CIV-E1010 Building Materials Technology - Hot Mix Asphalt

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Asphalt Mix Types (based on mixing temperature)

HMA- Hot Mix Asphalt
WMA- Warm Mix Asphalt
WMA Advantages compared to HMA

- The lower WMA production temperatures reduce emissions of volatile organic compounds (VOC) at mix plants, and fuel for heating.
- Reduces fume exposure for workers at the job site and burn hazard.
- WMA is more easily compacted, which is beneficial during extreme weather conditions, for stiff mixes and mixes with reclaimed asphalt pavement (RAP), and for reducing the amount of roller passes.
- The lower temperatures and longer workability allow longer transport, enabling construction at more remote locations as well as more flexibility in transportation schedules.
- May be opened to traffic sooner than HMA, which reduces user-delay costs.
- The lower temperatures mean that the asphalt binder is age hardened less during the mixing process, providing longer pavement service life. (NOT SURE)
- Some WMA additives can be pre-blended with the liquid asphalt at the refinery.
- The additives improve workability and constructability and may improve moisture resistance of the mix.
WMA Disadvantages

- WMA may be more expensive than traditional asphalt mixes.
- Lower temperatures used for WMA can result in incomplete drying of the aggregates. The resulting trapped water in the coated aggregates may cause moisture damage. Care must be taken to monitor this.
- Performing handwork and luting with some WMA technologies can be difficult at the lower temperatures.
- WMA mixtures are still being reviewed for long term performance. To date no known pavement failures or concerns have been observed.

Disputed – the CO₂ emissions behind the additives
WMA usage is rapidly increasing in the US and Europe, but in Finland there are only some trials so far.
30% of all asphalt works in Finland are connected with recycling

Fresh overlay may have up to 15% recycled asphalt pavement

Massapintaus – overlay
Uusiopäällyste – recycled wearing course layer
(2 kertaan) – twice

Figure. The percentage of all surfaces by the type of construction as calculated on 1.1.2009 for different traffic classes 1500-3000 cars/day, 3000-6000 cars/day and over 6000 cars/day, in Häme and Uusimaa regions.
Asphalt Mix Types
(based on gradation and compactability)

- Dense-graded mix (DGM)
  - Large stone
  - Sand mixtures
- Gap-graded mix
  - Stone Mastic Asphalt (SMA)
- Open-graded or porous mix
  - Open Graded Friction Course (OGFC) in US
  - Porous Asphalt in Europe
- Mastic asphalt (gussasphalt)
- Open-graded permeable base
  - Asphalt Threaded Permeable Base (ATPB) or cement treated (CTPB) in the US

FIGURE 5.10 Types of aggregate grain-size distributions plotted on a 0.45 gradation chart.
FIGURE 16. STONE MASTIC ASPHALT SMA 11

AGGREGATE
Proportion of crushed material in the aggregate: at least 85 %

BINDER
Dilutum
D35/50...D100/150, PMB65, PMB75
Binder content: 6.5 - 7.5 mass-%

ADDITIVE
Cellulose fibre
Natural asphalt (if necessary): 0.3 - 0.5 mass-%

FIGURE 17. STONE MASTIC ASPHALT SMA 16

AGGREGATE
Proportion of crushed material in the aggregate: at least 85 %

BINDER
Bitumen
B35/50...B100/150, PMB65, PMB75
Binder content: 6.0 - 7.0 mass-%

ADDITIVE
Cellulose fibre
Natural asphalt (if necessary): 0.3 - 0.5 mass-%

Voids content of a single sample
in different mix design categories, which are set out in Table 15
A, B ≤ 5.0 vol-%
C ≤ 6 vol-%

The mass per unit area of a layer with a constant thickness is generally selected between
The recommended mass per unit area is
60 - 100 kg/m²
80 kg/m²

Voids content of a single sample
A, B ≤ 5.0 vol-%
C ≤ 6 vol-%

The mass per unit area of a layer with a constant thickness is generally selected between
The recommended mass per unit area is
80 - 125 kg/m²
100 kg/m²
FIGURE 4. ASPHALT CONCRETE AC 16

AGGREGATE

Of the over 5.6 mm aggregate, totally or partially crushed or broken particles should account for the following percentages in the following mix design categories:

A, B at least 70 %
C, D at least 50 %

BINDER

Bitumen
E35/50, H160/220, PMB65, PMB75

Binder content
5.0 - 6.0 mass-%

Voids content of a single sample in different mix design categories, which are set out in Table 15
A, B ≤ 5.0 vol-%
C ≤ 5.0 vol-%
D ≤ 6.0 vol-%

The mass per unit area of a layer with a constant thickness is generally selected between
10 - 125 kg/m²

The recommended mass per unit area is
100 kg/m²

FIGURE 5. ASPHALT CONCRETE AC 22

AGGREGATE

Of the over 5.6 mm aggregate, totally or partially crushed or broken particles should account for the following percentages in the following mix design categories:

A, B at least 75 %
C, D at least 60 %

BINDER

Bitumen
H35/50, H100/220, PMB65, PMB75

Binder content
4.8 - 5.8 mass-%

Voids content of a single sample in different mix design categories, which are set out in Table 15
A, B ≤ 5.0 vol-%
C ≤ 5.0 vol-%
D ≤ 6.0 vol-%

The mass per unit area of a layer with a constant thickness is generally selected between
110 - 150 kg/m²

The recommended mass per unit area is
125 kg/m²
Mechanical performance of mixtures (structural load carrying function)
Structural load carrying function

**Mastic concept (frozen liquid principle)**
- High binder content and virtually no air voids, aggregates "swim" in bituminous mortar matrix, load is mainly carried by the binder

**Packing concept (concrete principle)**
- Densest packing of aggregates with minimal binder film thickness, load carried by aggregates and binder

**Skeleton concept (macadam principle)**
- Corn-to-corn contact an interlock of stones; load primarily carried by aggregate skeleton, lateral support and confinement within layer necessary.
Example of Concrete Principle: Dense-Graded Mixtures (tiiviiksi sulloutuva rakeisuus) (AC)

- **Purpose:** Suitable for all pavement layers and for all traffic conditions
- Works well for structural, friction, leveling and patching needs

- **Materials:** Well-graded aggregate, asphalt binder with or without modifiers, RAP = Reclaimed Asphalt Pavement
- Water permeability depends on air voids content (<3% impermeable, <6-7% usually no interconnected pores)

[Additional information can be found here](http://www.hawaiiasphalt.com/HAPI/modules/04_pavement_types/04_mix_types.htm)
Example of skeleton concept: Stone Mastic (Matrix) Asphalt (SMA) (semi-water permeable)

- **Purpose**: Improved rut resistance and durability

- SMA is almost exclusively used for surface courses on high volume interstates and U.S. roads

- **Materials**: Gap-graded aggregate, modified asphalt binder, fibers, fillers

- Developed in Germany (Stone Mastics Asphalt) at 70’s, came to the U.S. at the beginning of 90’s, was introduced in Finland in mid 80’s
Example of Skeleton concept: Open Graded Mixtures: (designed to be water permeable)

- **Purpose:** used in surface courses only
  - Reduce tire splash/spray in wet weather.
  - High air voids reduces tire-road noise

- **Purpose:** permeable bases are used in structural layers
  - ATPB - Used as a drainage layer below dense-graded HMA, SMA or PCC

- **Materials:** Aggregate (crushed stone or gravel and manufactured sands), asphalt binder (with modifiers)
Dense graded vs. open graded or porous mixture - Safety

Dense graded: after rain wet surface

Open graded: after rain dry surface (no splash and spray) – more safer
Oil Gravel – a unique Cold-mix Asphalt (CMA) used in Sweden and Finland – NOT USED ANYMORE due to environmental protection

Trials started in Finland 1958 and in the 60’s technology developed enough to start paving low volume roads in large quantities (roads with less than 1000 vehicles per day)
What is Oil Gravel? 1/2
Oil gravel is a mix of road oil and gravel

Road oil is a cutback asphalt (bitumen)

Cutback asphalt is a liquid asphalt cement blended with petroleum solvents:
• When the solvents evaporate the remaining material is the high viscosity asphalt cement
• The process of evaporation of the solvent is known as curing
• The rate of curing depends on the type of solvent
What is Oil Gravel? 2/2
Oil gravel is a mix of road oil and gravel

- Binder is heated to 80°C
- Aggregate can be cold and wet

- For good adhesion antistripping agents must be used
Advantages of using cutback asphalt

Due to the solvents the asphalt mixture stayed soft. Mixture could be scarified and re-compacted after placement.

Repairs of frost heave damages and other surface defects developing over time were easy.
Oil gravel could be mixed during wintertime and stored to a stockpile for road repairs… and patching was cheap and easy.

but

- Environmental concerns caused to abandon the oil gravel in the 90’s
- Development of Soft Asphalt pavements begun

In Soft Asphalts road oil is replaced by soft bitumen with Pen > 330 1/10 mm at 25° C.
The Nordic invention of Soft Asphalt Concrete (PEHMEÄ ASFALTTIBETONI) (PAB)…. There is a reason why in English we do not call it “SAC”

It is a dense mix with a bitumen of pen grade over 330 1/10 mm @25° C
Allowed bitumen grades: 250/330…650/900

Used on the low traffic roads, replaced the oil gravel

PAB11…PAB22 (size of aggregate)

PAB-B is a mass in which the bitumen and/or its emulsion was graded by penetration
PAB-V is a mass in which the bitumen and/or its emulsion was graded by viscosity

Second most popular mass type in Finland and Sweden
Surface Treatments: Fog seal or surface dressing (Pintaus tai pintasively)

- A fog seal is a light application of a diluted slow-setting asphalt emulsion to the surface of an aged (oxidized) pavement surface.
- Fog seals are low-cost and are used to restore flexibility to an existing HMA pavement surface.
- They may be able to temporarily postpone the need for a chip seal or non-structural overlay.

http://www.hawaiiasphalt.com/HAPI/modules/04_pavement_types/04_mix_types.htm
Surface Treatments: Slurry Seal
(Lietepintaus tai emulsiopintaus)

- A slurry seal is a mixture of emulsified asphalt, water, well-graded fine aggregate and mineral filler.
- Slurry seals are used to fill existing pavement surface defects as either a preparatory treatment for other maintenance treatments or as a wearing course.

http://www.hawaiiasphalt.com/HAPI/modules/04_pavement_types/04_mix_types.htm
Surface Treatments: Chip Seal

- High viscosity emulsified surface coat incorporating rolled-in-rock screenings (chips)

Sirotepintaus (SIP)
Soratien pintaus (SOP)
Recycling of Asphalt Concrete
Pavement structure

Wearing course /overlay
Base course
Subbase (granular)
Subgrade (granular)

Bituminous
(bituminous or composite)
Non-bituminous
The cost of recycled pavement can be 50% of the new overlay, but its performance can be the same
Recycling of asphalt concrete

- **Why?**
  - Recycling started in the 1920s but gained popularity in 1970s → crude oil price change. (1991 depression, 2007 real estate crisis and crude oil price increase)
  - Lower CO2 emission than the new asphalt (how it is calculated?)
  - Preservation of natural resources – also aggregate
  - Improved resistance to permanent deformation

- **How?**
  - Asphalt Pavement meeting a criteria of exchange, fresh ("virgin") aggregate, fresh bitumen and rejuvenator.
  - Rejuvenator can be oils, fluxes, emulsions, foams, very soft bitumens (Pen 650/900 or V1500)
Cold Planning

- Removal of asphalt by milling machine † the RAP is created
- Disadvantage
  - the noise and the dust (contained with water)
- Advantages:
  - Removal of wheel ruts, deteriorated surfaces, potholes, correction of profile, removal of seal coats, improvement of friction, bridge overlay exchange, low energy consumption in field
Hot Recycling

The process in which RAP is mixed with hot virgin aggregate and binder, typically in plant

- Up to 15% is normal and doesn’t require saying RAP was used
- Up to 30% ‡ mix name RC30, e.g. AB16RC30
- Up to 50% needs a special design and choice of bitumen/aggregates to mitigate the deterioration of subcomponents
- Up to 100% requires special plant and special RAP processing

Advantage: reduced landfill, lower CO2 emission during the life of the asphalt if part of lifecycle, reduced price

More on 100%RAP Go to: www.zaumanis.com
Recycling, how much fresh and old?

If the Penetration of the bitumen recovered from aged asphalt concrete is 25 dmm, how much new bitumen 70/100 (Pen 85 dmm) needs to be added so that the final blend meets the requirements of the 50/70 binder?

What if you additionally used 5% rejuvenator of Penetration 800 dmm?

Source: Finnish Asphalt Specifications 2000
Hot In-Place recycling (HIR)

A layer of 2-5 cm is heated up and scarified while asphalt is soft, then mixed with the fresh admixture (virgin aggregate and binder, but prepared off-site) and recycling agents

- Allows for reuse of 100% of the material (no landfill)
- Lower truck hauling than with CP + HR (less CO2 emission)
- Reduced traffic disruptions
- End of day opening of road is not associated with road profile change
- Quickly allows to fix the pavement irregularities
- Allows for small increases of the layer thickness and bearing capacity
- 50% price of mill-and-fill-with-virgin-mix (CP+HR)
Statistics on 3rd HIR reveal 50% shorter lifespan as compared to overlay
Source http://cpmamerica.com/preventive-maintenance-can-save-you-money/
Hot In-place recycling

30 minutes later

Aalto University
School of Engineering
Hot In-Place recycling equipment
Cold In-Place Recycling

Typically executed on low volume roads (soft binder), the material is scarrified and mixed with bitumen emulsions at low temperatures

- Allows for reuse of 100% of the material (no landfill)
- Lower truck hauling than with CP + HR (less CO2 emission)
- Reduced traffic disruptions
- End of day opening of road is not associated with road profile change
- Quickly allows to fix the pavement irregularities
Full Depth Reclamation

Mixing of asphalt layer with subbase layer in order to create bitumen stabilized subbase course, which can then be overlayed with asphalt concrete

- For really deteriorated roads which need improved bearing capacity, before overlay
- Least environmentally friendly (bitumen reused in the place where it is not needed)
Review questions

What is the difference between SMA16 and SMA11, AC6 and AC16? Expand the abbreviations.
What is the difference between WMA and HMA?
Name at least 4 types of asphalt types and explain the differences between them in terms of application.
A civil engineer should know

- What type of asphalt to choose for order for a specific application (parking, driveway, bridge deck, roof, low volume road, high volume road)
- How to read quality control files and certificate files
- How to maintain and protect the asphalt pavement
- What to do when the pavement fails, which maintenance treatment to order
Reading/viewing material

Basic Asphalt Recycling Manual, ARRA
www.pavementinteractive.org
www.zaumanis.com