

**TRANSPORT and ROAD
RESEARCH LABORATORY**

Department of the Environment

TRRL REPORT LR 504

**THE EFFECT OF TRAFFIC AND AGGREGATE ON THE
SKIDDING RESISTANCE OF BITUMINOUS SURFACINGS**

by

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**Materials Division
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Crowthorne, Berkshire
1972**

CONTENTS

	Page
Abstract	1
1. Introduction	1
2. Factors affecting frictional properties of road surfaces	2
2.1 Microtexture	2
2.1.1 Bituminous surfacings	2
2.1.2 Concrete surfacings	2
2.2 Macrotexture	2
2.3 Traffic and other factors	2
2.4 Factors considered in the present Report	3
3. Polished-stone value and sfc	3
4. Traffic and sfc	5
4.1 Effect of traffic density	5
4.2 Effect of vehicle weight	6
5. Final analysis	6
5.1 Sources of data	6
5.2 Correlation between sfc, PSV and traffic	7
6. Acknowledgements	8
7. References	8
8. Appendix - Estimation of number of vehicles in traffic lanes	10

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THE EFFECT OF TRAFFIC AND AGGREGATE ON THE SKIDDING RESISTANCE OF BITUMINOUS SURFACINGS

ABSTRACT

The polishing characteristics of the aggregate used in a bituminous road surfacing are a major factor in determining its resistance to skidding. The amount and weight of traffic is also a determining factor on heavily trafficked roads. Analysis of measurements made on roads over the last 10 years has shown a direct correlation between traffic intensity and the skidding characteristics of the wet road surface, a correlation that varies consistently with the polishing characteristics of the aggregate. Thus it has been possible to derive an empirical formula which indicates the expected resistance to skidding of the surfacing from a knowledge of the polished-stone value of the aggregate and the expected traffic on the road. This formula will be of use to engineers in selecting aggregate to obtain surfacings of a required resistance to skidding under given circumstances. It applies only to surfacings which present a continuous mosaic of coarse aggregate to the motor tyre, i.e. to bituminous surface dressings and to bituminous premixes with a substantial proportion of exposed aggregate in the surface.

1. INTRODUCTION

Earlier standards of skidding resistance, first proposed by Giles in a paper to the Institution of Civil Engineers in 1957¹, were based on studies of the relationship between skidding resistance and the risk of skidding accidents. Giles proposed minimum values of sideways-force coefficient (sfc) for different categories of site, ranging from "most difficult" where the risk of accidents was particularly high, to "easy" sites which were relatively free from skidding risks. These values were later used as a basis for setting minimum polished-stone value (PSV) limits for each category of road site².

The proposed minimum values of skidding resistance have been subsequently embodied, without much alteration, in the recommendations of the Marshall Committee³, published in 1970 where they are described as "recommended target values".

A significant change in the condition affecting the skidding resistance of roads has resulted from a large increase in the volume, speed and weight of traffic that has taken place during the last 15 years. The more recent measurements carried out by TRRL for research purposes indicate that the "target values" of sfc are rarely being met on heavily trafficked roads, even when using aggregates of the currently recommended quality. Since the first motorways were opened in the late 1950's there has also been evidence that those traffic lanes which carry heavy commercial vehicles are particularly liable to become slippery.

In recent years, the number of sites on which regular measurements of sfc have been made has increased to a degree which has made it possible to study the relationship between the skidding resistance of a road surface and both the volume of traffic carried and the PSV of the stone used. The nature of the association between these three variables was, therefore, sought and the results of the relevant investigation are given in this Report.

2. FACTORS AFFECTING FRICTIONAL PROPERTIES OF ROAD SURFACES

2.1 Microtexture

Many factors can be shown to influence the frictional properties of road surfaces, but in most cases the basic mechanism by which a road becomes slippery is the loss of microtexture brought about by the polishing of the exposed surface by the tyres of passing vehicles.

2.1.1 Bituminous surfacings In the case of bituminous surfacings, notably surface dressing and chipped hot rolled asphalt, the contact area of the exposed surface is composed largely of the mosaic of chippings, the properties of which are clearly definable. In determining the degree of skidding resistance of a road surface the type of aggregate, as characterised by its resistance to polishing, is undoubtedly the most important single factor contributed by the surfacing material

2.1.2 Concrete surfacings In concrete surfacings, the exposed aggregate comprises a variety of mineral ingredients differing both in size, proportion and quality; thus the concept of microtexture is more difficult to identify with any particular component. It has recently been shown⁴ that the performance of concrete in relation to skidding is determined largely by the fines in the mortar rather than by the coarse aggregate and further studies are continuing.

