Engineering Brief # 60

January 2001

Subject: INFORMATION: Engineering Brief No. 60, Semi-flexible wearing course

FROM: Manager, Engineering and Specifications Division, AAS-200

TO: All Regions

Attn: Manager, Airports Division

Engineering Brief No. 60 furnishes information on a recent paving development known as semi-flexible wearing course, which employs Densit, a cement-based slurry.

The information contained in this brief is not to be construed as general approval by the Office of Airport Standards. Use of this product will be on a case-by-case basis and will require prior approval by this office.

Any comments you care to offer will be appreciated.

ORIGINAL SIGNED BY JOHN L. RICE

Attachment

ENGINEERING BRIEF NO. 60

Semi-flexible wearing course

GENERAL

Densiphalt is described by the manufacturer as a semi-flexible surfacing process consisting of an open-graded asphalt concrete filled with a special cement grout. The jointless wearing surface is approximately 1 1/2 to four inches thick, applied to an existing asphalt pavement. We envision the primary use of Densiphalt will be on asphaltic concrete surfaces to provide protection against fuel spillage and resistance to abrasion and rutting.

Densiphalt has been applied to various types of pavements in Europe over the past 15 years. These include a parking area for heavy trucks, an apron at a commercial airport, and a staging area for shipping containers. The material has been tested in the eastern United States on several high-traffic situations, including a shipping container port and several commercial service airport apron areas. Based on information to date, Densiphalt pavement can withstand abrasive action from heavy vehicles, heavy point loads, and pavement deterioration from fuel spills.

MATERIALS AND CONSTRUCTION

The open-graded asphalt concrete mixture is similar to a porous friction course and is placed using standard paving techniques. There is no mix design procedure used to determine the optimum asphalt content. The aggregate gradation band used is based on field experience and combined with an asphalt content of about 4 percent will produce a mixture with 25-30 percent voids. A relatively small amount of a cellulose fiber additive is utilized to stabilize the mixture and to avoid segregation. The air voids content is critical since the grout cannot penetrate the mix if sufficient voids are not present.

When the in-place porous mix has cooled down the grout is introduced into the voids. The grout is composed of Densit (a proprietary material) mixed with water, which is poured onto the open-graded mixture, and squeegeed over the surface. Excess surface grout may be removed to improve skid resistance through a slight exposure of the surface aggregates.

CONCLUSIONS

Use of the Densiphalt material appears to be a viable paving process. However, several areas require additional observation and level of experience prior to its acceptance as a standard paving technique.

These include:

- Performance under various climatic conditions i.e., freeze-thaw cycles
- Material specifications and mix design for grout
- Standardization of laboratory tests for mix design and acceptance testing
- Construction procedures

According to the manufacturer, the level of concern for these factors should be quite low:

1) Behavior regarding freeze/thaw. Test reports show that Densiphalt mortar is absolutely freeze/thaw resistant. This is due to the very dense nature of the material. The voids are extremely small. This means that water penetrates very slowly and once in the voids freezes at very low temperatures. Test reports on the Densiphalt composite shows very good freeze/thaw resistance. Our references in tough climatic conditions in Denmark, Norway and even Greenland shows that Densiphalt is resistant to freeze/thaw. Our experience is that freeze/thaw resistance is one of the most interesting proporties of this pavement solution.

2) Material specification/mix design. The material specification for the mortar is in the Densiphalt datasheet. The mortar is a one component powder that is under strict control tested according to ISO 9000. The mix design for the mortar is addition of water (17%) according to the Densiphalt handbook and labels on each Densiphalt bag.

3) Tests of Densiphalt composite are adequate when conducted in accordance with the Densiphalt handbook.

4) Construction procedures are adequate when conducted in accordance with the Densiphalt handbook.

This process makes use of proprietary material. Based on field performance we believe that the Densiphalt process has some applications for airport apron pavements. In particular, those apron areas that have been damaged due to fuel spillage can be milled and replaced with Densiphalt, inch-for-inch, thereby maintaining grade and pavement strength.

