Development and use of a skidding strategy for a local authority

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ABSTRACT

At the previous Cheltenham Conference in 2008 the first author presented a paper [Catt 2008] describing the development of a local authority skidding strategy. This paper presents the developments, refinements and use of that strategy. In essence it is a local authority version of the Highways Agency's HD28.

It describes why the original investigation levels (IL) were set at those recommended by the Highways Agency for use on trunk roads and motorways. As part of the strategy it was decided to simplify the characteristic SCRIM coefficient (CSC) by using the average of the last three years data.

The paper describes the process by which site investigations are carried out, the collection of data, the use of that data including CSC (of course) together with injury collision data for the same 3 year period, SCANNER data including texture, rut depth and ride quality. The paper discusses the reasons for their use.

Additionally the paper describes various information obtained during the use of the strategy including a general reduction of IL in 30 mph areas, additional classes in the IL table, anomalous relationships between PSV and CSC, and comparison of collision risk at pedestrian crossing with and without high friction surfacing.

All of the above have now been incorporated in the revised strategy published in 2013. This is described in the paper. Further refinement of the strategy will occur as more knowledge is gained of the inter-relationship between surface characteristics and crashes.

1 INTRODUCTION

At the previous Cheltenham conference the first author [Catt 2008] presented the setting up and early operation of the skid resistance strategy for Warwickshire [Allinson 2006]. This has been used and modified over the subsequent 7 years and a second edition was published early in 2013 [Allinson 2013]. This paper describes the modifications generated and the reasons and justifications for them.

Modifications include site specific reductions in investigation levels (ILs) after site investigation, additional site categories obtained mainly by splitting existing categories to make them more suitable for local authority roads and a general reduction in ILs for 30 mph speed limit sites.

As a result of the site investigations that have been carried out over a number of years evidence has emerged for justifying that high friction surfacing is not normally needed for approaches to pedestrian crossings or similar site categories; the Warwickshire surfacing and structural maintenance strategy [Catt 2009] has been altered to that effect. Site investigations have been simplified considerably compared to the procedure set out in HD28/04 [Highways Agency 2004]. Also as a result of the site investigations it has been noted that some aggregates behave better than and some worse than would be expected from their polished stone value (PSV). The results from a formal trial of three aggregates is reported here using 3 years of SCRIM data.

2 SETTING OF INITIAL INVESTIGATION LEVELS

In general two strategies were used by local authorities to set the initial ILs for their network. They either followed the recommended initial levels given in HD28/04 or assumed that the local authority network had an overall lower risk and used an initial level one step lower. Warwickshire opted to begin by following the 'default' levels given in HD28 as it was decided that there was no demonstrable evidence that the second strategy was sufficiently robust particularly as the collision frequency on single carriageway roads was considered likely to be higher than on dual carriageways and motorways. The only change compared to HD 28/04 was that bends were split into two categories: above and below 250 m radius as this continued the split given in HD28/94 [Highways Agency 1994] and there was no evidence to change this for the local network. The initial IL on the 250-500 m radius bends was 1 step below the HA recommended level for all bends.

The only other significant change from HD28/04 was the definition of CSC (Characteristic SCRIM Coefficient). HD28/04 uses a complex procedure which requires the determination of all surfacing works over the previous 5 years so that sections with new surfacing within that period can be eliminated from the calculation of CSC. Although surfacing data is available in several sets of records it was not certain that any existed is a form suitable for automatic application of the Highways Agency method and manual application would have been very time consuming. It was decided, therefore to implement a simpler version which was to take the average of the last three years SCRIM coefficient (SC) to determine the WCC version of CSC. As it was expected that there would be changes to the IL set for a significant number of sites so the new levels would be set against this simpler version of CSC.

3 DEVELOPMENT OF THE TABLE FOR INVESTIGATORY LEVELS

As experience was gained from the large number of site investigations and trials the permitted investigation levels were extended beyond those permitted in HD28/04. The current version of the table of investigatory levels is shown in tale 1 The first amendment was to reinstate the concept of risk rating from HD28/94 as it was found much easier to explain the changes to IL to non-specialists with this in place.

Table 1: Site Categories and Investigatory Levels

Site category and definition		Investigatory Levels at 50 kph.					
		0.30	0.35	0.40	0.45	0.50	0.55
	Risk Rating	**1**	**2**	**3**	**4**	**5**	**6**
B	Dual carriageway non-event.		B	B+(iii)			
C	Single carriageway non-event		C-	C			
Q	Approaches to and across minor and major junctions, approaches to roundabouts			Q#	Q-	Q	
K	Approaches to pedestrian crossings and other high risk situations			K#	K-	K	
M	Approaches to single carriageway minor junctions (D roads and heavily trafficked private accesses)		M#(ii)	M-	M		
R	Roundabouts		R#(ii)	R-	R		
G1	Gradient 5-10% longer than 50m		G1#(ii)	G1-	G1		
G2	Gradient >10% longer than 50m			G2#(ii)	G2-	G2	
S1	Bend radius <500m - dual carriageway		S1#(ii)	S1-	S1		
S2	Single carriageway 40 mph or above Bend radius 500m – 250m		S2#(ii)	S2-	S2		
S3	Single carriageway 40 mph or above Bend radius <250m – 100m			S3#(ii)	S3-	S3	
S4	Single carriageway all speeds (i) Bend radius < 100m			S4#(ii)	S4-	S4	

(i) Bends on single carriageways in 30mph zones will only be categorised when less than 100m radius. Bends above 100m radius in 30mph areas will be categorised “C” – non-event.

(ii) May only be used after appropriate assessment AND when the preceding IL is lower or equal. NOT to be used if the preceding IL is greater.

(iii) B+ is used at the merging of slip roads. See HD36 for description where higher PSV may be used in this location.

Figures in dark shading are to be used as starting point when setting an IL for the first time. They reflect the initial IL values in Paragraph 4.9 and Table 4.1 of HD28/04. Minus (-) values represent one risk rating below the initial IL value. # values represent two risk ratings below the initial IL value.

It was decided that the initial IL category would be a plain letter. A plus sign (+) indicates an increase of risk rating by one step; a negative sign (-) a reduction in risk rating by one step and a hash sign (#) a reduction in risk rating by 2 steps. The only time an increase has been applied is on 70 mph dual carriageways where B+ has been used alongside lay-bys and slip road entries.

It was found useful to add an additional site category for very minor junctions (M) and busy private accesses. In HD28/04 category Q includes these minor junctions. The boundary between Q and M minor junctions is somewhat blurred but is based on a subjective assessment of the relative risk. In the long run the actual IL that emerges is likely to be the same whichever category (Q or M) is used initially but using different categories highlights an assessment of the relative risk and sets out the possibility of lower permitted values.

It was decided, as part of the strategy, that however low the collision rate the lowest IL that would be allowed would be 0.35 (risk rating 2). This ensured that any site with a CSC below 0.35 would be investigated on an annual basis thus minimising the risk of collisions increasing without being noticed.

The investigatory levels for categories S3 and S4 are the same but it is advantageous to distinguish between bends and sharp bends.

Except for the limited use of category B+ (above) it has not been found necessary to increase the IL above the level set initially.

4 SITE INVESTIGATIONS

Site investigations are carried out on all sites where the CSC is at or below the current IL. The CSC is determined manually using spread sheets. This is deliberate in that any obvious anomalies are seen by the person doing the determination thus reducing the risk of any errors being propagated in a totally electronic environment. Low CSC sites are given one of 4 categories:

1. Category 1 – single 10 m lengths with a current year SC at or below 0.25. these are investigated as soon as possible. There are usually about 10 of these sites each year and are rarely the same from year to year. They are usually caused by local agricultural contamination but occasionally they trigger a need for urgent attention.
2. Category 2 – CSC at 0.1 or more below IL over the relevant length of 50 or 100 m as appropriate.
3. Category 3 – CSC at or more than 0.05 below IL and less than 0.1 below IL over the relevant length of 50 or 100 m as appropriate.
4. Category 4– CSC at or below IL and less than 0.05 below IL over the relevant length of 50 or 100 m as appropriate.

In addition all sites with 6 or more crashes of which at least one third were on wet roads are investigated as high crash sites. These can be on any class of road and not necessarily on one that is routinely skid tested.

It was originally intended that the site visits would take place in category order. However this was found to be unrealistic as it meant traversing the road network 3 times. All site visits take place in such a way as to reduce travelling to a reasonable minimum. The categories are still serving their main purpose of highlighting levels of risk.

Initially investigation sites were quite long and included a number of junctions and other risk sites. This was particularly so in 30 mph sections. However in recent years each individual junction, for example, has been treated as a single site. This has meant that the number of sites has apparently increased but the assessment of each is simplified. For the last two survey years that have had the site investigations completed (2011 and 2012) there have been over 500 individual sites.

Each site has a 1 page summary sheet which summarises the CSC for the site, texture, rutting and 3m longitudinal variance (measure of ride) – all extracted from SCANNER data and crash data. The term crash is used deliberately to highlight there is virtually always a cause. In six years of reading crash reports the authors have only found 2 that were genuine accidents; one was a heart attack and the other a tree fell on a car in a high wind.

The crash reports that are used are summaries of STATS 19 information including, most importantly, the narrative describing what happened. Crashes involving drunks or excessive speed are particularly noted. The summary sheets include the number of crashes in the 3 year period ending December 31st of the survey year. The crashes are split into 'on line' and 'off line' and also into wet/dry and skid/non-skid. On line are caused by traffic on the surveyed road and off line are the others in the vicinity including those on an approach road to, for example, a junction. They also includes crash data from the previous year's investigation where the site is the same.

All sites are visited and most are assessed by an initial drive over. Sites with particular problems are looked at in more detail from the verge. In town centres it has been found advantageous to use a pedal cycle as it is much easier to stop on an adjacent footway to make notes than to keep parking a car. All the site investigations over the 6 years up to and including the 2012 survey year have been carried out by the first author who has built up a good experience and picture of most of the sites as they are often the same from year to year.

There have been no cases where the investigation level has been increased as a result of a site investigation and in most cases there has been sufficient justification for them to be reduced. In many cases, even after IL reduction, the CSC of the site remains below this lower IL. The 'do nothing' option is the most frequent recommendation now that the IL levels have stabilised after 6 years of surveys. If there is no justification for resurfacing – ie no wet crashes – the low CSC ensures continued monitoring. Where surface treatment has been recommended it is usual to recommend a higher PSV than the current value is required or alternatively a smaller aggregate size which will also increase CSC. In fewer than 1% of sites has work other than surface treatment been recommended such as improving visibility from give way signs or installing various traffic management schemes.

Each site report, as hard copy, includes the Site Investigation summary sheet, a SCRIM printout, a SCANNER printout, map of crash positions and the crash data. It was decided to produce hard copy reports as they are easier to access and read as each report includes all or part of 4 computer files in various formats.

The investigation starts in November of the survey year with the determination of the low CSC sites. These are then forwarded to the road safety intelligence team who return a crash report for each site requested, (the length of site requested is about 50 m longer at each end than the site defined in HD28/04). These reports include a map showing location and for each crash a

summary of standard features plus a narrative describing each crash. They cannot start this until about mid-February to allow time for all crash data to be included up to the end of December of the survey year. It takes them about 2 months to work through the list and forward the crash reports to the Highway Information Manger (second author). These are then assessed and the site visits started together with writing up the reports. The target completion date for delivery of all the reports together with a summary and a covering report highlighting particular problem sites is the end of July following the SCRIM survey year.

4.1 CHANGING INVESTIGATION LEVELS

4.1.1 Raising ILs

It has not been found necessary at any time to raise the IL for any individual site. It would only be done where it was a high crash site and the CSC was above the existing IL. Even then an assessment of the causes of the crashes would need to show that the wet skidding resistance of the road surface was a problem.

4.1.2 Reducing IL

The IL for a site may only be reduced by a single step during any one assessment. The total amount of reduction depends on the site category and will never exceed 2 steps.

All proposals as to whether to reduce the IL are a matter of judgement and must be made by an engineer experienced in such matters and is always subject to approval by the Highway Information Manager.

The following procedures are minimum requirements for reducing ILs.

To reduce the IL by one step two criteria are paramount:

1. The existing CSC is below the IL (otherwise there is no evidence that a lower IL is valid)
2. There should be no crashes on line in three years that would have been made worse by having a lower skidding resistance. Crashes on approach roads caused, for example, by failure to give way, are omitted from any calculations.

The criteria for reducing the IL by a second step are much tighter:

1. The existing CSC is below the (reduced) IL (otherwise there is no evidence that a lower IL is valid)
2. There must have been no crashes at the site for at least 4 years; and the CSC must have been below IL for those 4 years (or there would be no data from a previous survey). The only exception to this is if a crash off line was a rear end collision and there was no involvement with traffic on line.
3. The IL cannot be reduced below that of the adjacent road, normally category C (IL=0.4)

In either case even if all the criteria are met the IL should not be reduced if any doubts regarding the safety of the site remain. If there are any such doubts then the site should be listed for consideration for resurfacing with a more skid resistant surfacing either immediately or more likely when the time for a routine resurfacing arrives. Resurfacing is only likely to be needed where the current CSC is more than 0.05 below the current IL. Situations could arise (and have done) where it is justified to reduce the IL but also to recommend a higher PSV when the site is next resurfaced.

5 JUSTIFICATION FOR GENERAL REDUCTION OF ILS ON 30 MPH SITES

It had been noted at the completion of site investigation after the 2009 SCRIM survey that almost all investigated sites in 30 mph areas had had their ILs reduced (this did not apply to category C sites) so a statistical investigation was instituted to determine whether a general reduction of ILs in 30 mph zones was justified.

To this end comparisons were made between crashes in 30 mph zones and crashes on the rest of the network. The following comparisons were made:

- Proportion of crashes on wet (includes ice and snow) roads
- proportion of wet skid crashes
- proportion of dry skid crashes

the results are summarised in Table 2. Also investigated was the percentage of wet crashes on 30 mph roads for each level of deficiency in CSC ranging from 0.01 to 0.15; ie from just below the IL to 3 risk ratings below. This is shown in Graph 1.

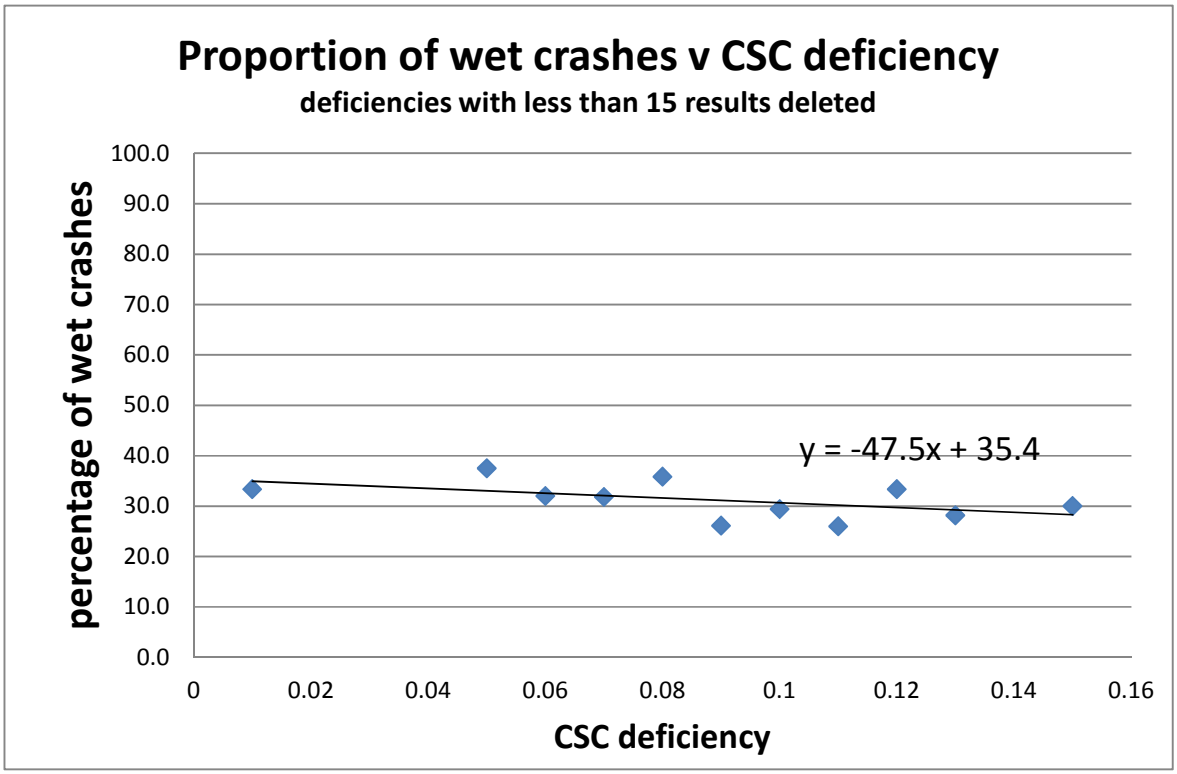
Table 2 comparison of crash proportion inside and outside 30 mph zones.

Factor	**Proportion in 40-70 mph zones**	**Proportion in 30 mph zones**	**Significance level of difference**
Total no of crashes	4381 (number)	689 (number)	
Wet crashes	34.9%	31.7%	5% (probably significant)
Wet skid crashes	13.1%	5 7%	About 1 in 10^8
Dry skid crashes	13.6%	4.8%	Beyond 1 in 10^9 (limit of statistical tables in the author's possession)

The conclusion from this work was that there were good statistical data to justify an overall reduction of the ILs for 30 mph zones by one risk rating except for category C. There are very limitted lengths of dual carriageway 30 mph roads in the county. Summarising the reasons:

1. the risk of wet crashes being reduced was probably significant.
2. the risk of wet and dry skid crashes being reduced was hugely significant.
3. the variation of risk of wet skid crashes with variations in CSC is virtually non-existent. As can be seen from the trend line the risk of wet crashes seems to reduce slightly as the CSC reduces.

More recently a similar examination was carried out for 40 mph zones. The outcome was inconclusive as the number of results was too low to generate adequate statistical robustness although the data pointed to there being evidence for the ILs to be reduced on the same basis as in 30 mph zones. However all the 40 mph sites that had a low CSC have had their IL reduced on a site by site basis. Further work is planned as more data becomes available.



Graph 1 crash proportion against level of CSC below IL.

(note: the number of results for each level varied; the number of crashes for CSC deficiencies of 0.02, 0.03, 0.04 and 0.14 were very low and have been removed from the correlation)

6 OTHER INVESTIGATIONS

6.1 SURFACING ON APPROACH TO PEDESTRIAN CROSSINGS

A comparison was made of the crash rate at pedestrian crossings. About half of the pedestrian crossings had high friction surfacing on the approach and the rest had 'normal', bituminous, surfaces. Although there were very few crashes at any of the crossings, insufficient in total for a valid statistical analysis, the indication was that the use of high friction surfacing on approach did not reduce the crash rate. Nearly all WCC crossings are light controlled and most of the crashes were caused by either pedestrians or motor vehicles jumping red lights. There was a slight indication that at the few Zebra (non-light controlled) crossings the crash rate was higher but there were too few data to be statistically significant. .

6.2 SKIDDING RESISTANCE OF VARIOUS AGGREGATES

At the last Cheltenham conference a paper was presented [Allen et al 2008] which showed that by using a different method of testing aggregates the likely effect on road skidding resistance could be different from that given by the UK standard PSV test. It was ascertained after the conference that the three aggregates used were three that Warwickshire either used currently or

had used in the past. It was decided to carry out a trial of the three aggregates on a section of road that was routinely tested. A trial using the aggregates in new surface dressing was carried out in 2010 on the B4451 between Bishops Itchington and M40 junction 12. This consisted of 4 sections. Three of these were laid to a 10/6 racked in design using the three different sources of aggregates with polished stone values of 55, 60 and 65; aggregates C, B, and A respectively, using the same code letters as used in Allen's paper. The fourth section was a 6 mm design using aggregate B.

B4451 is surveyed annually with SCRIM as part of the routine survey programme. SCRIM coefficients have been extracted from these results are shown on graph 2. These results are the average over each section but the 100 m at the start and end of each section are ignored to eliminate any cross contamination with aggregates from the adjacent section. This left a minimum of 40 SC results in each direction

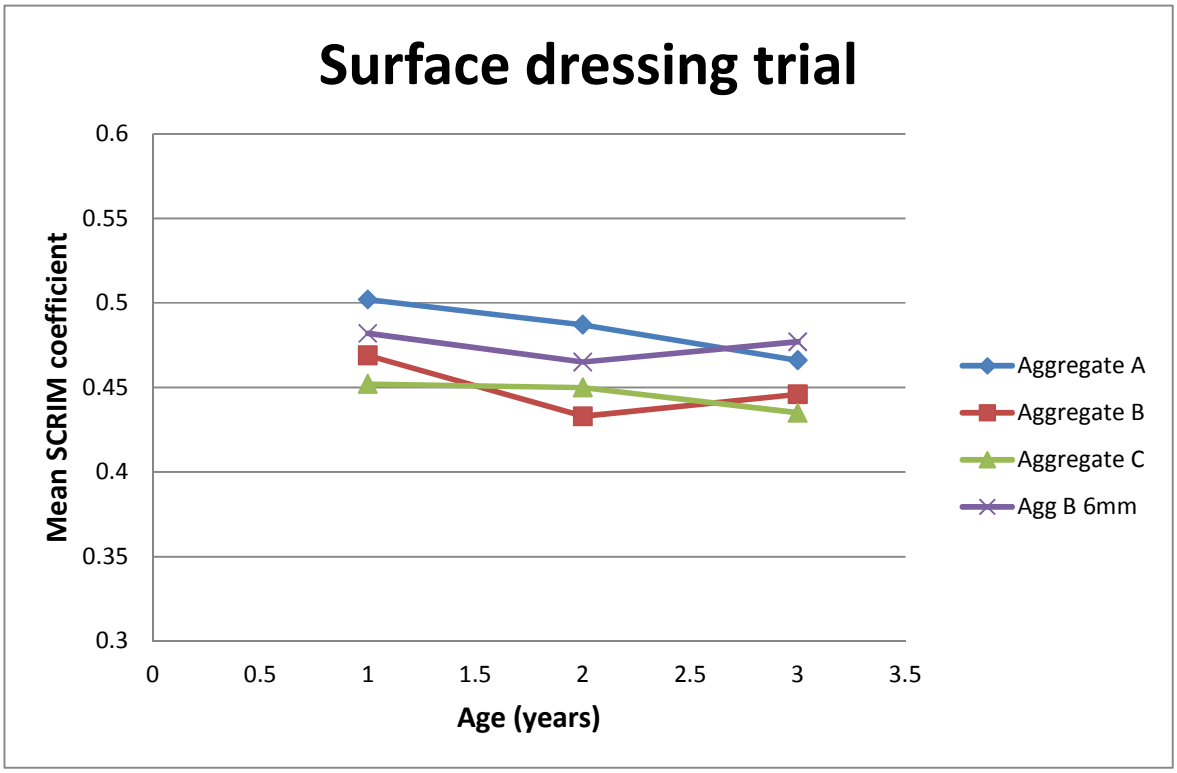
The results for the three years data available so far are shown in Graph 2. As can be seen from the graph the skidding resistance comparison between the aggregates on the road does not reflect the range of PSVs used; of course this only reflects the results for these three aggregates on this particular road. It should be noted that the surface using 6 mm aggregate B has a higher skidding resistance than the same aggregate using 10 mm aggregate; the difference is statistically significant. This agrees with much research regarding the skidding resistance of different size aggregates; for example [Hosking 1973]

Other sources with comparable PSVs would be likely to give different results. It has been recommended that 2 further trials are carried out – one using the same aggregates but in a 30 mph urban area and the other to use any different aggregates that would be economically available.

7 OBSERVATIONS

During the site investigations a number of observations have been made regarding aggregate and surfacing performance. They have not been formally assessed to provide definitive conclusions but may be followed up in future to refine and codify the data.

1. For many years the same aggregate (aggregate B) has been used for surface dressing. In the longer term this provides a CSC of about 0.43 in rural areas but typically only 0.38 in 30 mph zones. There are no obvious reasons why.
2. Aggregates can continue polishing for many years with CSC dropping with time. An extreme example was a 63 PSV chipping in asphalt whose CSC had dropped to 0.25 after about 20 years. This long term change is not inconsistent with the findings reported at the last conference [Sinhal et al 2011a] of a drop in SC of about 0.006 per year. The section was resurfaced as a matter of urgency although the crash rate was low.
3. High quality surface dressing lasts as long as the substrate is structurally sound. Examples in excess of 20 years are frequent, i.e. surface dressing is not necessary short lived.
4. 55% stone content HRA starts to fret after about 10 years but this is slow process and it is easy to prevent further deterioration with planned surface dressing.
5. Thin surfacing, unless of a type with voids less than 6%, typically last 6-8 years and tend to fail fast unlike HRA with either high stone or low stone content.



Graph 2 development of skidding resistance with time for different aggregates

6. The durability of white lines is poor and yet some trial lines put down 14 years ago are still performing reasonably well. In some circumstances lack of clear lines can affect safety. Min-roundabouts are a of particular note.

8 RECOMMENDATIONS AND CONCLUSIONS

The following constitute a mix of recommendations and conclusions

1. As a result of observation 1 it has been recommended that classes A and B roads in urban areas are treated in future using 65 PSV aggregates so that the CSC is more likely to reach 0.40 which would reduce the number of site investigations significantly.
2. Neither PSV nor the Wehner-Schulze test can give definitive indications of the likely in-service skidding resistance of an aggregate. See the surface dressing trial results and observation 2. This could be as a result of neither test taking weathering into account and, in the case of very hard aggregates, the inability of either test to reach the final level of polishing may mean that the PSV is unduly optimistic..
3. The skidding strategy has developed over time into a system which can be an efficient means of assessing the optimum skidding resistance of any site. It is unlikely to need significant change in the future unless the revised HD28, previewed at last conference and dated 2011 [Sinhal et al 2010b], introduces significant changes. None were flagged up in that paper except possibly the recommendation that crashes caused by drivers not driving within the highway code are ignored..

4. Now that CSCs have been shown to reduce year on year there is likely to be more scope for retexturing to be used to bring back skidding resistance at a higher level so that adequate skidding resistance is maintained for a longer period. Only retexturing methods that expose new aggregate surfaces would be suitable.

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I am a materials engineer with over 50 years' experience of testing materials and assessing pavements. Until 1994 I was the materials for Warwickshire. I was made redundant and given early retirement in that year. Since then I have worked for a number of clients including TRRL and Highways Agency. For the last 10 years I have worked extensively for Warwickshire County Council on a freelance basis mainly on materials strategies and development of the strategy for assessing the skidding resistance of the main road network with particular reference to HD28.

In particular, in conjunction with the second author modified HD28 to suit the particular requirements of Warwickshire's roads.

Over the past 30 years I have had some two dozen papers published of which over a third have been at European or international conferences. This will probably be my last.

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Highway Information Manager; Warwickshire County Council

I am an Engineer with almost 40 years' experience in Highway Maintenance in Warwickshire. I have been engaged in all aspects of highway maintenance including design and management of a variety and range of schemes covering the whole network from Motorways (as Agents to DfT) to the narrowest unclassified road.

In the late 70's and early 1980's, at the same time working with SCRIM and Deflectograph, I was involved in the development of in-house condition surveys in the county, culminating in the successful launch of our own visual survey package.

I became responsible for all visual and machine based surveys over ten years ago, including Highway Safety Inspections, and for SCRIM I have published two editions of the County's Skid Testing Strategy.