Road Surfacing Revisited – a new look at an old countermeasure

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The importance of road surfacing for good safety performance has been understood from the earliest days of motorised transport. Laser profilometers offer new ways of assessing road surfaces but little has been done to match this information to the crash histories of roads. Macrotexture, defined as surface irregularities between 0.5 mm and 50 mm in height, seems particularly promising as indicator of satisfactory road surface on high speed roads. This paper briefly reviews existing studies, and reports results of two exploratory studies. The first of these examined the relationship between macrotexture and crashes, and revealed a moderate but consistent increase in crashes when sensor-measured texture depth fell below 0.4 mm. The second study examined the relation between macrotexture, rutting and roughness, and their relation to crashes. There was a stronger association between macrotexture and crashes in the second study, probably because crash data and survey data were more closely associated in time. The relationships between the variables and their relation to crashes will be described. Discussion will focus on how this information can be used to manage road surfacing to provide safer travel conditions and how this information can be used in risk management for the road system.

1 Introduction

In nearly all crashes or near-crash situations, drivers attempt to avoid a collision by braking, and possibly by steering as well. The success of these manoeuvres depends on the state of the vehicle's tyres and the 'grip' of the road surface. Road surface has traditionally been assessed by skid resistance, which depends on a combination of microtexture (the roughness of the stone chip faces, surface variations of less than 0.5 mm) and macrotexture (the gaps between the stones, surface variations between 0.5 mm and 50 mm). The relationship between skid resistance and crash frequency was established as long ago as the 1950's and is well documented (see e.g. Cairney 1997 for an overview).

There are a number of disadvantages on relying on skid resistance measurements to manage surface condition. Skid resistance is not a stable measure, as it reduces after long periods of polishing from traffic in dry weather, and recovers after periods of rainfall renew the surface roughness of the aggregate. In general, road authorities in Australia have not measured skid resistance at sufficiently short intervals to provide comprehensive monitoring of this parameter.

The mechanism of hysteresis, i.e. the deformation and recovery of the tyre as it is pressed into the road surface as the vehicle brakes, is thought to be the critical mechanism at higher speeds. This process is affected primarily by macrotexture. Adhesion, i.e. the wearing away of tyre and stone particles, is thought to be more important at lower speeds and is affected primarily by microtexture. Thus in high speed environments, it may be sufficient to manage surfaces on the basis of macrotexture alone.

Modern road survey equipment relies on lasers to capture information about the road surface. They can be configured to measure surface irregularities in the macrotexture range. Although the technology is advanced, the process of measuring macrotexture is simpler and cheaper than measuring skid resistance, which requires large quantities of water and frequent attention to calibration.

For some time now, evidence from the UK and France (Roe et. al. 1991, Gothie 1993).has been available which shows that crash rates are much higher where macrotexture is low, and that this cannot be explained by an association of low macrotexture with greater traffic flow (see e.g. Cairney and Styles 2005 for a review of this material). This paper reports recent work to investigate the relationship between macrotexture and crashes under Australian conditions, carried out as part of two separate projects. Fortuitously, both investigations were carried out on the same stretch of road, but used macrotexture surveys and crash data some few years apart.

2 METHOD

2.1 The studies

The first study was an exploratory study of the relationship between macrotexture and crash occurrence on major routes in three different states (Cairney and Styles 2005), including the route discussed in this paper. The focus of the second study was to investigate the relationship between rutting and crashes; the study design included examining the relationship between rutting and other surface characteristics, including macrotexture, and the relationship between these characteristics and crashes. The road which was thought to be most subject to rutting was the same as one of the routes in the first study.

2.2 The Route – Princes Highway West

The route selected for study was the Princes Highway West, between Geelong and Portland. The route was 280.94 kilometres in length, of which 244.58 kilometres were rural, defined as having a speed limit of over 80 km/h) and 36.36 kilometres were urban (defined as having a speed limit of 80 km/h or less). Macrotexture data was available from a survey in one direction only, and was analysed in 20 metre sections.

2.3 Macrotexture surveys

Two macrotexture surveys were carried out by ARRB Group for VicRoads using the ARRB Multi-laser profilometer. This unit measures texture while the vehicle travels at. All macrotexture records are GPS-referenced, so they can readily be related to maps of the road.

The first survey was carried out in 2000. This survey was used as the sole source of macrotexture data in the first study, in which it was matched with crash data for the years 1998-2002. It was also used in the second study, when it was matched with data from 1999 and 2000 only.

The second survey was carried out in 2002, and in the second study it was matched with crash data from 2001-2003.

2.4 Traffic flow data

In the first study, it was not possible to obtain traffic flow data in fine enough detail to calculate meaningful estimates of crash rates. However, in the second study, VicRoads provided estimates of traffic flow along each link between junctions with other declared roads which enabled the calculation of crash rates.

2.5 Crash data

Crash data were provided by VicRoads. The data items provided included the geocode for each crash, which allowed accurate placement of the recorded location of the crash in relation to the macrotexture records. The geocode does not resolve any of the usual problems with ensuring that the reported location is accurate.

3 RESULTS

3.1 Study 1

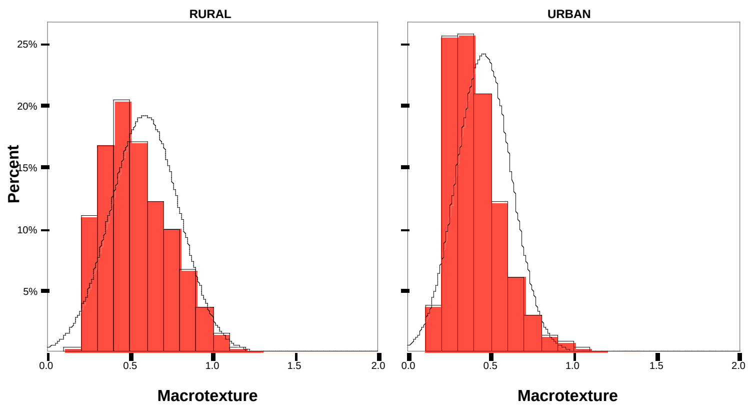

Figure 1: Distribution of macrotexture on rural and urban sections, Princes Highway West.

The distributions of macrotexture on the rural and urban sections of the Princes Highway West are shown separately in Fig 1. The distribution for the urban sections has a much higher proportion of sections with low macrotexture than does the distribution for the rural sections.

3.1.1 Macrotexture on sections where crashes occurred

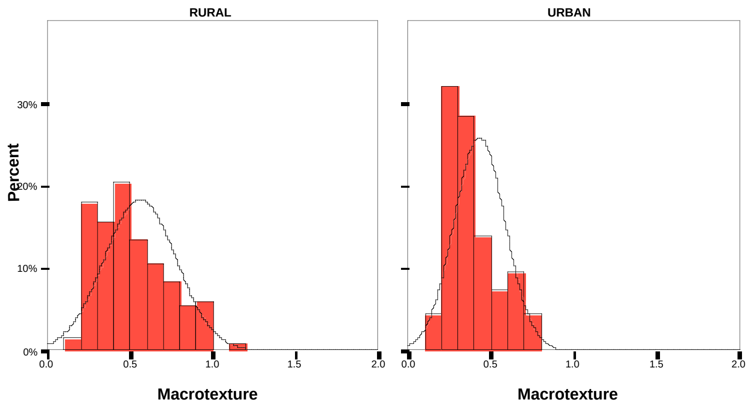

Figure 2: Distribution of macrotexture on rural and urban sections where crashes occurred, Princes Highway West.

Macrotexture distributions on the sections where crashes occurred are shown in Figure 2, separately for rural and urban parts of the route. Many more of the urban sections had low macrotexture than was the case for the rural sections.

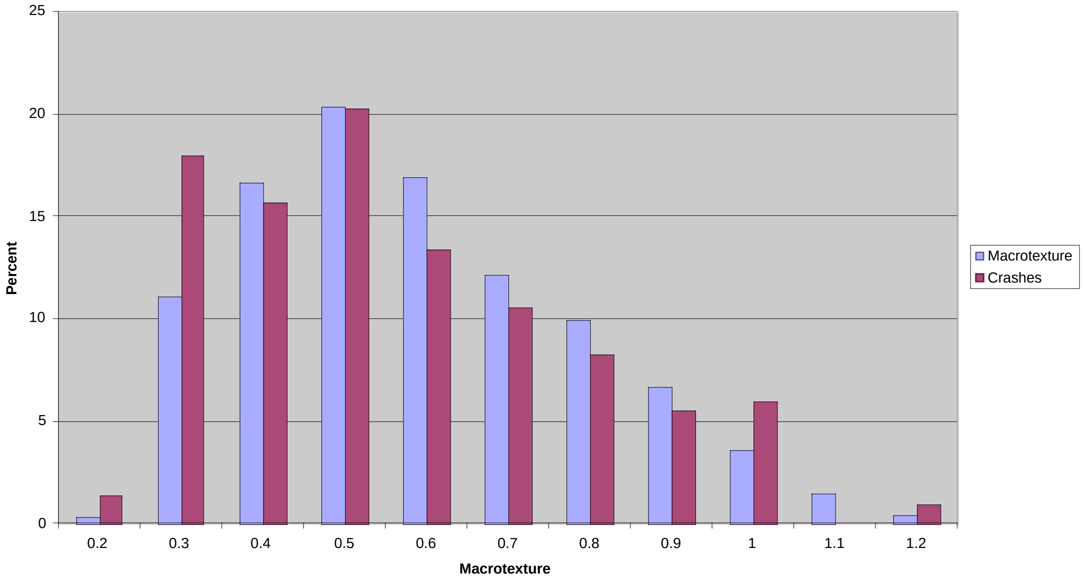

Figure 3: Comparison of distributions of macrotexture on all sites and at crash sites, Princes Highway West, rural.

Figure 3 indicates that for rural sections, there are a considerably higher proportion of crash sites than of all sites in the lower macrotexture categories, especially in the 0.3 category. Figure 14 indicates a similar pattern for urban sites, although the excess of crash sites over all sites is less pronounced for the 0.3 macrotexture category, and extends to the 0.4 category.

Further analyses were carried out which showed:

- no increase in the percentage of low macrotexture sites for fatal and serious injury crashes
- no increase in the percentage low macrotexture sites for of heavy vehicle crashes
- no increase in the percentages of low macrotexture sites for crashes involving young drivers
- no increase in the percentage low macrotexture sites for of wet weather crashes
- a significant increase in the percentage of low macrotexture sites at intersections.

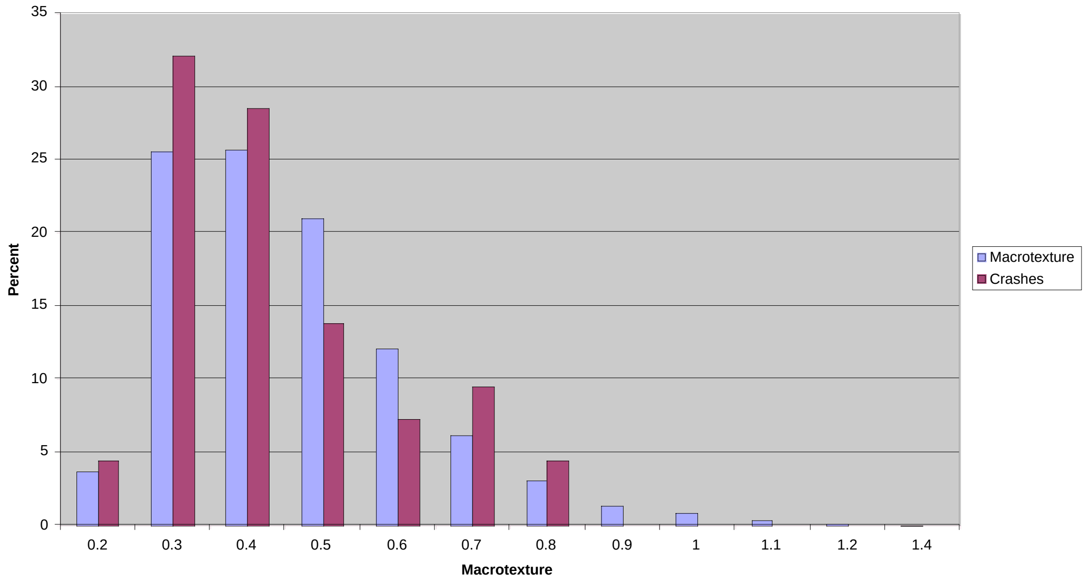

Figure 4: Comparison of distributions of macrotexture on all sites and at crash sites, Princes Highway West, urban.

3.2 Study 2

The second study was carried out as part of a larger study to examine the inter-relationships between rutting, macrotexture and roughness, and their relation to crashes (Cairney et al 2005).

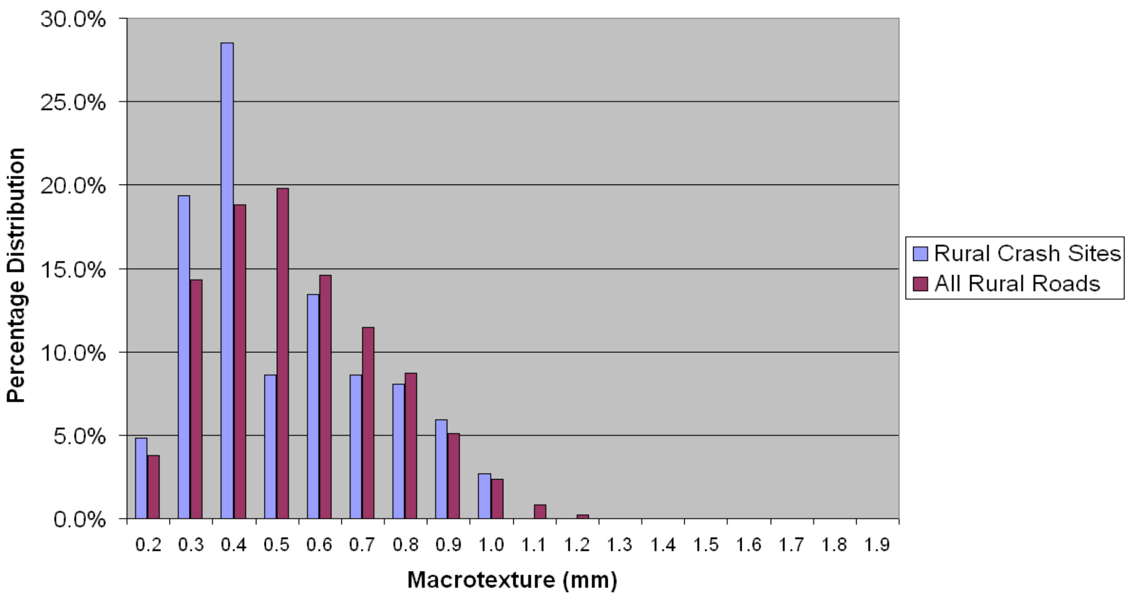

Figure 5: Comparison of macrotexture distributions at crash sites and at all sites

The distribution of macrotexture at crash sites and at all sites found in the second study is shown in Figure 5. For sites with an SMTD of 0.4 mm or less, there is a greater percentage of crash sites than for all sites, while for sites with an SMTD of 0.5 or greater, the reverse is generally true, except for sites with an SMTD of 0.9-1.0 mm, where there are slightly more crash sites, but note that the numbers are small.

The percentage of sites falling above or below the cut-off point of an SMTD of 0.4 is shown in Table 4. It can be seen that with an SMTD of 0.4 mm or less, the proportion of crash sites considerably exceeds the proportion of other sites. Analysis by the chi-square test shows the association between crashes and low macrotexture to be highly significant (Chi square =20.02, df=1, p< 0.0001).

Table 1: Macrotexture at crash sites and other sites

Macrotexture (SMTD)	Crash sites	Other sites
0.4 or less	98 (52.7%)	15,540 (36.8%)
0.5 or more	88 (47.3%)	26,630 (63.2%)
Total	186 (100.0%)	42,389 (100.0%)

Sites with an SMTD of 0.4 or less accounted for 36.8% of other sites and 52.7% of crash sites. Compared to the average, for the road, the risk of crashing at a site with SMTD of 0.4 or less is 52.7/36.8 = 1.43, or 43% greater.

The second study did not repeat the analyses in relation to crash severity, heavy vehicles, young drivers and intersections that were carried out in the first study, but it did examine the relationship between macrotexture and wet weather crashes. The data are displayed in Table 2, inspection of which shows little difference between the percentage of low macrotexture sites for wet weather crashes and dry weather crashes. However, the numbers of crashes occurring in the wet is small.

Table 2: Road conditions at crash sites by macrotexture

Macrotexture (SMTD)	Wet	Dry
0.4 or less	5 (19.2%)	36 (23.7%)
more than 0.4	21 (80.8%)	116 (76.3%)

In this second study, it was possible to obtain estimates of traffic flow broken down in sufficiently fine detail to produce meaningful estimates of crash rates in relation to macrotexture. These results are presented in Table 3. From the table it appears that the crash rate is approximately 80% higher when macrotexture drops below an SMTD of 0.4.

Table 3: Crash rates per million vehicle/km

Macrotexture (SMTD)	10^6Vehicle/km 1999-2003	No of crashes	Crashes/million vehicle/km
0.4 or less	251	46	0.1833
more than 0.4	838	84	0.1002

4 DISCUSSION

This discussion focuses on the relationship between crashes and macrotexture on rural roads. The evidence is clear, from the studies reported in this paper and a number of other studies in Australia and overseas, that the relative risk of a crash increases once threshold falls below a critical threshold. The results from different studies differ slightly, with a threshold SMTD values of 0.3 mm for study 1 and 0.4 mm for study 2. Study 1 found an increase in crash risk of 90% below that threshold, and Study 2 found an increase of 43%. Study 2 had the advantage of sufficiently detailed traffic flow data, which enable crash rates per million vehicle/kilometres to be calculated. The rate for sections below threshold was approximately 80% higher than for sections above the threshold.

Some further working is required to reconcile these results. The lower threshold and higher increase in crashes for Study 1 suggests the overall pattern of results might be quite close.

Further work is also required to provide a better basis for threshold values and the crash reductions which can be expected. This work is well worth persisting with, as the following analysis shows, based on Study 1.

Crash risk for low macrotexture sites was 1.9 times greater than sites with satisfactory macrotexture, and the proportion of crashes at low macrotexture sites was 36.5%.

Increasing macrotexture where required would reduce crashes to 1/1.9 of their formal level, and the expected reduction in total crashes would therefore be 36.5 x (1-(1/1.9) %, i.e. 19%.

Macrotexture fell below the critical value on 29% of the route. Although this represents a considerable investment in resurfacing to achieve a 19% crash reduction, two strategies are available which might make it feasible.

The first is to target improvements more narrowly at high risk sites. Two possible examples are intersections and curves. The analysis showed that low macrotexture sites were over-represented in crashes at intersections, and it seems reasonable to expect low macrotexture would pose more of a risk when travelling around curves than travelling along straight sections, due to reduced sight distance on some curves and possible high lateral forces in the event of hard braking. Focussing on ensuring satisfactory macrotexture at intersections and curves may result in greater crash reductions at these sites than the 19% implied by the overall results. This process can be further refined by considering factors such as the sharpness of curves, gradient and superelevation, not available in the present study.

The second strategy would be to make a one-off investment to bring the whole road up to a satisfactory level on macrotexture. It is generally assumed that a road surface has an effective life of around ten years and therefore that approximately 10% will require renewal every year. The effect of the one-off investment would be that current maintenance levels would ensure that the entire road had satisfactory macrotexture for the remaining life of the road, provided maintenance is held at its current level. This would mean that the 19% reduction in crashes would also apply for the life of the road.

The next steps in the research involve examining the relationship between crash risk and crash rates for a much wider sample of roads to allow the threshold for increased risk, and the extent of the increased crash risk and crash rate to be put on a sound empirical footing. This should be accompanied by a comprehensive investigation of other risk factors, such as curvature, gradient and the presence of crossings, and an investigation of the extent to which different types of crash event are over-represented on surfaces with low macrotexture. Fortunately, current systems for recording crashes, measuring road geometry and monitoring road condition make these goals achievable – at least in theory. No doubt the success with which these endeavours are met will form the basis of future presentations at this conference.

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