Synthesis title:

# Surfaces

## Category: Roads

**Other Relevant Topics:**

- Tyres (Vehicles)
- Rural Roads (Roads)
- Urban Roads (Roads)
- Road Works (Roads)

**Keywords:**

**Surface Condition, Wet Surfaces, Road Surface Treatments, Skid Resistance, Texture**

# About the Road Safety Observatory

**The Road Safety Observatory aims to provide free and easy access to independent road safety research and information for anyone working in road safety and for members of the public. It provides summaries and reviews of research on a wide range of road safety issues, along with links to original road safety research reports.**

The Road Safety Observatory was created as consultations with relevant parties uncovered a strong demand for easier access to road safety research and information in a format that can be understood by both the public and professionals. This is important for identifying the casualty reduction benefits of different interventions, covering engineering programmes on infrastructure and vehicles, educational material, enforcement and the development of new policy measures.

The Road Safety Observatory was designed and developed by an Independent Programme Board consisting of key road safety organisations, including:

- Department for Transport
- The Royal Society for the Prevention of Accidents (RoSPA)
- Road Safety GB
- Parliamentary Advisory Council for Transport Safety (PACTS)
- RoadSafe
- RAC Foundation

By bringing together many of the key road safety governmental and non-governmental organisations, the Observatory hopes to provide one coherent view of key road safety evidence.

The Observatory originally existed as a standalone website, but is now an information hub on the RoSPA website which we hope makes it easy for anyone to access comprehensive reviews of road safety topics.

All of the research reviews produced for the original Road Safety Observatory were submitted to an Evidence Review Panel (which was independent of the programme Board), which reviewed and approved all the research material before it was published to ensure that the Key Facts, Summaries and Research Findings truly reflected the messages in underlying research, including where there may have been contradictions. The Panel also ensured that the papers were free from bias and independent of Government policies or the policies of the individual organisations on the Programme Board.

The Programme Board is not liable for the content of these reviews. The reviews are intended to be free from bias and independent of Government policies and the policies of the individual organisations on the Programme Board. Therefore, they may not always represent the views of all the individual organisations that comprise the Programme Board.

Please be aware that the Road Safety Observatory is not currently being updated; the research and information you will read throughout this paper has not been updated since 2017. If you have any enquiries about the Road Safety Observatory or road safety in general, please contact **help@rospa.com** or call **0121 248 2000**.

## How do I use this paper?

This paper consists of an extensive evidence review of key research and information around a key road safety topic. The paper is split into sections to make it easy to find the level of detail you require. The sections are as follows:

| | |
|---|---|
| **Key Facts** | A small number of bullet points providing the key facts about the topic, extracted from the findings of the full research review. |
| **Summary** | A short discussion of the key aspects of the topic to be aware of, research findings from the review, and how any pertinent issues can be tackled. |
| **Methodology** | A description of how the review was put together, including the dates during which the research was compiled, the search terms used to find relevant research papers, and the selection criteria used. |
| **Key Statistics** | A range of the most important figures surrounding the topic. |
| **Research Findings** | A large number of summaries of key research findings, split into relevant subtopics. |
| **References** | A list of all the research reports on which the review has been based. It includes the title, author(s), date, methodology, objectives and key findings of each report, plus a hyperlink to the report itself on its external website. |

**The programme board would like to extend its warm thanks and appreciation to the many people who contributed to the development of the project, including the individuals and organisations who participated in the initial consultations in 2010.**

## *Key facts*

- Skid resistance is considered one of the most important surface characteristics as it has a direct impact on traffic safety.

(N. Piyatrapoomi *et al*, 2008)

- A larger-scale study of the link between skid resistance and personal injury accidents, based on 1,000km of road network (Rogers and Gargett, 1991), confirmed the different levels of accident risk for different types of road site and the increase in risk for sites with lower skid resistance.

(H. E. Viner *et al*, 2005)

- Overall a reduction in RTIs of 39 per cent was seen in areas treated with high friction surfacing.

(C. Simpson, 2005)

- In 2015, 26 per cent of all RTIs recorded in Great Britain occurred in wet surface conditions.

(RRCGB, DfT, 2016)

- The skid resistance offered by a wet road surface decreases with increasing travel speeds.

(J. McLean and G. Foley, 1998)

- The average number of potholes filled by authorities in England and Wales, reported over the past year in the 2012 survey, represents a 21 per cent decrease on the previous year.

(ALARM Survey, 2012)

## *Summary*

This document has been compiled to highlight and summarise the safety aspects of road surfaces, primarily in the United Kingdom. Research from outside of the UK is also included where it was felt that UK-based research was incomplete.

The purpose of this document is to provide the reader with an overview of the topic of road safety relating to road surfaces. The topic has been sub-categorised broadly in to the following areas:

- Surface condition;
- Wet surfaces;
- Accidents relating to road surface;
- Road surface types and treatments; and,
- Skid resistance and texture.

The skid resistance offered by wet road surfaces decreases as vehicle travel speeds increase. In 2015, 26 per cent of all Road Traffic Incidents (RTIs) recorded in the UK occurred in such surface conditions and it has also been proven that RTI rates in wet weather increase as the skid resistance of the surface decreases. Improvements have been made to the wet-road driving experience in the UK by the addition of spray suppression devices and negative-textured surfaces.

Skid resistance is considered to be one of the most important surface characteristics and although a wide variety of road surface characteristics are studied and measured at present, only skid resistance is regulated as a standard for roads maintenance.

In addition to skid resistance, surface texture can also have a profound effect on stopping distances. A surface with low texture traversed by a vehicle moving at high speed can result in very long stopping distances and therefore an increased chance of RTI.

High Friction Surfacing is a proven road surface treatment that increases skid resistance and reduces braking distance, thereby reducing the potential for RTIs. With a skid RTI reduction of up to 50 per cent often being reported, high friction surfacing can save lives and money at the appropriate locations, although the initial cost of installation can be prohibitive – and the material can have a detrimental effect on the underlying surface.

## *Methodology*

This synthesis consists of research identified as relating to the topic of Surfaces within the category of Roads, focussing on general safety and Road Traffic Incident (RTI) prevention.

This synthesis was compiled during August – September 2012.

**Note**
This review includes statistics from Reported Road Casualties Great Britain 2011, which were the latest available data when the review was written. More recent statistics are available in Reported Road Casualties Great Britain 2013, Reported Road Casualties Great Britain 2014 and Reported Road Casualties Great Britain 2015.

A detailed description of the methodology used to produce this review is provided in the Methodology section of the Observatory website at http://www.roadsafetyobservatory.com/Introduction/Methods.

The steps taken to produce this synthesis are outlined below:

- **Identification of relevant research** – searches were carried out on pre-defined research (and data) repositories. However, some additional information sources were consulted at the suggestion of a subject matter expert, such as the Road Surface Treatments Association (RSTA) and the archives of http://www.ingentaconnect.com. Various search terms were used to identify papers of relevance, including:
    - 'Road surfaces';
    - 'Road surface safety';
    - 'Anti-skid surfaces';
    - 'Wet road surface';
    - 'Road surface texture';
    - 'Surface microtexture';
    - 'Surface macrotexture';
    - 'Surface megatexture';
    - 'High friction surfacing';
    - 'Potholes';
    - 'Porous asphalt';
    - 'SCRIM'; and,
    - 'Rutting'.

  A total of 105 pieces of research were identified during this phase.
- **Initial review of research** – primarily involved sorting the research items based on key criteria, to ensure the most relevant and effective items went forward for inclusion in this synthesis. Key criteria included:
    - Relevance – whether the research makes a valuable contribution to this synthesis, for example robust findings from surface testing

- Provenance – whether the research is relevant to drivers, road safety policies or road safety professionals in the UK. If the research did not originate in the UK the author and expert reviewer have applied a sense check to ensure that findings are potentially relevant and transferable to the UK.
- Age – priority given to the most up to date titles in the event of over-lap or contradiction.
- Effectiveness – whether the research credibly proves (or disproves) the effectiveness of a particular surface or treatment type.

Following initial review 31 pieces of research were taken forward to form the basis for this synthesis.

- **Detailed review of research** – key facts, figures and findings were extracted from the identified research to highlight pertinent issues and interventions.
- **Compilation of synthesis** – the output of the detailed review was analysed for commonality and a synthesis written in the agreed format. However, please note that the entire process from identifying research to compiling the synthesis was conducted in a time-bound manner.
- **Review** – the draft synthesis was subjected to extensive review by a subject matter expert, proof reader and an independent Evidence Review Panel.

Please note that:

- Research material conducted in the United Kingdom was used where possible in the compilation of this document, however, where there was found to be insufficient material in a particular field, research from worldwide sources was used in order to provide as comprehensive coverage as possible.
- Guidance and Standards material was not included in the compilation of this document; however, the reader may wish to consult these areas in addition to the research covered within this synthesis (e.g. Standard HD 28/04).
- All referenced URL were correct at the time the initial research was conducted.

## *Key statistics*

This section collates key statistics relating to the safety implications of surfaces.

### Road surface condition

The following section highlights key statistics relating to the general condition of the road surfaces and the maintenance required. These are primarily related to roads within the UK; however, some comments relating to international roads are also included.

- From surveys of AA members between July 2008 and August 2011, those who listed road condition as their primary worry increased from 11 per cent to 42 per cent. This compares with a reduction in the concern for the cost of motoring from 55 per cent to 19 per cent for the same period.
- This concern about road condition was also reflected in another 2011 poll which showed that 81 per cent of AA members think the roads have deteriorated in the last three years with:
    - 57 per cent of respondents saying conditions had deteriorated significantly and 24 per cent saying conditions had deteriorated slightly;
    - Only 1 per cent thought conditions had improved considerably;
    - 6 per cent thought they showed slight improvement; and,
    - 12 per cent of those who responded thought conditions were unchanged.

  *Please note that references from the AA may contain bias due to membership demographic characteristics.*
- The ALARM 2011 survey revealed that poor road condition was costing businesses around £4.1 billion per year in lost productivity and increased costs such as damage to vehicles, and higher fuel bills resulting from congestion or diversions.
- The 2010 English Road Condition Report has already identified that a quarter of main roads do not meet initial skid resistance standards and require further investigation. In London this is 49 per cent.

  (P. Watters, 2011)
- The GMB union reports that one in 20 of England's roads have more potholes than a year ago.

  *Please note that references from the GMB may contain bias.*
- 30 per cent of the Local Authority roads in England need attention with 25 per cent showing some deterioration and 5 per cent showing serious deterioration and requiring urgent remedial action.
- The ALARM survey reports a local authority annual road maintenance funding shortfall of £800m.

  (RSTA, 2012a)

  *Please note that material from the RSTA may be biased towards certain treatment types.*

- AA Streetwatch survey (2011) has found that roads in many parts of the UK are already plagued with potholes before the impact of any major winter freeze. The survey, involving 1,000 Streetwatchers noting the condition of their neighbourhood roads, reported an average pothole count of 14.9 potholes per street compared to 12.5 per street in 2010.

  *Please note that references from the AA may contain bias due to membership demographic characteristics.*

- A survey of RAC patrol drivers found that 89 per cent of them believe that current road conditions are the result of underinvestment in road repairs. Three quarters of them think the condition of rural roads is poor or very poor whilst two-thirds felt the same about suburban roads.

  (RSTA, 2011a)

  *Please note that material from the RSTA may be biased towards certain treatment types.*

- The average number of potholes filled by authorities in England and Wales, reported over the past year in the 2012 survey, represents a 21 per cent decrease on the previous year.

  (ALARM Survey, 2012)

## Wet surfaces

The following statements highlight that when a surface is wet, the skid resistance and other surface parameters change resulting in an increase in RTIs.

- In 2011, 25 per cent of all RTIs recorded occurred in wet surface conditions.
- In 2011, 2 per cent of all RTIs recorded occurred in icy or snowy surface conditions.

(P. Kilbey et al, 2012)

This review includes statistics from Reported Road Casualties Great Britain 2011, which were the latest available data when the review was written. More recent statistics are available in Reported Road Casualties Great Britain 2013, Reported Road Casualties Great Britain 2014 and Reported Road Casualties Great Britain 2015.

- In the US, fatal RTIs occur on wet roads at a rate of between 3.9 and 4.5 times the rate of occurrence on dry roads.
- The NTSB and the Federal Highway Administration (FHWA) have reported that 13.5 per cent of fatal RTIs and 18.8 per cent of all RTIs occur when the road surface is wet.

(K. Smith and R. Larson, 2011)

## *Research findings*

Summaries of key findings from several research reports are given below. Further details of the studies reviewed, including methodology and findings, and links to the reports are given in the References section.

### Road surface condition

The following section examines how safety is affected by the condition of a road surface, and how surface defects become progressively worse if not acted upon at an early stage.

- There is a distinct link between road surface condition and road safety. Budgetary cut-backs means that local authorities need to get more for less. Planned programmes of road maintenance and the use of recognised anti-skid surfacing techniques will deliver roads that are not only safer for drivers and pedestrians but are also cheaper to maintain.

  (RSTA, 2012a)

  *Please note that material from the RSTA may be biased towards certain treatment types.*

- Shallow pot holes can quickly become deeper and present a significant hazard to motorists, particularly when travelling at speed.
- Potholes can cause motorists to swerve between lanes in order to avoid them.

  (RSTA, 2011b)

  *Please note that material from the RSTA may be biased towards certain treatment types.*

- Road surfaces that are subject to weathering and heavy use can experience a variety of problems that have health and safety implications.

  (Health and Safety Executive, 2011)

### Wet surfaces

This section examines moisture which may reduce skid resistance on a road surface and therefore may produce an increase in RTIs.

- In addition to vehicle speed, hydroplaning potential is largely governed by water film thickness, which is influenced by the longitudinal and transverse profile of the road and by road macro-texture.
- While adequate surface resistance generally exists on dry roads (although there are exceptions); the presence of water reduces the direct contact between the road surface and the tyre.

  (K. Smith and R. Larson, 2011)

- Some evidence suggested that the number of wet road RTIs increased as the road life increased, however, the frequency of RTIs was not sufficient to statistically support this.
- The fact that more RTIs occurred at low Friction Numbers (FNs) is an important indication that skid resistance may indeed be a factor affecting wet weather RTIs.

(D. Noyce *et al*, 2007)

- Tyre/road friction in dry conditions is generally high but the presence of even a very thin film of water dramatically reduces the coefficient of friction.

(P. G. Roe *et al*, 1998)

- The skid resistance offered by a wet road surface decreases with increasing travel speeds.
- At low speeds surface aggregate microtexture is the primary contributor to skid resistance.
- Macrotexture and water film thickness influence the extent to which skid resistance decreases with increasing travel speed.
- Wet weather RTI rates increase with decreasing skid resistance.
- For rural arterial roads, wet weather RTI rates increase markedly for Sideway-force Coefficient Routine Investigation Machine (SCRIM) values of less than 0.5.

(J. McLean and G. Foley, 1998)

### Effect of contaminants

- De-icing operations will not increase the risk of skidding RTIs on most, if not all, of the network. Only on roads that are close to their investigatory level is there a small theoretical increase in risk, but this is unlikely to be significant.
- There is no evidence from national statistics that the use of de-icers increases personal injury RTIs, including those at junctions and those involving motorcycles.
- Winter maintenance practitioners that are responsible for de-icing the network provided little or no hard evidence of RTIs associated with reduced skid resistance from de-icers.

(P. Roe *et al*, 2008)

## Skid resistance and texture

The following section examines the relationship between texture and skid resistance relating to road safety. Texture may be sub-divided in to microtexture (the surface texture of a particle in aggregate material), macrotexture (the difference in aggregate particle size) and megatexture (includes roughness, cracks, potholes and other major surface irregularities). Skid resistance is an important property which plays a critical role in road safety.

- Skid resistance is an important feature which should be considered while evaluating road safety.

(D. Noyce *et al*, 2007)

- Skid resistance is considered one of the most important surface characteristics as it has a direct impact on traffic safety.

(N. Piyatrapoomi *et al*, 2008)

- In general, providing good skid resistance will improve road safety and will not adversely affect traffic noise.

(R. Elvik and P. Greibe, 2005)

However, the link between skid resistance and RTIs is more difficult to definitively prove, as the following authors have shown.

- Many attempts have been made to understand the relationship between skid resistance and RTIs using statistical regression and correlation methods but results have been mixed and inconclusive.

(N. Piyatrapoomi *et al*, 2008)

- A larger-scale study of the link between skid resistance and personal injury accidents, based on 1,000km of road network (Rogers and Gargett, 1991), confirmed the different levels of accident risk for different types of road site and the increase in risk for sites with lower skid resistance.

(H. E. Viner *et al*, 2005)

- Macrotexture is generally believed to affect braking through the two mechanisms of hysteresis (the deformation of the tyre which converts mechanical energy in to heat) and the prevention of a water film masking the microtexture.
- A literature review concluded that RTI risk is greater at sites with low macrotexture, but studies differ as to the macrotexture values at which risk begins to increase, as it depends on the shape and porosity of the surface.
- In nearly all cases, there was an association between macrotexture and RTIs.
- The results agree with previous studies regarding the increase in risk with low macrotexture.

(P. Cairney and E. Styles, 2005)

- Both skidding and non-skidding RTIs, in both wet and dry conditions, are less if the macrotexture is course than if it is fine. This is observed at all levels of underlying skid resistance.
- The texture level below which RTIs begin to increase is about 0.70 mm sensor measured texture depth.

(P. Roe *et al*, 1991)

- The study aimed to find a relationship between road skid resistance on asphalt surfaces and crash frequency, particularly wet weather skid RTI. However, the results of the analysis did not indicate a relationship between RTI frequency and road skid resistance.
- It was not possible to determine a skid friction threshold value that indicates the critical point where road maintenance would be needed.

(D. Noyce *et al*, 2007)

- In percentage terms, increasing skid resistance has a greater effect in reducing 'wet road RTIs' than in reducing 'all RTIs'.
- The primary emphasis should be on increasing skid resistance rather than texture.

(R. Davies *et al*, 2005)

Skid resistance is a mandated property concerning safety in use of highway construction products by the European Union.

- Although a wide variety of road surface characteristics are studied and measured, at present, only skid resistance is regulated as a standard for roads maintenance.

(S. Shaffer *et al*, 2006)

- National policy for in-service skid resistance was introduced in the UK in 1988.
- 20 years of experience since then has led to further developments of the standards.
- Highway Authorities need to work towards a truly national standard for in-service skidding as well as exploring alternative strategies to reduce RTI risk.

(P. Roe and L. Caudwell, 2008)

The testing of skid resistance properties of road surface materials, in order to provide necessary changes in policy, is regularly undertaken by the Highways Agency and others.

- The Highways Agency has established a number of benchmark sites for long term study of the in-service performance of surfacing materials.
- This has allowed trends to be established to provide early warnings of changes that may be required in policy.

- The results have:
    - Confirmed that SCRIM surveys should not be carried out in heavy rain;
    - Confirmed the link between the extent of polishing each year and the amount of rainfall;
    - Identified that skid resistance does not appear to plateau but is continuously changing; and,
    - Indicated that different correction factors are required for bituminous and concrete surfaces.

(R. Sinhal *et al*, 2011)

Certain conclusions made on surface testing relating to road safety are as follows:

- Texture depth is related to high speed skid resistance in wet conditions, but not to low speed measurements, such as those made by a SCRIM or Griptester.
- Current technology is not capable of measuring the fine scale surface microtexture, such as that on the surface of aggregate chips, as part of SCANNER surveys.
- There is no evidence to justify texture depth measurements being used as a surrogate for skid resistance measurement.
- RTI studies strongly support the need for skid resistance data in addition to texture depth data.

(H. Viner *et al*, 2006)

- Research by TRL in 2005 proposed new investigatory levels. In most cases, this included a range of investigatory levels for each site category.
- This range of risk emphasises the need for the reaction to low skidding resistance to be based on investigation rather than automatic intervention.
- As well as helping to meet RTI reduction targets, the costs of making the changes were mitigated by the savings associated with the reduction in RTIs.

(A. Parry and H. Viner, 2005)

- At present, PSV (Polished Stone Value) is the only parameter relating to the microtexture properties of an aggregate which can be measured in a standardised manner and which has been related to traffic and site conditions. It therefore remains an appropriate property to use in specifications, provided that its limitations are recognised.

(P. G. Roe and S. A. Hartshorne, 1998)

- The maintenance of good adherence values on roads is an essential requirement for road safety and aggregate characteristics play an important role in this.
- The evaluation of aggregate properties by means of empirical indexes obtained from standard tests cannot fully explain the reason why some materials are suitable and others not.

(S. Cafiso *et al*, 2006)

- According to the behaviour of skid resistance in low traffic levels, it can be concluded that for paved low-volume roads the frequency of Skid Resistance (SR) monitoring can be reduced. It is especially true when using aggregates with low polishing susceptibility in construction because the polishing rate is low and it is possible that the starting SR values remain fairly unchanged over the time.
- When high traffic levels exists, independent of the aggregate's quality, the polishing rate is higher and high frequency monitoring is needed to prevent the SR dropping under the thresholds established by standards.

(T. Echaveguren *et al*, 2010)

Freshly laid road surfaces may adversely affect the number of RTIs during the period following installation.

- It has been suspected for a number of years that newly laid asphalt surfaces may have different skid resistances to those that have been in use for some time.
- This is thought to be from the layer of fresh bitumen binder on the material which is eventually worn by weathering and traffic.
- Research has identified physical phenomena that might lead to an increase in RTI risk in some circumstances.
- In the 12 months following resurfacing the RTI risk is similar or lower than before resurfacing, however, there is a small but statistically significant increase in the initial months after laying modern asphalt surfacing (mainly on motorways in dry conditions).
- The period of risk appears to last for about 6 months after resurfacing. The risk is statistically significant but the evidence did not suggest that it was a widespread problem.

(M. Greene and L. Caudwell, 2008)

However, a decrease in fatal RTIs was also shown during this period.

- There was a significant decrease in fatal RTIs on the resurfaced sections after this period.

(M. Greene and L. Caudwell, 2008)

## Road Traffic Incidents

The following section examines the causes of RTI relating to faulty or inadequate road surfaces.

- Inappropriately low surface resistance leads to greatly increased community costs in hospitalisation, lost time etc.
- Road frictional properties are likely to have a marked influence on wet road RTI rates.
- High speeds and low texture depths can result in very long stopping distances with increased chances of RTI.

(R. Rallings, 2010)

- RTI rate was higher for road sections with low macrotexture; a power relationship provided a good fit to the data.
- RTI rate was also higher for roads where roughness was extreme, with a polynomial relationship providing a good fit to the data.
- No clear relationship emerged between rutting and RTI rate.

(23rd ARRB Conference – Research Partnering with Practitioners, 2008)

- RTI studies strongly support the need for skid resistance data in addition to texture depth data.

(H. Viner *et al*, 2006)

- Inadequate microtexture, as a result of the presence of polishable material, drops skid resistance and enhances RTI risk.
- Inadequate macrotexture, as a result of faulty construction practice or wear, drops skid resistance, especially in the medium to high speed range, thus enhancing RTI risk.

(O. Panagouli *et al*, 1997)

## Surface types and treatments

The section examines various surface types and treatments that are available to treat or lay a road surface. How these relate to RTIs is also addressed, in addition to maintenance schedules. These are primarily UK sources; however, some international material has also been included for comparison.

- High Friction Surfacing is a proven road surface treatment that increases skid resistance and reduces braking distance thereby reducing the potential for RTIs. A skid RTI reduction of 50 per cent is often reported.
- Other surface treatments suitable for restoring the skid resistance of roads include retexturing where the existing surface is mechanically reworked to improve friction and surface dressing which involves the even spray application of an emulsion bituminous binder followed by aggregate chippings. This seals the road surface and restores the level of skid resistance and helps to reduce the spray resulting from vehicles travelling on wet road surfaces.

(RSTA, 2012a)

*Please note that material from the RSTA may be biased towards certain treatment types.*

- The service life for hot applied high friction surfacing ranges from 3 – 5 years giving a mid-point of 4 years.
- For cold applied high friction surfacing the service life ranges from 5 – 11 years giving a mid-point of 8 years.

(RSTA, 2012b)

*Please note that material from the RSTA may be biased towards certain treatment types.*

- High friction surfaces are very effective at reducing loss of control RTIs on high speed curves with free flowing traffic.
- The treatment appears to be more effective when placed on the approach and the centre of signalled junctions.
- Better selection of sites with regard to crash numbers and types of crash may be the key to maximise the benefits of high friction surface treatments.

(C. Simpson, 2005)

- Surfacing materials do not always deliver appropriate levels of both macro- and micro-texture throughout their service lives.
- The mechanical treatment of a sound road surface to restore skidding resistance and texture depth can provide an effective short to medium-term solution to micro- and macro- texture deficiencies, which may need treatment more immediately than can be achieved by conventional resurfacing technique.
- Spray suppression devices and negative-textured surfaces have improved the wet-road driving experience in the UK.

(J. Bullas, 2004)

## How effective?

The following statements present statistics regarding how effective interventions to increase skid resistance can be in reducing RTIs.

- High friction surfacing is a proven road surface treatment that increases skid resistance and reduces braking distance thereby reducing the potential for RTIs. A skid RTI reduction of 50 per cent is often reported.

  (RSTA, 2012a)

  *Please note that material from the RSTA may be biased towards certain treatment types.*

- Overall a reduction in RTIs of 39 per cent was seen in areas treated with high friction surfacing compared with a reduction of 17 per cent on untreated sites.

  (C. Simpson, 2005)

## Gaps in research

While there is much research material on the topic of Skid Resistance, much of this originates from outside of the United Kingdom. International material has been included for completeness but more research in to this topic should be conducted in the UK and freely published. This would allow for a more comprehensive understanding of the relationship between road surface condition and road safety. However, the UK also has an excellent and unique record in the production of road surface policies which should be consulted in addition to this document.

## *References*

### Department for Transport research and statistics

| **Title: Reported Road Casualties Great Britain: 2011 Annual Report** |
|---|
| **Author / organisation:** P. Kilbey, D. Wilson, W. Huang, P. McEvoy and A. Bhagat (Department for Transport)<br>**Date:** 2012<br>**Format:** Pdf<br>**Link:**<br>https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/9273/rrcgb2011-00.pdf<br>**Free / priced:** Free |
| **Objectives:** The Reported Road Casualties in Great Britain (RRCGB) Annual Report: 2011 presents detailed statistics about the circumstances of personal injury RTIs, including the types of vehicles involved, the resulting casualties and factors which may contribute to RTIs. |
| **Methodology:** Most of the statistics in the report are based on information about RTIs reported to the police. However, other sources such as mortality, survey and hospital data are also used as well as population and traffic data to provide a wider context. |
| **Key Findings:**<br>• In 2011, 25 per cent of all reported accidents occurred in wet surface conditions.<br>• In 2011, 2 per cent of all reported accidents occurred in icy or snowy surface conditions. |
| **Themes:** Wet Surfaces |
| **Comments:** Annual reported road casualty report from DfT. |

| **Title: Reported Road Casualties Great Britain: 2013 Annual Report** |
| --- |
| **Author / organisation:** Department for Transport<br>**Date:** 2014<br>**Format:** Pdf<br>**Link:**<br>https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/359311/rrcgb-2013.pdf<br>**Free / priced:** Free |
| **Objectives:** The Reported Road Casualties in Great Britain (RRCGB) Annual Report: 2013 presents detailed statistics about the circumstances of personal injury RTIs, including the types of vehicles involved, the resulting casualties and factors which may contribute to RTIs. |
| **Methodology:** Most of the statistics in the report are based on information about RTIs reported to the police. However, other sources such as mortality, survey and hospital data are also used as well as population and traffic data to provide a wider context. |
| **Key Findings:**<br>• In 2013, 20 per cent of all reported accidents occurred in wet surface conditions.<br>• In 2013, 2.5 per cent of all reported accidents occurred in icy or snowy surface conditions. |
| **Themes:** Wet Surfaces |
| **Comments:** Annual reported road casualty report from DfT. |

**Title: Reported Road Casualties Great Britain: 2014 Annual Report**

**Author / organisation:** Department for Transport)**Date:** 2014
**Format:** Pdf
**Link:**
https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/463797/rrcgb-2014.pdf
**Free / priced:** Free

**Objectives:** The Reported Road Casualties in Great Britain (RRCGB) Annual Report: 2014 presents detailed statistics about the circumstances of personal injury RTIs, including the types of vehicles involved, the resulting casualties and factors which may contribute to RTIs.

**Methodology:** Most of the statistics in the report are based on information about RTIs reported to the police. However, other sources such as mortality, survey and hospital data are also used as well as population and traffic data to provide a wider context.

**Key Findings:**

In 2014:

- 42,182 (28%) of all reported accidents occurred in wet surface conditions.
- 1,898 (1%) of all reported accidents occurred in icy or snowy surface conditions.
- Poor weather has a strong influence on exposure. In severe conditions, such as widespread heavy snowfall (as happened at both the start and end of 2010) people can postpone or cancel journeys, or switch to safer modes of transport (e.g. pedal and motorcyclists moving to other vehicle types, or road users switching to rail instead).
- In less severe, but still unpleasant weather, such as windy or wet conditions, some road users, especially vulnerable road users such as pedal and motorcyclists and pedestrians, tend to switch to safer enclosed modes, such as cars and buses.
- 2014 was much warmer**,** and was the warmest year on record at 1°C above the long term average. It was also one of the wettest years; the fourth wettest year, behind 2000, 2012 and 1954.
- These weather patterns might partly explain some of the increases in casualties. The combination of warm and dry weather in September is estimated to have led to 19 more killed vulnerable road users than if temperature and rainfall had been average.

**Themes:** Wet Surfaces

**Comments:** Annual reported road casualty report from DfT.

Other works

| **Title: Increased Road Safety Concerns Mirrors Lack of Road Maintenance Spending** |
|---|
| **Author / organisation:** RSTA<br>**Date:** 2012a<br>**Format:** HTML<br>**Link:** http://www.rsta-uk.org/news/62.htm<br>**Free / priced:** Free |
| **Objectives:** Report in to road safety concerns |
| **Methodology:** N/A |
| **Key Findings:**<br>• The GMB union reports that one in 20 of England's roads have more potholes than a year ago.<br>• 30 per cent of the roads in England need attention with 25 per cent showing some deterioration and 5 per cent showing serious deterioration and requiring urgent remedial action.<br>• Of all the local authorities the Isle of Wight had the worst roads in England with 55 per cent of all roads needing attention. Next in the league for the worst roads is North Lincolnshire with 47 per cent, followed by the City of London, Nottingham and Camden all with 42 per cent.<br>• The ALARM survey reports a local authority annual road maintenance funding shortfall of £800m.<br>• High Friction Surfacing is a proven road surface treatment that increases skid resistance and reduces braking distance thereby reducing the potential for RTIs. With a skid RTI reduction of often 50 per cent being reported the success of high friction surfacing speaks for itself: it saves lives and money.<br>• Other surface treatments suitable for restoring the skid resistance of roads include retexturing where the existing surface is mechanically reworked to improve friction and surface dressing which involves the even spray application of an emulsion bituminous binder followed by aggregate chippings. This seals the road surface and restores the level of skid resistance and helps to reduce the spray resulting from vehicles travelling on wet road surfaces.<br>• There is a distinct link between road surface condition and road safety. Budgetary cut-backs means that local authorities need to get more for less. Planned programmes of road maintenance and the use of recognised anti-skid surfacing techniques will deliver roads that are not only safer for drivers and pedestrians but are also cheaper to maintain. |
| **Themes:** Maintenance, High Friction Surfacing, Re-texturing |
| **Comments:** Some useful statistical content and UK-based material. *Please note that material from the RSTA may be biased towards certain treatment types.* |

| **Title: High Friction Surfacing for Improved Road Safety** |
|---|
| **Author / organisation:** RSTA<br>**Date:** 2012b<br>**Format:** HTML<br>**Link:** http://www.rsta-uk.org/news/61.htm<br>**Free / priced:** Free |
| **Objectives:** Investigating the role of high friction surfacing to improve road safety. |
| **Methodology:** N/A |
| **Key Findings:**<br>• The service life for hot applied high friction surfacing ranges from 3 – 5 years giving a mid-point of 4 years.<br>• For cold applied high friction surfacing the service life ranges from 5 – 11 years giving a mid-point of 8 years. |
| **Themes:** High Friction Surfacing, Maintenance |
| **Comments:** *Please note that material from the RSTA may be biased towards certain treatment types.* |

| **Title: Annual Local Authority Road Maintenance (ALARM) Survey 2012** |
|---|
| **Author / organisation:** Asphalt Industry Alliance<br>**Date:** 2012<br>**Format:** Pdf<br>**Link:** http://www.asphaltuk.org/images/library/files/alarm_2012_report.pdf<br>**Free / priced:** Free |
| **Objectives:** The aim of the survey is to build a picture of the general condition of local roads and the levels of maintenance activity as well as the levels of funding required to ensure that they are in reasonable condition. |
| **Methodology:** Annual survey |
| **Key Findings:**<br>• The average number of potholes filled by authorities in England and Wales, reported over the past year in the 2012 survey, represents a 21 per cent decrease on the previous year. |
| **Themes:** Potholes, Surface Condition |
| **Comments:** UK-based annual highway departments survey. |

| **Title: Surveys Underline Pothole Plague but lack of Funding is not the Only Problem** |
|---|
| **Author / organisation:** RSTA<br>**Date:** 2011a<br>**Format:** HTML<br>**Link:** http://www.rsta-uk.org/news/48.htm<br>**Free / priced:** Free |
| **Objectives:** Review of current state of potholes and funding. |
| **Methodology:** N/A |
| **Key Findings:**<br>• The AA Streetwatch survey (2011) has found that roads in many parts of the UK are already plagued with potholes before any major winter freeze gets to work on them. The survey, involving 1,000 Streetwatchers noting the condition of their neighbourhood roads, reported an average pothole count of 14.9 potholes compared to 12.5 in 2010.<br>• A survey of RAC patrol drivers found that 89 per cent of them believe that current road conditions are the result of underinvestment in road repairs. Three quarters of them think the condition of rural roads is poor or very poor whilst two-thirds felt the same about suburban roads. |
| **Themes:** Maintenance, Potholes |
| **Comments:** *Please note that material from the RSTA may be biased towards certain treatment types.* Surveys of AA members and RAC drivers may also exhibit bias. |

| **Title: Motorway Repairs to be Reduced** |
|---|
| **Author / organisation:** RSTA<br>**Date:** 2011b<br>**Format:** HTML<br>**Link:** http://www.rsta-uk.org/news/42.htm<br>**Free / priced:** Free |
| **Objectives:** Report in to the reduction in expenditure on UK motorways. |
| **Methodology:** N/A |
| **Key Findings:**<br>• The cost to repair potholes is £75 per sq. metre compared with the cost to surface dress and maintain a road which is £2 per sq. metre.<br>• Shallow pot holes can quickly become deeper and present a significant hazard to motorists, particularly when travelling at speed.<br>• Potholes can cause motorists to swerve between lanes in order to avoid them. |
| **Themes:** Maintenance, Potholes |
| **Comments:** Useful statistics on potholes. *Please note that material from the RSTA may be biased towards certain treatment types.* |

**Title: Long Term Study of Skid Resistance On In-Service Roads In England**

**Author / organisation:** R. Sinhal (Highways Agency), J. Donbavand and C. Kennedy (WDM Ltd)
**Date:** 2011
**Format:** Pdf
**Link:**
http://saferroadsconference.com/wp-content/uploads/2016/05/John-Donbavand-Long-Term-Study-of-Skid-Resistance-on-in-service-Roads-in-England.pdf
**Free / priced:** Free

**Objectives:** To present the findings from a 9 year study on skid resistant surfacings and show how this has influenced policy.

**Methodology:** Comparison of SCRIM surveys conducted since 2002 over 39 benchmark sites.

**Key Findings:**

- Highways Agency have established a number of benchmark sites for long term study of the in-service performance of surfacing materials.
- These sites have provided a source of historical skid resistance measurements from across the network.
- This has allowed trends to be established to provide early warnings of changes that may be required in policy.
- The results have:
    - Indicated that summer has extended into autumn over the study period which has led to the survey season being extended;
    - Confirmed that SCRIM surveys shouldn't be carried out in heavy rain;
    - Confirmed the link between the extent of polishing each year and the amount of rainfall;
    - Identified that skid resistance does not appear to plateau but is continuously changing; and,
    - Indicated that different corrections factors are required for bituminous and concrete surfaces.

**Themes:** skid resistance, long term study

**Comments:** Useful long-term UK-based research in to SCRIM data.

**Title: Road Surface**

**Author / organisation:** Health and Safety Executive
**Date:** 2011
**Format:** Pdf
**Link:** http://www.hse.gov.uk/pubns/wpt28.PDF
**Free / priced:** Free

**Objectives:** Workplace transport site safety information sheet WPT28

**Methodology:** This information will be useful to anyone who uses workplace transport or who works where it is used. It will help employers, managers and supervisors to assess their workplace and make improvements. The checklists will help the preparation of your risk assessments.

**Key Findings:**

- A road surface can be described as any surface that vehicles drive on, either in a workplace or a traffic route within the site boundary.
- Road surfaces that are subject to weathering and heavy use can experience a variety of problems that have health and safety implications.
- What to look out for:
  - Cracks in the road surface;
  - Potholes where the surface of the road or footway has failed and a hollow has formed;
  - Standing surface water where there is nowhere for the water to drain; and,
  - Spillages of chemicals, oil or diesel from vehicles or activity taking place on site.
- How can common problems be dealt with:
  - Fill any isolated potholes and repair the road surface;
  - Improve drainage by providing new drains and or reprofiling the road;
  - Provide a new surface dressing where the surface has become worn and has low skid resistance;
  - Resurface the road if it is uneven and has a large number of potholes; and,
  - Reconstruct the road if the problem is widespread and runs deeper than the road's surface.
- What might it cost?
  - Repairing a pothole: £300 for a hole 2m x 2m x300mm deep;
  - Surface dressing: £100 for an area of $10m^2$;
  - Resurfacing: £200 for an area of $10m^2$; and,
  - Reconstruction: £750 for an area of $10m^2$.

**Themes:** Potholes, Skid resistance

**Comments:** HSE guidance document but could be out of date now.

| |
|---|
| **Title: Engineering Safer Road Surfaces to Help Achieve US Highway Safety Goal** |
| **Author / organisation:** K. Smith and R. Larson (Applied Pavement Technology)<br>**Date:** 09/2011<br>**Format:** Pdf<br>**Link:** http://www.appliedpavement.com/RSS20113205_Smith.PDF<br>**Free / priced:** Free |
| **Objectives:** How safety is being addressed in the US from the realm of the road surface. |
| **Methodology:** Literature Review |
| **Key Findings:**<br>• In the US, fatal RTIs occur on wet roads at a rate of between 3.9 and 4.5 times the rate of occurrence on dry roads.<br>• The NTSB and the Federal Highway Administration (FHWA) have reported that 13.5 per cent of fatal RTIs and 18.8 per cent of all RTIs occur when the road surface is wet.<br>• In addition to vehicle speed, hydroplaning potential is largely governed by water film thickness, which is influenced by the longitudinal and transverse profile of the roadway and by road macro-texture.<br>• While adequate surface resistance generally exists on dry roads (although there are exceptions), the presence of water reduces the direct contact between the road surface and the tyre. |
| **Themes:** Wet Surface, Texture |
| **Comments:** US based study, but some information is relevant to UK. |

**Title: Road Maintenance – The Views of the AA**

**Author / organisation:** P. Watters (Automobile Association)
**Date:** 2011
**Format:** HTML
**Link:** http://www.rsta-uk.org/enews/issue5/clients-view.html#article3
**Free / priced:** Free

**Objectives:** Review of the views of the Automobile Association.

**Methodology:** Survey results.

**Key Findings:**

- In July 2008, 55 per cent of AA members, in an AA/Populus panel poll, listed the cost of motoring as their No 1 concern, with only 11 per cent most concerned by the state of the roads.
- In August 2011, 42 per cent listed road condition as their biggest worry while the cost of motoring most concerned 19 per cent of the sample.
- This concern about road condition is borne out by another AA Populus poll carried out at the start of 2011 which showed that 81 per cent of AA members think the roads have deteriorated in the last three years with 57 per cent of respondents saying conditions had deteriorated significantly and almost a quarter saying conditions had deteriorated slightly. Only 1 per cent thought conditions had improved considerably and 6 per cent thought they showed slight improvement. 12 per cent of those who responded thought conditions were unchanged.
- The 2010 English Road Condition Report has already identified that a quarter of main roads do not meet initial skid resistance standards and require further investigation, in London this is 49 per cent.

**Themes:** Maintenance

**Comments:** AA members survey which could contain bias due to membership demographics.

| **Title: Road Surfaces and Traffic Accident Risk** |
| --- |
| **Author / organisation:** R. Rallings (Organisation not listed)<br>**Date:** 2010<br>**Format:** Pdf<br>**Link:**<br>http://www.ract.com.au/uploaded/9/19890_28roadsurfacesandtraffica.PDF<br>**Free / priced:** Free |
| **Objectives:** To explain how the properties of the road surface affect the development of friction between tyres and the road. |
| **Methodology:** UK and Tasmanian RTI rates and standards for arterial roads are compared. |
| **Key Findings:**<br>• Inappropriately low surface resistance leads to greatly increased community costs in hospitalisation, lost time etc.<br>• Road frictional properties are likely to have a marked influence on wet road RTI rates.<br>• High speeds and low texture depths can result in very long stopping distances with increased chances of RTI. |
| **Themes:** Friction, Texture, Wet Surfaces |
| **Comments:** Not associated with company or academic institution, therefore unclear if report is biased in any way. |

| |
|---|
| **Title: Long-term behaviour model of skid resistance for asphalt roadway surfaces** |
| **Author / organisation:** T. Echaveguren, H. de Solminihac and A. Chamorro (Canadian Journal of Civil Engineering)<br>**Date:** 2010<br>**Format:** Pdf<br>**Link:**<br>http://www.ingentaconnect.com/search/article?option1=tka&value1=road+skid+resistance&sortDescending=true&sortField=default&pageSize=10&index=5<br>**Free / priced:** $28.66 |
| **Objectives:** This study proposes a model that describes the long-term behaviour of Skid Resistance (SR) on asphalt road surfaces. A sub-product of this work is a traffic-based model that incorporates the concepts of the PEF and vehicle wandering from the lane's right border. |
| **Methodology:** Study of existing models; Data collection and processing; Calibration and validation of traffic model; Calibration and validation of Skid Resistance model. |
| **Key Findings:**<br>• In Chile, road maintenance is scheduled each 4 or 8 years depending on the road condition, budget availability, and road hierarchy.<br>• According to the behaviour of Skid Resistance (SR) in low traffic levels, it can be concluded that for paved low-volume roads the frequency of SR monitoring can be reduced. It is especially true when using aggregates with low polishing susceptibility in construction because the polishing rate is low and it is possible that the starting SR values remain fairly unchanged over the time.<br>• When high traffic levels exists, independent of the aggregates quality, the polishing rate is higher and high frequency monitoring is needed to prevent the SR dropping under the thresholds established by standards. |
| **Themes:** Skid Resistance |
| **Comments:** Non-UK source (Chilean) but some content is relevant to the UK. |

| |
|---|
| **Title: Skid Resistance Policy in the UK – where did it come from and where is it going** |
| **Author / organisation:** P. Roe (TRL), L. Caudwell (Highways Agency)<br>**Date:** 2008<br>**Format:** Pdf<br>**Link:** http://saferroadsconference.com/wp-content/uploads/2016/05/Peter-Roe-Skid-resistance-policy-in-the-UK-where-did-it-come-from-and-where-is-it-going.pdf<br><br>**Free / priced:** Free |
| **Objectives:** To review the historical background to the introduction of UK policy for managing skid resistance on trunk roads, its subsequent evolution and application to other parts of the UK network. |
| **Methodology:** Literature review. |
| **Key Findings:**<br>• National policy for in-service skid resistance was introduced in 1988 in the UK.<br>• 20 years of experience since then has led to further developments of the standards.<br>• Challenges remain for the future – changing technologies, climate change and other environmental considerations.<br>• All will have an impact on future development of standards.<br>• Highway Authorities need to work towards a truly national standard for in-service skidding as well as exploring alternative strategies to reduce RTI risk. |
| **Themes:** Skid resistance, Policy and standards |
| **Comments:** UK-based research. Useful policy comments. |

**Title: Early life skid resistance – an assessment of accident risk**

**Author / organisation:** M. Greene (TRL) and L. Caudwell (Highways Agency)
**Date:** 2008
**Format:** Pdf
**Link:**
https://trl.co.uk/reports/PPR493
**Free / priced:** Free

**Objectives:** To summarise the methods and results of a study to investigate if a link could be observed between new surfacing and RTI risk.

**Methodology:** The study used a combination of an analysis of RTIs before and after resurfacing on the HA's network, along with the collation and review of anecdotal evidence from highways practitioners.

**Key Findings:**

- It has been suspected for a number of years that newly laid asphalt surfaces may have different skid resistances to those that have been in use for some time.
- This is thought to be from the layer of fresh bitumen binder on the material which is eventually worn by weathering and traffic.
- New types of surfacing introduced in mid 90s raised concerns that length of time that this phenomenon lasts may have increased.
- Research has identified physical phenomena that might lead to an increase in RTI risk in some circumstances.
- There were some variations but overall the following was found:
    - In the 12 months following resurfacing the RTI risk is similar or lower than before resurfacing;
    - There is a significant decrease in fatal RTIs on the resurfaced sections;
    - There is a small but statistically significant increase in RTI risk in the initial months after laying modern asphalt surfacing (mainly on motorways in dry conditions);
    - The period of risk appears to last for about 6 months after resurfacing; and,
    - The risk is statistically significant but the evidence did not suggest that it was a widespread problem.
- The study suggests that warning signs are used for the period after resurfacing has occurred and that further research would be beneficial in order to better understand the cause of the phenomena.

**Themes:** Skid resistance, RTIs, Resurfacing,

**Comments:** UK-based research. Useful statistical content.

| |
|---|
| **Title: Relationship Between Road Surface Characteristic And Crashes On Victorian Rural Roads** |
| **Author / organisation:** 23rd ARRB Conference – Research Partnering with Practitioners<br>**Date:** 2008<br>**Format:** Pdf<br>**Link:**<br>http://www.arrb.com.au/admin/file/content13/c6/6-relationship%20between%20road%20surface%20characteristics%20and%20crashes%20on%20Victorian%20rural%20roads.PDF<br>**Free / priced:** Free |
| **Objectives:** This paper reports an analysis of the relationship between road surface characteristics and RTIs on undivided two-way roads in the state of Victoria, Australia. |
| **Methodology:** Surface condition data from multi-laser profilometer surveys was linked to geometry, traffic and RTI data using GIS and the resulting tables analysed to investigate the relationships. |
| **Key Findings:**<br>• RTI rate was higher for road sections with low macrotexture; a power relationship provided a good fit to the data.<br>• RTI rate was also higher for roads where roughness was extreme, with a polynomial relationship providing a good fit to the data.<br>• No clear relationship emerged between rutting and RTI rate.<br>• An economic analysis suggests that resurfacing sites with macrotexture of 1 mm SPTD or less might produce RTI savings which would provide a very good return on the investment. |
| **Themes:** Road surface characteristics, RTIs |
| **Comments:** Australian-based research, however it is relevant to the UK. |

| |
|---|
| **Title: Identifying Relationship between Skid Resistance and Crashes using Probability-based approach** |
| **Author / organisation:** N. Piyatrapoomi, J. Weligamage, A. Kumar and J. Bunker (Queensland University of Technology)<br>**Date:** 2008<br>**Format:** Pdf<br>**Link:**http://79.170.40.229/saferroads.org.uk/2008Papers/Noppadol%20Piyatrapoomi_34_V1_200815[1].PDF<br>**Free / priced:** Free |
| **Objectives:** To present a probability based method of an ongoing study in identifying the relationship between skid resistance and road RTIs. |
| **Methodology:** Historical skid resistance and RTI data from a road network located on the east coast of Queensland were analysed using a probability based method. |
| **Key Findings:**<br>• Skid resistance is considered one of the most important surface characteristics as it has a direct impact on traffic safety.<br>• Many attempts have been made to understand the relationship between skid resistance and RTIs using statistical regression and correlation methods but results have been mixed and inconclusive. |
| **Themes:** Skid resistance |
| **Comments:** Australian-based research. Mixed findings, therefore may be of limited use. |

| **Title: The effect of de-icers on skid resistance and skidding accidents** |
| --- |
| **Author / organisation:** P. G.Roe, L. Crinson, M. Evans, R. Jordan and J. Martin (TRL)<br>**Date:** 2008<br>**Format:** Pdf<br>**Link:** https://trl.co.uk/reports/PPR220<br><br>**Free / priced:** Free |
| **Objectives:** To determine the effect of de-icers on skid resistance and skidding RTIs on the HA network. |
| **Methodology:** Direct measurement of skid resistance made in winter conditions on two types of road surfacing treated with different types of de-icer, in order to assess the physical effects. Analysis of STATS19 RTI data. |
| **Key Findings:**<br>• De-icing operations will not increase the risk of skidding RTIs on most, if not all, of the network. Only on roads that are close to their investigatory level is there a small theoretical increase in risk, but this is unlikely to be significant.<br>• There is no evidence from national statistics that the use of de-icers increases personal injury RTIs, including those at junctions and those involving motorcycles.<br>• Winter maintenance practitioners that are responsible for de-icing the network provided little or no hard evidence of RTIs associated with reduced skid resistance from de-icers.<br>• Drivers should be aware that de-icers can make roads wet, and they can remain wet for longer than they would otherwise be. |
| **Themes:** Surface Contaminants, Wet Surface, Skid Resistance |
| **Comments:** UK-based research paper containing much relevant information on the role that contaminants in de-icers have on the skid resistance of road surfaces. |

**Title: Incorporating Road Safety into Pavement Management: Maximizing Surface Friction for Road Safety Improvements**

**Author / organisation:** D. Noyce, H. Bahia, J. Yambo, J. Chapman and A. Bill (University of Wisconsin-Madison
Traffic Operations and Safety Laboratory)
**Date:** 2007
**Format:** Pdf
**Link:**
http://www.wistrans.org/mrutc/files/04-04_MRUTC_FR.pdf
**Free / priced:** Free

**Objectives:** This research explored the relationship between asphalt mix design, skid friction, and roadway safety. Initial tasks attempted to find a relationship between road skid resistance (friction) and RTI frequency, particularly wet weather RTIs.

**Methodology:** Friction and RTI data collected over 10 years at six study sites in Wisconsin were analysed.

**Key Findings:**

- The results of the analysis did not indicate a relationship between RTI frequency and road skid friction.
- Some evidence suggested that the number of wet road RTIs increased as the road life increased, however, the frequency of RTIs was not sufficient to statistically support.
- The fact that the more RTIs occurred at low friction numbers (FNs), is an important indication that skid resistance may indeed be a factor affecting wet weather RTIs.
- It was not possible to determine a skid friction threshold value that indicates the critical point where road maintenance would be needed.
- A possible indicator of friction on high-speed roadways is macrotexture.
- Plots of MTD and FN values did not show a clear relationship between the two values, although it was evident that the larger FNs were concentrated in low MTD values.
- Skid resistance is an important feature which should be considered while evaluating roadway safety.

**Themes:** Skid resistance, Wet weather, RTIs

**Comments:** US-based research. Some correlation with UK studies.

**Title: Surface Texture Measurement on Local Roads**

**Author / organisation:** H. Viner, P. Abbott, A. Dunford, N. Dhillon, L. Parsley and C. Read (TRL)
**Date:** 2006
**Format:** Pdf
**Link:** https://trl.co.uk/reports/PPR148
**Free / priced:** Free

**Objectives:** This project is concerned with the use of surface texture measurements on local roads with the specific requirements to:

- Identify how texture depth varies across the network and how this information can be used to characterise the condition of roads.
- Establish whether there is a sufficiently reliable link between measured surface texture depth and skid resistance.
- Develop techniques or methods for the use of texture depth measurements to identify road condition as well as a method for capturing this information automatically.

**Methodology:** A consultation followed by a review of relevant literature was used to deliver the project.

**Key Findings:**

- Texture depth is related to high speed skid resistance in wet conditions, but not to low speed measurements, such as those made by a SCRIM or Griptester.
- Current technology is not capable of measuring the fine scale surface microtexture, such as that on the surface of aggregate chips, as part of SCANNER surveys.
- Consequently, there is no evidence to justify texture depth measurements being used as a surrogate for skid resistance measurement.
- RTI studies strongly support the need for skid resistance data in addition to texture depth data.

**Themes:** Texture, Skid resistance

**Comments:** UK-based research. Some repetition of other sources.

| **Title: Heavy Vehicle Safety Research** |
| --- |
| **Author / organisation:** S.J Shaffer, A.-C. Christiaen and M.J. Rogers(National Transportation Center, Inc.)<br>**Date:** 2006<br>**Format:** Pdf<br>**Link:** http://www.ntrci.org/Uploads/Files/ResearchReports/FHWA-Assessment%20of%20Friction-Based%20Pavement%20Methods%20and%20Regulations.PDF<br>**Free / priced:** Free |
| **Objectives:**<br>1. Investigate procedures used to evaluate road conditions;<br>2. Determine the criteria, if any, used to qualify road conditions;<br>3. Identify, amongst those used, whether they are based on friction or not; and,<br>4. Characterize the actions required based on the specific values of the criteria used. |
| **Methodology:** Literature review and survey. |
| **Key Findings:**<br>• Some have attempted to correlate findings obtained from different methods, but limited correlations could be found. The large number of methods and practices used makes the task of finding a universal correlation unlikely successful. To complicate matters, some methods are also based on subjective assessments.<br>• Although a wide variety of road surface characteristics are studied and measured, at present, only skid resistance is regulated as a standard for roads maintenance. |
| **Themes:** Skid Resistance, Maintenance |
| **Comments:** US based study, but relevant to UK. |

| |
|---|
| **Title: Texture analysis of aggregates for wearing courses in asphalt pavements** |
| **Author / organisation:** S. Cafiso and S. Taormina (University of Catania)<br>**Date:** 2006<br>**Format:** Pdf<br>**Link:** http://dx.doi.org/10.1080/10298430600898307<br>**Free / priced:** £27 |
| **Objectives:** The relationship between adherence and aggregate texture is analysed, using superficial geometrical profiles, by means of both aggregate descriptors and the power spectral density function (PSD). |
| **Methodology:** Surface texture analysis of aggregates for road wearing courses. |
| **Key indings:**<br>• The maintenance of good adherence values on roads is an essential requirement to guarantee road safety and aggregate characteristics play an important role.<br>• The evaluation of aggregate properties by means of empirical indexes obtained from standard tests (LA, MDU, CLA) cannot fully explain the reason why some materials are suitable and others not.<br>• The polishing process causes a reduction in the height of the peaks and an increase in asperity density with a consequent reduction of the British Pendulum Number (BPN). |
| **Themes:** Texture |
| **Comments:** Non-UK source (Italian) but material has some relevance to UK. |

| |
|---|
| **Title: Linking Road Traffic Accidents With Skid Resistance – Recent UK Developments** |
| **Author / organisation:** H. E. Viner (TRL), R. Sinhal (HA), A. R. Parry (TRL)<br>**Date:** 2005<br>**Format:** Pdf<br>**Link:**<br>https://www.researchgate.net/publication/237680807_Linking_Road_Traffic_Accidents_With_Skid_Resistance_-_Recent_UK_Developments<br><br>**Free / priced:** Free |
| **Objectives:** To review the historic background behind “investigatory levels”, forming part of skid resistance surveys, and then describe in more detail the recent study and its findings, how the results compare with the historic work and the changes that were shown to be appropriate for application in the revised standard introduced in August 2004. |
| **Methodology:** Reviewing the historic background behind “investigatory levels” which form part of skid resistance surveys. |
| **Key Findings:**<br>• A larger-scale study of the link between skid resistance and personal injury accidents, based on 1000km of road network (Rogers and Gargett, 1991), confirmed the different levels of accident risk for different types of road site and the increase in risk for sites with lower skid resistance. |
| **Themes:** Skid resistance |
| **Comments:** UK historical review content and insight in to more recent findings. |

| **Title: The Effect of Skid Resistance and Texture on Crash Risk** |
| --- |
| **Author / organisation:** R.B. Davies, P.D. Cenek and R.J. Henderson (Statistics Research Associates and Opus International Consultants)<br>**Date:** 2005<br>**Format:** Pdf<br>**Link:** http://www.robertnz.net/PDF/SkidResistanceTextureCrashRisk.PDF<br>**Free / priced:** Free |
| **Objectives:** To analyse New Zealand state highway data for the period 1997 to 2002 in order to provide a preliminary indication as to what road condition and road geometry factors affect RTI rate and the involvement of Poisson regression modelling to better identify the important predictor variables and how they influence RTI rate. |
| **Methodology:** Four subsets of road crashes were investigated: all reported injury and fatal RTIs; selected injury and fatal RTIs covering loss of control events; reported injury and fatal RTIs occurring in wet conditions; and selected injury and fatal RTIs occurring in wet conditions. One and two-way tables and Poisson regression modelling were employed to identify critical variables and the form of their relationship with RTI risk. |
| **Key Findings:**<br>• In percentage terms, increasing skid resistance (SCRIM) has a greater effect in reducing 'wet road RTIs' than in reducing 'all RTIs'.<br>• A road should have adequate skid resistance and texture.<br>• The primary emphasis should be on increasing skid resistance rather than texture. |
| **Themes:** Skid Resistance, Texture, SCRIM |
| **Comments:** Research largely conducted in on New Zealand state highways. |

| **Title: Safety Aspects Related to Low Noise Road Surfaces** |
| --- |
| **Author / organisation:** R. Elvik (TOI) and P. Greibe (DTF-Atkins)<br>**Date:** 2005<br>**Format:** Pdf<br>**Link:** https://trl.co.uk/reports/SR696<br>**Free / priced:** Free |
| **Objectives:**<br>1. To develop a classification procedure combined with a conformity of production testing method. It will start from existing measurement methods, improve some of them and possibly develop new ones.<br>2. To test and specify road construction and maintenance techniques that would achieve satisfactory durability of the acoustic performances while complying with other requirements of sustainability like safety, pollution and mobility.<br>3. To develop a procedure for cost-benefit analysis of noise abatement measures, with emphasis of low noise road surfaces.<br>4. To issue a European Guidance Manual on the Utilisation of Low-Noise Road Surfaces designed to help decision makers to rationally plan noise abatement measures, integrating low-noise surfaces with other noise control measures. |
| **Methodology:** A systematic literature review has been undertaken. This review is to a large extent based on a previous literature survey (Greibe 2000). That survey indicated that only a few studies have evaluated the effects on road safety of low noise road surfaces. Furthermore, it indicated that the findings of the evaluation studies are conflicting and difficult to summarise. It was therefore decided to collect additional information fromthe partners of the SILVIA-consortium. A systematic review of evidence from evaluation studies is presented. This review includes a meta-analysis of some of the studies that have been retrieved. |
| **Key Findings:**<br>• The findings relating to the effects on RTIs of porous asphalt are highly inconsistent.<br>• No statistically significant effect on road safety of porous asphalt can be detected.<br>• In general, providing good skid resistance will improve road safety and will not adversely affect traffic noise. Good alternatives to porous asphalt do therefore exist. |
| **Themes:** Porous Asphalt, Skid Resistance |
| **Comments:** Inconsistent results but useful literature review of the topic. |

| **Title: Performance of High Skid Resistant Surfaces – Crash Trends** |
| --- |
| **Author / organisation:** C. Simpson (VicRoads, Australia)<br>**Date:** 2005<br>**Format:** Pdf<br>**Link:**<br>http://saferroadsconference.com/wp-content/uploads/2016/05/Cassandra-Simpson_32_V1_2008131.pdf<br>**Free / priced:** Free |
| **Objectives:** To investigate the performance of high skid resistant road surfaces with regard to the impact on traffic RTI trends. |
| **Methodology:** The project investigated 23 high skid resistant treatments with Melbourne and Geelong, Australia. Data from five years before, and five years after were reviewed to assess the impact of the skid resistant surfaces. |
| **Key Findings:**<br>• Overall a reduction in RTIs of 39 per cent was seen in areas treated with high friction surfacing compared with a reduction of 17 per cent on untreated sites.<br>• High friction surfaces are very effective at reducing loss of control RTIs on high speed curves with free flowing traffic.<br>• The treatment appears to be more effective when placed on the approach and the centre of signalled junctions.<br>• Although the total number of RTIs was reduced the proportion of different RTI types remained the same.<br>• A minority of sites showed an increase in RTIs and a larger increase in severity of injury although the reasons for this shift are unclear.<br>• Better selection of sites with regard to crash numbers and types of crash may be the key to maximise the benefits of high friction surface treatments. |
| **Themes:** Skid resistance, RTI reduction, Wet surface |
| **Comments:** Australian-based research but of some relevance to UK. |

| |
|---|
| **Title: A Pilot Study of the Relationship between Macrotexture and Crash Occurrence** |
| **Author / organisation:** P. Cairney and E. Styles (ARRB Transport Research, Victoria, Australia)<br>**Date:** 2005<br>**Format:** Pdf<br>**Link:**<br>http://www.infrastructure.gov.au/roads/safety/publications/2005/PDF/CR223_Text_Crash.PDF<br>**Free / priced:** Free |
| **Objectives:** To establish the relationship between macrotexture and RTIs. |
| **Methodology:** A pilot study of the relationship between macrotexture and RTIs was undertaken by locating each RTI on the macrotexture measurement record. |
| **Key Findings:**<br>• Macrotexture is generally believed to affect braking through the two mechanisms of hysteresis and the prevention of a water film.<br>• A literature review concluded that RTI risk is greater at sites with low macrotexture, but studies differ as to the macrotexture values at which risk begins to increase.<br>• In nearly all cases, there was an association between macrotexture and RTIs.<br>• There was a significant association between low macrotexture and RTIs at all rural intersection sites, but no association between low macrotexture and wet road RTIs, nor between macrotexture and young driver cashes.<br>• There was insufficient data to do formal testing for heavy vehicle involvement, but the pattern of the data suggests that low macrotexture was underrepresented at the sites of RTIs involving heavy vehicles.<br>• The results agree with previous studies regarding the increase in risk with low macrotexture. |
| **Themes:** Surface texture, RTIs |
| **Comments:** Australian-based research but relevant to UK. |

| |
|---|
| **Title: Accidents and the skidding resistance standard for strategic roads in England** |
| **Author / organisation:** A. Parry and H. Viner (TRL)<br>**Date:** 2005<br>**Format:** Pdf<br>**Link:**<br>https://trl.co.uk/reports/TRL622<br>**Free / priced:** Free |
| **Objectives:** To review the standard for skidding resistance in HD28 Design Manual for Roads, and undertake an RTI analysis of the UK road network. |
| **Methodology:** A network level analysis of the influence of skid resistance on RTI risk was carried out using existing databases of information. This included 29,250 RTI records. |
| **Key Findings:**<br>• New investigatory levels have been proposed. In most cases, this includes a range of investigatory levels for each site category.<br>• This range of risk emphasises the need for the reaction to low skidding resistance to be based on investigation rather than automatic intervention.<br>• As well as helping to meet RTI reduction targets, it appeared that the cost of the changes would be covered in the savings associated with the RTIs reductions. |
| **Themes:** Skid resistance, RTI reduction |
| **Comments:** Comprehensive UK research paper. |

**Title: Tyres, road surfaces and reducing accidents: A review**

**Author / organisation:** J. Bullas (AA Foundation for Road Safety Research)
**Date:** 2004
**Format:** Pdf
**Link:**
http://www.roadsafetyfoundation.org/media/11323/aa_foundation_fdn34.PDF?bcsi_scan_E956BCBE8ADBC89F=0&bcsi_scan_filename=aa_foundation_fdn34.PDF
**Free / priced:** Free

**Objectives:** To investigate whether any relationship exists between the surface characteristics of the road surface and the RTIs that occur, and, in particular, to investigate influencing factors such as wet/dry conditions, lighting and road markings.

**Methodology:** The method used was to review the information available on the various aspects and to draw it together into three chapters on surfacings, tyres and RTI databases, carrying out additional research as appropriate to each area.

**Key findings:**

- Surfacing materials do not always deliver appropriate levels of both macro- and micro-texture throughout their service lives.
- The Skidding Standard has provided a soundly-based structure for the effective allocation of resources to maintain the frictional properties of the Highway Network.
- The new skid resistance indicator in the NRMCS provides a single benchmark statistic for the overall skid resistance condition of the highway road network. However, this single statistic does not reflect the distribution of skidding resistance deficiency, or its consequential effects on RTIs, across the network.
- The mechanical treatment of a sound road surface to restore skidding resistance and texture depth can provide an effective short to medium-term solution to micro- and macro- texture deficiencies, which may need treatment more immediately than can be achieved by conventional resurfacing technique.
- Spray suppression devices and negative-textured surfaces have improved the wet-road driving experience in the UK.

**Themes:** Surfacings, Texture, Skid resistance

**Comments:** Useful UK-based content investigating links between state of the road surface and RTIs.

| |
|---|
| **Title: TRL Report 367: High and low speed skidding resistance: the influence of texture depth** |
| **Author / organisation:** P. G. Roe, A. R. Parry, H. E. Viner (TRL)<br>**Date:** 1998<br>**Format:** Pdf<br>**Link:** https://trl.co.uk/reports/TRL367<br>**Free / priced:** Free |
| **Objectives:** The provision of adequate friction between the tyre and the road surfacing, especially in wet conditions, is a key factor contributing to road safety.<br>Over many years, research has enabled specifications to be developed which allow newly laid surfaces in the UK to be designed to provide adequate skidding resistance performance for their expected life. These requirements are further supported by Standards for the skidding resistance of in-service roads which include routine monitoring of low-speed skidding resistance.<br>Since the time of the research on which current standards are based, traffic volumes have increased. Also, an increasing number of proprietary materials have been developed that were not covered by the earlier work.<br>Therefore, given the importance attached to skidding resistance policy in the UK, the Highways Agency commissioned further research which would re-visit the earlier work and assess the influence of texture on the relationship between high- and low-speed skidding resistance for the wide range of surfaces now used on UK trunk roads.<br>This report describes the main programme of this project and the results of the first phase of analysis. |
| **Methodology:** A database has been built from measurements of friction and texture depth on a wide range of surfacing types. This includes examples of all the major surfacing types used on main roads in the UK, together with some additional surfaces on the TRL test track. Where possible, a range of levels of low-speed skidding resistance and a range of texture depths representative of each surfacing type have been sampled. |
| **Key Findings:**<br>• Tyre/road friction in dry conditions is generally high but the presence of even a very thin film of water dramatically reduces the coefficient of friction. |
| **Themes:** Skid resistance, Texture |
| **Comments:** Useful UK-based research. |

| |
|---|
| **Title: The Polished Stone Value of aggregates and in-service skidding resistance** |
| **Author / organisation:** P. G. Roe and S. A. Hartshorne (TRL)<br>**Date:** 1998<br>**Format:** Pdf<br>**Link:** https://trl.co.uk/reports/TRL322<br>**Free / priced:** Free |
| **Objectives:** To determine the relationship of in-service roads to the polishing resistance of aggregates and the level of traffic using such roads. |
| **Methodology:** The study compared an analysis of skidding resistance measurements from in-service roads. This was supported by some limited laboratory studies of extended polishing. A database was established in phases to cover as extensive a range of aggregates, site categories and traffic levels as was practical. This was used to consider models for predicting skidding resistance from PSV and traffic data. A series of laboratory studies of polishing was then carried out to investigate some of the phenomena observed in the field data. Initial investigations of alternative PSV test regimes for small-particle size materials were also made. The interpretation of the results was supported by a background desk-top review of earlier research on the topic. |
| **Key Findings:**<br>• At present, PSV (Polished Stone Value) is the only parameter relating to the microtexture properties of an aggregate which can be measured in a standardised manner and which has been related to traffic and site conditions. It therefore remains an appropriate property to use in specifications, provided that its limitations are recognised. |
| **Themes:** Skid Resistance |
| **Comments:** Informative UK-based research. |

| |
|---|
| **Title: Road Surface Characteristics and Condition: Effects on Road Users** |
| **Author / organisation:** J. McLean and G. Foley (ARRB Transport Research Ltd)<br>**Date:** 1998<br>**Format:** Pdf<br>**Link:**<br>http://www.arrb.com.au/admin/file/content13/c6/ARR314%20Road%20surface%20characteristics.PDF<br>**Free / priced:** Free |
| **Objectives:** To provide a review of the effects of road surface type and condition on safety, vehicle operating costs and noise generation. |
| **Methodology:** Literature review. |
| **Key Findings:**<br>• The skid resistance offered by a wet road surface decreases with increasing travel speeds.<br>• At low speeds surface aggregate microtexture is the primary contributor to skid resistance.<br>• Macrotexture and water film thickness influence the extent to which skid resistance decreases with increasing travel speed.<br>• Wet weather RTI rates increase with decreasing skid resistance.<br>• For rural arterial roads, wet weather RTI rates increase markedly for SCRIM measured Side Force Co-efficients less than 0.5<br>European and US research has found that for rural roads with asphalt concrete surfaces, RTIs typically increase by about 5 per cent after resurfacing projects. |
| **Themes:** Skid resistance, Wet surface |
| **Comments:** Australian-based research but included as relevant to UK. |

| **Title: Skid Resistance and Fractal Structure of Pavement Surface** |
| --- |
| **Author / organisation:** O. Panagouli(Aristotle University) and A. Kokkalis (Democretus University)<br>**Date:** 1997<br>**Format:** Pdf<br>**Link:** http://dx.doi.org/10.1016/S0960-0779(97)00085-4<br>**Free / priced:** $39.95 |
| **Objectives:** To examine the road surface contribution to tyre-road skid resistance. |
| **Methodology:** An attempt is made to approximate the road surface texture with fractals, in order to take into account its accurate geometry. A qualitative relationship between road surface texture, expressed through fractal concepts, and skid resistance is recognised. |
| **Key Findings:**<br>• Inadequate microtexture, as a result of the presence of polishable material, drops skid resistance and enhances RTI risk.<br>• Inadequate macrotexture, as a result of faulty construction practice or wear, drops skid resistance, especially in the medium to high speed range, thus enhancing RTI risk. |
| **Themes:** Skid Resistance, Texture |
| **Comments:** Greek-based research but included as relevant to UK. |

| |
|---|
| **Title: Relation between surface texture of roads and accidents** |
| **Author / organisation:** P.G. Roe, D.C. Webster and G. West (TRL)<br>**Date:** 1991<br>**Format:** Pdf<br>**Link:**<br>http://www.thenbs.com/PublicationIndex/DocumentSummary.aspx?PubID=538&DocID=71473<br>**Free / priced:** Subscription required |
| **Objectives:** To determine High-Speed Texture Meter (HSTM) measurements on a wide range of roads which have been used to relate texture depth directly to RTIs. |
| **Methodology:** SCRIM and HSTM surveys were performed on a network of roads and then compared with the RTI records for those roads. |
| **Key Findings:**<br>• Both skidding and non-skidding RTIs, in both wet and dry conditions, are less if the macrotexture is course than if it is fine. This is observed at all levels of underlying skid resistance.<br>• The texture level below which RTIs begin to increase is about 0.70 mm sensor measured texture depth.<br>• All major types of surfacing contribute texture depths across the practical range.<br>• Macrotexture has similar influence on RTIs if they occur near hazards such as junctions or elsewhere<br>• The study notes that further research is required to confirm the hypothesis that improving texture reduces RTIs – research since this report was produced, would suggest that this hypothesis has been confirmed. |
| **Themes:** Texture, RTI reduction |
| **Comments:** UK content but could be out of date now. |

28 Calthorpe Road, Edgbaston, Birmingham, B15 1RP

**Telephone:** 0121 248 2000

**Registered Charity No:** 207823

**www.rospa.com**