Low Dry Friction - Measurement and Imaging

Dr John C Bullas
Atkins Ltd
Research Consultant
John.bullas@atkinsglobal.com/
john.bullas@gmail.com

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**Negative Texture** The New Generation of Road Surfaces.. why use them?

OLD: roadwork delays, perceived rutting problem(?), noise and spray issues. Two Part Installation

~Positive Textured Hot Rolled Asphalt (HRA) Asphalt + Rolled in Coated Chippings

NEW: Lower noise, lower spray, use for thin resurfacing/regulating, Less rutting(?), Single Stage Installation = less delay

~ Stone Mastic/Matrix Asphalt (SMA), a Negative Textured Surface (NTS)
A Brief History of Time(s when it has been “Slippery When Dry”)
The 1930s ...
Highway Engineers didn’t measure DRY road friction because it was assumed to be OK

We once measured the dry friction of roads in 1936* with a motorbike wet skid tester and the dry friction was pretty good so we didn’t really try again…

….until the 1970’s when it was still really good so we stopped looking ** (again)


The 1940s...
1944: Asphalt and the effect on Friction

“…..On some road surfaces, the melting point of the binder may be reached before that of the tread rubber, in which case the slipping coefficient will have a different value from that on which the rubber melts first” ..... Remember this quote for later!
To compare Zipkes (1944) with Bullas (2006):

Tyre/Road Maximum Temperature Data extracted using FLIR Researcher: NTS top, PTS bottom

NTS (mastic film) Dry

110°C

PTS (no mastic film) Dry

130°C
The 1980s...
1985, The M4 Motorway (UK) 13 are dead...

13 dead owing to a combination of:

• Poor driving
• Substandard central barrier height
• Extended DRY braking distances [longer than in the WET] on a coated stone chippings with a thick layer of bitumen

“…..some of the worst DRY skid resistance seen in 10 years” were measured by the Police Crash Investigator

ANON (1986) Low barriers conceded at M4 accident site. New Civil Engineer.


SHELSHEAR, G. (1986?) Statement by Mr D Simpson Concerning Safety Fences - M4 Berkshire Crossover Accident 23.6.86

SHELSHEAR, G. (1986?) Statement on Skidding resistance by Mr P E Nutt - M4 Berkshire Crossover Accident 23.6.86
...A road **more Slippery in the Dry** than in the **Wet**

The 1990s...
The Netherlands 1990’s
ABS v NOABS - SURF 2004!

Porous Asphalt

- 20% voids
- 13 micron film
- >2.0mm TD
- 3-4 dB (A) less noise


Porous Asphalt (P.A.) Negative Texture, low noise, low spray

Portorož, Slovenia

Figure 1. Deceleration during an emergency stop on a) new porous asphalt, b) dense asphalt and c) new porous asphalt with a car equipped with ABS.
“The low skid resistance (was) caused by melting of the mortar” (the bitumen)

The Porous Asphalt had a thick layer of bitumen on the chippings when new.. this doubled the stopping time when ABS was turned off!

Research published by D.W.W. (NL) in 1997**

Into the New Millenium...
UK 2001: Two fatal crashes on early life S.M.A.

DRY $\mu = 0.56, 0.48, 0.48, 0.49, 0.51$

Fatal Crash: Police NOABS Skid Testing

DRY $\mu = 0.52, 0.51$ Downhill 1:100
DRY $\mu = 0.53, 0.55$ Uphill 1:25

← Fatal Crash: Police NOABS Skid Testing

NB: Low values of Dry $\mu$ were NOTHING to do with the circumstances of the crashes

Dry Friction from SkidMan tests

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We (the highway engineers) probably had assumed..

**NTS Negative Textured Road Surfaces** (SMA Porous Asphalt etc) would behave typically the same (or better) than **Positive Textured** ones like HRA

..... Especially with respect to their untested but unquestioned **DRY frictional properties** during emergency braking...

But “Bituplaning” was occurring!

