30 Years Experience with Hot Recycling of Asphalt Mixtures in the Netherlands

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August 10, 2009

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Some Statistics about the Netherlands

Size of the country: 41,500 km²
16 * 10⁶ inhabitants

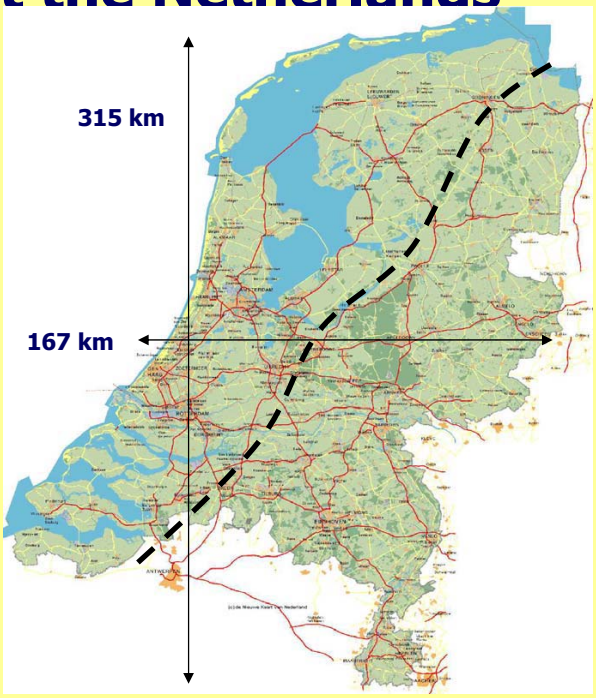
2500 km main highway system

100.000 vehicles/day
15 % trucks
3.5 axles of 100 kN/truck
9 % overloaded

time slot for maintenance 21u – 5u

9 * 10⁶ tons asphalt mix per year

2 % < CBR < 5 % in western part of the country



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Asphalt mixtures in the Netherlands

Asphalt layer	Asphalt mix
Base layer	GAC (history)
	STAC
Binder layer	OAC
Surface layer	DAC
	SMA
	PA

Layer	% of total production
Base layer	56 %
Binder	7 %
Surfacing	37 %

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Re-use of asphalt mixtures in Europe

Country	Available reclaimed asphalt mix	% re-used in hot mix	% re-used in cold mix	% of new hot mix production
Germany	$14 * 10^6$	82	18	60
Spain	$2.25 * 10^6$	8	4	3.5
Italy	$14 * 10^6$	18	2	
France	$6.5 * 10^6$	13	< 2	< 10
Norway	$0.59 * 10^6$	7	26	8
Netherlands	$3 * 10^6$	75		63

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Asphalt plants in Europe

Country	Stationary plants	Mobile plants	% fit for re-use
Germany	680	0	91
Spain	385	95	3
Italy	650	10	38
France	427	79	30
Norway	90	14	19
Netherlands	47	0	96

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Availability of RAP in South Africa

- Thick layers seldom used in RSA (only heavily trafficked ones).

50 mm asphalt
150 mm very high quality unbound base

250 mm cement treated subbase

- Type of RAP:
  - 1960's to 70's = Gap graded RAP
  - 1970's to 90's = Semi-gap graded RAP
  - 1990's + = Continuously graded & PMBs

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Some general values

- In South Africa, less than 5% of total RAP used in HMA.
- Only 4 million tons of new HMA every year.

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Mix Design in South Africa

- Recovered Pen, Tr&b and η if >15% RAP in new HMA.
- Remember BC in RAP is higher in fines than coarse fraction.
- Limits of RAP based on mix type:
  - <2% in SMA <12% in PMA
  - <18% in unmodified <23% in binder layer
  - <27% in base

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Barriers to recycling of RAP in South Africa

- Lack of understanding (perceived to be low quality materials).
- Lack of specs/legislation.
- Variability of HMA's in situ.
- 80% of surfacing in SA = seals.
- Economic benefits not realized (need legislation to enforce recycling then contractors will use it for competitive edge).

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History of hot recycling in the Netherlands

- Mid 1970 a serious impuls was given to the recycling of old asphalt mixtures.
  - Oil crisis
  - Environmental issues (scarce materials, no space for waste disposal)
  - Base courses were made with round river gravel from local sources until mid 1970s. Large problems with rutting of the base layers in 1970s (hot summers, heavy traffic). Solution was needed.

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Government policy

- Recycling is a must.
- Costs per ton for dumping RAP are very high, close to costs of producing new mixture.
- Active policy in development of techniques, specifications, test methods etc.

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From milling: cold feed

- Cold RAP (mostly in mixing unit): most asphalt plants had the possibility to add into the pugmill (batch plant) or half way drum (drum mix plant).
- Typical amounts:
  - Maximum 20 % without any special research for base course mixes.
  - Maximum 10% without special research for surface mixtures.

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Test program

- Hot re-use really started in mid 1980's.
- Contractors had to prove that they were able to produce good quality mixtures using RAP.
- Test program consisted of:
  - building test section and taking slabs and cores,
  - 4 point beam bending fatigue tests,
  - mixture stiffness tests (4p bending),
  - static creep tests,
  - wheel tracking test,
  - mixture composition and bitumen properties.

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Fatigue equipment

- 4 point bending rig was designed by Lab of Ministry of Transport.
- Clamping system was not very well defined. Room for "play".
- Initially only average value for stiffness was specified later on also standard deviation was specified.

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Fatigue and stiffness test program

Fatigue

- 2 temperatures (0 and 20 ^{o}C).
- 1 frequency (30 Hz).
- 3 strain levels.
- 6 tests per strain level.

Stiffness

- 2 temperatures (0 and 20 ^{o}C).
- frequency sweep.

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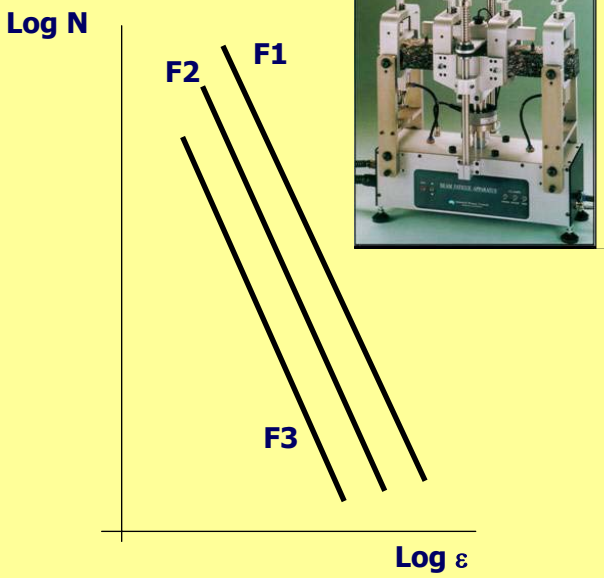
Required fatigue resistance



Shell pavement design manual (late 1970's) defines two fatigue classes being F1 and F2

Requirements for asphalt mixtures containing RAP:
1. Equal or better fatigue resistance than reference mix,
2. Equal or better than F2.

Req. 1 could easily be achieved, req. 2 never.

This resulted into the development of F3 class.

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Important role of the Dutch government to promote RAP re-use

- Two large projects, roads agency together with a group of contractors:
  - 1976: Renofalt (100 % re-use)
  - 1988: MARS (re-use up to 100% with micro-wave system)
- Purpose: recycling in the highest possible application and increase of recycling to the highest possible level (hardly new roads, predomimantly maintenance in the future).

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Tar: important role government

- Tar is not allowed in RAP
- Since 1991 tar containing products are not allowed to be used any more in the Netherlands (one exception)
- In 2008 practically all RAP could be considered free of tar in the Netherlands

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Developments in the 1980s and 1990s

- Recycling market becomes a commercial market.
- Asphalt producers invested in parallel drums and special handling of RAP.
- Government pushed the market approach with legislation on waste deposits.
- Since 1990 RAP officially in the Dutch standard.
- Since 1990: RAP is a "normal" building material.

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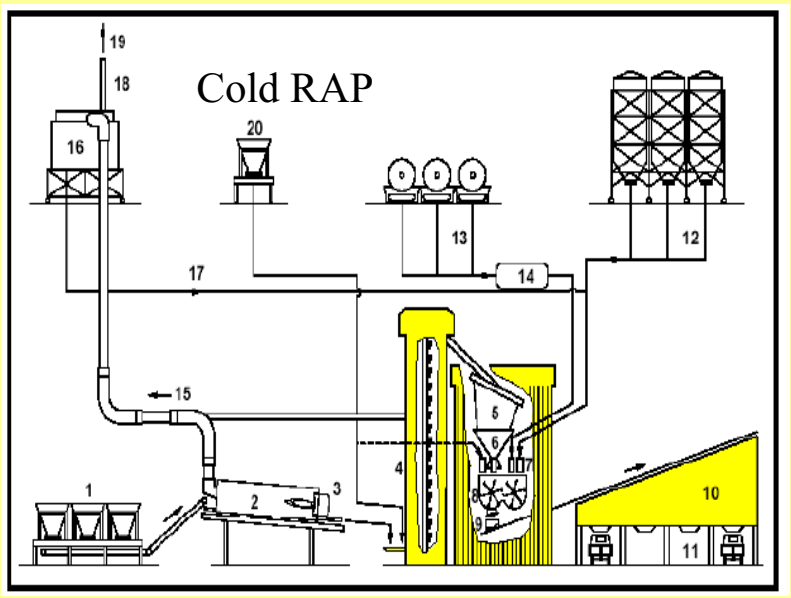
Cold feed of RAP



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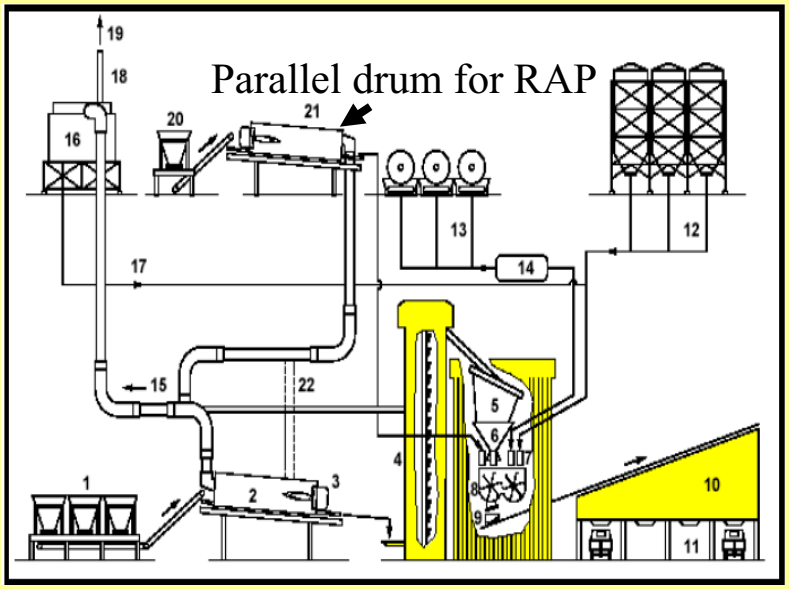
Parallel drum (RAP heated to 130 C)



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Hot mix Asphalt plants (partial recycling PR) in the Netherlands (2006)

Type of plant	Number
Batch plant with seperate PR drum	38
Batch plant with cold RAP input	1
Drum mixer suitable for PR	5
Installation without PR	-
Total	44

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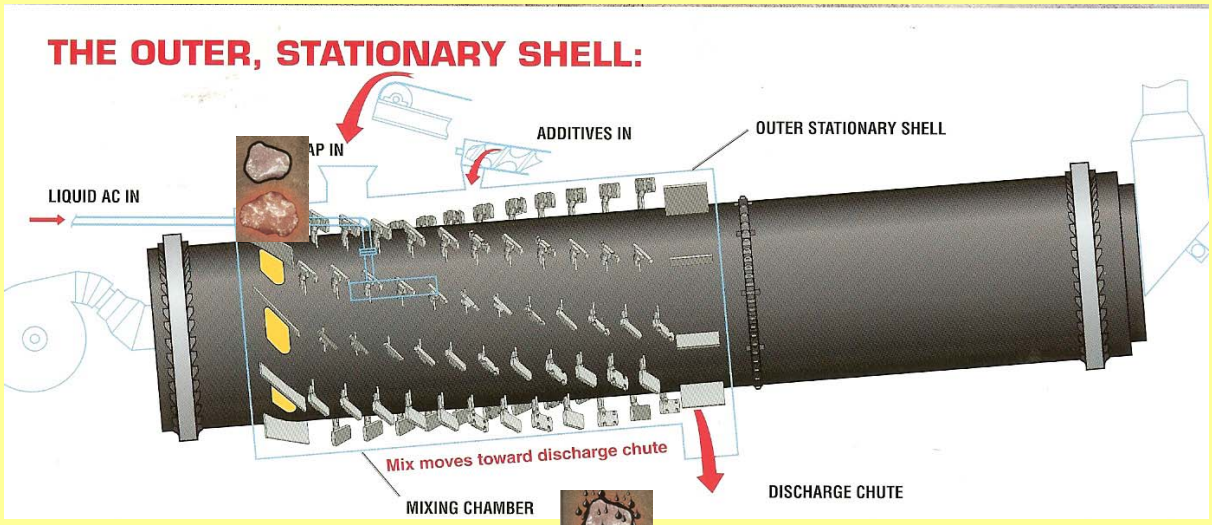
New technology (Astec double drum)



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Separate storage

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State of the art for all mixes in the Netherlands

- **Recycling in STAC (base layer) maximum 50 %.**
- **Recycling in OAC (binder layer) maximum 50%.**
- **Recycling in DAC (wearing course) maximum 50%.**
- **Recycling in PA maximum 20 %.**
- **No recycling in SMA.**

- **Requirements for the combined Penetration (old –new bitumen) in the mix design for all mixes.**

$$a.\log pen_1 + b.\log pen_2 = (a+b).\log pen_{mix} \qquad a+b=1$$

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State of the art in the Netherlands (2008)

- At the moment 3.5 * 10^6 ton/year of RAP.
- 80 % of the RAP is used in hot mix.
- 65 % of new HMA production contains RAP.
- Consumption of bitumen in 2006 : 0.37*10^6 ton (on 9*10^6 ton asphalt mix)

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Latest developments/problems

- How to keep the temperature of virgin aggregate at reasonable level at higher RAP contents.
- PSV stone (> 57): for surface layers requirements are increased. Is aggregate in base layer RAP good enough?

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Typical Dutch problems

- From max 50% to 70% recycling in base layers: very important in the western part of the Netherlands (not enough space for storage of RAP)
- Many PA layers are to be replaced in a first or second maintenance cycle (RAP with extremely hard bitumen).
- Higher percentages of RAP in higher placed layers. Asphalt production of $9*10^6$ ton/year mostly for binder and surface layers. Increase amount of RAP in these layers?

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Important Research questions

- Fatigue properties at very high percentages RAP.
- Use of logPen rule: must be proven.
- Healing of mixes with RAP.
- How to recycle with PMB (results in the Nederlands based on Pen bitumen RAP).
- Re-use of PA RAP (typical Dutch).
- More general: re-use of RAP in the top layers

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CE marking: effective since January 2009

- **Functional requirements in CE marking also for RAP mixtures:**
  - **water sensitivity (retained ITS),**
  - **stiffness (4 point bending),**
  - **fatigue (4 point bending),**
  - **permanent deformation (triaxial test).**

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Thank you for your attention

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