Slippery when DRY? - Low dry friction and binder-rich road surfaces

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ABSTRACT

Highway engineers believe that wet, rather than dry, road surfaces deliver the lowest levels of surface friction.

A mechanism that could lead to the generation of low levels of surface friction on the road surface, by the action of a locked tyre sliding over a dry binder-rich road surface, was first postulated in 1944. This phenomenon, termed “bituplaning” by some highway professionals, has been shown to occur on a number of binder-rich road surfaces in Europe.

This paper describes the history of the bituplaning phenomenon, documents its occurrence in the literature and briefly describes the development of one standard procedure to alert the road user to the inherent risk.

Bituplaning has previously been documented twice in the United Kingdom, first in 1986 then in 2001. The first case of bituplaning related to a “traditional” hot-rolled-asphalt (HRA) surface, reinforcing the belief that any surface course aggregate coated with excess binder could exhibit the bituplaning effect.

The bituplaning phenomenon has been shown not to occur when ABS (Anti-Blockier-System, anti-lock braking) is in operation.

A number of experiments to measure the temperatures generated at the tyre/road interface of a locked wheel on a dry road surface are also described, along with comments concerning features of negative textured road surfaces, which though divorced from the frictional properties, may influence road user behaviour to increase accident rates on these new surfaces.

Various strategies for signing new surfaces are in operation in the UK . A standard, based on detailed research, is already in place to monitor and warn road users of the manifestation of the bituplaning phenomenon on new porous asphalt surfaces in the Netherlands.

Suggestions are given as to the basics of an effective signing strategy to alert road users to the risk of bituplaning.

1 INTRODUCTION

Highway engineers believe that wet, rather than dry, road surfaces deliver the lowest levels of surface friction. This belief is born of many years of studying the wet frictional characteristics of surfacing materials such as chipped hot rolled asphalts (HRA) with their 'positive' macrotextures and relatively thin (if any) bituminous coatings on the aggregate particles embedded in them (See Figure 1 below for an idealised typical positive macrotexture).

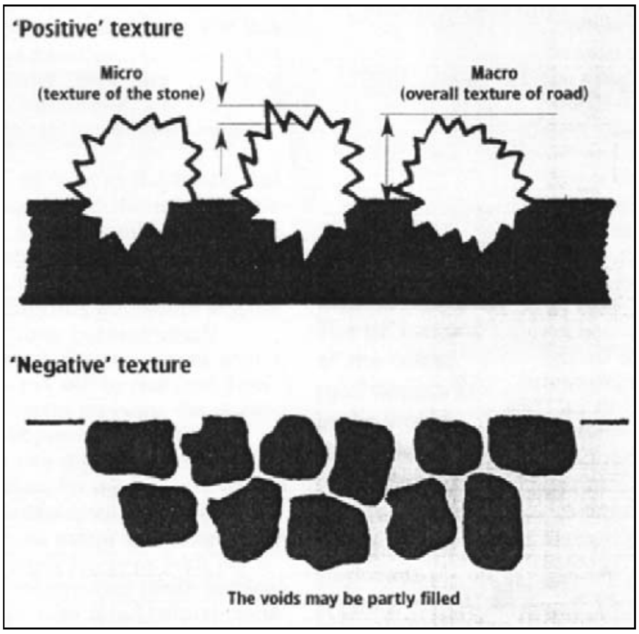

Figure 1: Idealised positive and negative macrotextures (from Walsh, 2000).

The UK Highways Agency's Design Manual for Roads and Bridges (Highways Agency, 2005) states*:*

*"**In practice, it is found that the skid resistance measured on dry, in service road surfaces is generally high**, but lower and more variable measurements are obtained when the same road surfaces are wet or damp. For this reason, measurements of skid resistance for the purpose of routine condition monitoring are made on wetted road surfaces."*

However, recent innovations in road construction have resulted in the increasing use of "negative textured" pavement surfacing materials (see Figure 1 above for an idealised negative textured surface). The bituminous coatings of these particular materials are commonly thicker and may possess properties necessary for long term

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durability but less than ideal for the rapid generation of the direct tyre/aggregate contact necessary for the delivery of optimum skidding resistance.

Thus these negative textured road surfacings may produce surface friction characteristics that challenge the widely held belief that uncontaminated bituminous road surfaces cannot be “slippery when dry”.

This paper does not attempt to describe the use of police test devices in the calculation of collision dynamics, this would be a paper in itself, nor does it attempt to describe in great detail the research already undertaken in this area by other European researchers, the reference section will satisfy those who wish a comprehensive understanding of the issues discussed here. This paper aims to inform the Highway Engineer of the past history of the low dry friction phenomenon and its recent association with the new generation of binder-rich negative textured road surfaces rapidly proliferating around the highways of the world.

2 BACKGROUND

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In 1944 E Zipkes (Zipkes, 1944) postulated:

“On some road surfaces, the melting point of the binder….(the bituminous layer) …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”.

This may have been the first suggestion that a bituminous coating could directly contribute towards the overall frictional characteristics of the road surface.

Zipkes work was later summarised in a more accessible British publication (DSIR, 1963). Figure 2 below is reproduced from this work.

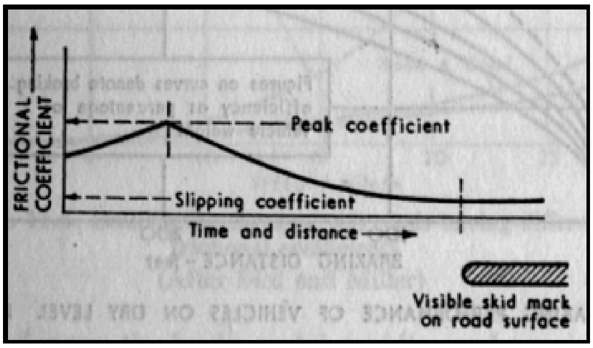

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Figure 2: Zipkes postulation regarding locked wheels and surface friction (DSIR, 1963)

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2.1 BITUPLANING: A NEW TERM TO DESCRIBE THE PHENOMENON

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The generation of low levels of surface friction as a result of the presence of a thick bituminous layer between the tyre and the road surface has been described by some highways professionals as “bituplaning”. This term has also been adopted by the researcher.

The dynamics of *aqua*planing are broadly understood by many but commonly misunderstood in detail, (Gallaway et al, 1979). In the case of *bitu*planing, the bitumen layer is thought to generate a low level of friction, just as a thick film of water does (but to a greater degree) when it gets between the tyre and the surface course aggregate during aquaplaning (or hydroplaning, as it is termed in the US).

At this point it is valuable to discuss some of the published literature documenting the occurrence in real life of the phenomenon Zipkes postulated half a century ago.

2.2 HISTORICAL EVIDENCE

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On the 23rd June 1986, a multiple vehicle collision on the M4 motorway in Berkshire UK (4 vehicles, 13 deaths) was investigated by Graham Shelshear of Thames Valley Police who observed:

“The worst dry skid resistance… in ten years of testing road conditions”
(Shelshear, 1986)

These values of dry friction he also described as

“Abnormally low…..”
(Shelshear, 1998).

Shelshear suggested that the low level of dry friction on the road surface was caused by an excessively thick layer of bitumen on the pre-coated chippings used in the hot-rolled asphalt (HRA). This idea was greeted with the following comment from Associated Asphalt: they had ***“…never heard such rubbish’”*** and Shelshears’ thoughts were considered ***“not credible”*** by Wimpey Hobbs, the surfacing contractors.

A more rigorous approval process for pre-coated chippings may well have resulted from this incident but the fact this was an early manifestation of bituplaning on a “traditional” road surface, appears to have generally been forgotten about.

2.3 RECENT RESEARCH

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2.3.1 DWW (Netherlands): Research on low dry friction porous asphalt

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Porous asphalt (a negatively textured freely draining road surfacing material) is the material of choice for the motorways in the Netherlands. The investigation of a crash in 1991 prompted research that subsequently has set a benchmark for the measurement and specification of acceptable levels of in-service DRY friction.

Skid tests by the police at the scene of an accident on a new porous asphalt, in dry conditions, initially suggested a carriageway speed well in excess of the true speed of the vehicle later determined from other evidence and a reduced level of DRY friction was ultimately shown to be the cause of the over estimate. (J Fafié, 2004)

Research carried out by DWW (Dienst Weg- en Waterbouwkunde) (Bennis & Leusink 2000) identified widespread extended DRY stopping distances on new porous asphalt when ABS (Anti-Blockier-System, anti-lock braking) braking was turned off and the wheels were free to lock.

Figure 3 below (from Jutteo & Siskens, 1997) illustrates the deceleration profiles obtained during skid car tests on new porous asphalt, with ABS (graph c), without ABS (graph a) along with a control test on dense asphalt (graph b).

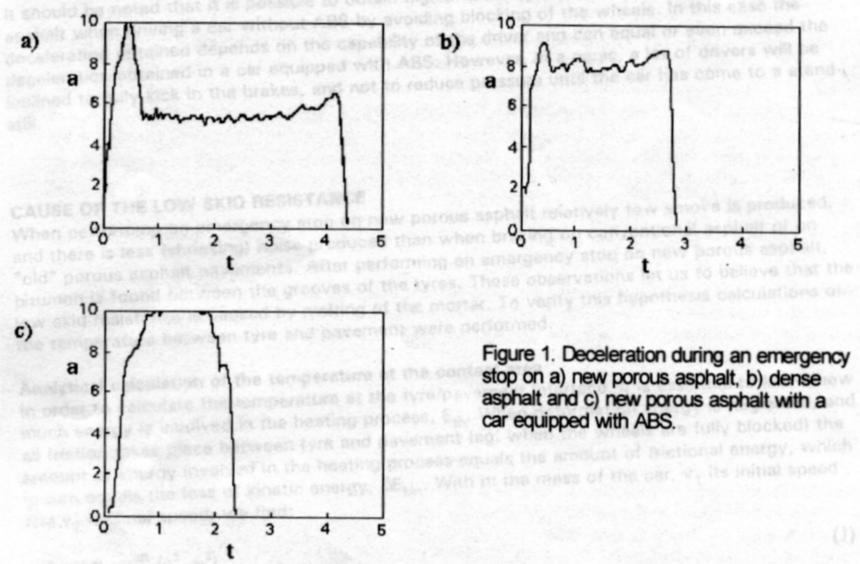

Figure 1. Deceleration during an emergency stop on a) new porous asphalt, b) dense asphalt and c) new porous asphalt with a car equipped with ABS.

Table 1. Deceleration, a, during an emergency stop and skid resistance as measured with Dutch standard measuring device on different pavements

pavement type	a (m/s^2)	f
porous asphalt, newly laid	6,0	0.61
polymer modified asphalt, 11 months old	6,7	0.60
porous asphalt, 3 months old	6,7	0.50
porous asphalt, 1 year old	7,0	0,45
dense asphalt, 3 years old	8,0	0.43

Figure 3: Deceleration plots on various surfaces (from Jutteo & Siskens, 1997).

The NON ABS test on new porous asphalt (graph a) gives a deceleration plot with a short period of peak friction (the maximum deceleration level shown in m/s^2) followed by an extended period of far lower sliding friction (the remainder of the deceleration of the skid test car to a standstill). This “high peak” and “low slide” is characteristic of the bituplaning phenomena identified in both the earlier work by Shelshear and in later works yet to be discussed. The duration of the braking manoeuvre is noticeably

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longer on the same surface with the same test vehicle at the same speed simply by turning the ABS off: compare graphs a and b from Figure 3.

The research progressed to the development of a dry friction testing trailer to replace car skid tests to avoid the associated necessary road closures for testing, and then to the drawing up of a specification for an acceptable level of routinely measured dry friction on porous asphalt, to enable the signing of the risk to be managed in a manner proven to be effective statistically. An example of the sign used to warn drivers is shown in Figure 4c, below.

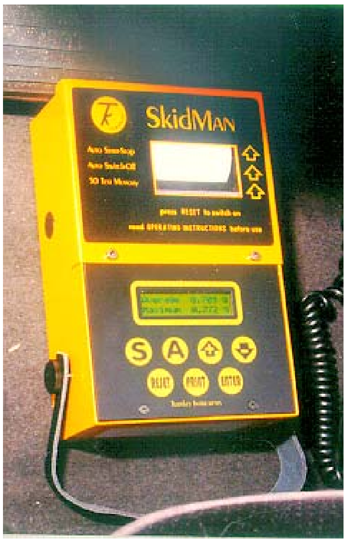

Figure 4a: Turnkey Instruments Skidman decelerometer used to estimate coefficient of friction (Mu – μ) from the results of controlled skid tests using the collision vehicle or investigation vehicle (Photo from Turnkey Instrument Ltd)

Figures 4b & 4c : Warning signs used in Derbyshire UK (Photo from Derbyshire Police) and on Dutch Motorways on Porous Asphalt - "longer braking distance, new road surface" to alert drivers of new road surfaces (Photo from DWW)

The research carried out by DWW was reported in the proceedings of an international symposium on porous asphalt in 1997 (Jutteo & Siskens, 1997), however the fact that porous asphalt was not (and still is not) in common use in the UK at that time may have limited the dissemination of this valuable work to the highway engineers across the Channel.

2.3.2 TRL and Derbyshire Constabulary: Research for Derbyshire County Council on Certain SMA Surfaces

A research report commissioned by Derbyshire County Council in 2001 (Derbyshire County Council, 2001) described an investigation (using the Skidman (shown in Figure 4a below), Pavement Friction Tester (PFT - Dynatest 1290) and SCRIM) of the frictional characteristics of negative textured road surfaces associated with two fatal collision locations.

The Police had initially identified low levels of dry friction for non ABS braked vehicles via decelerometer tests using the Skidman device.
Though probably unaware at the time, the findings of the Police in Derbyshire strongly mirrored those which prompted the initial investigation by DWW described above, nearly 10 years earlier.

Though the circumstances of the two fatal crashes were complex and were not attributable to the road surfaces, the occurrence of bituplaning appears to have prompted a local policy of alerting road users to the presence of new bituminous surfaces with a "slippery road" warning sign (Figure 4b illustrates a typical sign in use), however no policy of follow-up dry friction testing appears to exist to trigger the subsequent removal of this signing; as already discussed a policy does exist for motorways in the Netherlands (Bennis & Leusink 2000) and Figure 4c below shows a typical sign in use there.

Considerable interest was generated within the UK road engineering and road safety communities as a result of the Derbyshire investigation, and an interim guidance note was issued by the HA to advise on a strategy for warning signs on new bituminous surfaces of ALL types (Highways Agency, 2003).

The TRL Derbyshire report identified:

"A significant coating of binder on the SMA (Stone Mastic Asphalt) at both sites".

"The thick binder film was obscuring any microtexture on the surfaces of the aggregate particles".

"The Skidman tests in dry conditions gave levels of friction…. similar to those obtained in wet conditions".

"It is generally considered that, in dry conditions, road/tyre friction is high and largely independent of speed. This work has demonstrated that, although the skid resistance of relatively new SMA may be adequate in wet conditions, in the exceptional circumstances of dry locked-wheel skidding the friction available may be markedly lower than for most dry road surfaces. "

The following observation was also made:

"Although lower than expected, the dry friction of the SMA was no worse than for the usual worst case of wet friction at intermediate speeds".

The question must be asked, is the ‘typical driver’ prepared for dry roads which under extreme braking can be: “no worse than for the usual worst case of wet friction”? Are they prepared for road surfaces which may perform in a way unlike that previously experienced in the dry? Research appears lacking to either reject or confirm these suggestions.

More “progressive” drivers/riders might generally expect dry roads to deliver higher levels of grip than wet ones (unless visibly contaminated); do they then drive “as hard” as their past experiences of dry roads suggests is “safe”?

2.3.3 Common Elements Between the Earlier Works

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Neither the earlier work by Shelshear in the 1980s nor the findings of DWW in the 1990s were mentioned in the TRL Derbyshire report (though the M4 crash was discussed in a later TRL document including some of the Derbyshire findings (SCI, 2002)); this would have highlighted the fact that other negative textured surfaces, and indeed other more traditional materials such as HRA with pre-coated chippings, had already been seen to share the potential to exhibit bituplaning despite having acceptable frictional properties in WET conditions.

Neither of the reports by Shelshear (1986 & 1998) or TRL (Derbyshire County Council, 2001) included deceleration (or peak/sliding friction) plots, thus making direct comparison between the dynamics of the bituplaning events impossible. The 1980’s investigation is likely to have lacked the technology to deliver this kind of output. An unpublished pamphlet by Graham Shelshear (Shelshear, 1993) which formed a revision of a paper originally circulated in 1988, did however include the output of from a Motormeter brake performance tester: this output bore a good similarity to the “high peak / low slide” deceleration form shown in the later work by Jutteo and Siskens.

2.4 ONGOING RESEARCH

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This paper describes some of the research being undertaken by John C Bullas, a PhD researcher from the Transportation Research Group of the University of Southampton.

This work is attempting to address issues raised during a desk-based study of the tyre-road interface carried out by the Researcher for the AA Foundation for Road Safety Research (now the AA Motoring Trust) in 2000-2003.

Early life friction research is also ongoing at TRL as a joint Highways Agency (HA) /CSS (formerly the County Surveyors Society) project; this research appears to have been prompted by the great interest, and concern, shown throughout the UK highway engineering community regarding the events that took place in Derbyshire in 2001.

3 METHODOLOGY

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3.1 SURFACE FRICTION AND COLLISION DATA COLLECTION

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The UK Design Manual for Roads and Bridges (Highways Agency, 2005) states:

"Police skid tests are carried out in differing conditions and are used at accident sites to assist in accident reconstruction. They are frequently made in dry conditions. The measurements are not suitable for assessing whether a road surface is substandard or in need of remedial treatment."

The Manual continues:

"*However, **if a dry skid test** indicates a lower than expected dry road skid resistance, this should be drawn to the attention of the highway authority so that the cause can be investigated*"

The Skidman was thus considered a suitable tool for the purpose of investigating dry skid resistance and to identify any occurrences of bituplaning.

Shelshear commented in his report on the M4 crash in 1986, that the SCRIM device was unsuitable for measuring dry friction; the Findlay Irving Grip Tester is equally designed only for wet testing. The only devices readily accessible for the measurement of dry road friction are the Turnkey Instruments Skidman decellerometer, the Vericom VC Series decelerometers and the Dynatest 1290/95 Pavement Friction Tester (PFT). The PFT can deliver a direct output of friction throughout the test wheel locking event of a form not dissimilar to that of the deceleration plots from Skidman, to be discussed later.

Working within the financial constraints of a very limited research budget, devices such as the SCRIM and the PFT could not be utilised, however Skidman deceleration skid tests are being routinely carried out by professional collision investigators at the scene of most fatal and life threatening collisions in the UK. Thus approaches were made, following a number of presentations to senior collision investigators, to work closely with Police Forces nationwide to:

1) Compile details of any collisions where the frictional characteristics of new surfaces (other than external contamination) were considered pivotal in the circumstances of the collision.

2) Obtain the Skidman decelerometer data collected during ALL valid Skidman tests executed pursuant to collision investigations, along with details of the braking system used, surface conditions and broad surfacing type. The surfacing type being determined using both the experience of the investigating officer and with reference to a photographic identification guide produced with the assistance of a local authority technical advice group. Photographs of the road surfaces at the scene are also accompanying a small number of the data submissions.

It should be noted that statistical evidence based on police collision records suggests that very few collisions are contributed to by the surface conditions of the road where they occurred (Broughton et al, 1998), The collection of data from collision sites therefore should not be viewed as sampling from a non-representative population of road surfaces. In any case the budgetary constraints of the research precluded the use of routine dry friction measurement devices, the cost of using a PFT was estimated at approximately £750-£1000 per day.

It was hoped that the data collected would deliver a better understanding of the frictional characteristics of road surfaces in general as measured by the Skidman device, but more specifically shed light on the nature of the bituplaning phenomena already observed by TRL in Derbyshire, by Shelshear on the M4 and by DWW in the Netherlands

The level of Police interest in the project has varied between forces, very few have not be willing to assist, many have actively sought to submit data and a small number have offered to carry out regular testing of specific sections, as a surrogate for the expensive SCRIM and PFT testing.

Data collection has been taking place since late 2003, using an MS-DOS SIMRET package and a SKIDCALC cable kindly provided by Turnkey Instruments.

Typically the Skidman devices are downloaded at the individual police units but exceptionally this is done by Turnkey Instruments during routine servicing or by the police themselves, using SIMRET and the forces own data transfer cable.

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3.2 EXPERIMENTAL TRIALS

3.2.1 Skid testing

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To extend the knowledge of the behaviour of binder-rich surfaces in the dry when exposed to the action of a sliding locked tyre, a number of experiments have been undertaken. These have attempted to directly measure the temperature generated between tyre and road surface during locked wheel braking on dry roads, these temperatures have been mathematically estimated at in excess of 350°C by Dutch workers (Jutteo & Siskens (1997).

Initially skid tests were carried out using a Vauxhall Astra vehicle (with switchable ABS) belonging to Devon & Cornwall Police, instrumented with Datron infrared sensors and GPS equipment.

The Vehicle speed, wheel rotation and temperature sensors' outputs enabled the period of locked wheel skidding to be identified. Non contact infra-red sensors were used to measure the temperatures generated both on the road surface and on the surface of the tyre in contact with the road during the skid, as the "hot patch" on the tyre could be measured as it "rolled out" of the contact area as the vehicle rolled forward following braking.

Hampshire Constabularies collision investigation vehicle (Ford Galaxy) was later used in skid tests which were recorded using a FLIR Systems high speed infra-red video camera.

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3.2.2 Investigation of the influence of negative textured surfaces on critical path behaviour

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A number of collision investigators have raised possible concerns over the frictional behaviour of negative textured surfaces at the point of loss of control during attempted cornering or evasion manoeuvres.

Collision investigators place a lot of importance on the skid marks left by a vehicles' tyres as it crosses a "critical path" beyond which it loses control. A number of cases where the critical path marks have been absent for incidents involving negative textured surfaces in the dry, where the investigator would normally have expected to "see marks", have been brought to the attention of the researcher.

Investigation of this "critical path" behaviour is presently **outside of the scope of this project** both logistically and financially, however this does not mean it cannot be investigated in the future. Such an investigation would require complex instrumentation, a duplicated expanse of different road surfaces and tightly controlled driving.

4 RESULTS & OBSERVATIONS

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4.1 SKIDMAN DECELEROMETER DATA COLLECTION AND ANALYSIS

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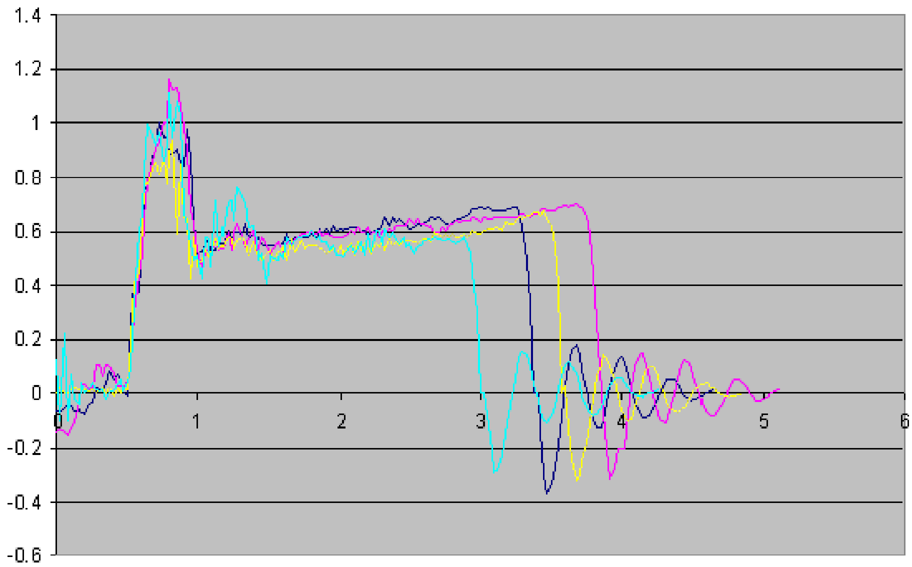
The output from over 1000 Skidman deceleration "events" have been collected with matching supporting information being assembled as an ongoing exercise; this work is in tandem with the downloading of additional Skidman tests and day-to-day liaison with collision investigation teams nationwide to extend the database.

Work is also ongoing to combine the individual 250+ data points (two- to five-second deceleration event recordings) with the associated braking system, surface condition and surfacing type information in an attempt to develop a number of representative models for different surfacing types. Critical markers such as the time between the achievement of peak friction and the onset of sliding friction, the magnitude of both and the slope of the curve during sliding friction are being established for each deceleration event.

The contrasts between wet and dry frictional values for the same road were discussed both by TRL (Derbyshire County Council, 2001) and by workers in the Netherlands (see Figure 3 and elsewhere in Jutteo & Siskens, 1997). Table 1 shows a limited analysis of the database of maximum and average deceleration values (as calculated internally by the Skidman), this also appears to suggest that SMA shows the greatest proportional difference between maximum and average deceleration of the road surfaces documented

Initial evidence has also been collected that suggests a greater proportional difference between peak and sliding friction for dry negative texture SMA type surfaces than for either wet SMA or other wet traditional "positive texture" surfaces. This contrast can be seen in the decelerometer plots already illustrated for SMA and Porous Asphalt and it is also tabulated in Table 1 below for the results from one police force.

The most valuable result of this area of the research to date is shown in Figure 5. Skidman deceleration outputs for NON ABS tests in the UK on a number of negative textured surfaces show a broad similarity to the general form of those obtained for skid tests on porous asphalt in the The Netherlands where bituplaning was identified (as discussed earlier and shown in Figure 3).



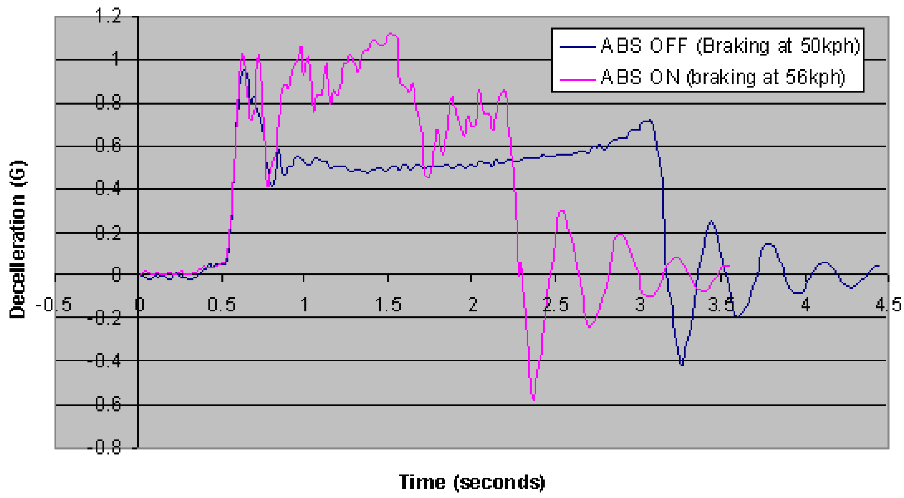


Figure 5: Top: A typical sequence of dry ABS OFF Skidman tests carried out on DRY new SMA (Y axis: deceleration in G, X axis: time in seconds). Bottom: Comparison between ABS ON and ABS OFF skidding tests for a dry/damp one month old thin surfacing (negative textured but not SMA)

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4.2 STUDY OF UK COLLISIONS AS PART OF THE DATA COLLECTION PROCESS

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There are indeed circumstances where the bituplaning phenomenon has been

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identified from the analysis of Skidman data collected at the scene of collisions, but to date **there has been no evidence of any fatal or near-fatal collision precipitated or significantly contributed to by the bituplaning phenomenon.**

4.3 EXPERIMENTAL TRIALS

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The results of the initial emergency braking manoeuvres (on a dry negative textured surface) using infra-red sensors were inconclusive, as there was a lack of confidence in the extrapolation of the limited and indirect temperature measurements of the tyre contact patch made after the braking event. After a single NON ABS emergency stop (Figure 6), a temperature of approximately 70˚c was measured on the road surface, (with an ambient temperature of only 30˚c, a 40˚c increase after one manoeuvre), and a temperature of approximately 55˚c was subsequently measured on the "rolled out" tyre contact patch, also with a pre-test temperature of approximately 30˚c, a 25˚c increase after one manoeuvre.

Further experiments on a closed road on NEW HRA using a calibrated FLIR Systems infra-red camera not only identified a difference in the temperatures generated on the road surface between ABS and non ABS braking and visualised the heating of the road by ABS braking, but also enabled a temperature of 150°C to be directly measured on the tyre surface immediately after locked wheel braking (ambient temperature was approaching freezing, refer to Figure 7 for a snapshot of the IR video recorded)

Direct visualisation of the temperatures generated during a NON ABS dry skid event have supported earlier work (Jutteo & Siskens, 1997) suggesting temperatures are generated between tyre and road surface that may well be capable of melting or softening the bituminous layer and generating the reduced levels of surface friction observed during a bituplaning event.

The Dutch work did however suggest theoretically calculated temperatures in excess of 350˚c

The most valuable outcome of this work is the confirmation that temperatures considered well in excess of those necessary to soften/melt bituminous materials can be measured during locked wheel braking events (braking events very similar in type to those carried out in previously investigations of the bituplaning phenomenon).

4.4 HOW TO ALERT THE ROAD USER TO THE POSSIBLE RISK OF BITUPLANING?

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The logical approach undertaken in the Netherlands to the signing, testing, and subsequent removal of signing, designed to alert the road user to the specific risk of bituplaning should be taken as a good example of the strategy to adopt elsewhere.

The use of ambiguous signage suggesting a WET rather than DRY friction problem, if combined with a lack of initial and/or ongoing monitoring of the frictional problem, could potentially expose both road user and maintaining authority to unnecessary risk.

A proliferation of warning signs accompanying the appearance of every new length of

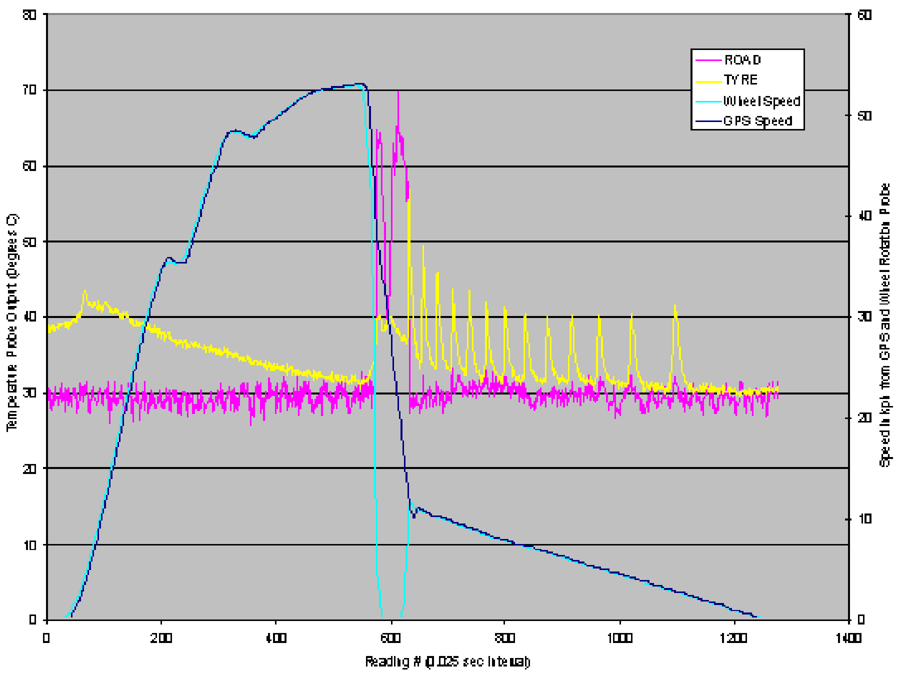

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Figure 6: Sensor outputs during a locked wheel braking event on a negative textured surfacing: NO ABS, lock-wheel test vehicle skidded to 10 kph and then rolled forwards (Light blue: wheel speed, blue: vehicle speed, yellow: temperature sensor looking at back of tyre, pink: temperature sensor looking at road behind tyre)

surfacing does not deliver the right message to those who may both drive upon and indeed fund the new construction from their local or national taxation:

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"Why has the new road got a warning sign on it when the old one did not?" *……they may ask.*

Location and traffic effects are already taken into consideration in the interpretation of wet skidding requirements (Highways Agency, 2005), the same should be considered when attempting to estimate the longevity of the bituplaning phenomenon between locations

Without a proven justification for both their erection and subsequent removal, the use of warning signs to highlight the risk of bituplaning could, at the least, generate negative PR for the Authorities involved and, at the worst, possibly contribute to the outcome of litigation if either a sign is removed prematurely before the dry friction is acceptable or the message given by the sign is ambiguous or misunderstood.

If an engineer believes there is a problem "in the dry", should a sign typically understood to indicate a problem "in the wet" be used?

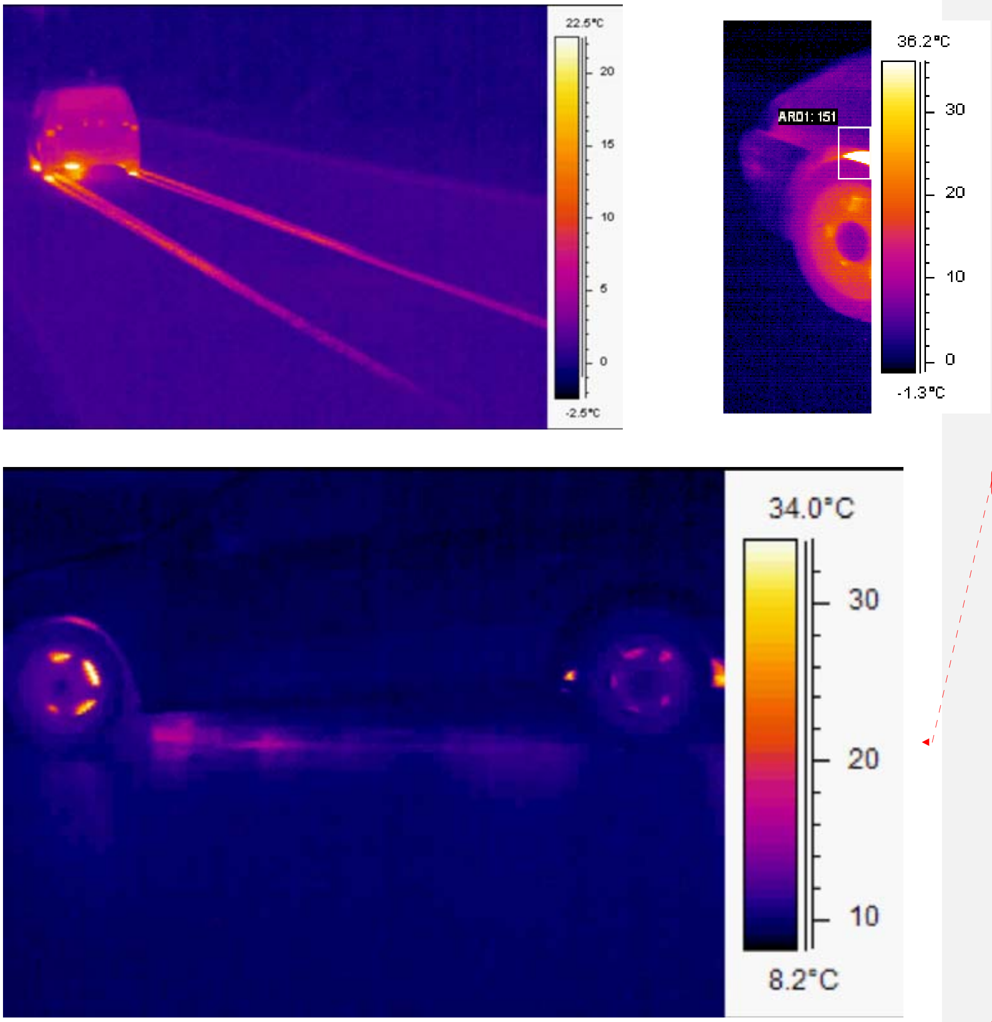

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Figure 7:

Top right: FLIR Systems infrared photogram of the 151˚c hot patch generated on a tyre during a locked wheel braking event on DRY NEW HRA.

Top left: The area of the tyres in contact with the road during emergency braking have just "rolled out" following a NON ABS skid test on a DRY NEW HRA.

Bottom right: The FLIR camera is sufficiently sensitive to resolve the 'hot patches' generated on the road surface by ABS braking and to show the steam generated by the heat transfer on (ABS ON test: traditional road surface with water film)

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Remember, the warning signs in the Nederlands simply read:

"New road surface, longer stopping distance".

4.5 POSITIVE CHARACTERISTICS OF NEGATIVE TEXTURED SURFACINGS IN THE WET?

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Does a recent TRL report (Figure 8 taken from Nicholls and Carswell, 2004), possibly suggest that a review of the DRY frictional behaviour of negative textured surfaces in the UK should be accompanied by a review of the processes at play in the long term development and maintenance of their WET frictional properties?

Findings from the often discussed (but sadly as yet unpublished) Macrotexture and Road Safety (MARS) report (Parry, 1998), may well explain why there is a need to better understand the fundamental frictional properties of negative textured surfaces.

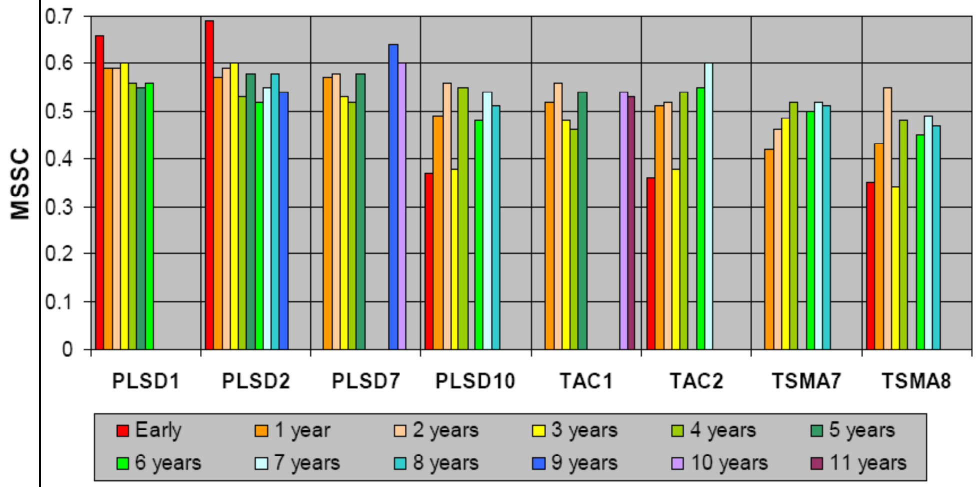

Figure 8: Summary figure showing SCRIM MSSCs (Mean Summer SCRIM Coefficients) for sites with at least 6 years of SCRIM data, (from Nichols & Carswell, 2004)

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5 CONCLUSIONS

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The work carried out to date, and to continue through to summer 2006, is extending the knowledge of the bituplaning phenomenon as it applies to roads in the United Kingdom.

5.1 SKIDMAN DATA ANALYSIS

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Initial analysis of the Skidman database has yielded some valuable results however more detailed work is required to fully exploit the depth of information stored within the Skidman deceleration profiles when combined with surface type, braking system and surface condition data.

Manifestations of the bituplaning phenomenon have been identified from visualisation of the Skidman decelerometer time series data along with quantifiable differences in deceleration values between surface types, suggesting the bituplaning phenomenon may be reflected in the relationship between peak and average deceleration values for the surfaces in question.

5.2 STUDY OF UK COLLISIONS AS PART OF THE DATA COLLECTION PROCESS

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The observation that there is a lack of evidence of the role of bituplaning in real collisions is a valuable one for UK engineers. There have been somewhat unfounded concerns over the safety aspects of the use of binder-rich negative textured materials since the events in Derbyshire in 2001.

5.3 EXPERIMENTAL TRIALS

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Temperatures generally considered in excess of those necessary to soften/melt thin-surfacing bituminous materials have been directly measured during locked wheel braking events, supporting the theory melting bitumen is responsible for the bituplaning phenomenon.

5.4 THE NEED FOR MORE RESEARCH BEYOND ROAD SURFACE FRICTION: RIDE QUALITY?

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Beyond the scope of this research, but worthy of investigation, is the possible role the improvement in ride quality, reduced spray and noise, that are all delivered by negative textured surfaces, may have on driver behaviour.

The replacement of a fretted, rutted, potholed or irregular “positive textured” road surface, with a smoother, quieter “negative textured” one could possibly lead to an increase in vehicle speed with the improved ride quality. *Independent of road surface frictional characteristics*, this could theoretically contribute to an increase in crashes.

More than simply the frictional properties of a new road surface may need to be considered when investigating post installation collision records on new negative textured road surfaces.

5.5 THE NEED FOR MORE RESEARCH INTO THE FUNDEMENTAL NATURE OF SKIDDING RESISTANCE AND NEGATIVE TEXTURED ROAD SURFACES

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The initial findings of this research along with recent observations on the long term WET skidding resistance of certain negative textured surfaces may suggest a need to question the fundamental assumptions made relating to the generation of both their WET and DRY skidding resistances.

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7 REFERENCES

Bennis TA and Leusink J (2000). Nieuwe Meetmethode voor de Aanvangsstroefheid van ZOAB. Report no P-DWW-97-080 (ISBN 90-369-3733-7) May 29, 2000, DWW Delft, The Nederlands.

Broughton J, et al. (1998). A new system for recording contributory factors in road accidents. Transport Research Laboratory Report 323, TRL, Crowthorne.

Derbyshire County Council (2001). An Investigation of the skid resistance of certain SMA surfacings in Derbyshire. Document Ref 05918/H1. Investigations and Risk Management Group, Transport Research Laboratory, Crowthorne.

DSIR (1963). Research on Road Safety. Department of Scientific Research, 1963 Her Majesty's Stationery Office, London.

Fafié, J (2004) Early Life Dry Skid Resistance. Paper presented at "Surf 2004", 5th Symposium on Pavement Surface Characteristics. June 6-10, 2004. Toronto, Ontario, Canada.

Gallaway BM, Ivey DL, Hayes G, Ledbetter WB, Olson RM, Woods DL and Schiller Jnr. RF (1979). Pavement and Geometric Design Criteria for Minimizing Hydroplaning. Report FHWA-RD-79-31 Texas Transportation Institute, College Station, Texas.

Highways Agency (2003). Interim Advice Note IAN 49/03. "Use Of Warning Signs For New Asphalt Road Surfaces". HMSO, London.

Highways Agency (2005). Design Manual for Roads and Bridges. HMSO, London.

Jutteo RH and Siskens CAM (1997). A Material Technological Approach to the Low Initial Skid Resistance of Porous Asphalt Roads. European Conference on Porous Asphalt, Madrid, March 12 1997. Papers volume ii, Ministerio de Fomento, Direccion General de Carreteras, Madrid, Spain.

Formatted: Justified

J C Nicholls and I Carswell (2004) Durability of thin asphalt surfacing systems. Part 2: Findings after three years, Report No. TRL606, August 2004. Transport Research Laboratory, Crowthorne.

Formatted: Justified

Parry AR (1998). Macrotexture and Road Safety: Final report. Unpublished Project Report, PR/CE/56/98. Transport Research Laboratory, Crowthorne.

Formatted: Justified

SCI. (2002). Abstracts from the proceedings of “Early life skid resistance of asphalt”. 17 October 2002, Society of Chemical Industry, London.

Formatted: Justified

Shelshear, G (1986). “Poor Skid Resistance cited at Crash Inquest”. New Civil Engineer, 11 Sept 1986. London.

Formatted: Justified

.
Shelshear, G (1993). “Skid Resistance of New Surfaces, A report by Graham Shelshear BEM, Thames Valley Police, May 1993”. Revision of unpublished(?) pamphlet originally circulated in 1988.

Formatted: Justified

Shelshear, G (1998). “Newly Laid Road Surfaces, Skid Resistance an Update”. IMPACT, Spring 1998. Pp4-5. Institute of Traffic Accident Investigators (ITAI).

Formatted: Justified

Walsh I (2000). “Out of the skid pan….” Surveyor, pp 12-15, 9 November 2000. Hemming Group London.

Formatted: Justified

Zipkes, E (1944). Die Reibungskennziffer als Kriterium zur Beurteilung von Strassenbelägen Eidgenössissche Technische Hockschule Zűrich, Institute für Strassenbau Mitteilung Nr. 2 Zurich, 1944 (Verlag A.G. Gebr. Leeman and Co.) .

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