AGEING, DETERIORATION AND LONGEVITY OF LOW NOISE PAVEMENTS

By Ulf Sandberg
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Longevity of pavements (west of the Atlantic)
What is longevity?
Merriam-Webster says:
1: length of life
2: long continuance: permanence, durability

Durability of road surfacings (east of the Atlantic)
What is durability?
Merriam-Webster says:
able to exist for a long time without significant deterioration
What we really mean (both sides of the Atlantic)
Longevity / Durability =

Long-term (life-cycle) properties
What kind of pavements do I consider as "low noise" ("quiet")?

Reference = 0 dB = SMA 0/12 mm, or HMA 0/12 mm

- Porous asphalt concrete
- Porous cement concrete
- Asphalt rubber – open-graded (ARFC)
- (Asphalt rubber – gap-graded)
- Thin asphalt layers (some)
- Diamond-ground cement concrete (some)
- Exposed aggregate cement concrete (EACC) (some)
- Chip seals with very small chippings ("high-friction courses")
- Expanded clay pavements
Changing/deteriorating processes

**Chemical ageing:**
- Oxidation – makes the binding weaker – disintegration may result
- Hardening of the binder – stiffer pavement

**Mechanical influences and damages:**
- Compaction – gives stiffer pavement and rutting
- Rutting -- gives texture differences – side forces
- Ravelling (loss of aggregate) - gives increased mega- and macrotexture
- Stripping (ravelling over areas) – gives increased megatexture
- Cracking – may cause water penetrating the substructure - instability
- Wear (loss of material; small particles) – gives lower micro- and macrotexture
- Clogging – voids filled
- Joints damaged, slabs displaced (old cement concrete) – higher unevenness
Acoustical effects (Noise reduction - NR - loss)

Chemical ageing:
Oxidation – disintegrated surface will give higher texture – noise increase
Hardening of the binder – stiffer pavement may possibly give noise increase

Mechanical influences and damages:
Compaction – gives stiffer pavement and thus possibly noise increase
Rutting - gives texture change, usually reducing noise – side forces incr noise
Ravelling (aggregate loss) - gives increased texture, which increases noise
Stripping (ravelling over areas) – increased megatexture increases noise
Cracking – no documented effect on noise
Wear (loss of material; small particles) – changed texture, uncertain effect
Clogging – voids filled, dramatic effect in terms of increasing noise
Joints damaged, slabs displaced (old cement concrete) – transient noise
Why pavement longevity is important

We tend to measure noise properties mainly on pavements in new or almost new condition

… but longevity is the other equally important parameter

Often, initial noise reduction and lifetime are inversely correlated

Considering only initial noise reduction means poor suboptimization

Pavement engineers and road authorities tend to look more at longevity than initial noise reduction (economical reasons)

Maybe best descriptor for acoustical efficiency would be:

\[(\text{Initial noise reduction}) \times \text{lifetime} \quad \text{[dB-years]}\]
Starting with porous asphalt concrete, whether single-layer (SPAC) or double-layer (DPAC) ("open-graded friction course" – OGFC – in USA)

Top layer: 25 mm thick, 8 mm max aggr.size, voids content target 20 %, mod. binder

Bottom layer: 45 mm thick, 16 mm max aggr.size, voids content target 25 %
Noise reduction of porous pavements as a function of their voids content and thickness – data compilation from various countries
Effect of changes in voids (clogging) and thickness (wear)
Ravelling and other texture changes not considered in this case

R² = 0.74

Product of voids and thickness [mm]

Noise reduction [dB(A)]

0.25 x 50 = 12.5
0.20 x 45 = 9
0.15 x 40 = 6

R² = 0.74
N = 36
Some report a loss of 0.25 dB/year, some report a loss of 2.5 dB/year; how come?
Most positive achievements: The Netherlands

....after spending 75 million dollars
Structural lifetime of DPAC

Best estimate of structural lifetime = 9 years

A dense DAC would last approx. 12 years on same roads
Noise level as a function of time for DPAC in the Netherlands – Status of 2008

Loss of 0.25 dB/year only!

Motorways 90-110 km/h

SPBI = 75.8 + 0.25*lifetime

Diagram from IPG Scientific Strategy Document, author P. Morgan, TRL
Japanese experience
tire/road noise versus pavement age in Japan

From presentation by Mr Kubo, NILIM, Japan, 2007

Regression before setting performance requirement

0.8 dB/year

Hong Kong experience
tire/road noise versus pavement age in Hong Kong

Data based on porous asphalt measured at 50 km/h, Yokohama tire

\[ y = 4.1784 \ln(x) + 73.437 \]

\[ R^2 = 0.4417 \]

Level of ref surfaces

1.0 dB/year

Final overall loss: 0.9 dB/year

Slope measured in other project on same or similar pavements
Conclusions of the age influence
(Hong Kong)

Age influence is very high; approx 1 dB/year.
Accounts for approx. half of variance of the measured values; probably by far the highest individual effect.
Remaining acoustical effect is nil at approx 4 years of age.
Avoid longer use since pavement may then become worse than conventional asphalt pavement.
Results of the experiment in central Copenhagen with double-layer porous asphalt

Note: 50 km/h, mixed traffic!

[J Kragh, Danish Road Institute, July 2007]
Results of the experiment in central Copenhagen with double-layer porous asphalt

Note: 50 km/h, mixed traffic!

Processing of NR loss with time made by Ulf Sandberg, VTI

Noise reduction in relation to a dense asphalt concrete 0/11 mm

Loss in NR with time

- 0.6 dB/year
- 0.8 dB/year
- 1.7 dB/year
Swedish experience
Laid on motorway and highways 80-110 km/h: Double-layer porous asphalt
Data for motorway E18 westwards from Stockholm to Oslo, experiment 2003-2005, 110 km/h, AADT 20000
Measurements with CPX method, CPXI

\[ y = -0.9839x + 6.1481 \]
\[ R^2 = 0.9708 \]

-1 0 1 2 3 4 5 6

-1 0 1 2 3 4 5 6 7

Noise reduction [dB(A)]

Age [years]

1.0 dB/year

\[ y = -0.9839x + 6.1481 \]
\[ R^2 = 0.9708 \]
Data for motorway E4 westwards from Stockholm to Södertälje, experiment 2005-2009, 90 km/h, 2x2 lanes, AADT 75000

Measurements with Leq method (large symbols) and CPX method (smaller symbols)

\[ y = -2.5077x + 7.8919 \]
\[ R^2 = 0.8457 \]

\[ y = -1.9805x + 11.743 \]
\[ R^2 = 0.7678 \]

Original pavement

New top layer

- Double-layer porous asphalt 11 mm + 16 mm
  - 2.5 dB/year
  - \[ y = -2.5077x + 7.8919 \]
  - \[ R^2 = 0.8457 \]
  - 2.0 dB/year
  - \[ y = -1.9805x + 11.743 \]
  - \[ R^2 = 0.7678 \]
Notes about other pavements
Porous cement concrete in Germany smoothed by diamond grinding
Much the same durability properties as porous asphalt, but …

… potential for lower loss of NR, due to binder less subject to oxidation …

… and better wear resistance

No data on long term performance available yet
Asphalt rubber pavements
Evaluation of ARFC Surfaces in Arizona
Source: ADOT 2007

AR_ACFC Noise Levels Versus Pavement Age

\[ y = 0.5453x + 93.279 \]
\[ R^2 = 0.5805 \]

Loss = 0.5 dB/year
8 mm aggregate, 1-2 mm rubber granules
15% voids initially, 5-10% rubber of total mix by weight

Not structurally durable at all!
Asphalt rubber (AR) sections in Sweden 2007-2009

Approx 15 test sections laid in Sweden 2007-2009
57000 tonnes  100 lane-km
Much the same properties as for normal asphalt:
AR open-graded ~ Porous asphalt (single)
AR gap-graded ~ SMA

... but binder is highly modified and much more binder is used

Potential for improved durability due to:
less exposure of material to air (oxygen) and sun radiation …
… gives slower deterioration of binder strength

Very good performance in Sweden so far (3 years)
Effect of cleaning with high-pressure water
By R Nilsson et al, Sweden, at Inter-Noise 2010

Double-layer porous asphalt 8 mm + 16 mm

Gain 1.7 dB
Loss 0.5 dB
Factors affecting the NR loss

- Pavement type (porous vs dense, binder, size of aggregate)
- Pavement age
- Traffic volume (AADT)
  - Proportion of heavy vs light vehicles
- Speed
  - Self-cleaning by traffic
- "Artificial" cleaning
- Amount of dirt
  - Dirt from wear - Use of studded tires
  - Dirt transported in (from side of road or from adjacent pavement)
- Loss of aggregate (ravelling/stripping - structural durability)
  - Longitudinal or transversal forces (start/stop, curves, intersection)
  - Studded tires
- Texture changes due to wear (strength of the aggregate)
- Measurement method (CPX/OBSI vs SPB, ref tire used)
Factors affecting – Most important ones

- Pavement type (porous vs dense, binder, size of aggregate)
- Pavement age
- Traffic volume (AADT)
  - Proportion of heavy vs light vehicles
- Speed
  - Self-cleaning by traffic
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How can we model this?
Model for loss of noise reduction with time

By Hans Bendtsen, DRI, et al

Presented at TRB, Washington, DC, Jan 2010
followed-up at Inter-Noise 2010
Major findings by Bendtsen et al

Based on Danish and Californian asphalt surfaces, noise reduction loss is approx. 0.5-0.8 dB/year.

Tried age as explaining factor.

Tried accumulated traffic as explaining factor.

Combination of both gave the best model.

Age weighted by 25%, accumulated traffic weighted by 75%, was the best combination.

Next steps: testing against conditions in other countries and various speeds.
Conclusions

• For at least porous pavements, age is the most important factor, more important than pavement construction.

• Acoustical longevity is equally or more important than initial noise reduction.

• Rate expressed as loss of noise reduction (NR) per year is an important factor.

• Several factors affect this rate (e.g. age & accum. traffic).

• Any model for the loss of NR will be rather complicated.

• Consider the parameter NR x lifetime [dB-years] as descriptor.
The End