1000fps video
Bullas/Atkins, Highways Agency (UK) sponsored PhD study
\( \mu_{dry} \approx 0.5? \). This **IS NOT** a ‘typical’ value for dry road friction.

Figure 8 Distribution of Typical Southern UK Values of Dry Friction (Lambourn, 2004) compared against that given in Goudie et al (Goudie et al., 2000)
References to past research from NL and even the UK on slippery dry roads?

- Little (if any) reference was made to the research from the 1940’s, 1980’s and 1990’s by those in the UK commenting on the “dry slippery” events of 2001 ...

- The surfacing industry however DID SAY in their defence that “slippery in the dry” was not a new phenomenon...... THEY REMEMBERED at least...

- The work from NL was presented at a conference in 1997 on Porous Asphalt held around the time highway engineers in the UK lost interest in using it.... So who would pay to attend from the UK?
So who did know most about the dry friction of the highway in the UK?
Police Collision Investigators

......to estimate the braking speed and/or speed at inception of loss of control from skid marks at the scene of fatal or near-fatal crashes
Dry Friction Tests using Decelerometers

SkidMan/Vericom decelerometers and data output from a skid test

hard copy [right] and downloaded [below]
SKID TEST TRIAL: NORTH WALES
ABS v NoABS Skid tests

Devon & Cornwall Constabulary Testing at Westpoint Skidpan

Critical Speed

\[ r = \frac{c^2}{8M} + \frac{M}{2} \]

\[ v = \sqrt{\mu gr} \]

\[ v = \sqrt{\frac{gr (\mu + \tan(\phi))}{1 - \mu \tan(\phi)}} \]

Equations of Motion (adapted)

Skidding: \[ u = \sqrt{v^2 + 2\mu gs} \]

Coefficient of Friction from Skid Tests: \[ \mu = \frac{u^2}{2gs} \]

Coefficient of Friction from Drag Tests: \[ \mu = \frac{\text{pulled force}}{\text{actual weight}} \]

Force \[ F = m\mu g \]
Dry “Mu” is used in reconstruction of the crash scene by combining survey data and skid test results to estimate “critical speed” from the tyre marks’ curve radii.
Skidman: NO ABS v ABS on a DRY road: extended stopping time & distance for a NEW binder rich surface

Devon & Cornwall Constabulary Testing at Westpoint Skidpan

Hampshire Constabulary Testing at Winnall Waste Processing Facility

Portorož, Slovenia
Dry NOABS skid tests on two adjacent surfaces (lanes 1&2 versus Lanes 3&4), the older surface shows a higher dry friction level but still below 0.7

Metropolitan Police data Bullas (2006) PhD Study
Research UK (Atkins): Thermal Imaging of Braking
What can be seen during emergency braking to give the low dry friction – sadly chippings and bitumen are not see-through!

Compare ABS Emergency Braking in the DRY... With Emergency Braking Without ABS in the DRY...
Is HEAT really causing the “bituplaning” event?

Scraping + shearing + loading

Heat soaking > Melting

Friction = HEAT

Locked Wheel Skidding – 100% Slip
HEAT?: Typical Bitumen Properties with Temperature