Densiphalt may be specified for use on apron pavements on a case by case basis. When this process is specified in a project, the engineer must furnish evidence to show that equal or better performance can be achieved than with conventional methods, commensurate with any increase in costs. Because this process is relatively unfamiliar in this country, it is recommended that only trained, supplier-qualified installers be used.

Approval for each project is required by the Office of Airport Standards in order to monitor the locations where Densiphalt has been used and to evaluate its performance.

Attached, for your information, is a specification for Densiphalt, which is termed a semi-flexible wearing course, provided to this office by the supplier.

ORIGINAL SIGNED BY DAVID L. CROSS

Engineer, Engineering and Specifications Division, AAS-200

SPECIFICATIONS

SEMI-FLEXIBLE WEARING COURSE FOR APRON PAVEMENT

Scope

The work shall consist of the general requirements for mixing and placing of an open-graded asphalt mineral mixture filled with a High Performance (HP) slurry grout. It includes the requirements for aggregate, bituminous binder and additives, mixing at a hot mix asphalt plant, surface preparation, spreading and compacting of porous asphalt mixture, mixing and pouring of HP slurry grout or similar, where shown on drawings or as directed by the Engineer.

The asphalt mineral mixture shall consist entirely of crushed aggregate coated with a mixture of asphalt cement, filler and stabilizing fiber. The voids in the finished mixture must comprise between 25 and 30 % of the total volume. The unit weight for the porous asphalt mixture is approximately 115 lb/ft^3.

The semi-flexible wearing course shall be laid in a thickness of 1½-4 inches constructed in one of two layers of porous asphalt and filled with HP slurry grout after cooling down. The type used shall be:

Porous Asphalt Type ½”

The wearing course shall be laid on a prepared surface of high strength bituminous base.

1. Asphalt mixture

Bituminous material	3.6-4.6%
Filler	4%
Cellulose fiber	0.2%
#7 aggregate (ASTM D448)	91.2 - 92.2%

The Contractor shall establish the Job Mix Formula. Mix design shall confirm with the following requirements:

Grading.	Percent passing:
¾"	100%
½ "	95-100%
5/16"	< 20%
#4	< 12%
#10	< 10%
#200	3-5%

Mix design procedures shall conform to the Marshall method of mix design and relevant procedures contained in the Asphalt Institute Manual MS-2. All of the criteria shown below shall be considered in establishing the optimum bitumen content using 50 Blows Mechanical to each end of Specimen at 275-284 ° F (135-140^{o}C). All trial mixes shall be prepared and tested by the Contractor in the presence of the Engineer.

Bitumen Drain-down	< 0.3%
Air Voids (ASTM D 3203)	25-30%

2. Materials

2.1 Aggregate

The Aggregate shall consist of clean, hard, durable and sound crushed granite, diorite, porphyry, limestone or similar. The aggregates shall satisfy the following requirements:

- L.A. Abrasion, tested in accordance with AASTHO T 96, shall not exceed 25%
- Angularity, ASTM D5821 100/100
- Apparent Specific Gravity, AASHTO T85 above 2.6
- Sodium Sulphate Soundness, AASHTO 104, shall not exceed 10 %
- Friable particles, clay lumps and other deleterious matter, AASHTO T112, less than 0.5%
- Flat and Elongated Particles, tested in accordance with ASTM D4791, (3 to 1) 20% max.
- Washable Particles, tested in accordance with ASTM C117 shall not exceed 2.5%

Aggregates shall be of uniform quality with a cubical particle shape.

Aggregate grading shall be appropriate to achieve correct grading of the final asphalt mix during production.

Mineral filler shall consist of finely divided mineral matter such as Hydrated Lime or similar non-plastic mineral filler, conforming to AASTHO M17.
Tested in accordance with ASTM D546 or for Hydrated Lime AASTHO T219, the mineral filler shall conform to the gradation shown in table 1.

Table 1. Grading Requirements for Mineral Filler

Sieve Designation Square openings	Percent Passing by Dry Weight
600 µm	100
150 µm	85
75 µm	75

Hydrated Lime shall conform to the requirements in AASTHO M303 Type I.

When Portland Cement is used as mineral filler, it shall conform to the requirements in AASTHO M85 Type I, II or III.

2.2 Bituminous Material and Tack Coat

The type of Asphalt Cement shall comply with Superpave Performance Based Binder Specification PG 64-22.

Emulsified bitumen shall be CSS 1h or CRS-2 cationic emulsified bitumen in accordance with AASTHO M208 or SS 1h anionic emulsified bitumen in accordance with AASTHO M140 unless otherwise directed by the Engineer.

2.3 Cellulose Fibers

For the porous asphalt 0.1-0.3 % of approved granulated cellulose shall be added to avoid drain off.

2.4 Micro silica cement mortar for the HP slurry grout

The HP slurry grout shall be one-component Densiphalt dry mortar or similar. The HP slurry grout shall be a durable, freeze/thaw resistant micro-silica-enriched cement mortar with fluid properties that allows to fully penetrate the asphalt without vibration.

The sand fraction of the HP slurry grout shall be quartz sand resistant to alkali reactions.

The density tested in accordance with AASTHO T121 shall be 138.8 lb/ft^3 (2220 kg/m^3)

After curing the HP slurry grout compressive strength after 28 days at 68^{o} F (20^{o}C) tested in according to AASTHO T106 shall be not less than 14,000 psi. (100 MPa).

3. Equipment

3.1 Mixing Plant

Bituminous mix shall be produced in a Hot Mix Asphalt mixing plant of adequate size with a minimum capacity of not less than 100 ton/hour.

The plant should be equipped with separate bin for mineral filler material and bin for fibers.

3.2 Storage

The material cannot tolerate extended storage periods in silos or trucks due to the large percentage of voids. The Porous asphalt should preferably be used within two hours and under no instances the time for storage and transport should exceed more than three hours.

3.3 Hauling Equipment

Mixed materials shall be transported to the site in tight vehicles, constructed so as to prevent loss or undue segregation of materials after loading.

Hauling equipment for mixed materials shall have a tight, clean, smooth metal beds, having dump bodies or feeder band, suitable for dumping materials in the hopper. Hauling equipment shall be equipped with an approved type of cover.

3.4 Pavers

The porous asphalt mixture shall be spread and finished using the type approved by the Engineer, self-contained, power-propelled pavers.

Pavers shall be provided with electronically controlled vibratory screed or strike-off assembly with devices for heating the screed, and shall be capable of spreading and finishing the porous asphalt mix to the proper thickness.

The pavers shall employ mechanical devices such as equalising runners, straightedge runners, evener arms or other compensating devices, to maintain trueness of grade and confine the edge of the mix to true lines without the use of stationary side forms. Joint levelling devices shall be provided for smoothing and adjusting longitudinal joints between lanes.

The paver shall be equipped with a receiving hopper having sufficient capacity for a uniform spreading operation. The hopper shall be equipped with a distribution system to place the mix uniformly in front of the full length of the screed.

The screed or strike-off assembly and extensions shall effectively produce a finished surface of the required evenness and texture without tearing, shoving, or gouging the mix.

The paver shall be capable of being operated at forward speeds consistent with satisfactory laying of the mix. Speed shall be fully adjustable between 1.6 yd/min and 6.6 yd/min.

The automatic controls shall consist of an automatic linkage arrangement such that, through the process of automatically adjusting the screed thickness control, the mix can be placed and finished to a predetermined grade and a uniform crown or cross section.

The paver shall be equipped with infrared joint heater

3.5 Rollers

Only steel-wheel rollers (max. 10 ton, max. line pressure 225 lb/in (40 kg/cm)) without vibration shall be used.

Use of pneumatic rollers and vibratory rollers is prohibited.

3.6 Mixing and pouring of HP slurry grout

The Densiphalt HP slurry grout or similar shall be mixed in a modified continuous mixer and pumped on site according to instructions from the Manufacturer.

4. Trial Section

Immediately prior to finalisation of the Job Mix Formula, the Contractor shall lay a trial section of the porous asphalt mix intended for use in the project. The section shall be laid using the same materials, proposed Job Mix, mixing, spreading and compaction plant and spreading procedures, proposed for use in the project.

The trial section shall serve as a field verification of the Job Mix design. The mix density achievable and the air voids at that density shall be determined and, if less than required, the Job Mix Formula shall be adjusted accordingly.

Each trial section shall also demonstrate the adequacy of hauling, spreading and compaction equipment and the suitability of the construction methods and organisation proposed.

If the trial section meets the required specification, the Job Mix Formula will be approved.

5. Surface Preparation

The Contractor shall check the elevations of the asphalt base course pavement in sections of 30yd² (25m^2) maximum before paving of Porous Asphalt.

If necessary levelling up to ¾" (20mm) shall be made with suitable bituminous asphalt mix before the first layer of porous asphalt.

The surface shall be cleaned of all foreign material and broomed free of dust.

The tack coat shall be applied at a rate of 0.03-0.08 gal/yd^2 (0.15-0.35L/m²) residual binder, or as directed by the Engineer. If the surface to be paved is very porous and absorbing the rate of tack coat may be increased up to max. 0.1 gal/yd^2 (0.45 L/m²) residual binder. The Tack Coat shall be evenly applied to the surface and shall not give rise to bleeding on the surface of the completed pavement.

6. Mixing, Spreading and Finishing

Mixing, spreading and finishing shall be a continuos operation. Not more than 2 hours shall elapse between the porous asphalt is mixed and the time of completion of rolling.

During the tack coating and the paving work only traffic necessary for the execution of the paving work shall be allowed on the asphalt base course pavement.

6.1 Mixing

No mixed material shall be held in a storage bin for more than 30 minutes.

6.2 Hauling

Hauling equipment for the hot bituminous mix shall periodically be coated with a thin lime solution or similar approved material to prevent adherence of the mix.

All hauling units shall cover the material upon loading at the mixing plant and the cover shall not be removed until the mix is discharged into the paver.

6.3 Spreading and Finishing

The porous asphalt shall be laid only when the air temperature is at least 50^{o}F (10^{o}C), when the surface is free from moisture and when the weather is not foggy, rainy, dusty or windy (particularly at low temperatures).

The mix shall be delivered to the paver in time to permit completion of spreading, finishing and compaction of the mix during daylight hours.

Longitudinal joints shall be made by infrared heating of the previous laid porous asphalt and by overlapping the paver screed on the previous laid material so that the joint will be smooth and uniform.

6.4 Installation of HP slurry grout

Due to the risk of pollution, the time from completion of the porous asphalt course to completion of installation of HP slurry grout may not exceed 48 hours.

No traffic on the laid Porous Asphalt should be allowed before application of the grout.

The porous asphalt shall be free of any loose particles or other contaminants.

Before pouring of HP slurry grout the Contractor shall check the elevations of the finished Densiphalt pavement in sections of maximum 30 yd^2 (25m^2) and check the surface for depressions resulting in ponding water.

The HP slurry grout shall be poured only when the air temperature is greater than 40^o F (5^o C).

In hot weather, strong wind or when the voids in the porous asphalt are filled with water, pouring of HP slurry grout should be avoided.

Mixing and pouring shall be a continuos operation. Not more than 1 hour shall elapse between water is added to the mix and the time of completion. During the hauling, the mix shall be protected against segregation by rotating.

The HP slurry grout shall be controlled before pouring by use of a “Standard Densiphalt traverse funnel”. The outflow time target is 14 seconds and shall be not less than 10 seconds and may not exceed 18 seconds.

Surface finishing shall start when the cement mortar no longer has air bubbles and before a skin forms on the surface of the HP slurry grout. When the porous asphalt is completely filled with grout, the surface shall be scraped hard with rubber scrapers to achieve a uniform surface and so that the grout is no higher than the top of the porous asphalt surface.

7. Sampling and Testing

Sampling and testing shall confirm with the relevant requirements of this section.

Procedures for sampling mineral aggregate and commercial filler shall comply with ASTM D75 for coarse and fine aggregate, and comply with ASTM C183 for mineral filler.

Procedures for sampling bituminous materials shall comply with AASHTO T40.

Procedures for sampling of HP slurry grout shall comply with AASHTO T141 or as directed by the Engineer.

Procedures for sampling of the porous asphalt shall comply with AASHTO T168.

The minimum frequency of sampling and testing of constituent materials and mixtures shall be as shown below unless otherwise directed by the Engineer.

In addition, the temperature of each load of porous asphalt shall be measured and reported.

7.1 Raw Materials

Sampling and testing of raw materials shall conform to Table 2 below:

Table 2

Testing Item	Testing Method	Frequency for tests
Aggregates		
Grading	AASTHO T27	Each 500 ton or daily or Table 3
Filler	AASTHO T11	Each 500 ton or daily or Table 3
Los Angeles Abrasion	AASTHO T96	Initial testing
Flat and Elongated Particles	ASTM D4791	initial testing
Sulphate Soundness	AASTHO T104	Initial testing
Washable Particles	ASTM C117	Initial testing
Deleterious Materials	AASTHO T112	Initial testing
Filler		
Grading	ASTM D546	Initial testing
Hydrated Lime	AASTHO T219	Initial testing
Bitumen	By Certificate	Each delivery
Fibers	Approval by the Engineer	Initial testing
HP slurry grout		
Compressive Strength	AASTHO T106	Each Batch Delivery of Powder
Density	AASTHO T121	Each Batch Delivery of Powder

7.2 Porous Asphalt Pavement

Each control section represents the daily production or a maximum of 3.000 yd^2 (2500 m^2). If the daily production is more than 3.000 yd^2 additional tests shall be taken in accordance with Table 3:

Table 3

Testing Item	Testing Method	Frequency for tests
Bituminous Mix		
Marshall volumetric data: V_a,	AASHTO T245	Each day
Extraction	AASHTO T164	Each day and per 500 t
Grading	AASHTO T30	Each day and per 500 t
Max. Specific Gravity	AASHTO T209	Each day and per 500 t
Cores		
Air Voids	Visual inspection	See note
Density	AASHTO T 230	See note

Note for Table 3: General: minimum 3 cores each day at site specified by Engineer.

7.3 Micro-Silica HP slurry grout

All shipments of Micro Silica Cement Dry Mortar shall be accompanied by the Manufacturer's "Certificate of Guarantee" or "Test Certificate" from an independent laboratory approved by the Engineer.

The Contractor shall check outflow time by use of a "standard Densiphalt traverse funnel" and the Tensile strength on the micro silica powder for each 30 tons.

7.4 Completed Densiphalt Pavement

The Contractor shall check used quantity of HP slurry grout for each control section. The quantity being used at any section shall not exceed diverge by more than three percent from the "theoretical" quantity.

Compressive strength (120 hours at 68^o F (20^{o}C)) of cores shall be not less than 700 psi (5 MPa).

8. Surface Requirements and Tolerances

The fully compacted and completed Densiphalt pavement shall conform to lines, grades and cross sections as shown on the drawings.

9. Measurement & payment

Densiphalt shall be measured by [area: square meter or square yard] of mix furnished, spread and compacted on a surface prepared and sprayed with tack coat, filled with HP slurry grout, completed and accepted. The consumption of dry Densiphalt powder shall be approximately 28 lb/in/yd^2 (5-6 kg/cm/m^2).

Measurements shall be of the net areas and thickness as shown on the drawings.

Payment shall be made at the contract unit price per square [meter; yard] for the wearing course.

The price shall be full compensation for furnishing all materials; for all preparation including tack coat, hauling, and placing of these materials; and for all labor, equipment, tools, tests and incidentals necessary to complete the item.