Uses** – *as base course mix, including high stressed pavement applications, thin overlays, or to provide wear resistance from studded tires.*

ECONOMIC CONSIDERATIONS

SMA is generally more expensive than a typical dense-graded HMA due to its higher material, production and construction costs. It requires use of higher quality skid resistant aggregates and additives, higher binder content, and use of modified binders. However, the benefits from improved pavement performance and its frictional resistance properties make it more economical in the long term by reducing rehabilitation needs and extending service life.

ONTARIO's CHALLENGES WITH SMA

Overtime, Ontario's challenges with SMA mixtures have evolved through considerations of type and proportioning asphalt cement, mineral filler and fiber considerations in order to prevent the negative impacts on mix volumetric and density requirements, to exacting uniform QC/QA measures in all phases of production and placement. Another concern of considerable importance, that also led to an official pause of SMA usage in Ontario was the issue of early skid resistance. This concern was resolved through a joint MTO/Industry Task Force. SMA specifications now requires rolling sand into the still warm SMA surface - gritting. The sand is specifically sourced and processed through the HMA plant with a small amount of AC to make it slightly sticky. **Figure 2** shows the application of gritting sand on SMA pavement surface using specially designed steel wheel rollers with sand hoppers and calibrated distributors.

Figure 2 SMA Pavement – Gritting Sand Application

SMA MIX DESIGN

The SMA mix design philosophy revolves around developing a strong stone-on-stone contact, and providing a binder rich mortar to achieve the desired consistency. The design process also addresses durability by determining moisture and draindown sensitivities of the mix. Critical considerations for mix development include, asphalt cement content, aggregate properties, air voids, voids in mineral aggregates (VMA), voids in coarse aggregates (VCA), gradation, modifiers and stabilizing additives. **Figure 3** shows a flow chart for SMA mix design[2].

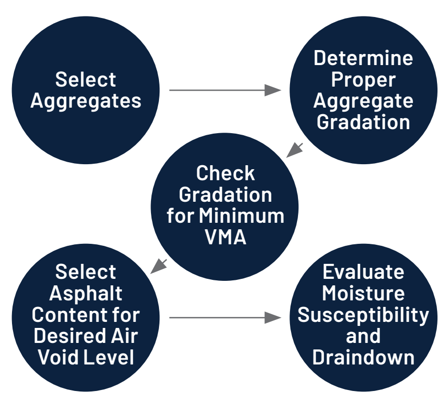

Figure 3 Flow Chart for SMA Mix Design

Aggregates used in SMA mixtures should be selected with adequate hardness, surface texture, shape and durability. Preference to aggregates with high angularity, cubical shape, and no flat or elongated particles provides the desired skeleton and strength characteristics. Proper grading and handling are critical for consistency in mix production. Performing dry rodded density analysis of different gradations of coarse aggregate is an effective method that can be used to maximize stone-on-stone aggregate structure during the mix design process. **Table 1** and **Table 2** details typical SMA gradation and mix properties applicable in Ontario. Designers are encouraged to consult applicable provincial or municipal specifications as necessary.

Table 1 Typical Ontario SMA Gradation Envelope

Sieve	9.5 mm	12.5 mm	19 mm
25.0 mm	–	–	100
19.0 mm	–	100	90 – 100
12.5 mm	100	90 – 100	50 – 88
9.5 mm	70 – 95	50 – 80	25 – 60
4.75 mm	30 – 50	20 – 35	20 – 28
2.36 mm	20 – 30	16 – 24	16 – 24
75 µm	8 – 12	8 – 11	8 – 11

Table 2 Typical Ontario SMA Mix Properties

Design Parameter	Design Criteria
AC Content	*Refer to Table 5, OPSS.PROV. 1151 for Specified Minimum Asphalt Content Based on Combined Aggregated Bulk Relative Density (BRD)**
Air Voids %	4.0*
VMA %	17 Minimum
VCAmix %	< VCADRC
TSR %	70 Minimum
Draindown %	0.3 Maximum

*Determine optimum binder at 4 percent air voids for warm climates and 3.5 to 4.0 percent for cold climates. Additional considerations apply when fibres are incorporated in the mix.

In Canada, polymer modified binders are increasingly being specified to accommodate temperature variations and extreme loading conditions. SMA binder grades in Ontario have typically met specifications for PG 70-22, PG 70-28 and PG 64-34; which also poses concerns for hand work and compaction[3].

Mineral fillers form the mastic or mortar with asphalt binders and stabilizing additive. Some commonly used mineral fillers include limestone dust, baghouse fines, agricultural lime, and marble dust. Mineral filler gradation considered as excess fine material passing the 20µm sieve size tends to stiffen the asphalt cement in the mix and may result in increased mastic thickness on the exposed aggregate top surface which could impact early skid resistance of the pavement. When selecting a mineral filler, the percentage of filler passing the 20µm sieve should be considered in an effort to minimize the effects caused by this fine material. Portland cement and hydrated lime should **NEVER** be used as mineral fillers – excessive stiffening results if used in amounts exceeding 2 percent by weight of mix[3]. Fly ash is also not recommended due to its round, smooth particle shape, since it results in a mix that becomes too difficult to compact due to tenderness[3].

Fibres as stabilizing additives in SMA mixtures prevents draindown or separation of the binder from the aggregate skeleton during mix storage, hauling and placement. Cellulose and mineral fibre compositions in Ontario SMA mixes are typically 0.3 and 0.4 percent respectively by weight of the mix.

The National Asphalt Pavement Association (NAPA) Quality Improvement Series 122 provides a detailed discussion on material selection and design procedures to obtain satisfactory SMA mixtures.

CONSTRUCTION PROCEDURES

The production, placement and compaction of SMA mixtures are different from conventional HMA mixtures. Plant revisions are required, the mix is difficult to work with and compaction must occur quickly. In order to achieve the required minimum amount of density, proper compaction equipment and rolling techniques should be applied, including tighter QC and QA measures.

PLANT PRODUCTION

The following recommendations apply to producing good SMA mixtures[2]:

- Maintain a tight tolerance on the production temperature, taking care not to overheat the mix;
- Stabilize and maintain consistent plant production temperature;
- Preheat plant, conveyors, and other moving parts with hot aggregate prior to adding polymer-modified asphalt;
- Maintain stockpiles properly and monitor gradation of incoming aggregates;
- Calibrate mineral filler, fiber, and anti-strip agent feed systems to plant production rate and maintain interlock system;
- Establish and maintain adequate mixing time taking into consideration that longer mixing times may be required for the use of mineral filler and fiber;
- Use three-drop loading system to minimize potential for segregation; and
- Minimize the time the SMA mixture is allowed to be kept in the storage silo.

1. Kennepohl G.J., and Davidson J.K., Introduction of Stone Mastic Asphalts (SMA) in Ontario, Association of Asphalt Paving Technologists (AAPT) Conference, 1992.
2. National Asphalt Pavement Association (NAPA) Quality Improvement Series 122. (2002), Designing and Constructing SMA Mixtures – State-of-the-Practice. ISBN 1-56051-049-8.
3. Scherocman J.A., and Tighe S.L., Improving Canadian Performance of SMA by Maximizing Best Practices, Canadian Technical Asphalt Association Annual Conference, 2005.

PLACEMENT AND COMPACTION

Placement and compaction procedures involve all operations from transporting the mixture to the construction site, placing it on the roadway, to compacting the mixture. Conventional asphalt paving equipment is used and a light tack coat is normally applied. Compaction is usually carried out by 4 to 6 passes of a steel drum roller. The SMA mix should not be opened to traffic until it has cooled. The following recommendations are critical for placement and compaction of SMA mixtures[2]:

- Assure that a minimum air temperature of 10°C is maintained when placing SMA;
- Start with a clean haul vehicle;
- Use only approved release agents, such as water-based liquid soap or dry soap powder;
- Drain all excess release agents from truck beds;
- Use tarps on truck beds and make sure they fit truck bed securely so as to prevent excessive cooling during haul;
- Provide area for truck clean-out after unloading;
- A material transfer device or other auxiliary equipment may be used to provide consistent mix temperature, avoid segregation, and improve continuity of operation;
- Maintain continuous paving operation;
- Minimize starts and stops of paver;
- Keep roller close to paver;
- Static rolling is recommended
- Vibratory rollers, if used, should only be operated in low amplitude and high frequency mode
- Keep augers going;
- Complete rolling before mixture reaches a temperature of approximately 140°C when using a modified asphalt and 130°C with a neat asphalt;
- Don't stop the roller on the hot mat;
- Pneumatic-tired rollers should not be used;
- Exercise care in folding wings of the hopper to ensure that cold mixture from the edge of the paver hopper is not dumped onto the conveyors;
- Perform placement and compaction to minimize temperature loss in the mixture;
- Consider the use of a vibratory roller for breakdown rolling, but use it with caution;
- Use two or three rollers as necessary to achieve a minimum density of 94 percent Maximum Density;
- Roll mat quickly while mixture is hot;
- Minimize hand work; and
- Use special care in inspection and construction of longitudinal joints to ensure proper alignment and compaction.

Figure 4 Placing and Rolling SMA Mix

QUALITY ASSURANCE

The following QA recommendations apply to obtaining good SMA mixtures[2]:

- Frequently monitor aggregate stockpiles and/or hot bin for gradation;
- Frequently monitor binder, especially modified binder;
- Construct a trial or demonstration section to allow contractor the opportunity to demonstrate ability to produce the JMF, required density, etc;
- Frequently monitor plant produced mixture properties, particularly volumetric properties;
- Frequently monitor in-place density results;
- Correlate nuclear density to cores to improve accuracy of the gauge;
- Consider sand as an aid to seating the nuclear gauge to improve the accuracy of the readings; and
- Monitor product quality continuously during production.

SUMMARY

SMA's trials and success in Ontario spans almost 30 years. During this period, significant advancements with the technology have been recorded with potentials for new improvements. SMA's use and specification require exercising sound engineering judgment to ensure that the important strong stone skeleton and binder mastic features are achieved to obtain a long-lasting pavement that is rut-resistant, durable, flexible, skid-resistant, and with reduced tire noise and splash properties. The very stringent requirements for aggregates and binder are critical factors for good strength, texture and stability. This makes SMA a good candidate for use in surface or base pavements requiring heavy or very heavy traffic applications. Given these and other benefits, municipal owners may consider the use of SMA at major arterial intersections with heavy truck traffic.

Ontario Asphalt Pavement Council (OAPC) remains committed to continuous improvement of quality of asphalt roads and betterment of Ontario's highway transportation network. The practice of exacting quality control in all phases of production and placement is emphasized for a successful SMA project.

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This brochure is designed as a general guide to pavement design. It is not a design manual. Professional engineers should be consulted to ensure that pavements are not only designed functionally but also economically to fit your budget requirements.

A Council of the Ontario Road Builders' Association

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