Hampshire Constabulary Testing at Winnall Waste Processing Facility


Portorož, Slovenia
<table>
<thead>
<tr>
<th>Fluid</th>
<th>Viscosity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk</td>
<td>1.2 cP / 0.012 Pa·s</td>
</tr>
<tr>
<td>Melted Butter</td>
<td>18 cP / 0.18 Pa·s @ 140ºC</td>
</tr>
<tr>
<td>Corn Oil</td>
<td>30 cP / 0.3 Pa·s</td>
</tr>
<tr>
<td>Cough Syrup</td>
<td>190 cP / 1.9 Pa·s</td>
</tr>
<tr>
<td><strong>Auto Lube Oil SAE 40</strong></td>
<td><strong>200 cP / 2.0 Pa·s @ 100ºC</strong></td>
</tr>
<tr>
<td>Yogurt</td>
<td>1,100 cP / 11 Pa·s</td>
</tr>
<tr>
<td>Honey</td>
<td>1,500 cP / 15 Pa·s @ 100ºF</td>
</tr>
<tr>
<td>Mayonnaise</td>
<td>5,000 - 10,000 cP / 50 - 100 Pa·s</td>
</tr>
<tr>
<td>Tomato Paste</td>
<td>7,000 cP / 70 Pa·s</td>
</tr>
<tr>
<td>Corn Syrup</td>
<td>15,000 cP / 150 Pa·s</td>
</tr>
<tr>
<td>Toothpaste</td>
<td>20,000 cP / 200 Pa·s</td>
</tr>
<tr>
<td>Hot Fudge</td>
<td>36,000 cP / 360 Pa·s</td>
</tr>
</tbody>
</table>
Dry Skid versus Skid on Engine Oil: Greasy
c/w Auto Lube Oil SAE 40 - 2.0 Pa·s @ 100ºC

TRL

Atkins (Bullas, 2006)
The Devil is in the detail…..

- Tabulation and visual classification of key phases within each simulated emergency braking event for a 300+ event database

- To identify (and statistically prove the significance of) any differences between the emergency braking deceleration delivered by the combination of NEGATIVE & POSITIVE surface texture types, ABS/NOABS braking systems and DRY and WET surfaces
Real Data but strong trends!

Figure 4 Variation in skid test friction measurements over three days (Rudram and Lambourn, 1981)

Need a Site by Site policy?
**ABS v NoABS / NTS v PTS**

**AVERAGE G with ABS:**
DRY NTS >> DRY PTS

**AVERAGE G without ABS:**
DRY NTS << DRY PTS
Statistically significant differences but NOT all new roads behave like this in the dry!

<table>
<thead>
<tr>
<th>ARE THE LEVELS OF SLIDING DECELERATION SIGNIFICANTLY DIFFERENT BETWEEN….?</th>
<th>Significance Levels (MiniTab 14)</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1 (FOR THE SAME BRAKING SYSTEMS / SURFACE STATES BETWEEN THE “TEXTURES”)</td>
<td></td>
</tr>
<tr>
<td>NOABS Negative v Positive DRY</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>ABS Negative v Positive WET</td>
<td>12.8%</td>
</tr>
<tr>
<td>ABS Negative v Positive DRY</td>
<td>25.7%</td>
</tr>
<tr>
<td>NOABS Negative v Positive WET</td>
<td>80.2%</td>
</tr>
<tr>
<td>#2 (FOR THE SAME SURFACE /SURFACE STATES BETWEEN THE BRAKING SYSTEMS)</td>
<td></td>
</tr>
<tr>
<td>ABS v NOABS Negative DRY</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>ABS v NOABS Negative WET</td>
<td>5.5%</td>
</tr>
<tr>
<td>ABS v NOABS Positive DRY</td>
<td>5.6%</td>
</tr>
<tr>
<td>ABS v NOABS Positive WET</td>
<td>9.2%</td>
</tr>
</tbody>
</table>
Findings to date:

- Bituplaning has been captured on film and is easy to trigger on some ‘new’ NTS and PTS bituminous surfaces.

- The ‘bituplaning’ deceleration characteristics observed are almost identical to those reported on in NL on PA.

- The ‘bituplaning’ phenomenon is NOT just a high speed event (just need 30mph+).

- ABS braking can lead to momentary low dry friction with “dash like” skidmarks (next slide).

- Temperatures high enough to melt bitumen have been measured.
ABS Dashes

New Negative Textured Surface - Dry SkidMan Tests

Deceleration (g)

Time (Seconds)

NOABS

ABS

Portorož, Slovenia
“Killer Roads”?

Only 4% of crashes DO NOT have human contributory factors associated with them.

AND few if any non-fatal crashes are ever investigated.

Thank you for listening!

Email: john.bullas@atkinsglobal.com
john.bullas@gmail.com

Research Support from: