Low Dry Friction - Measurement and Imaging

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International Symposium on Pavement Surface Characteristics of Roads and Airfields organized by PIARC TC 4.2 “Road/Vehicle Interaction” and Slovenian PIARC National Committees

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

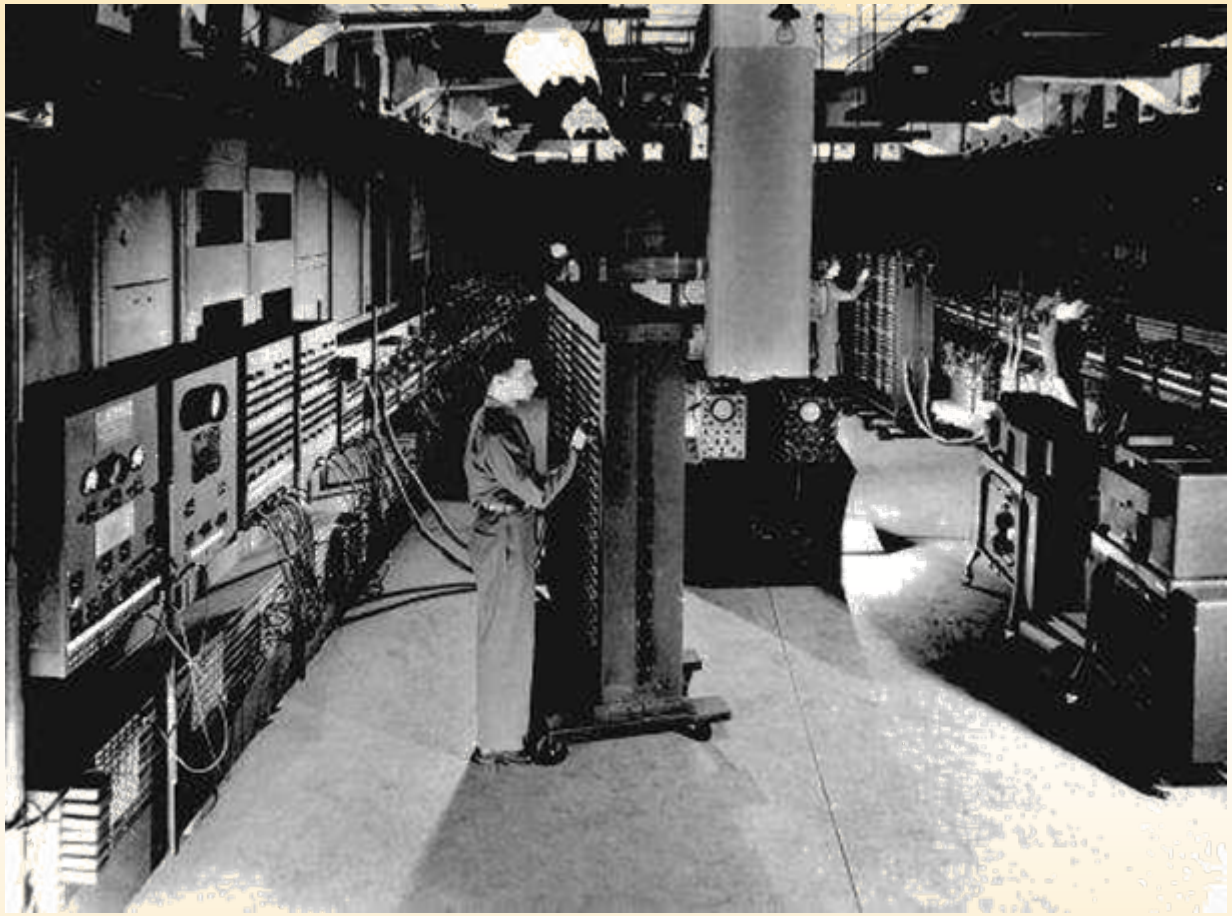
OLD: roadwork delays, perceived rutting problem(?), noise and spray issues. Two Part Installation

~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

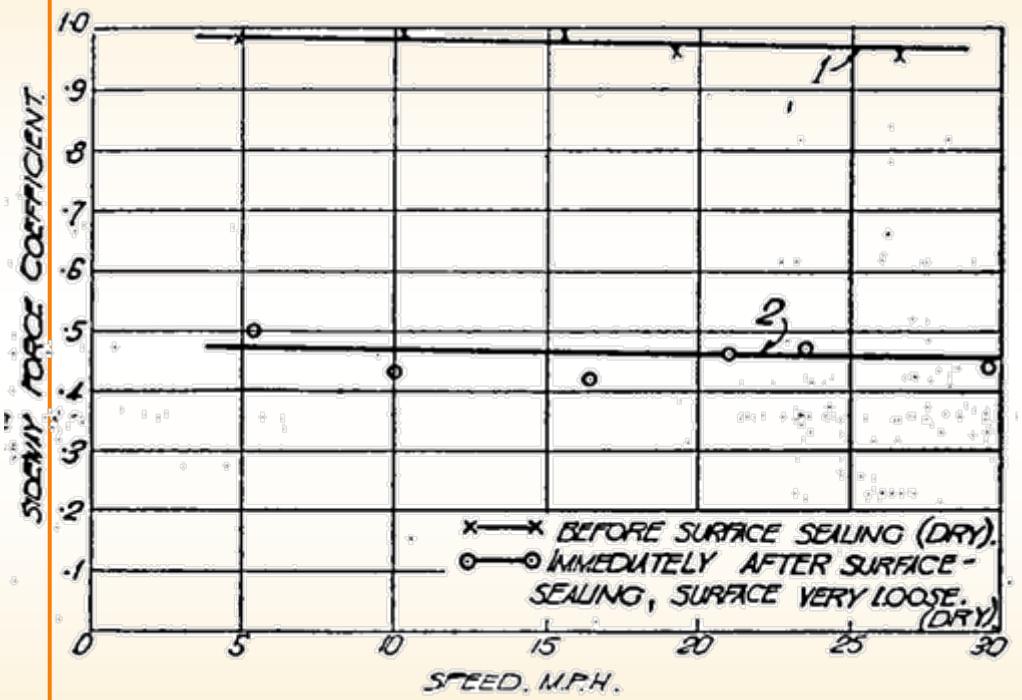
~ Stone Mastic/Matrix Asphalt (SMA), a Negative Textured Surface (NTS)

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

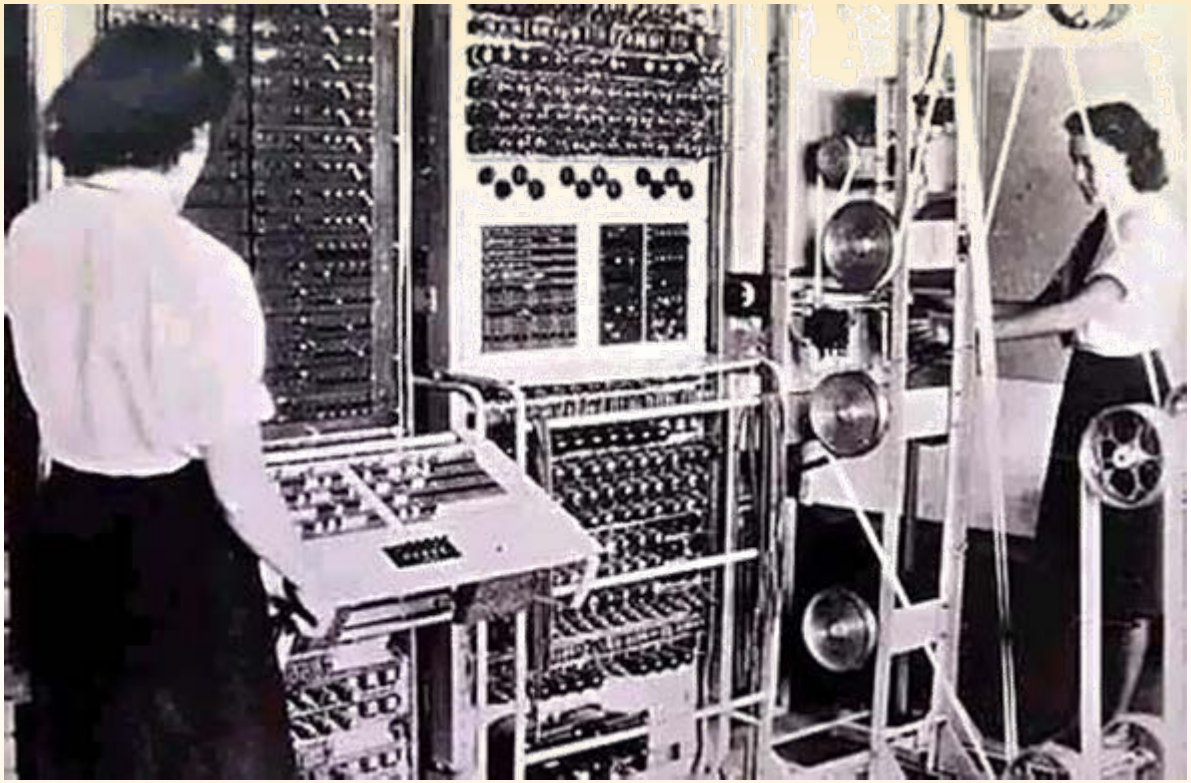


We once measured the dry friction of roads in 1936* with a motorbike wet skid tester and the dry friction was pretty good so we didn't really try again…

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

*BIRD, G. & SCOTT, W. J. O. (1936) Studies in Road Friction: I. Road Surface Resistance to Skidding Department of Scientific and Industrial Research / Ministry of Transport.

**HOSKING, J. R. & WOODFORD, G. C. (1976) Measurement of skidding resistance part i. guide to the use of SCRIM, Transport Research Laboratory Report LR737. Transport Research Laboratory.



The 1940s…

1944: Asphalt and the effect on Friction

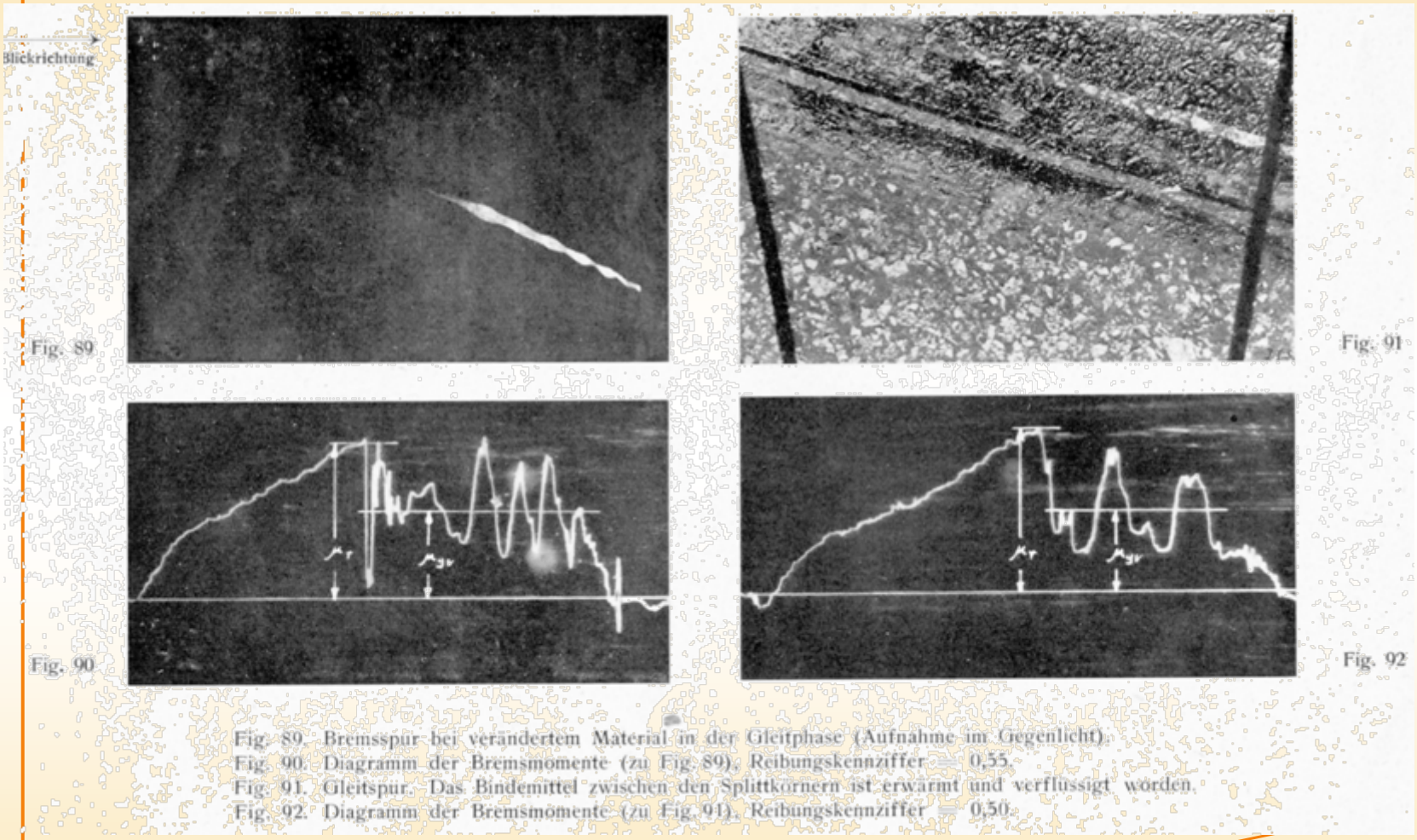


Fig. 89. Bremsspur bei verändertem Material in der Gleitphase (Aufnahme im Gegenlicht).
Fig. 90. Diagramm der Bremsmomente (zu Fig. 89). Reibungskennziffer = 0,55.
Fig. 91. Gleitspur. Das Bindemittel zwischen den Splittkörnern ist erwärmt und verflüssigt worden.
Fig. 92. Diagramm der Bremsmomente (zu Fig. 91). Reibungskennziffer = 0,50.

ZIPKES, E. (1944) Die Reibungskennziffer als Kriterium zur Beurteilung von Strassenbelägen Eidgenössissche. Verlag A.G. Gebr. Leeman and Co.

1944 E.Zipkes (Switzerland)

Fig. 1. Apparatur zur Messung der Bremsmomente nach der Methode *Schindler*.

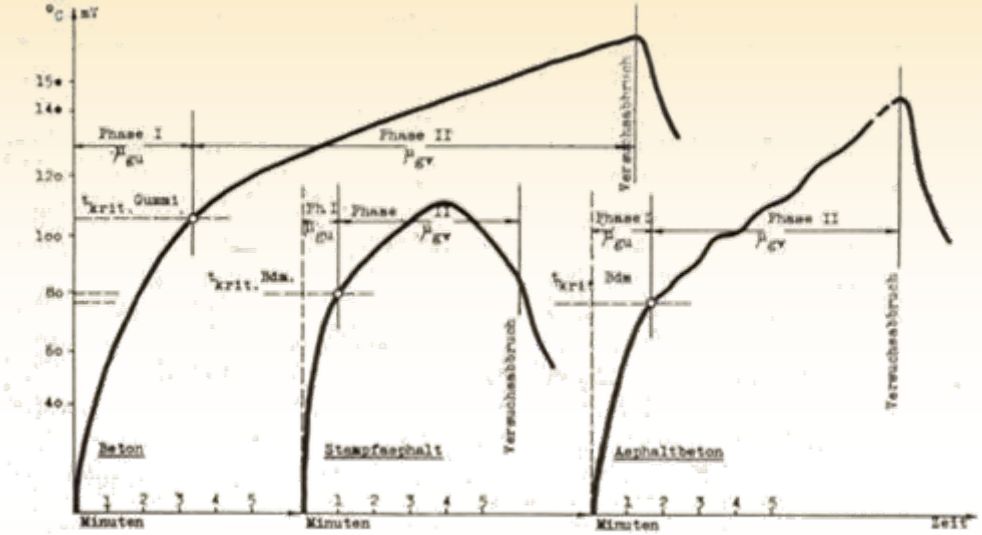
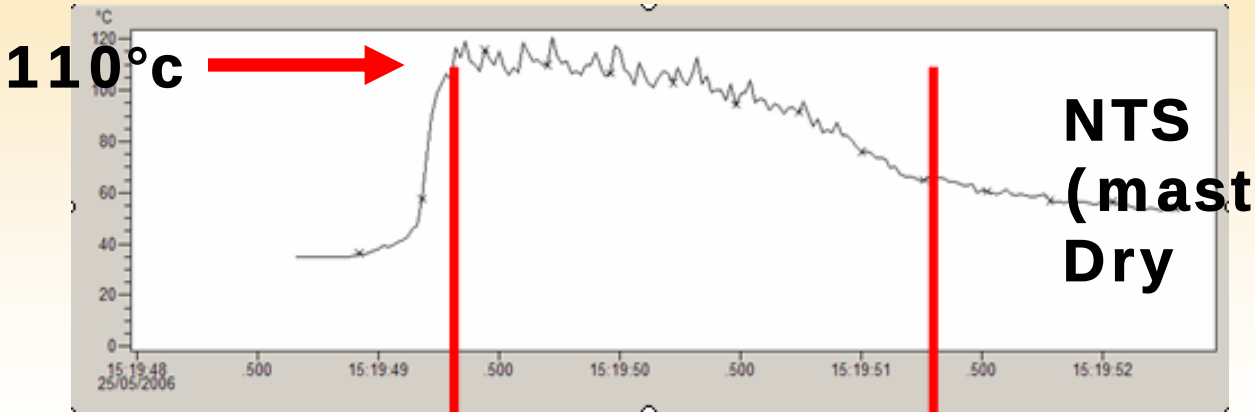


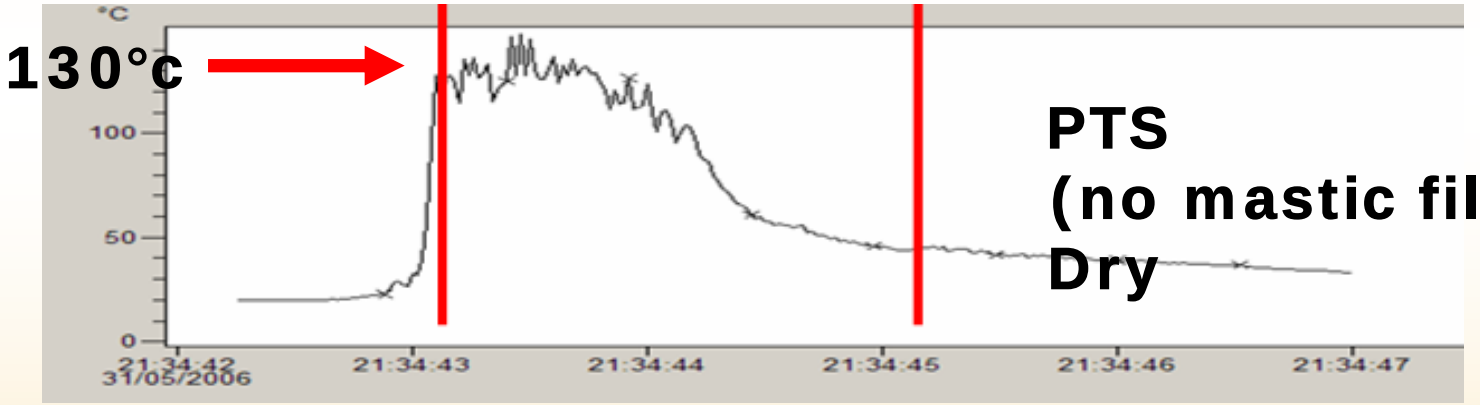
Fig. 50. Zusammenstellung der gemittelten Kurven aus Fig. 36, 42 und 46.

"…..On some road surfaces, the melting point of the binder may be reached before that of the tread rubber, in which case the slipping co-efficient will have a different value from that on which the rubber melts first" ….. Remember this quote for later!

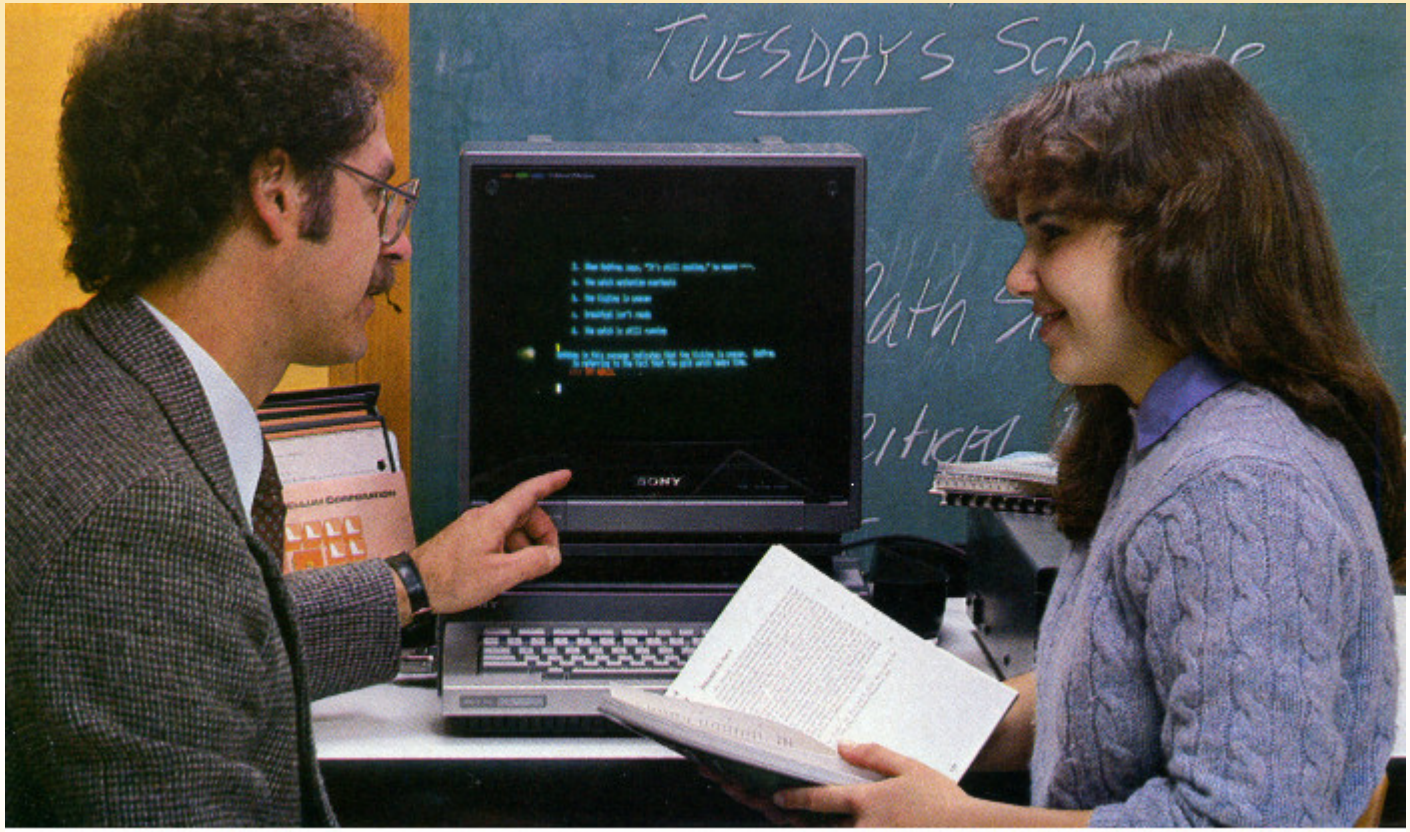
ZIPKES, E. (1944) Die Reibungskennziffer als Kriterium zur Beurteilung von Strassenbelägen Eidgenössissche. Verlag A.G. Gebr. Leeman and Co.

To compare Zipkes (1944) with Bullas (2006):





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



FROM "PERSONAL COMPUTING" MAGAZINE - JUNE 1983 - SCANNED BY VC&G - VINTAGECOMPUTING.COM

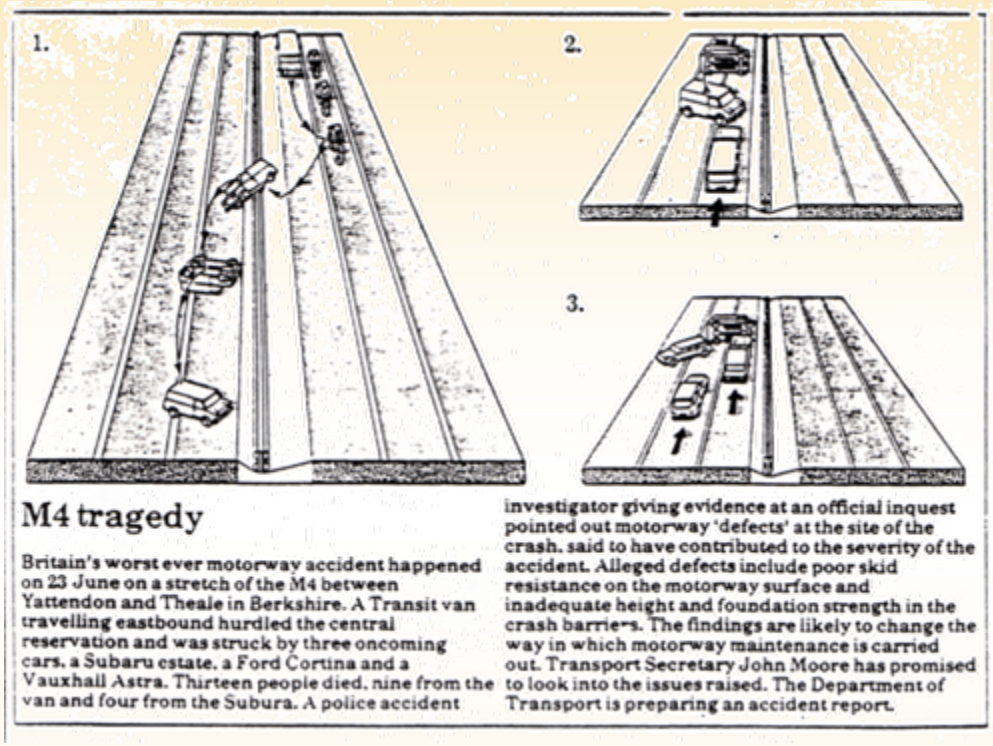
The 1980s…

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.*

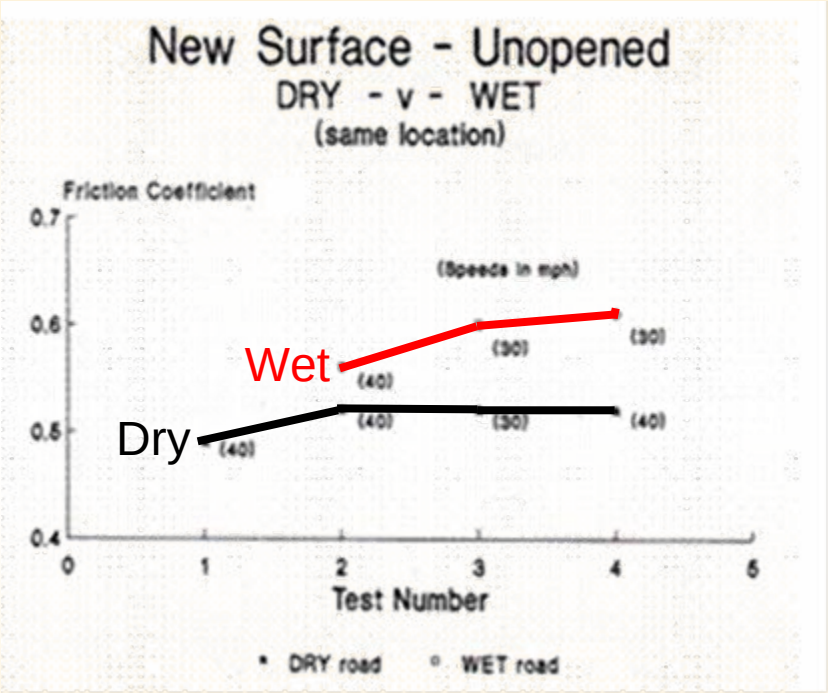
BYRD, T. & DADSON, J. (1986) Safety barrier review follows M4 carnage *New Civil Engineer. SHELSHEAR, G. (1986) Poor Skid Resistance cited at Crash Inquest. New Civil Engineer.*

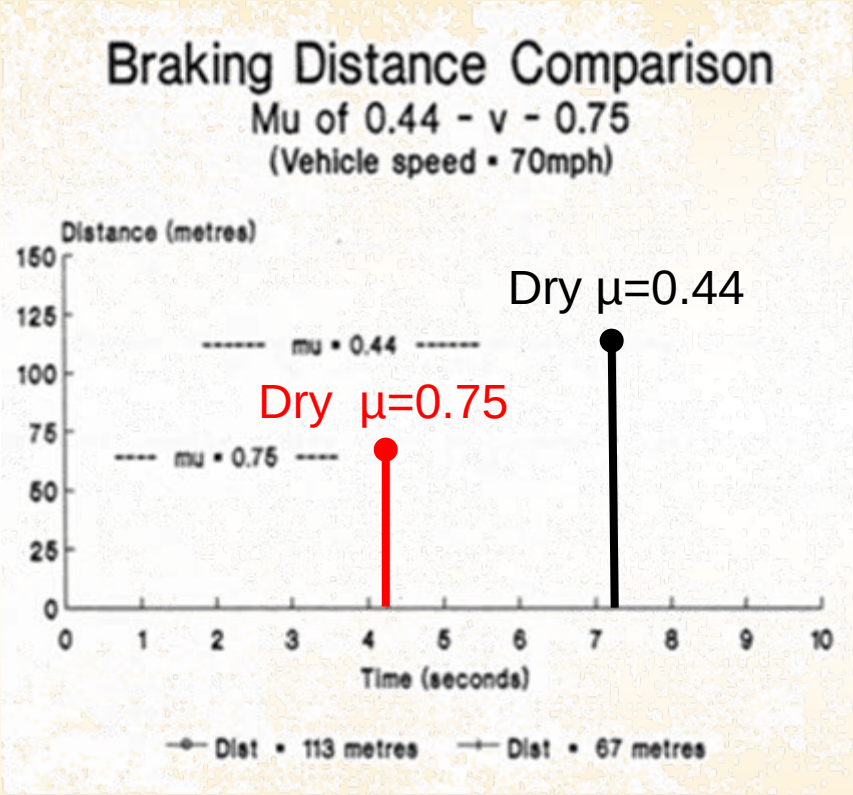
SHELSHEAR, G. (1986) Resume regarding "Poor Skid Resistance cited at Crash Inquest".

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

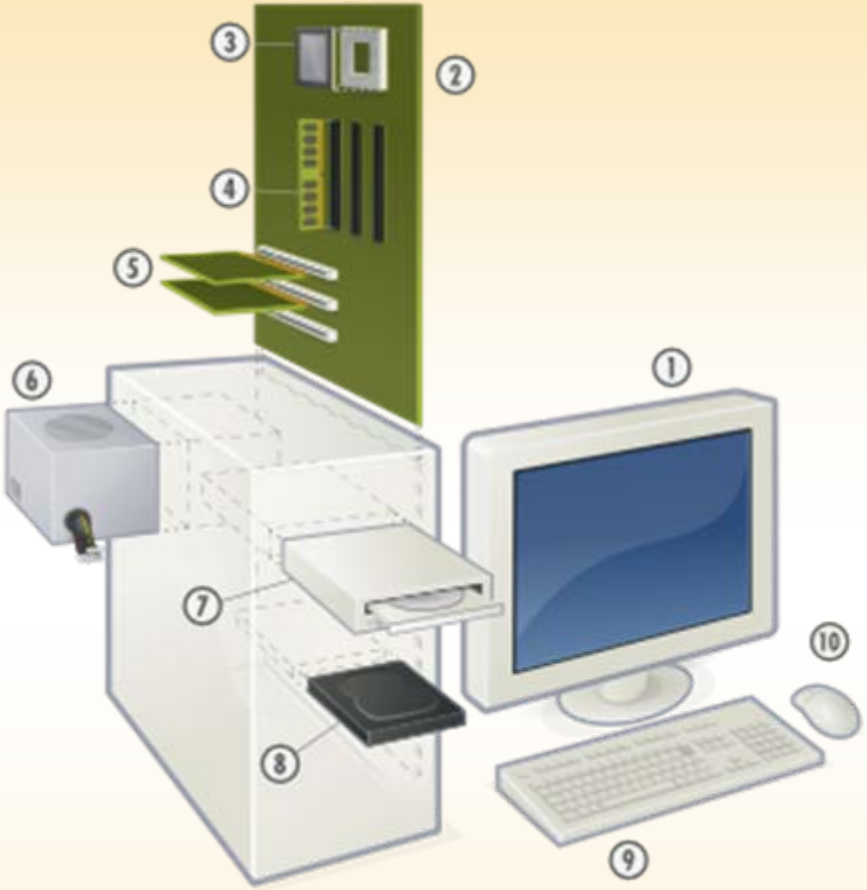
SHELSHEAR, G. (1986?) Statement on Skidding resistance by Mr P E Nutt - M4 Berkshire Crossover Accident 23.6.86

...A road more Slippery in the Dry than in the Wet





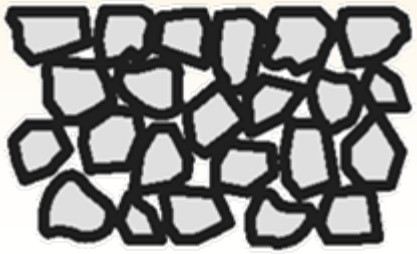
MANDERSON, J. & RUDRAM, D. (1993) The variation in tyre/road friction with time. IN JACOB, B. & BONTE, W. (Eds.) *Vol 3; Forensic criminalistics 1.* Dusseldorf; Germany, Berlin.



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

RICHARDSON, J. T. G. (1999) Stone Mastic asphalt in the UK. *SCI Lecture Series.* Society of Chemical Industry.

FAFIÉ, J. (2004) Early Life Dry Skid Resistance. *Paper presented at "Surf 2004", 5th Symposium on Pavement Surface Characteristics.* Toronto, Ontario, Canada.

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

NOABS on P.A.

ABS on ASPHALT

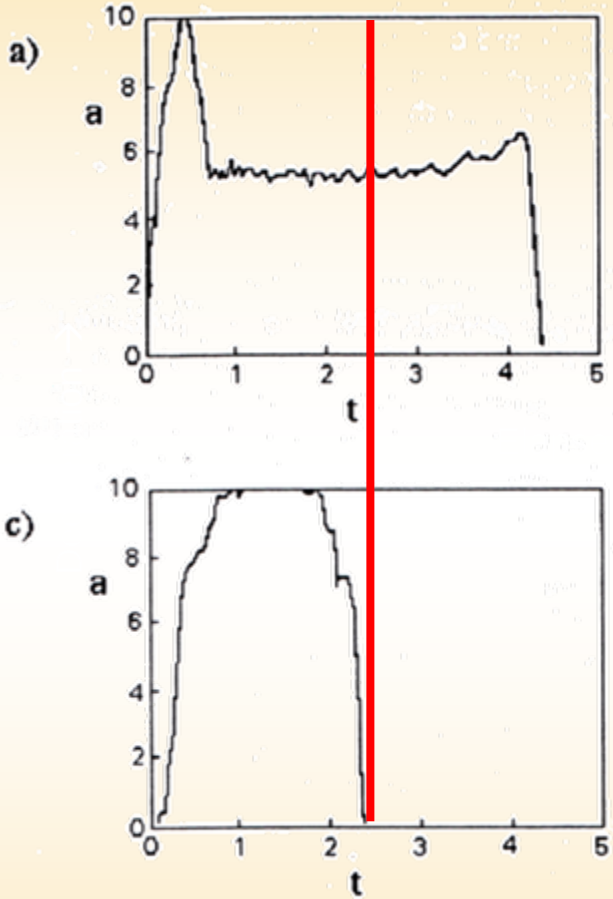


Figure 1. Deceleration during an emergency stop on a) new porous asphalt, b) dense asphalt and c) new porous asphalt with a car equipped with ABS.

**JUTTE, R. H. & SISKENS, C. A. M. (1997) A Material Technological Approach to the Low Initial Skid Resistance of Porous Asphalt Roads. *European Conference on Porous Asphalt, Madrid.* Ministerio de Fomento, Direccion General de Carreteras, Spain.

ABS on P.A.

"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**

**JUTTE, R. H. & SISKENS, C. A. M. (1997) A Material Technological Approach to the Low Initial Skid Resistance of Porous Asphalt Roads. *European Conference on Porous Asphalt, Madrid.* Ministerio de Fomento, Direccion General de Carreteras, Spain.

Into the New Millenium…

The New Millenium…

UK 2001: Two fatal crashes on early life S.M.A.

DRY μ=0.56, 0.48, 0.48, 0.49, 0.51

Fatal Crash: Police NOABS Skid Testing ➔

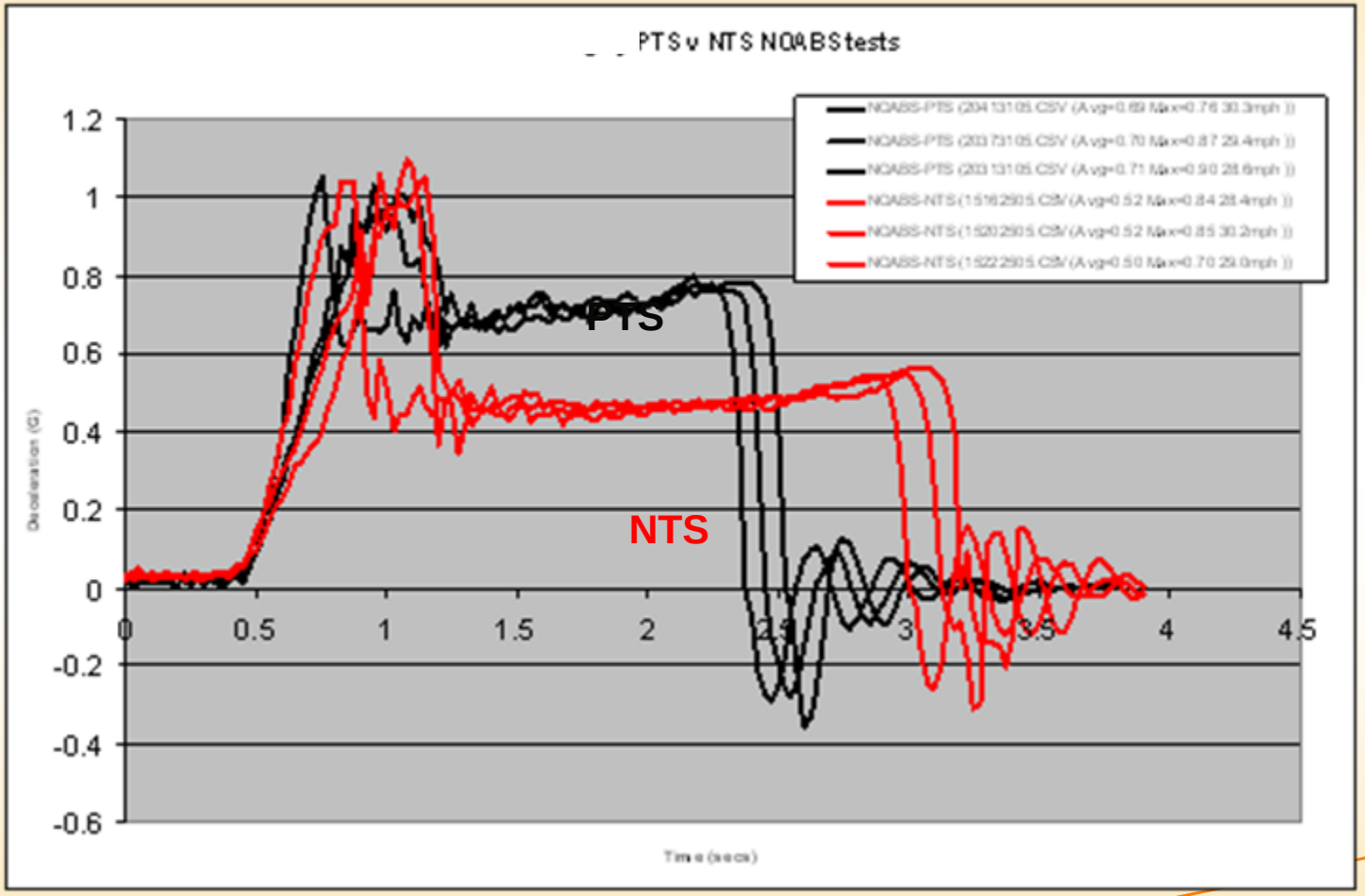
DRY μ=0.52, 0.51 Downhill 1:100
DRY μ=0.53, 0.55 Uphill 1:25

🡐 Fatal Crash: Police NOABS Skid Testing

NB: <u>Low values of Dry μ were NOTHING to do with the circumstances of the crashes</u>

ALLEN, J. (2001) "Stone Mastic Asphalt": Presentation to the ACPO Senior Collision Investigators Conference, Hull.

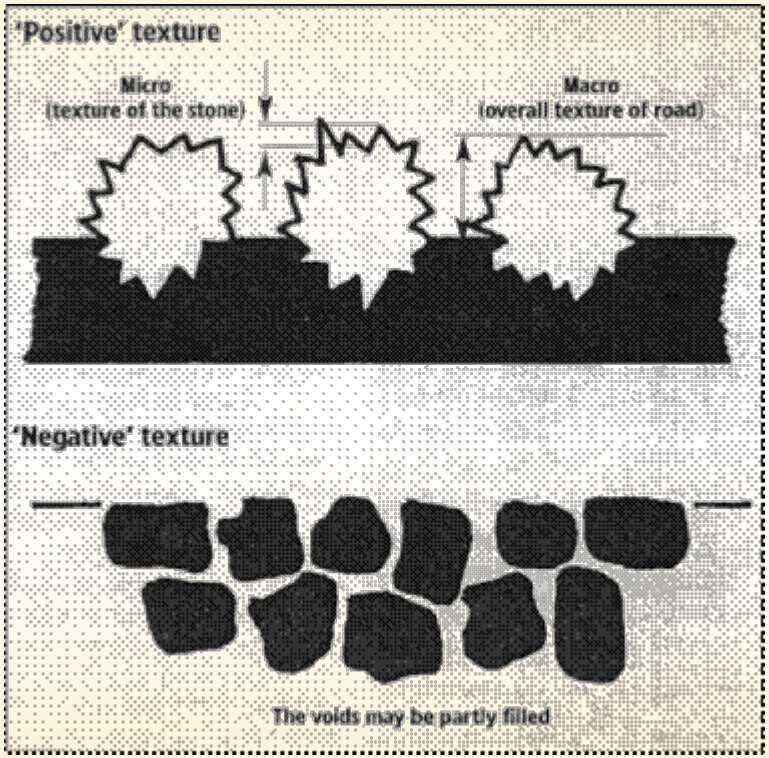
Dry Friction from SkidMan tests



We (the highway engineers) probably had assumed ..

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

….. Especially with respect to their untested but unquestioned <u>DRY frictional properties</u> during emergency braking…

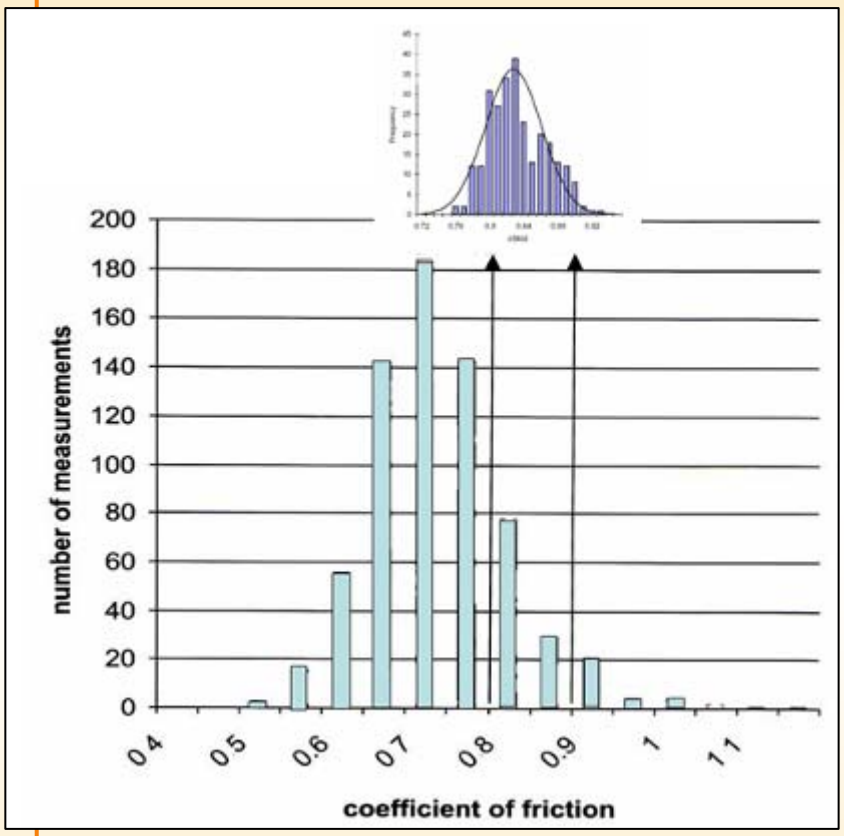


WALSH, I. (2000) Out of the skid pan…. *Surveyor.*

But “Bituplaning” was occurring!

1000fps video Bullas / Atkins, Highways Agency (UK) sponsored PhD study

$\mu_{dry} \approx 0.5$?.. This <u>IS NOT</u> a 'typical' value for dry road friction



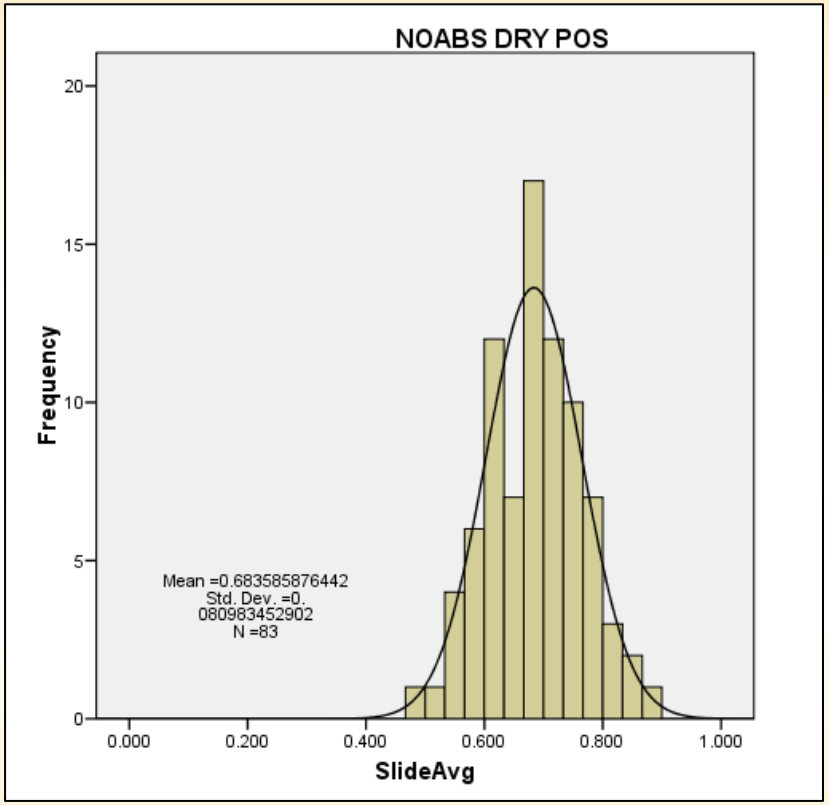
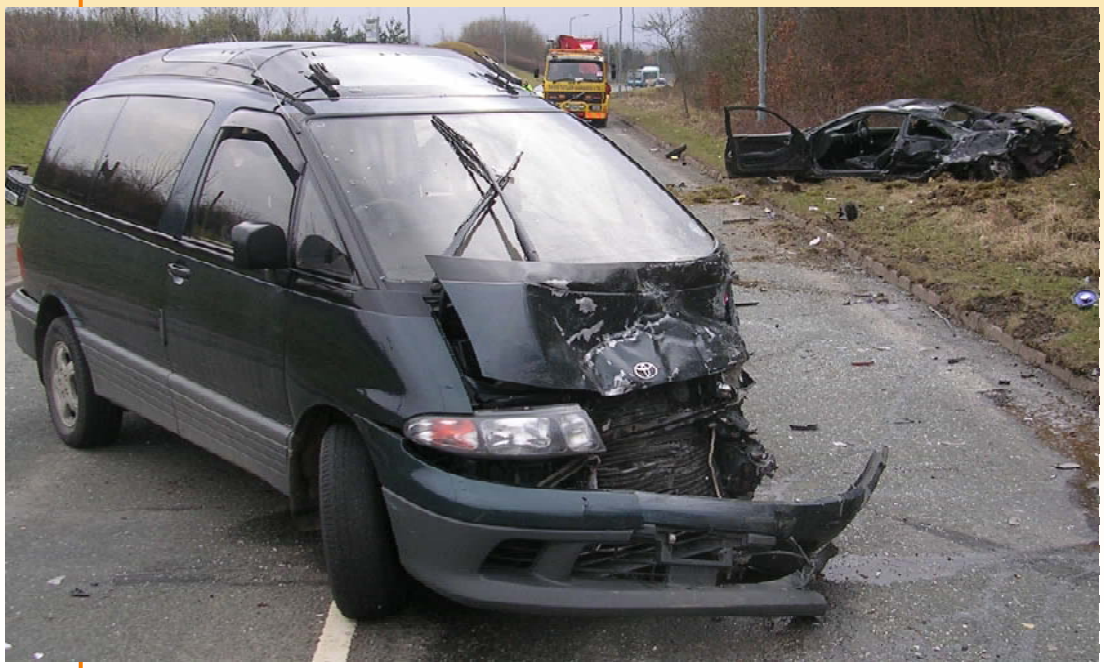


Figure 8 Distribution of Typical Southern UK Values of Dry Friction (Lambourn, 2004) compared against that given in Goudie et al (Goudie et al., 2000)

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?



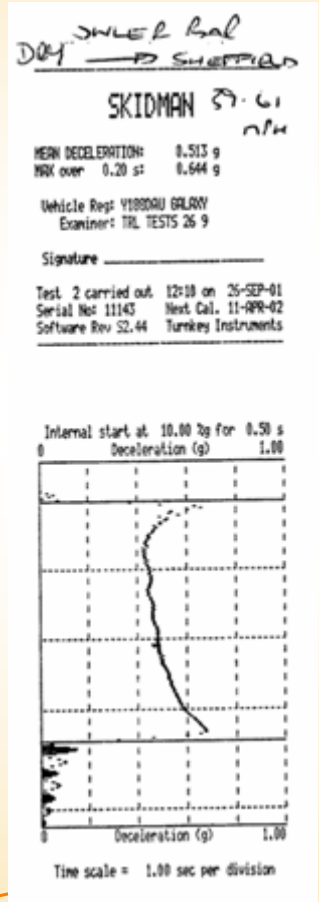
Police Collision Investigators

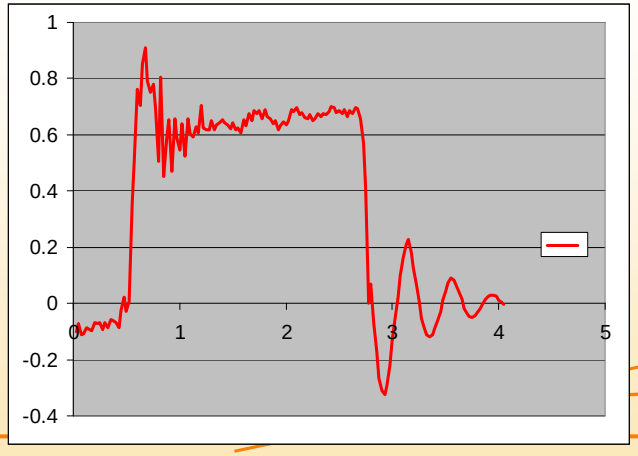
……to estimate the braking speed and/or speed at inception of loss of control from skid marks at the scene of fatal or near-fatal crashes

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

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

$$v = \sqrt{\mu g r}$$

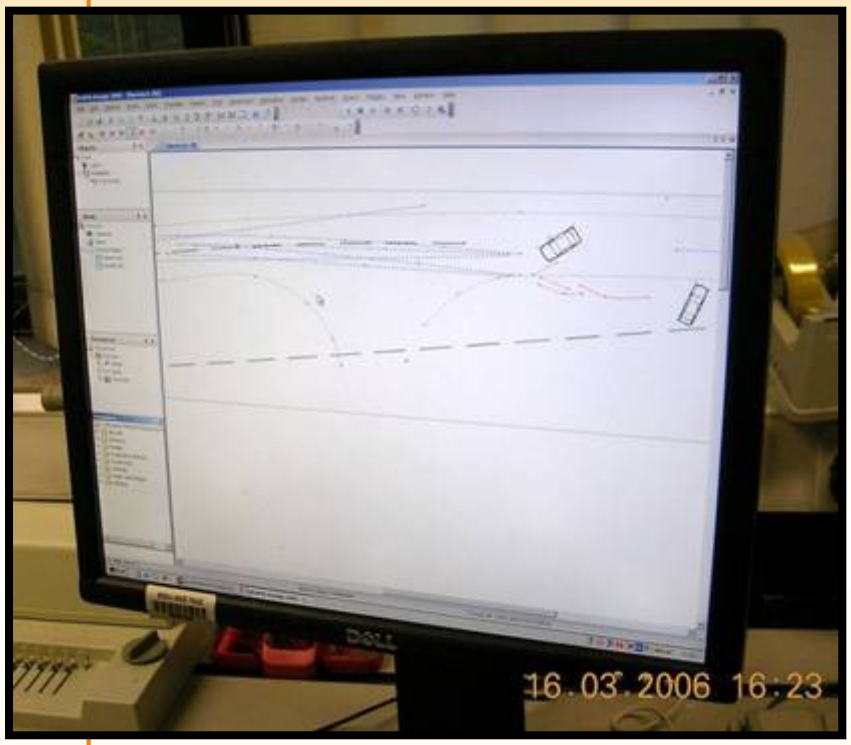
$$v = \sqrt{\frac{gr\,(\mu + \tan(\varnothing))}{1 - \mu \tan(\varnothing)}}$$

Equations of Motion (adapted)

Skidding:	$u = \sqrt{v^2 + 2\mu g s}$
Coefficient of Friction from Skid Tests:	$\mu = \frac{u^2}{2gs}$
Coefficient of Friction from Drag Tests:	$\mu = \frac{\textit{pulled force}}{\textit{actual weight}}$
Force	$F = m\mu g$

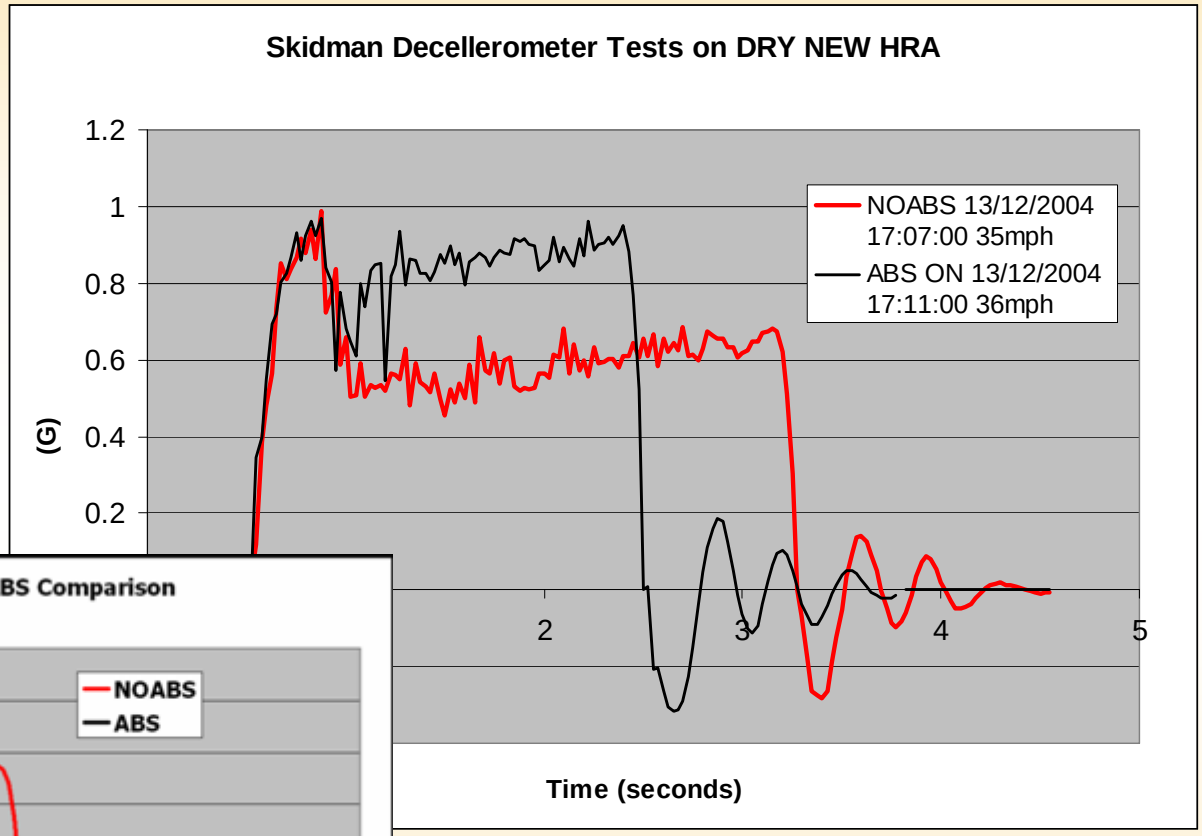
DERBYSHIRE CONSTABULARY ROAD POLICING SUPPORT UNIT (2005) Equations Sheet.

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

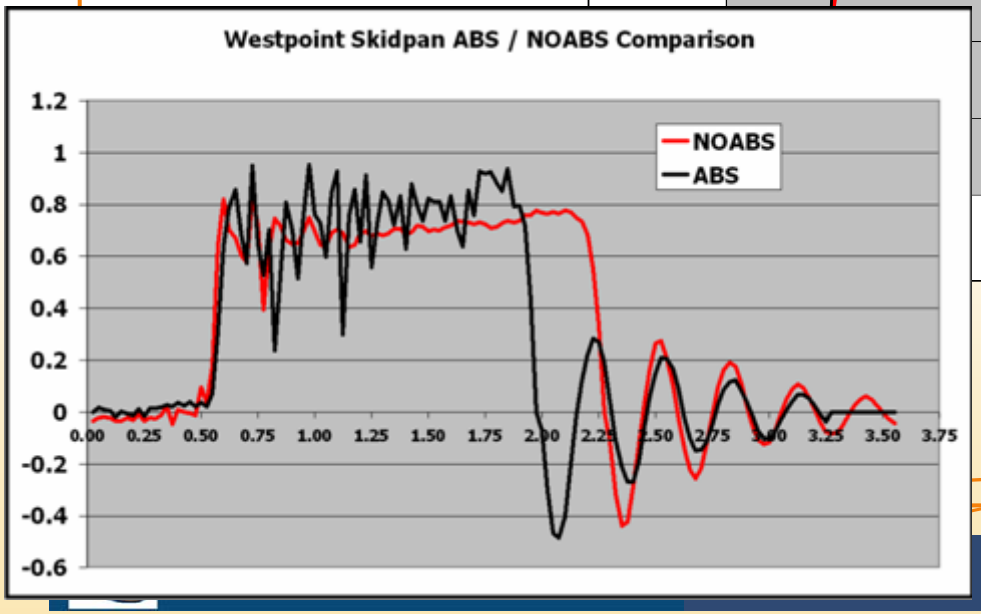


Skidman: NO ABS v ABS on a DRY road: extended stopping time & distance for a NEW binder rich surface

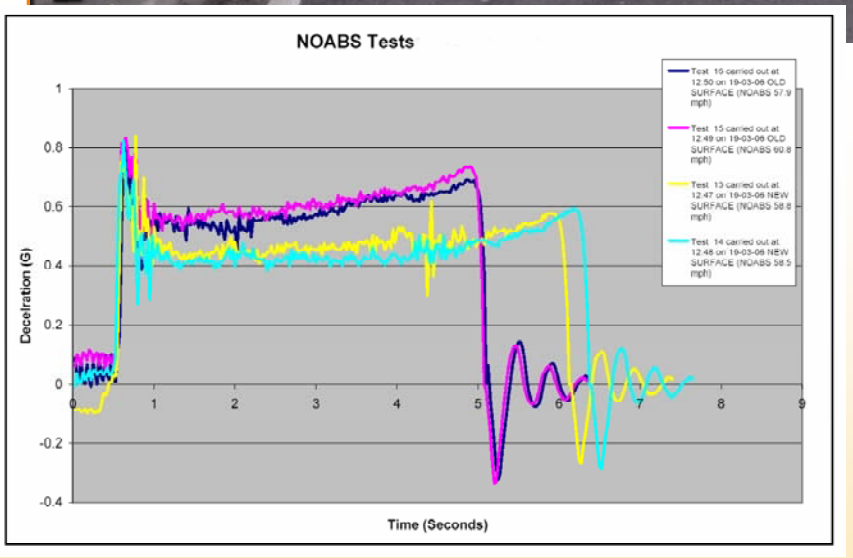
Hampshire Constabulary Testing at Winnall Waste Processing Facility



Devon & Cornwall Constabulary Testing at Westpoint Skidpan



Research UK: Dry Friction improves over time

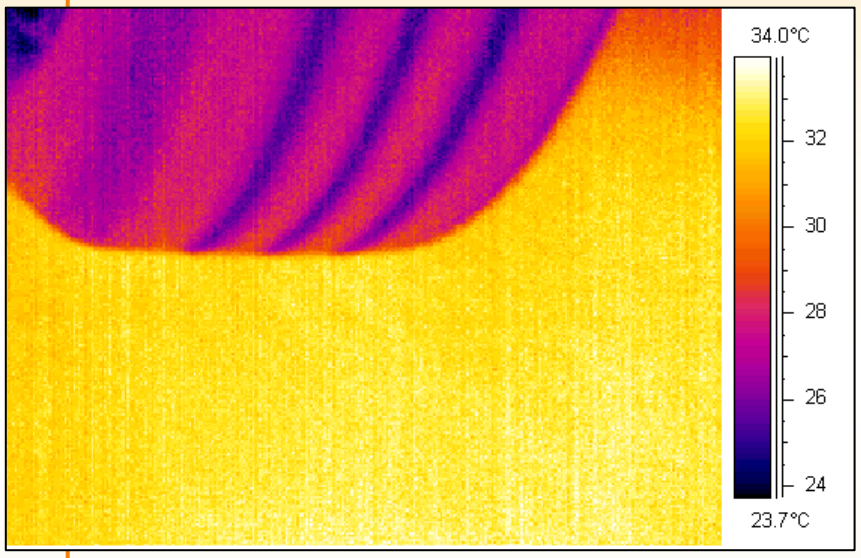


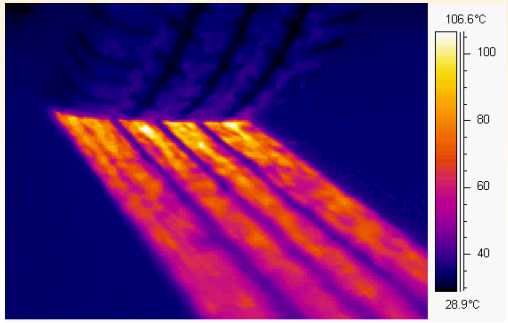
- Dry NOABS skid tests on two adjacent surfaces (lanes 1&2 versus Lanes 3&4), the older surface shows a higher dry friction level but still below 0.7
- Metropolitan Police data Bullas (2006) PhD Study

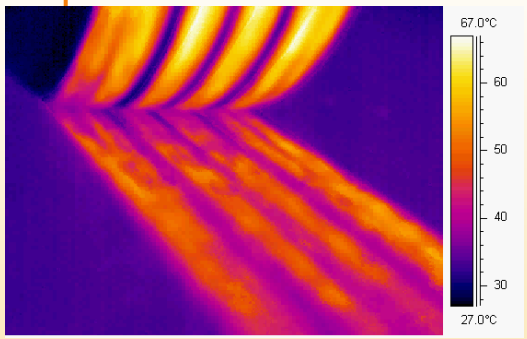
Research UK (Atkins) : Thermal Imaging of Braking

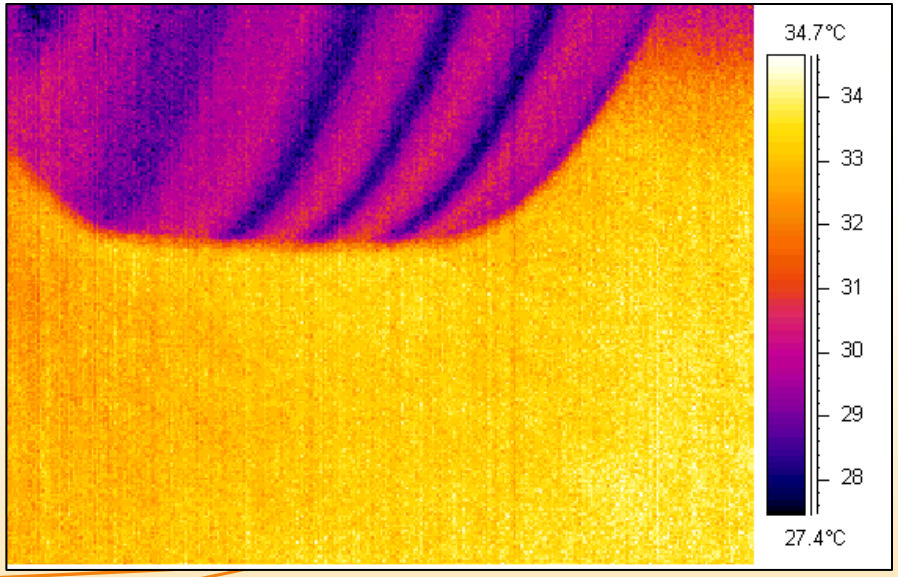
What can be seen during emergency braking to give the low dry friction – sadly chippings and bitumen are not see-through!

Compare ABS Emergency Braking in the DRY… With Emergency Braking <u>Without</u> ABS in the DRY…

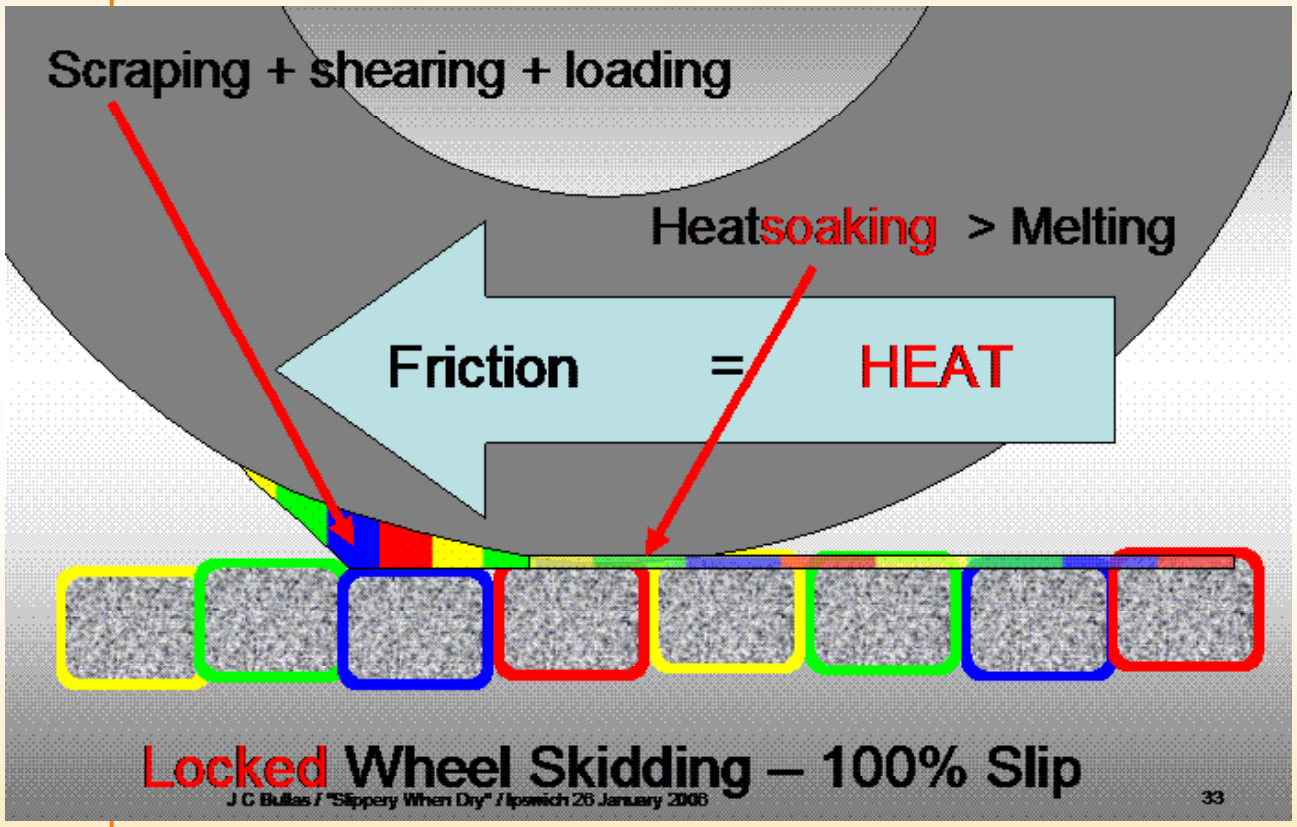




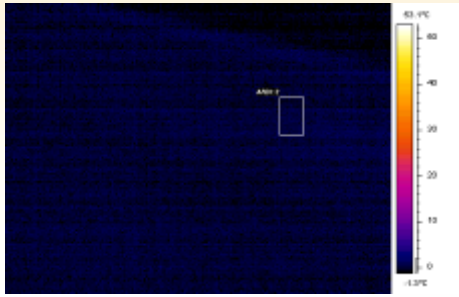


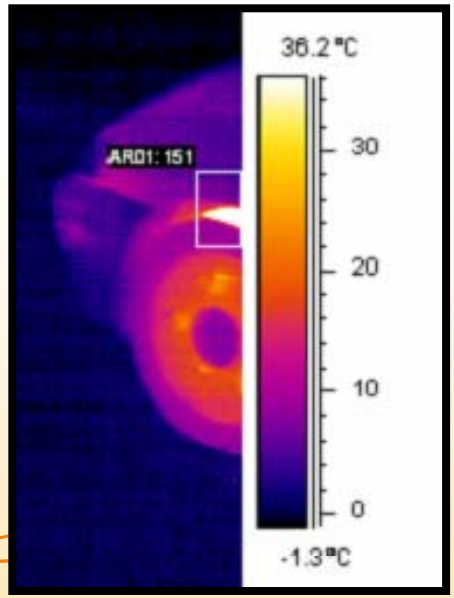


Is HEAT *really* causing the "bituplaning" event?

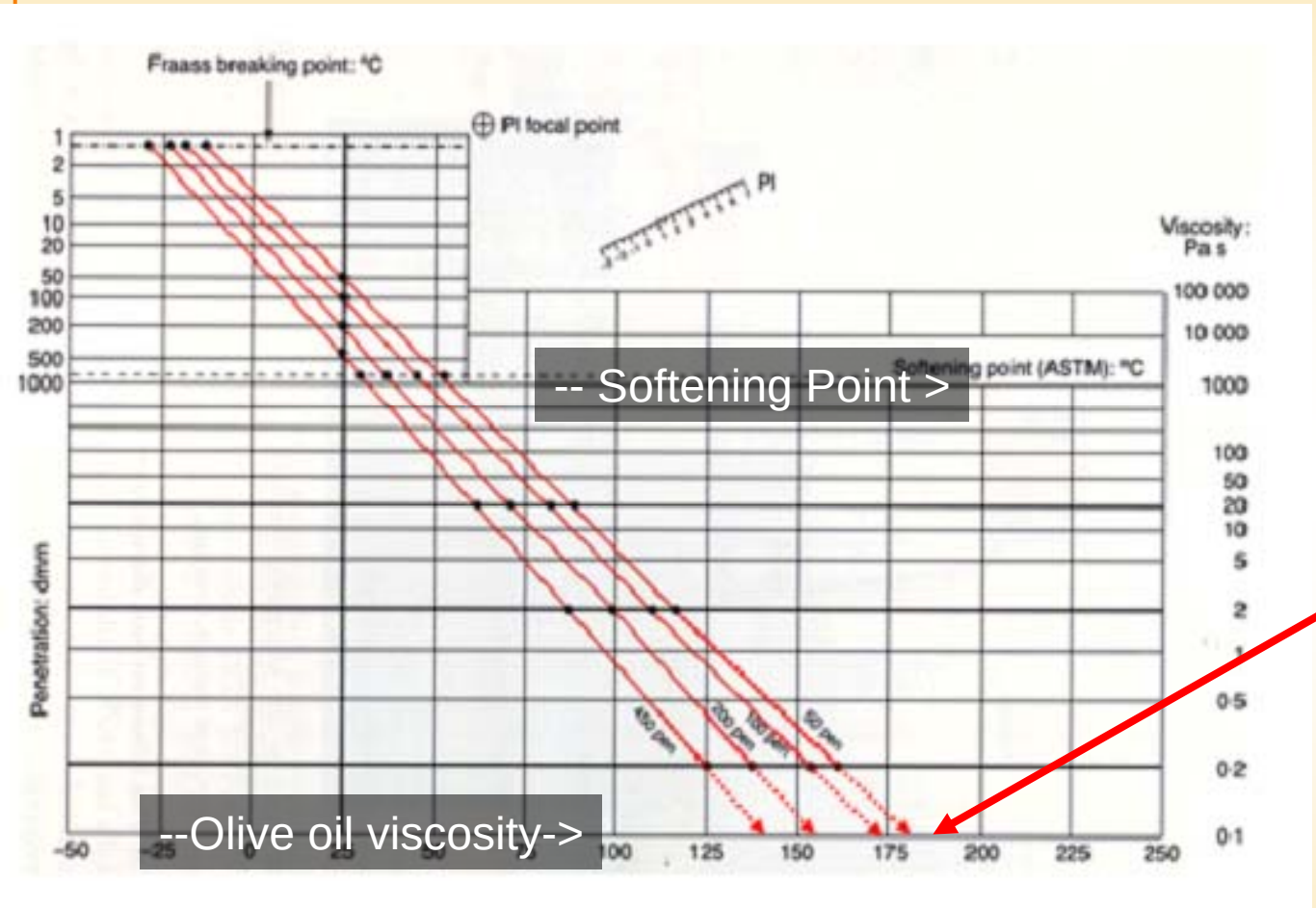


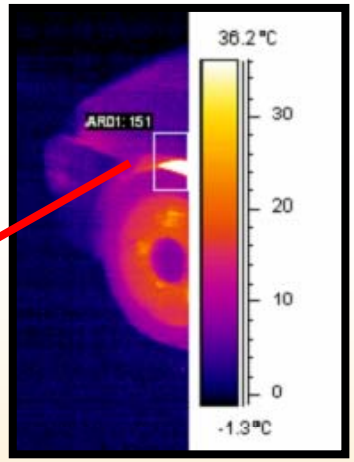
Hampshire Constabulary Testing at Winnall Waste Processing Facility





HEAT?: Typical Bitumen Properties with Temperature





Hampshire Constabulary Testing at Winnall Waste Processing Facility

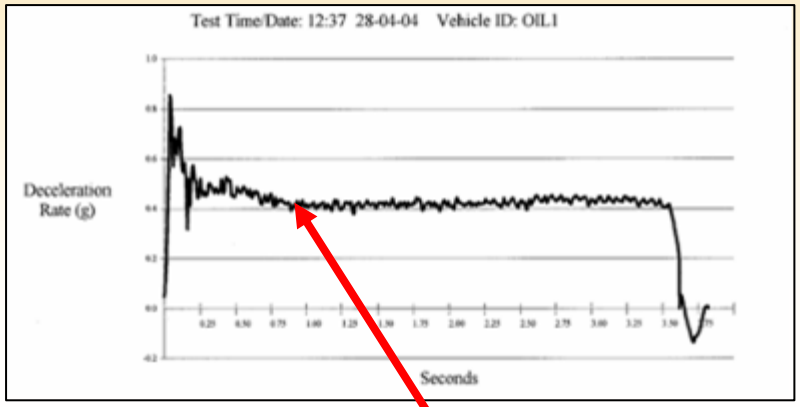
AFTER: READ, J. & WHITEOAK, D. (2003) *The Shell Bitumen handbook*, London, Thomas Telford.

SHEAR or HEAT? : Viscosities:

Fluid	Viscosity
Milk	**1.2 cP / 0.012 Pa·s**
Melted Butter	**18 cP / 0.18 Pa·s @ 140ºC**
Corn Oil	**30 cP / 0.3 Pa·s**
Cough Syrup	190 cP / 1.9 Pa·s
Auto Lube Oil SAE 40	200 cP **/ 2.0 Pa·s @ 100ºC**
Yogurt	1,100 cP / 11 Pa·s
Honey	1,500 cP / 15 Pa·s @ 100ºF
Mayonnaise	5,000 - 10,000 cP / 50 - 100 Pa·s
Tomato Paste	7,000 cP / 70 Pa·s
Corn Syrup	15,000 cP / 150 Pa·s
Toothpaste	20,000 cP / 200 Pa·s
Hot Fudge	36,000 cP / 360 Pa·s

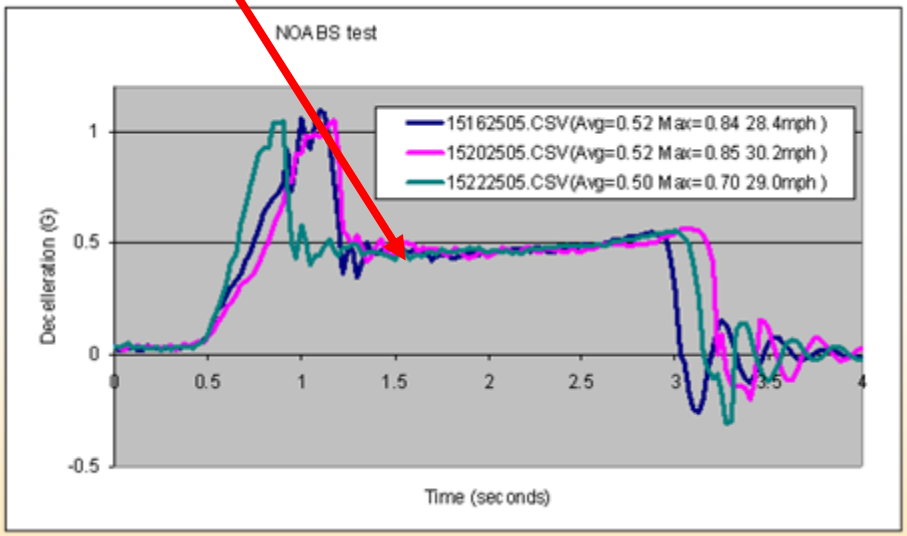
Dry Skid versus Skid on Engine Oil: Greasy

c/w Auto Lube Oil SAE 40 - 2.0 Pa·s @ 100ºC

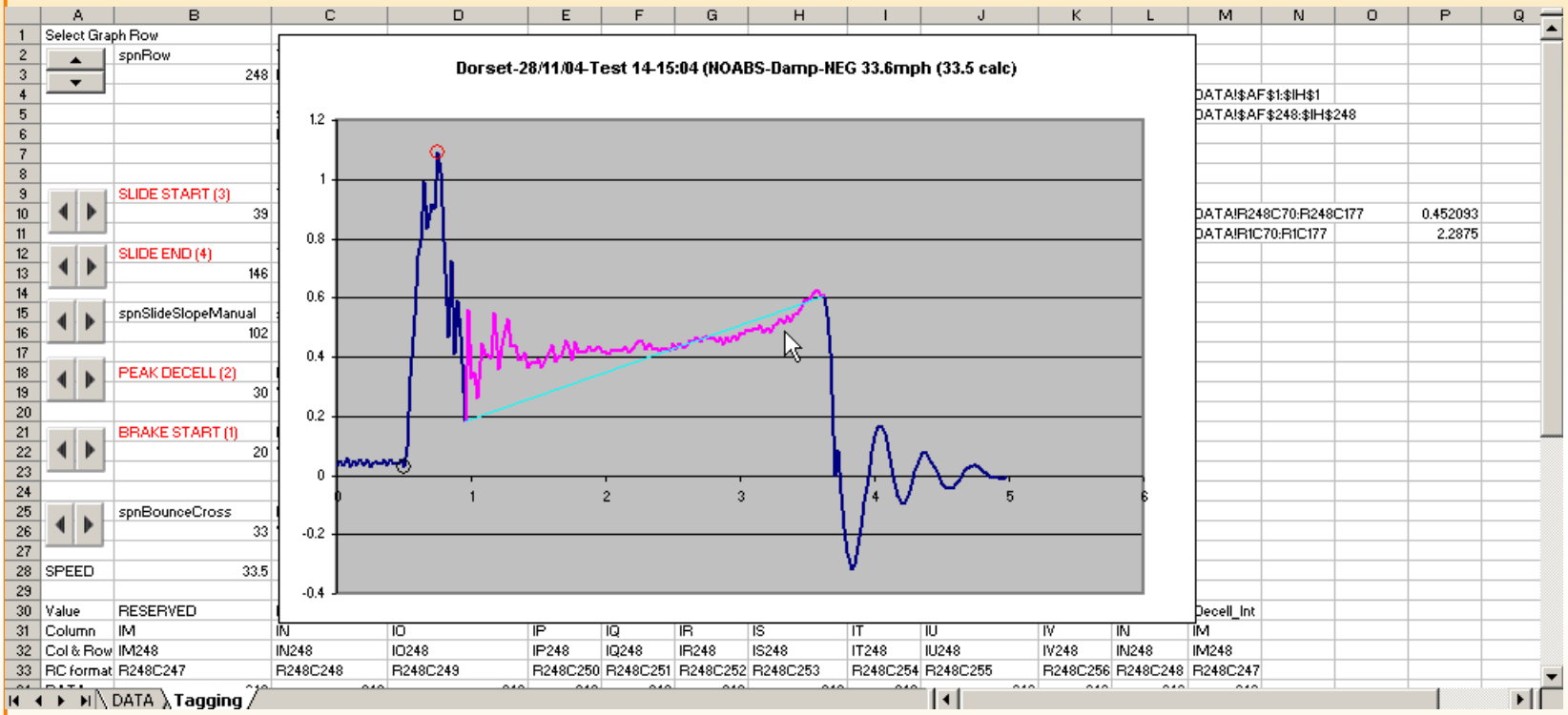


TRL

Atkins (Bullas, 2006)



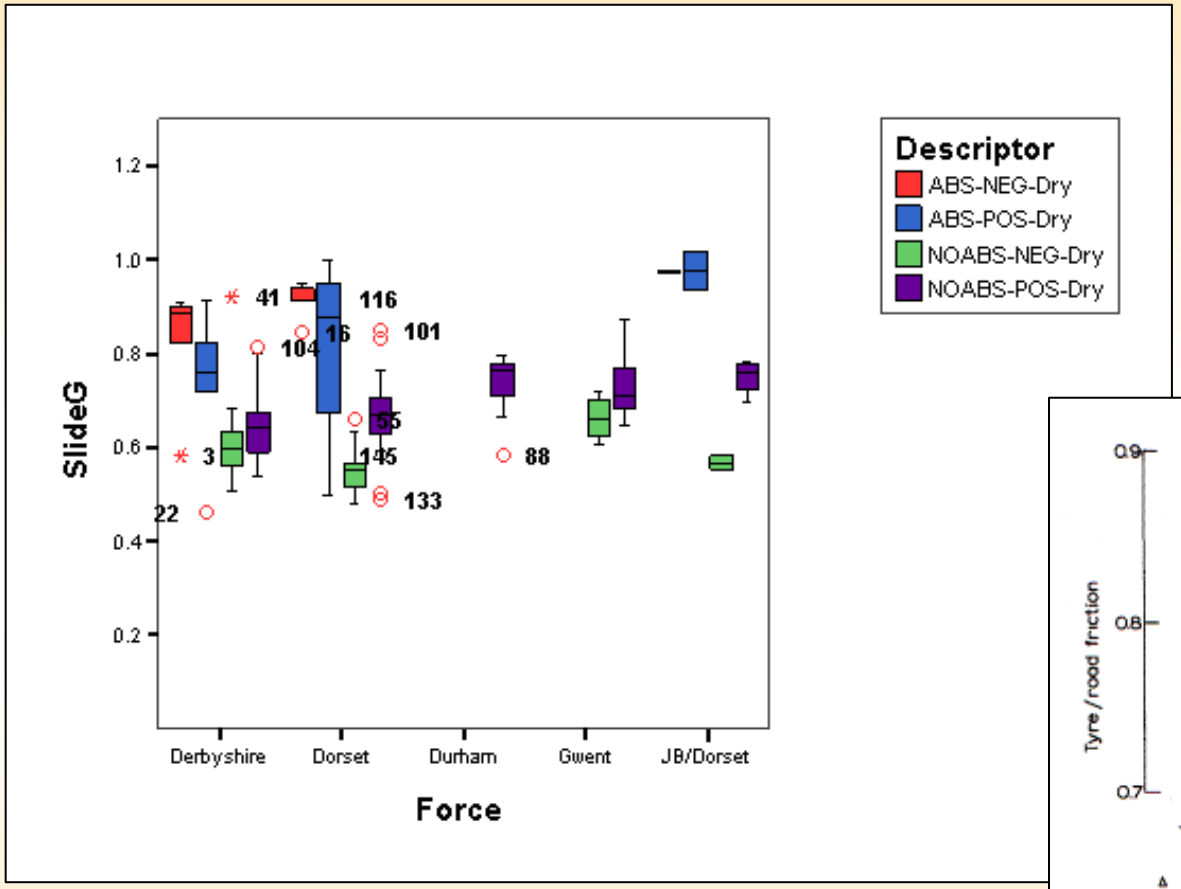
The Devil is in the detail.....



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

- To identify (and <u>statistically prove the significance of)</u> 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!



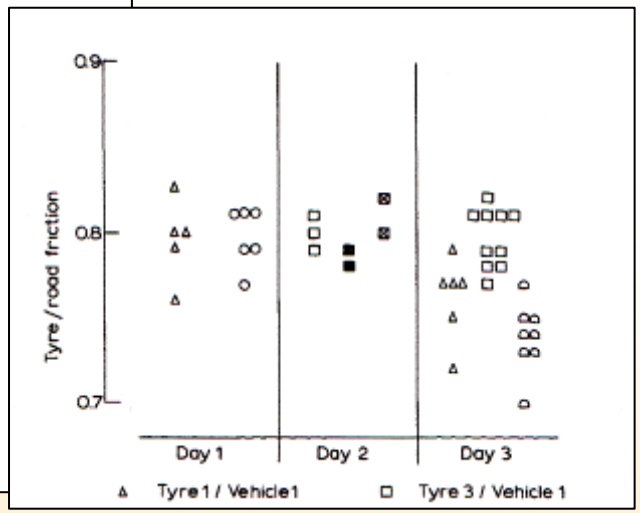
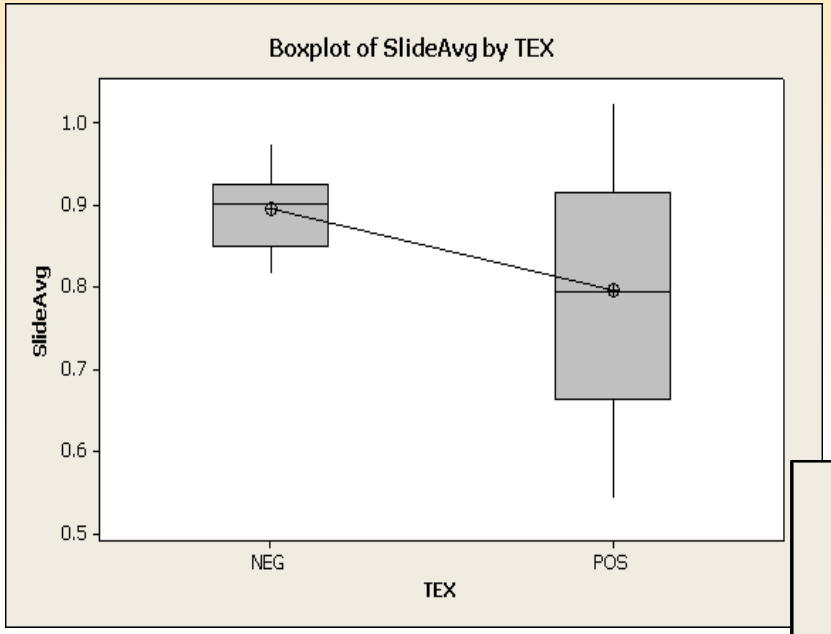


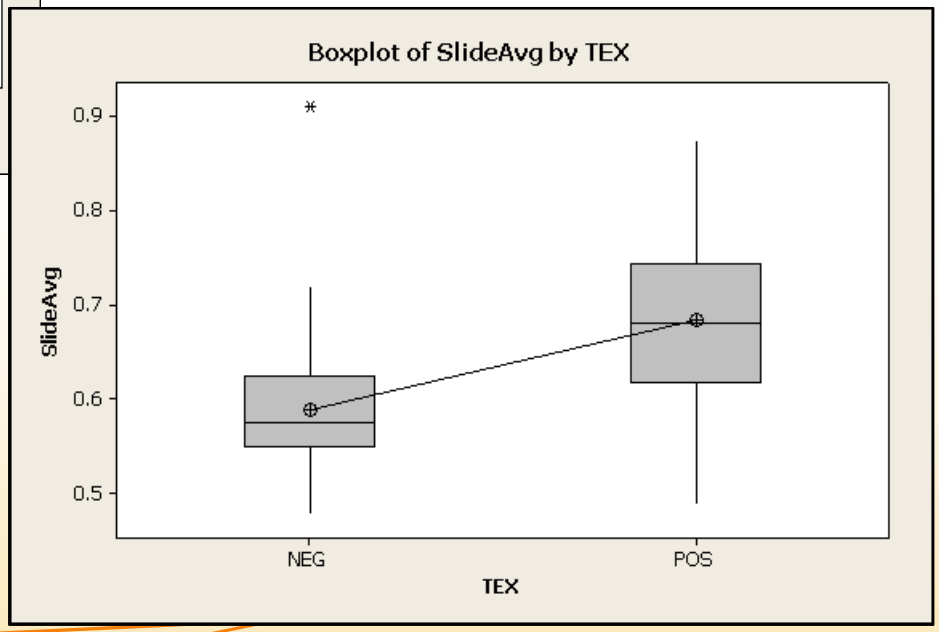
Figure 4 Variation in skid test friction measurements over three days (Rudram and Lambourn, 1981)

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

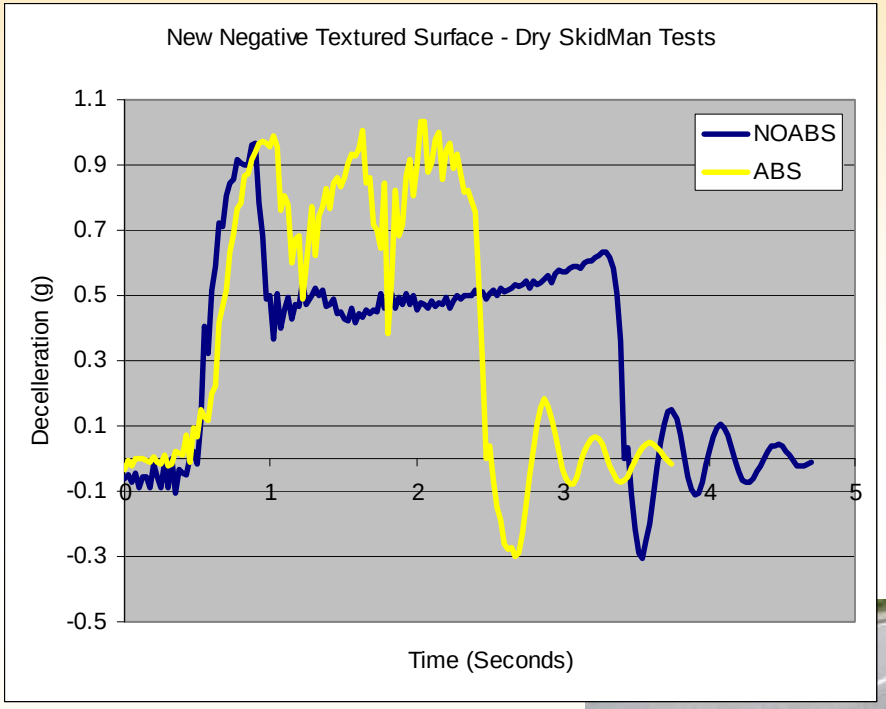
Statistically significant differences but NOT all new roads behave like this in the dry!

ARE THE LEVELS OF SLIDING DECELERATION SIGNIFICANTLY DIFFERENT BETWEEN….?	Significance Levels (MiniTab 14)
#1 (FOR THE SAME BRAKING SYSTEMS / SURFACE STATES BETWEEN THE "TEXTURES")	
NOABS Negative v Positive DRY	<1%
ABS Negative v Positive WET	12.8%
ABS Negative v Positive DRY	25.7%
NOABS Negative v Positive WET	80.2 %
#2 (FOR THE SAME SURFACE /SURFACE STATES BETWEEN THE BRAKING SYSTEMS)	
ABS v NOABS Negative DRY	<1%
ABS v NOABS Negative WET	5.5%
ABS v NOABS Positive DRY	5.6%
ABS v NOABS Positive WET	9.2%

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

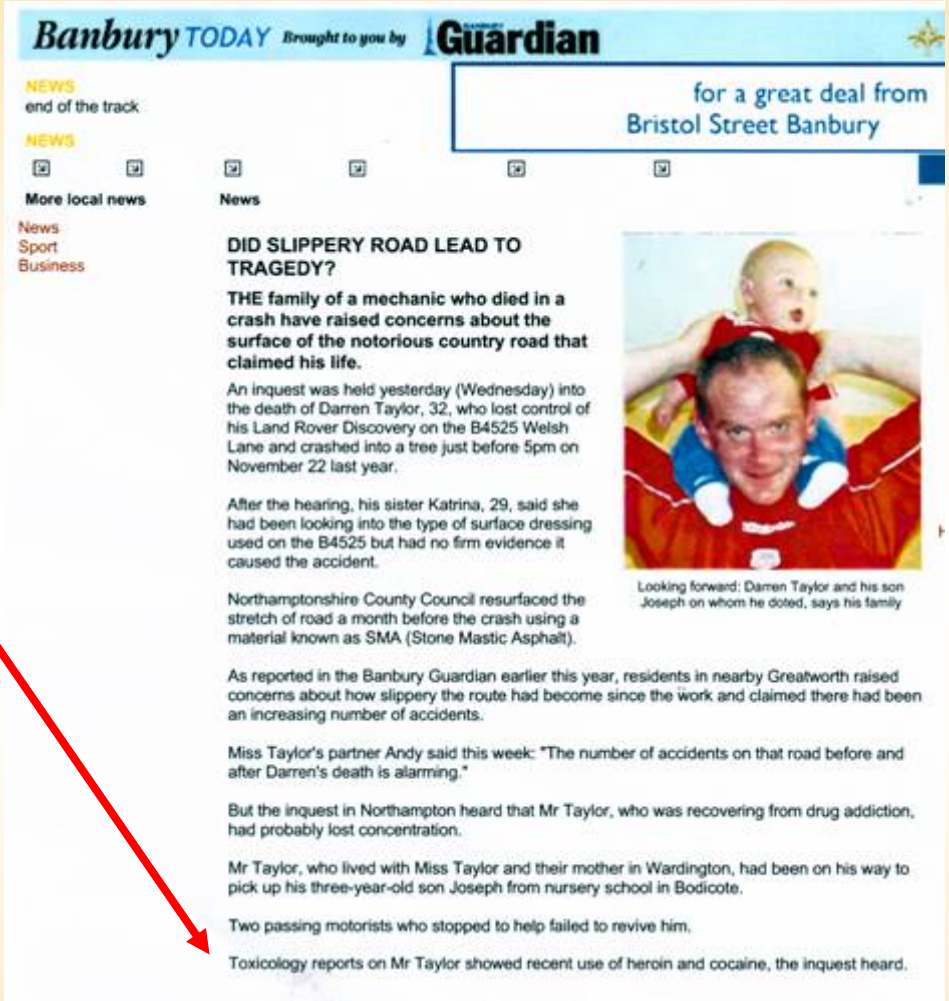
ABS Dashes


New Negative Textured Surface - Dry SkidMan Tests
1.1
0.9
0.7
0.5
0.3
0.1
-0.1
-0.3
-0.5
Decelleration (g)
0
1
2
3
4
5
Time (Seconds)
NOABS
ABS

“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



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DID SLIPPERY ROAD LEAD TO TRAGEDY?

THE family of a mechanic who died in a crash have raised concerns about the surface of the notorious country road that claimed his life.

An inquest was held yesterday (Wednesday) into the death of Darren Taylor, 32, who lost control of his Land Rover Discovery on the B4525 Welsh Lane and crashed into a tree just before 5pm on November 22 last year.

After the hearing, his sister Katrina, 29, said she had been looking into the type of surface dressing used on the B4525 but had no firm evidence it caused the accident.

Northamptonshire County Council resurfaced the stretch of road a month before the crash using a material known as SMA (Stone Mastic Asphalt).

Looking forward: Darren Taylor and his son Joseph on whom he doted, says his family

As reported in the Banbury Guardian earlier this year, residents in nearby Greatworth raised concerns about how slippery the route had become since the work and claimed there had been an increasing number of accidents.

Miss Taylor's partner Andy said this week: "The number of accidents on that road before and after Darren's death is alarming."

But the inquest in Northampton heard that Mr Taylor, who was recovering from drug addiction, had probably lost concentration.

Mr Taylor, who lived with Miss Taylor and their mother in Wardington, had been on his way to pick up his three-year-old son Joseph from nursery school in Bodicote.

Two passing motorists who stopped to help failed to revive him.

Toxicology reports on Mr Taylor showed recent use of heroin and cocaine, the inquest heard.

**BROUGHTON, J., MARKEY, K. A. & ROWE, D. (1998) A new system for recording contributory factors in road accidents. Crowthorne, TRL.

Thank you for listening!

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Research Support from: