SAFECOTE

making winter roads
safer

Effect of Safecote on Laboratory Measurement of Skid Resistance

HERG Report: 06321
Date: September 2006

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1. INTRODUCTION

This report details a laboratory investigation to determine the effect of Safecote on the skid resistance characteristics of 22 different sources of aggregate with a range of polished stone value. The effect of Safecote application was compared to materials that may cause change in skid resistance.

2. SAFECOTE MATERIALS RECEIVED FOR INVESTIGATION

Safecote is the product name for a de-icer, anti-icer, anti corrosion liquid supplied by Safecote Ltd. Safecote originated as an agricultural by-product and has been used for the last 10 years in America for winter de-icing and anti-icing.

Safecote is a non-hazardous dark brown syrupy liquid composed of a blend of evaporated co-products from the sugar, starch, cereal carbohydrate and distillation industries. Table 1 lists its physical and chemical properties.

Table 1 Safecote physical and chemical properties

Physical state at 25^{0}C	Low viscosity liquid
Colour	Very dark brown
Odour	Weak caramel, earthy, non pungent
Initial boiling point (^{0}C)	100
Density at 25^{0}C (kg/m^3)	About 1330 (SG = 1.33)
Vapour density (hPa)	Not applicable
Viscosity (cps) at 20^{0}C	About 50
Solubility in water (% weight)	Forms infinite aqueous solution
PH	About 7
Flash point (^{0}C)	Not applicable
Auto-ignition temperature	Not applicable
Explosion limits (lower) (kg/m^3)	Not applicable
Thermal decomposition (^{0}C)	Begins about 100

Two types of Safecote material were received for investigation i.e. net Safecote SN liquid and 6mm rock salt coated with 3% by weight of Safecote i.e. 23 litres of Safecote liquid per 1 tonne of rock salt.

3. OVERVIEW OF LABORATORY INVESTIGATION

The purpose of the laboratory investigation was to simulate the effect of Safecote treated salt application on the skid resistance properties of aggregate used in road surfacings.

Previous investigation by TRL had concluded that the S2 formulation showed no detrimental effect on skid resistance value of the pavement surfaces tested with their SCRIM vehicle (TRL, 2000 and 2003).

However, the studies at TRL were limited to the number of surfaces available, the aggregates that they were made from and the type of application and amount of Safecote applied to each surface.

Laboratory investigation allows greater control of the variables being investigated. The investigation devised used the test equipment used for the determination of polished stone value (BS EN 1097-8, 2000) i.e. the accelerated polishing machine to simulate trafficking and the pendulum tester to measure skid resistance.

This is commonly available equipment and found in many laboratories around the world.

Development of the research methodology considered three key aspects:

- Selection of aggregate types.
- Conditioning on test specimens.
- Simulative test conditions.

3.1 Selection of aggregate types

Twenty-two different rocks were chosen to represent to types of aggregate used as surfacing aggregate in the UK, mainland Europe and overseas. This enabled a wide range of PSV values to be evaluated.

The UK specification of aggregate skid resistance is dominated by the requirement for high values of PSV that would typically not be specified in many other countries. This has resulted in the main type of aggregate used for motorway and trunk roads to belong to what is known as the gritstone group.

The gritstone group is characterised by having sand sized grains held together by a matrix. Under trafficking the grains are worn out of the matrix revealing underlying grains that maintain a sand paper like texture.

However, many countries hard aggregate such as granite and basalt to withstand trafficking but which tends to become polished and slippery when wet. In these countries this type of aggregate is generally considered suitable for most applications.

Many countries around the world do not place the same / or any importance on skid resistance and depending on their geology may not even have hard aggregate. Aggregate such as soft limestone may be their only aggregate available.

These soft aggregates tend to become very polished and slippery when wet.

Table 2 summarises the aggregates selected for use in the investigation based on rock type. This also shows the number of sources within each rock type and the reference used to denote each source.

As the investigation was primarily of interest to UK surfacings, over half of the aggregates belonged to the high PSV gritstone group.

Table 2 Aggregate details

Group	Rock type	Number of sources	Aggregate reference
Gritstone	Greywacke	10	A, B, E, H, J, K, M, N, O, Q
	Sandstone	2	I, T
	Tuff	1	V
Granite	Granite	2	G, U
Basalt	Basalt	2	F, R
	Dolerite	1	L
Limestone	Hard limestone (Carboniferous)	2	P, S
	Soft limestone (Cretaceous)	1	D
Slag	Slag	1	C

3.2 Conditioning of test specimens

The purpose of the investigation was to assess the effect of Safecote application on the skid resistance properties of different aggregates. Therefore, it was important that each test specimen was pre-conditioned to ensure that any subsequent change in skid resistance was due solely to Safecote application and not to change in the test specimen properties as a result of the specific type of investigation.

PSV test specimens were prepared using 10mm sized aggregate as specified in the British Standard method for determination of the polished stone value (PSV). Each test specimen was subjected to the standard 6 hour test conditions i.e. three hours on the accelerated polishing machine using coarse emery abrasive and water followed by three hours using fine emery abrasive and water.

The test specimens were removed, soaked in water for 60 minutes and their skid resistance measured using the pendulum tester fitted with the 31.75mm wide rubber slider. This wet measure of skid resistance is known as an aggregates polish stone value or PSV. A higher value denotes an aggregate with higher skid resistance.

This is the standard method used to quantify the skid resistance properties of an aggregate. However, standard PSV result is not a measure of the ultimate state of polish of an aggregate but rather a simple ranking method under standard test conditions.

Alternative polishing methods were investigated during the Highways Agency, Quarry Products Association and County Surveyors Society funded SKIDPREDICT project. The methods included extended polishing for up to 40 additional hours.

One of the most promising methods developed during this project, to induce the lowest skid resistance in the laboratory in the quickest time, involved an additional period of three hours polishing after the standard 6 hour test using a modified test wheel offset by 6^0 (Roe and Woodward, 2003).

This method was further developed by Woodward in the EPSRC funded SKIDGRIP project (Woodward, 2003). Figure 1 shows a simple example of the additional loss in skid resistance possible using this method (Woodward et. al. 2004).

This shows PSV plotted against the value obtained after additional 6^0 offset testing ($PSV_{offset6}$) data for 32 hard aggregates. If there were no change in skid resistance due to offset polishing all the data points would plot along the line of equality.

However, all data plot below the line of equality showing that further loss in skid resistance occurred during the 3 additional hours of testing. One of the aggregates shown in this example lost a further 23 units of skid resistance compared to its PSV.

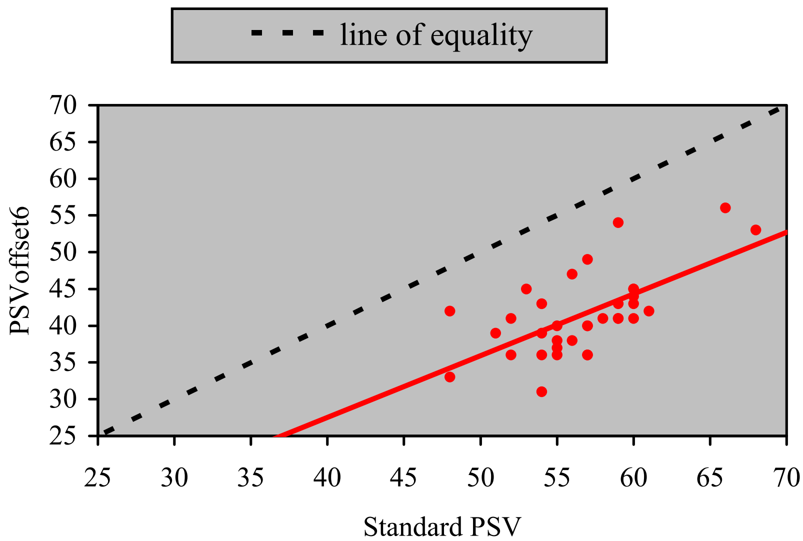

Figure 1 Example of additional loss in skid resistance using 6^0 offset polishing (Woodward et. al. 2004)

This simple example shows the importance of pre-conditioning the test specimens prior to this type of investigation. Each test specimen was therefore subjected to an additional 3 hours offset polishing at 6^0. They were then soaked in water for 60 minutes and their wet skid resistance measured using a pendulum tester ($PSV_{offset6}$).

This accounts for the lower than expected typical data quoted for some of the aggregates used in this investigation. For example, one of the sandstones gave a very good $PSV_{offset6}$ of 69 compared to a very poor 24 for a soft white limestone.

After determining wet $PSV_{offset6}$, each test specimen was allowed to dry and their dry skid resistance measured. These two values of wet and dry skid resistance were used as the skid resistance baseline reference for each aggregate used in the investigations.

Unless specified, the values of skid resistance quoted re expressed as Pendulum Test Values (PTV) and related to the testing condition being investigated.

3.3 Simulative test conditions

Four test conditions were devised to simulate differing conditions:

- Effect of neat Safecote concentration on skid resistance.
- Effect of rock salt coated with 3% Safecote on dry skid resistance.
- Effect of rock salt coated with 3% Safecote on wet skid resistance.
- Effect of other materials that may cause changes in skid resistance.

4. EFFECT OF SAFECOTE CONCENTRATION ON SKID RESISTANCE

Test solutions containing 0, 5, 25 and 50% by weight of neat Safecote liquid in water were prepared. This was liberally applied to the test specimen surface using a brush and its effect on skid resistance immediately assessed using the pendulum tester.

The test specimens were then washed in hot water and left to dry prior to application of the next test solution. The testing was carried out in order of increasing test solution concentration.

The data for each test solution is plotted in Figure 1. This shows the initial wet skid resistance ($PSV_{offset6}$) to range from 69 to 24. Each plot in Figure 1 shows how PTV changed as the Safecote concentration was increased.

The plots show that each aggregate behaved in a similar and predictable manner with the application of increasing concentrations of Safecote SN

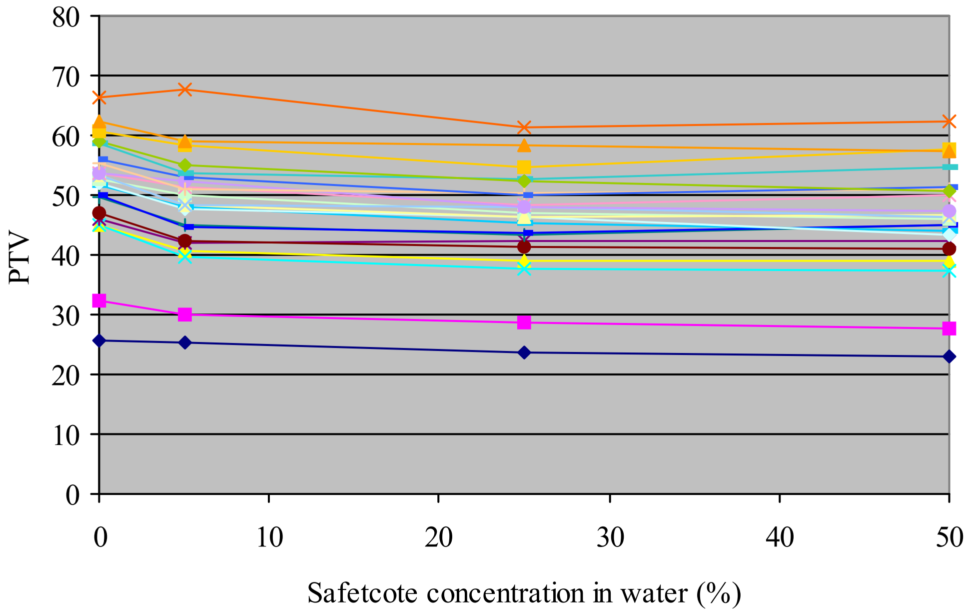

Figure 2   Effect of Safecote concentration in water on PTV

Table 3 shows the change in average PTV for all test specimens. This shows only a small decrease in average PTV up until 50% Safecote concentration. Only 3% by weight of neat Safecote liquid is used to coat the rock salt.

This simulation clearly shows that at 5% by weight concentration in water, the Safecote test solution caused <6.8% reduction in the average value of skid resistance determined. Even at 50% by weight in water concentration, this had reduced to only <11%.

Table 3   Summary of Safecote concentration on skid resistance

Safecote concentration in water	5	25	50
Average Pendulum Test Value	47.9	45.9	45.9
Average percentage decrease	6.8	10.8	10.7

5. EFFECT OF ROCK SALT TREATED WITH 3% SAFECOTE ON DRY SKID RESISTANCE

The purpose of this investigation was to determine whether the 3% Safecote treatment would accumulate on the surface of the test specimens during dry test conditions and effect their dry skid resistance properties.

The test specimens were subjected to 10 minutes on the accelerated polishing machine with 6mm rock salt coated with 3% Safecote applied at a rate of 27g/min. This is the same application rate used for the coarse abrasive during the standard PSV test. No water was used.

Discoloration of each test specimen during testing indicated a build-up of salt on its surface. The test specimens were removed from the accelerated polishing machine and their dry PTV determined. Testing was resumed for a further 20 minutes and PTV determined.

As the accelerated polishing machine operates at a speed of 320 rotations per minute, the 10 minute and 30 minute test durations equate to 3,200 and 9,600 wheel passes.

The results obtained before testing, after 10 minutes and after 30minutes testing are shown in Table 4 and plotted in Figure 3. The results show a small range in dry PTV despite considerable variation in their wet $PSV_{offset6}$.

Table 4 shows the % difference in dry PTV. For all the aggregates assessed the average decrease in skid resistance caused by the application of 27g/min of rock salt treated with 3% Safecote was 0.5% after 10 minutes and 2.1% after 30 minutes.

There was one exception to the data i.e. aggregate S which increased from the lowest value of dry skid resistance by 14.9 and 13.8 units respectively. If this aggregate is removed from the average calculation, the decrease in skid resistance was 1.6% and 3.3% respectively after 3,200 and 9,600 wheel passes.

Table 4 Effect of rock salt treated with 3% Safecote on dry skid resistance

Aggregate reference	Dry PTV before testing	After 10 minutes (3,200 wheel passes)		After 30 minutes (9,600 wheel passes)	
		Dry PTV	% difference	Dry PTV	% difference
S	65.0	74.7	14.9	74.0	13.8
D	75.0	73.3	-2.2	74.0	-1.3
A	75.0	75.0	0.0	75.0	0.0
T	75.0	74.0	-1.3	73.7	-1.8
C	76.0	78.0	2.6	76.3	0.4
F	76.3	76.0	-0.4	74.0	-3.1
K	76.3	76.0	-0.4	76.0	-0.4

P	76.3	74.0	-3.1	69.7	-8.7
I	78.7	75.0	-4.7	74.0	-5.9
O	79.0	75.0	-5.1	75.0	-5.1
M	79.3	80.0	0.8	77.7	-2.1
L	79.3	75.0	-5.5	72.7	-8.4
V	80.0	78.0	-2.5	79.0	-1.3
U	80.0	80.0	0.0	75.0	-6.3
Average	***76.5***	***76.0***	***-0.5***	***74.7***	***-2.1***
Average without aggregate S	***77.3***	***76.1***	***-1.6***	***74.8***	***-3.3***

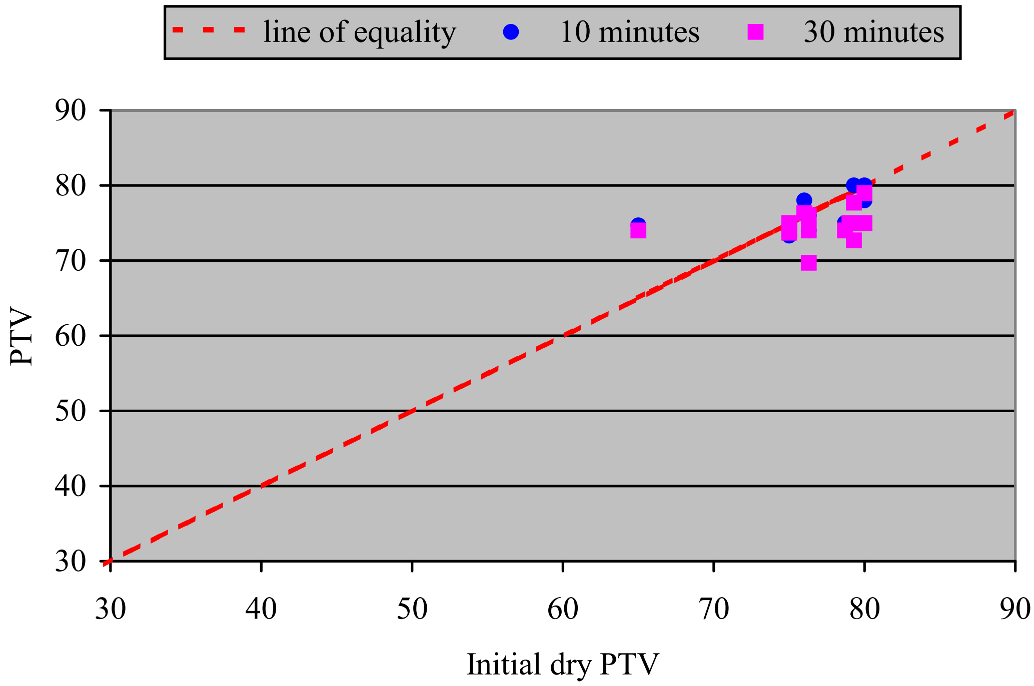

Figure 3 Effect of rock salt treated with 3% Safecote on dry skid resistance

6. EFFECT OF ROCK SALT TREATED WITH 3% SAFECOTE ON WET SKID RESISTANCE

The purpose of this investigation was to determine whether the 3% Safecote treatment would accumulate on the surface of the test specimens during wet test conditions and effect skid resistance.

Test specimens were tested using the accelerated polishing machine as in the previous dry investigation. The only difference was that water was applied during testing at a rate of 25ml/min. This is the same rate used during the standard PSV test.

The results obtained before testing, after 10 minutes and after 30minutes testing are shown in Table 5 and plotted in Figure 4. The results show the expected large range in initial wet PTV (i.e. $PSV_{offset6}$).

Table 5 shows the % difference in wet PTV during testing. For all the aggregates assessed the average decrease in skid resistance caused by the application of 27g/min of rock salt treated with 3% Safecote 27ml/min of water was 5.3% after 10 minutes and 8.9% after 30 minutes.

Table 5 Effect of rock salt treated with 3% Safecote on wet skid resistance

Aggregate reference	Wet PTV before testing	After 10 minutes (3,200 wheel passes)		After 30 minutes (9,600 wheel passes)	
		Wet PTV	% difference	Wet PTV	% difference
D	38.0	38.7	1.8	37.0	-2.6
S	38.0	37.7	-0.9	35.0	-7.9
P	44.0	44.0	0.0	43.7	-0.8
F	48.0	45.7	-4.9	44.0	-8.3
L	51.3	50.7	-1.3	48.0	-6.5
U	52.3	50.0	-4.5	48.7	-7.0
M	52.3	50.7	-3.2	49.0	-6.4
O	54.0	47.0	-13.0	45.0	-16.7
A	55.3	49.3	-10.8	45.0	-18.7
I	58.0	54.0	-6.9	50.0	-13.8
V	61.7	59.0	-4.3	54.7	-11.4
K	62.0	56.3	-9.1	55.0	-11.3
T	64.3	60.7	-5.7	65.0	1.0
C	64.3	56.7	-11.9	55.0	-14.5
Average	***53.1***	***50.0***	***-5.3***	***48.2***	***-8.9***

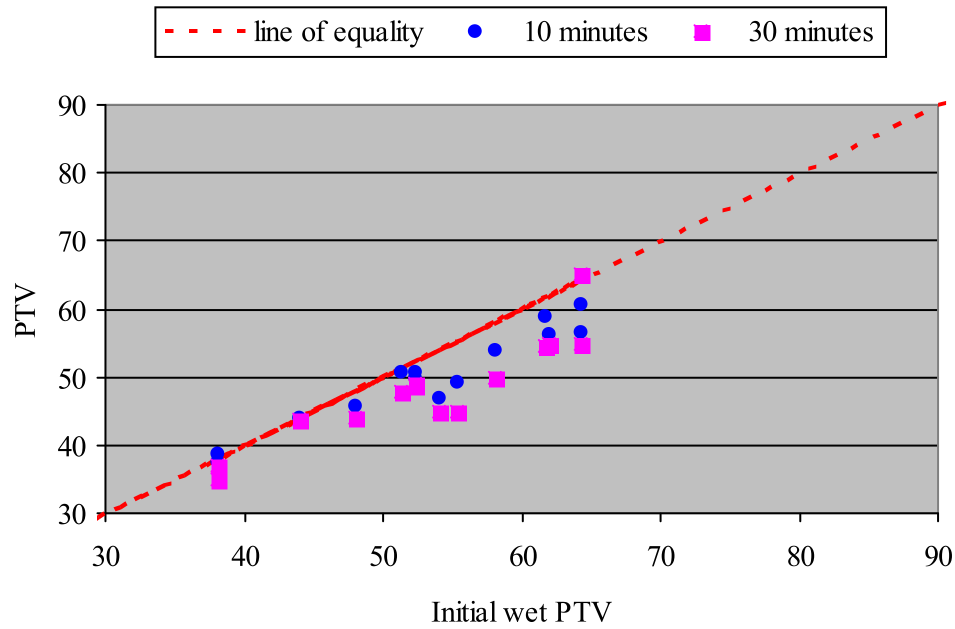

Figure 4 Effect of rock salt treated with 3% Safecote on wet skid resistance

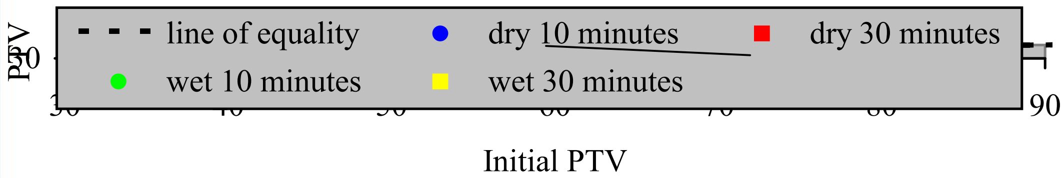

Figure 5 Comparison of rock salt treated with 3% Safecote on dry and wet skid resistance

Figure 5 combines the dry and wet data. This shows both data sets to plot close to the line of equality with the dry data clumping together and the wet data more spread out.

The wet test specimens were left to dry at room temperature and their dry PTV determined. The results are shown in Table 6 and plotted in Figure 6. This found considerable increases in skid resistance almost back to their dry values before this programme of testing. The increase ranged from 10 to 79% with an average increase of 36.3%. The biggest increase was for the aggregates with lowest wet skid resistance.

Table 6 Change in skid resistance due to drying

Aggregate reference	Wet PTV before testing	Test specimens left to dry and measured dry	% difference
D	38.0	68.0	78.9
S	38.0	65.7	72.8
P	44.0	67.3	53.0
F	48.0	67.0	39.6
L	51.3	70.7	37.7
U	52.3	72.0	37.6
M	52.3	74.0	41.4
O	54.0	70.3	30.2
A	55.3	75.3	36.1
I	58.0	70.0	20.7
V	61.7	76.0	23.2
K	62.0	71.0	14.5
T	64.3	72.3	12.4
C	64.3	71.0	10.4
Average	***53.1***	***70.8***	***36.3***

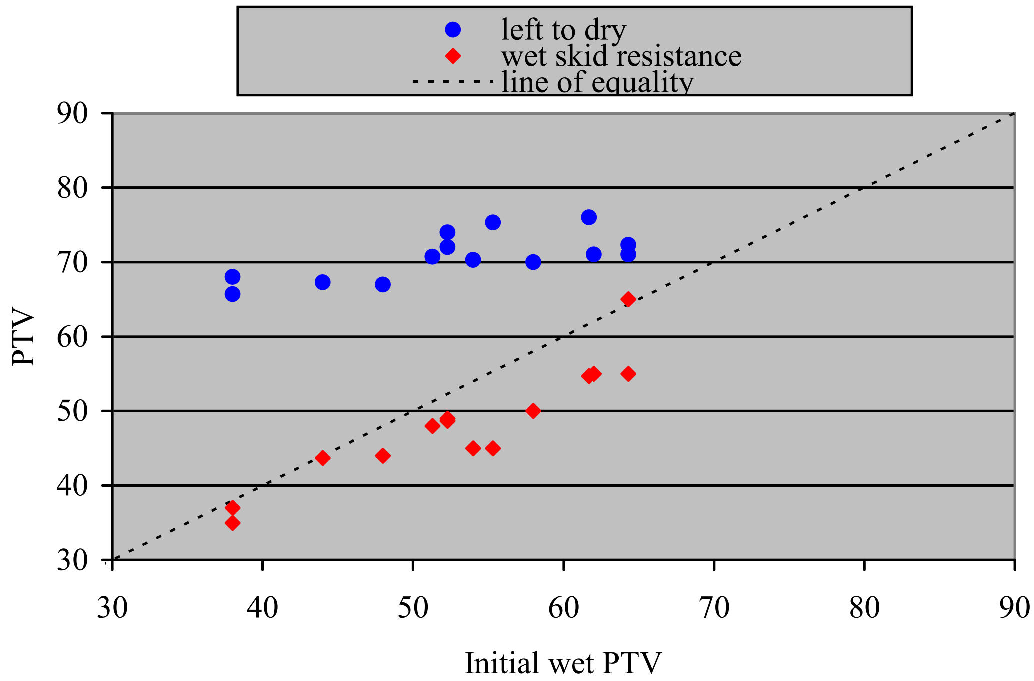

Figure 6 Effect of drying on skid resistance

7. EFFECT OF OTHER MATERIALS THAT MAY CAUSE CHANGE IN SKID RESISTANCE

Rock salt coated with 3% Safecote is applied to trafficked surfaces because of de-icer, anti-icer and anti corrosion properties. The fourth set of simulative test conditions considered the effect on wet skid resistance of other types of material that may occur on a trafficked surface.

Four materials were assessed i.e. engine oil, hydraulic oil and aviation oil containing a small concentration of dissolved bitumen.

In each case the material was applied to the surface of a range of rock types and its effect on skid resistance assessed.

7.1 Effect of engine oil on skid resistance

Table 7 and Figure 7 show the data obtained for engine oil. Table 7 includes the percentage change on skid resistance for the application of engine oil. This was found to range from -34 to –53% with an average decrease in skid resistance of 47.2%.

Table 7 Effect of engine oil on skid resistance

Aggregate reference	Wet PTV ($PSV_{offset6}$)	PTV after application of engine oil	% difference
S	24.4	16.0	-34.4
D	30.6	15.0	-51.0
F	45.6	21.2	-53.5
U	47.6	30.2	-36.6
G	48.2	25.2	-47.7
L	49.6	25.2	-49.2
N	53.8	25.2	-53.2
C	55.6	28.4	-48.9
V	62.2	29.2	-53.1
T	69.0	38.6	-44.1
Average	***48.7***	***25.4***	***-47.2***

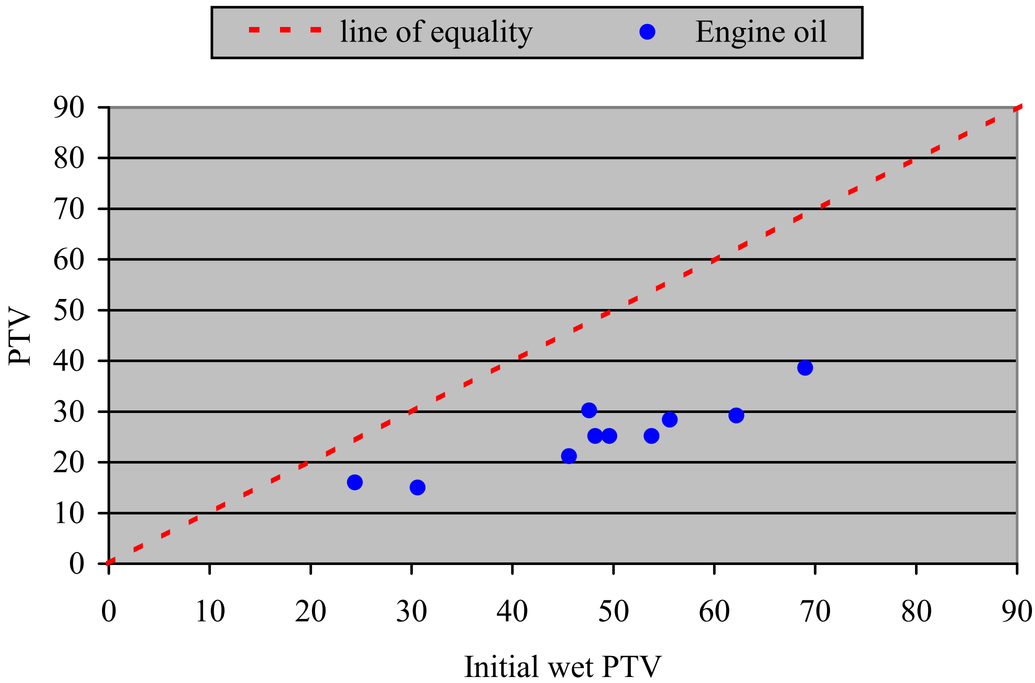

Figure 7 Effect of engine oil on skid resistance

7.2 Effect of hydraulic oil on skid resistance

Table 8 and Figure 8 show the data obtained for hydraulic oil. The percentage change on skid resistance for the application of hydraulic oil was found to range from -26 to –61% with an average decrease in skid resistance of 51.0%.

Table 8 Effect of hydraulic oil on skid resistance

Aggregate reference	Wet PTV ($PSV_{offset6}$)	PTV after application of hydraulic oil	% difference
S	24.4	18.0	-26.2
D	33.8	16.0	-52.7
F	44.2	17.4	-60.6
U	44.6	22.8	-48.9
G	45.6	24.8	-45.6
L	50.4	24.0	-52.4
N	53.4	22.4	-58.1
C	56.2	25.0	-55.5
V	62.8	27.2	-56.7
T	64.0	30.0	-53.1
Average	***47.9***	***22.8***	***-51.0***

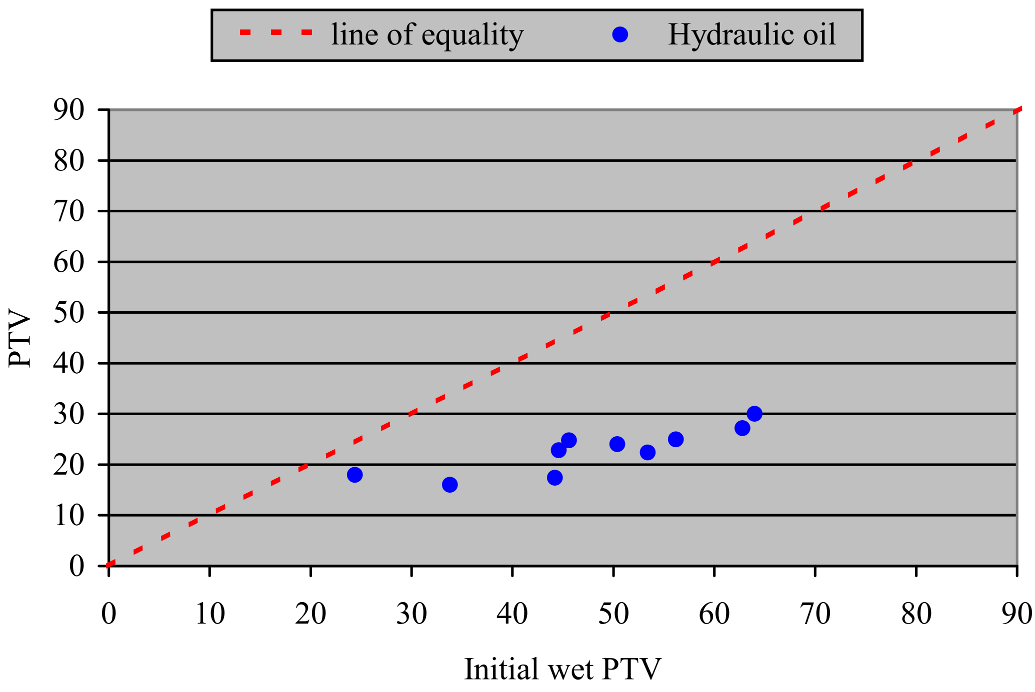

Figure 8 Effect of hydraulic oil on skid resistance

7.3 Effect of aviation fuel with dissolved bitumen on skid resistance

Table 9 and Figure 9 show the data obtained for aviation fuel containing dissolved bitumen. The percentage change on skid resistance for the application of hydraulic oil was found to range from -46 to -70% with an average decrease in skid resistance of 63.3%.

Table 9 Effect of aviation oil with dissolved bitumen on skid resistance

Aggregate reference	Wet PTV ($PSV_{offset6}$)	PTV after application of aviation fuel with bitumen	% difference
R	49.2	16.0	-67.5
H	51.0	17.6	-65.5
E	53.4	17.6	-67.0
B	54.0	16.0	-70.4
A	54.2	18.8	-65.3
Q	54.4	20.4	-62.5
K	57.8	24.2	-58.1
M	60.2	20.4	-66.1
I	61.0	21.8	-64.3
T	64.0	34.2	-46.6
Average	***55.9***	***20.7***	***-63.3***

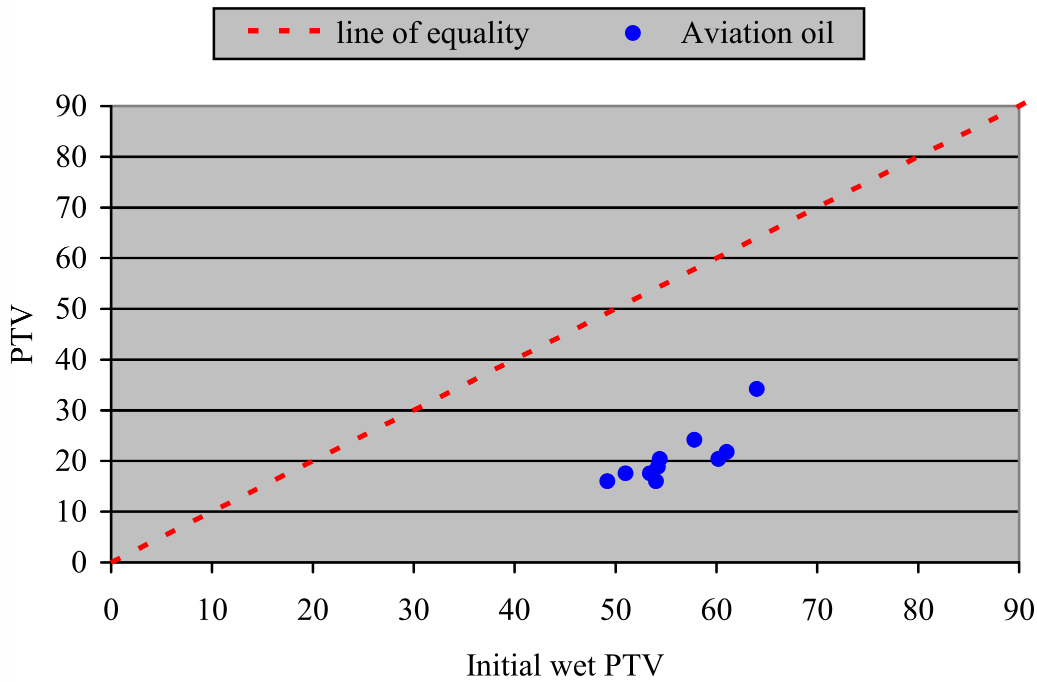

Figure 9 Effect of aviation oil with dissolved bitumen on skid resistance

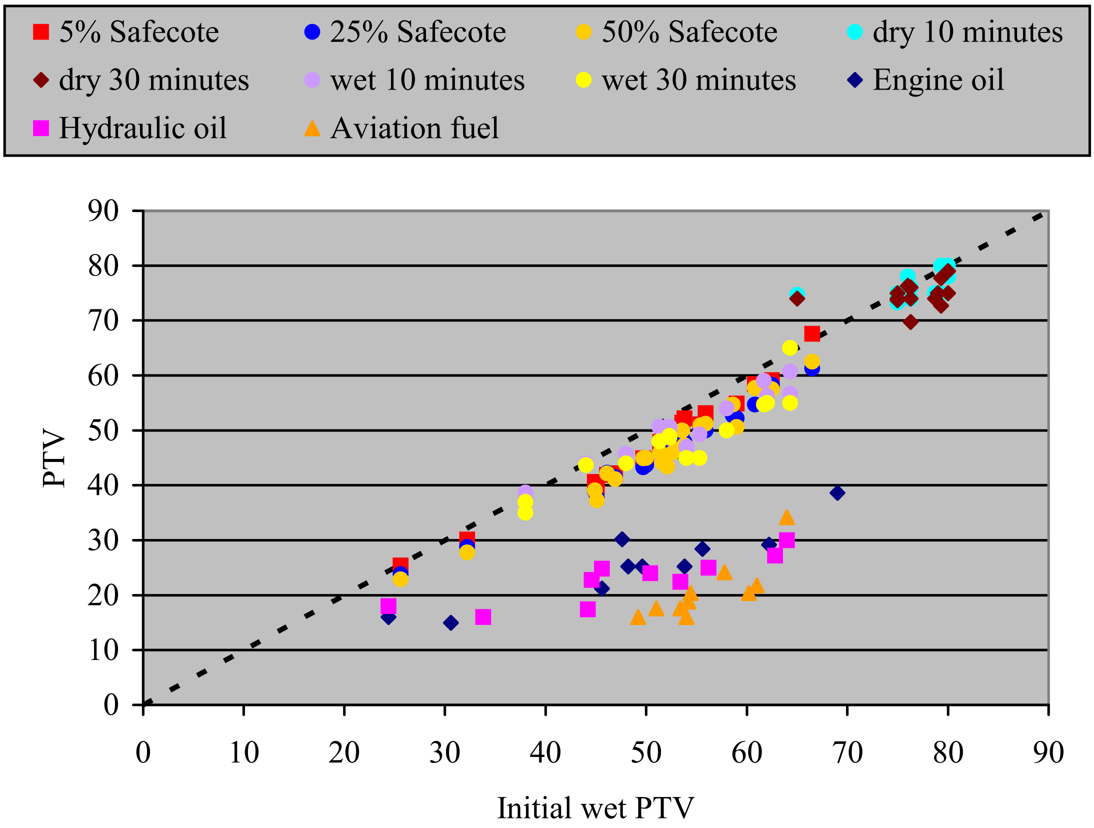

Figure 10 Summary of investigation data

8. DISCUSSION

The effect of Safecote application on the skid resistance properties of 22 different aggregates was assessed. Data was collected for 4 other types of material that may be found on trafficked surfaces and expected to effect skid resistance.

Figure 10 compares data from the different investigations with $PSV_{offset6}$. The data is distributed along both axis and show three main groupings. The first grouping is the dry polishing investigation data with high PTV values that plot just below the line of equality.

The second grouping plot just below the line of equality and is well distributed reflecting the skid resistance properties of the aggregates selected for investigation. This data clearly shows that rock salt coated with 3% Safecote wet polishing and 5%, 25% and 50% Safecote concentration in water to have minimal effect on wet skid resistance.

The third grouping plots well below the line of equality indicating significant effect on skid resistance. This grouping includes engine oil, hydraulic oil and aviation oil with dissolved bitumen. Table 10 ranks these different data sets in relation to their grouping and effect on average decrease in skid resistance.

Table 10 Ranked average decrease in skid resistance

Grouping	Application	Average % decrease in skid resistance
Group 1	Rock salt coated with 3% Safecote 10 minutes dry polishing	1.6
	Rock salt coated with 3% Safecote 30 minutes dry polishing	3.3
Group 2	Rock salt coated with 3% Safecote 10 minutes wet polishing	5.3
	5% Safecote concentration in water	6.8
	Rock salt coated with 3% Safecote 30 minutes wet polishing	8.9
	50% Safecote concentration in water	10.7
	25% Safecote concentration in water	10.8
Group 3	Engine oil	47.2
	Hydraulic oil	51.0
	Aviation oil with dissolved bitumen	63.3

When reviewing the data summarised in Table 10 it must be remembered that only 3% Safecote liquid is used to coated rock salt. The data shows that Safecote does not have a significant effect on skid resistance of the aggregates assessed, particularly compared to the materials in group 3 that may be expected to occur on a road surface.

9. CONCLUSION

The laboratory investigations have found that the amount of liquid Safecote used to treat rock salt has no significant effect on the skid resistance of surface aggregate.

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