2.2 Macrotecture

Macrotecture contributes to skidding resistance, particularly at high speeds in two ways: firstly it facilitates the drainage of water from the area of contact with the tyre and secondly it enables energy losses which occur in the tread rubber when it is deformed by large projections in road surface to be used in absorbing kinetic energy of the vehicle.

Loss of macrotecture may result, for instance, from the progressive embedment of the chippings in bituminous surfacings or from the failure of the binder to weather at an appropriate rate. Providing the chippings have adequate resistance to abrasion, these factors can be ultimately mastered by improved specifications and laying techniques. The susceptibility of polishing on the other hand, is characteristic of the material itself. Good skidding resistance therefore depends ultimately on the availability of high-PSV stone.

2.3 Traffic and other factors

There are also a number of other factors which can influence skidding resistance through their effect on micro- and macrotecture. The most important of these is the density of traffic, but other factors can also play a part. The same stone may give somewhat different performance in surface dressing than in rolled asphalt and different sizes of the same stone appear to give slightly different values of sfc under otherwise similar conditions. Type of binder can also play an important role. Furthermore, sfc on any particular surfacing will be affected by temperature, road layout (e.g. excessive polishing due to braking or cornering forces) and possibly other factors.

2.4 Factors considered in the present Report

A subject of this complexity can be treated in a number of different ways. One way would be to investigate the effect of traffic on sfc for different groups of surfacings, looking separately at rolled asphalts, macadams, surface dressings, concrete, etc. In bituminous materials these groups could be subdivided further according to the type of binder, filler and other characteristics. To adopt this approach would obviously call for an extensive statistical exercise requiring a very large number of observations to allow for adequate treatment of the many variables.

A different approach was chosen in this work. A large proportion of major roads in Great Britain are surfaced with hot rolled asphalt (with pre-coated chippings) or are surface dressed. Under the same traffic conditions, these two types of surfacing show very similar levels of sfc which appear to be governed largely by the PSV of the chippings. By limiting the scope of the present work to these two types of surfacings the relationship between sfc and traffic can be established for a large proportion of important roads, with a consequent reduction in the number of variables that need be considered. Such treatment should be adequate to indicate the levels of sfc achievable using currently available aggregates on roads carrying different volumes of traffic. This, it is hoped, will provide a basis for any recommendations of realistic standards of skidding resistance to be made.

Before making a comprehensive study of the effect of both PSV and traffic on resistance to skidding attention was first concentrated on obtaining a better understanding of the more simple relationships between (a) PSV and resistance to skidding and (b) traffic and resistance to skidding. These were studied by firstly comparing the performance of aggregates of different PSVs under the constant traffic conditions of full-scale road experiments, and secondly examining the effect of different traffic conditions on the sfc achieved by a number of particular aggregates.

Tables given at the end of this Report should be of some assistance to road engineers in predicting levels of sfc from the estimates of traffic flow.

A detailed study of the effects of variables such as type of binder, chipping size, texture depth and others on skidding resistance, form subjects of a separate research.

3. POLISHED-STONE VALUE AND SFC

Significant linear correlation has been found between PSV and sfc at all TRRL full-scale road experiments where a range of different road aggregates have been used in the surfacing. Although there is similarity between the relationships at the different sites, it is evident that traffic conditions were also affecting the PSV/sfc relationship.

In order to obtain a better understanding of the relationship between PSV and sfc, regression analyses were made of the data from all the full-scale aggregate experiments that have been the subject of recent sfc measurements. Six of these were carried out by the Transport and Road Research Laboratory, five by Kent County Council and two by Hampshire County Council. From these 13 sites, 20 analyses were possible because of division into different traffic lanes or types of surfacing at some of the sites. The sfc figures used were the means of measurements taken during the last three years and, wherever possible, the PSVs used were the means of more than one determination.

Details of the 20 experiments, together with the results of the regression analyses, are given in Table 1. Highly significant linear correlation was found at most sites, but rather less significant correlation was found at sites where the range of PSV was small in relation to the reproducibility of the test measurements. Examples of poorer correlations are the Darenth Hill and Roman Galley sites where the range of the PSVs was only 7 units in each case.

Inspection of the results given in Table 1 show that the relation between PSV and sfc takes the form:-

$$\text{sfc} = a + b \text{ PSV} \quad \text{.....} \quad (1)$$

where a and b are constants which are determined by the extent to which polishing has taken place at the site. Inspection of the results show that the coefficient b does not vary much over the sites (approximating to 1×10^{-2}), suggesting that the simplest way of obtaining an empirical relationship between sfc, PSV and traffic would be to assume a constant value for b from all sites and to regard the extent of the polishing as being a function of traffic conditions. This would yield the following general relationship:-

$$\text{sfc} = C_1 + C_2 f(T) + C_3 \text{ PSV} \quad \text{.....} \quad (2)$$

where $f(T)$ is a function of traffic conditions, and C_1 , C_2 and C_3 are constants. However a more complex relationship can be derived. For any given PSV, we would expect the sfc to be dependent on the intensity of polishing action at the site. The less the polishing the greater would be the expected sfc for a given PSV and vice versa. This concept is shown graphically in Fig. 1 where lines have been drawn to represent the different degrees of polish expected for different traffic conditions. Those lines have been made to converge on a point that represents a material of very high PSV that does not polish at all and so the sfc would be the same for all traffic conditions. In this relationship both the constant a and coefficient b in formula (1) above would be related to traffic (and therefore to each other) and the general formula would become:-

$$\text{sfc} = k_1 + k_2 f_1(T) + k_3 \text{ PSV} f_2(T) \quad \text{.....} \quad (3)$$

where k_1 , k_2 and k_3 are constants and $f_1(T)$ and $f_2(T)$ are functions of traffic.

In an attempt to find such a relationship the values obtained for a and b (Table 1) were plotted (Fig. 2) and regression analysis carried out. Linear correlation was, in fact, found (<0.1 per cent probability the regression line taking the form:-

$$a = 0.505 - 0.546b \quad \text{.....} \quad (4)$$

which suggests a general correlation between sfc and PSV of the form:-

$$\text{sfc} = 0.505 - 0.546b + b \text{ PSV} \quad \text{.....} \quad (5)$$

By substituting different values for b (to represent different traffic conditions) a series of relationships was obtained which showed convergence to a point where PSV is about 55 and sfc about 0.51. This conflicts with practical experience with high PSV aggregates which shows that convergence does not take place until the PSV is at least 80 and could be as high as infinity, when formula (2) would apply.

The anomaly probably results from the absence of high-PSV aggregates in the experiments, PSVs being mainly about 55. Because of this, and because there were rather similar traffic intensities at many of the sites, the sfc's also tended to be similar (about 0.51). This would mean that the regression calculations would tend to give lines that pivot about this point (55,51) and so differences due to site conditions would tend to have an exaggerated effect on the value of coefficient b which, in turn, would be compensated by exaggerated differences in the constant a. It is concluded that the available data are not suitable for the reliable estimation of the relation between coefficient b and constant a and therefore the simpler approach (Formula (2)) would be better employed. The value of C_3 in this formula can be estimated in two ways:-

- (i) By averaging the value of b obtained for all the experiments - this yields a value of 1.03×10^{-2}
- (ii) By reading off the value of b in Fig. 2 which corresponds to a line passing through the origin (i.e. where PSV and sfc are zero and a is therefore zero). This yields a value of 0.93×10^{-2} *

1×10^{-2} (to which both estimates approximate) would therefore be a useful practical value to use as a basis for further work; this would have the advantage of embodying the simple concept that a change of unit of PSV would mean a corresponding change in sfc of 1×10^{-2} unit. Justification of this approximation is further strengthened when it is considered that the formula is likely to be applied over only a relatively small range of PSVs (say 50-70) where the effect of convergence of the lines is likely to be small.

4. TRAFFIC AND SFC

4.1 Effect of traffic density

There is a definite association between the “weathering” of a road surface and the observed seasonal variation in its skidding resistance. Figures have been published⁶ (based on measurements taken with the Portable Skid Tester but the conclusions are equally valid for sfc) which show that results of any measurements of skidding resistance must be considered strictly in relation to the time of year in which they were taken and that lowest values are recorded during the summer (May-September). Accepted TRRL practice is to use “mean summer sfc” which is the average of at least 3 measurements distributed over one summer season. All data in this Report are quoted on this basis.

When results of measurements taken on one site over a period of years were examined it became evident that the high value of sfc obtained on a newly laid surfacing rapidly decreased, within about one year, to a constant value at which it remained for several years afterwards, providing no significant change in traffic volume occurred during that time. Examples of results from a few sites are shown in Figs 3 and 4. If identical surfacing materials were compared on different sites, the level of sfc was found to be negatively associated with the volume of traffic recorded on these sites. One such set of measurements is given in Table 2.

One conclusion which is already apparent from these observations concerns the manner in which sfc and traffic are inter-related. The effect of traffic on sfc is not cumulative from year to year and therefore the concepts used for example in fatigue studies of road pavements do not apply to skidding resistance. Instead, sfc is simply related to traffic volume for any aggregate of given PSV.

A possible explanation of these observations, and one that is generally accepted, is that at the same time as traffic is tending to polish the surface, other factors, usually identified as complex physio-chemical phenomena described as “weathering” are acting in the opposite way, restoring the microtexture of the exposed aggregate. Thus the resultant resistance to skidding represents an equilibrium between the effects of certain naturally occurring conditions on the one hand and those of traffic on the other.

If, on any particular site traffic flow changed (as a result, for instance, of road redevelopment in the area), there followed a corresponding change in sfc. Fig. 5 shows the increase in sfc which occurred on Trunk Road A4 at Colnbrook when traffic decreased after a nearby section of the M4 Motorway had been opened.

* This agrees very closely with the corresponding figures of about $\frac{1}{105} = 0.95 \times 10^{-2}$ that has been found for sfc and skid-resistance value⁵.

Referring to the levels of sfc (given in Table 2) which have been found on a typical surfacing material used on major roads today (in this case rolled asphalt with pre-coated chippings having a PSV of 58-60) it can be seen that with such chippings a sfc of 0.55 can be readily maintained under light traffic conditions, but that the sfc will fall to about 0.30 under heavy motorway traffic. These levels of sfc would be greater if stone of higher PSV had been used as has been described in Section 3, and illustrated in Fig. 4.

At junctions, roundabouts and other similar sites the relationship between sfc and traffic becomes more difficult to define, because, as a result of particular conditions, additional polishing will occur due to accelerating, braking and cornering forces. Such sections of road must be considered separately and, as they are more likely to become accident black spots, they qualify for special attention in any maintenance programme (Category A in the Marshall Report³). These sites, however, form a relatively small fraction of the total length of road considered for maintenance.

4.2 Effect of vehicle weight

When considering the effect of traffic on road surface it will be reasonable to suppose that the polishing effort exerted by an individual vehicle will depend on some of the vehicle's physical characteristics. A 10 Mg lorry for example, with tyre pressures of say 600 kN/m² is likely to have a polishing equivalent many times that of a saloon car with tyre pressures about 150 kN/m². Although a precise knowledge of these effects may improve our understanding of the mechanism of polishing, an engineer should be in a position to make use, with reasonable confidence, of the ordinary estimates of traffic flow, either in total vehicles or in commercial vehicles. The choice between these two forms of expressing traffic volume would be irrelevant if the spectrum of the distribution of vehicles of different size were reasonably uniform throughout the entire road network. This unfortunately is not the case. The average ratio of the number of vehicle-miles travelled by total motor vehicles and by commercial vehicles appears to be about 10:1⁷ but on individual sites this proportion may vary considerably. In left-hand lanes of three-lane motorways the ratio may be only 2:1, in the right-hand lanes 100:1, with some intermediate ratio in the centre lanes.

Present work has shown that sfc correlates better with traffic expressed as commercial vehicles (over 1500 kg unladen) than as total vehicles. It is, therefore, proposed to adopt the use of commercial vehicles per lane per day as the measure of traffic when making predictions of sfc levels on roads.

To allow for special circumstances when an engineer would prefer to use traffic estimates in total vehicles per lane, a suitable formula will also be given.

5. FINAL ANALYSIS

5.1 Sources of data

Analysis of conditions on individual sites, already discussed in Section 3, has provided strong evidence that a positive linear association exists between sfc and PSV, an increase in PSV of 1 unit causing an increase in sfc of about 0.01. At the same time, the data in Table 2 suggest that traffic and sfc are negatively associated in a linear manner.

The fact that these three variables: sfc, PSV and traffic, are inter-related seems logically justified. PSV can be considered as a measure of skidding resistance shown by material subjected to a fixed polishing effort, determined by the regime of the polishing test. This polishing effort can be assumed, in turn, to be equivalent to a certain intensity of traffic.

A regression analysis was therefore carried out to correlate the three variables simultaneously. To this end a survey was carried out of results of sfc measurements taken by TRRL in the years 1960-1970. A site was considered suitable for inclusion in the survey if it fulfilled certain basic conditions. The surfacing had to be rolled asphalt or surface dressing and the PSV of the chippings had to be known. To minimise any residual variation due to seasonal effects, each sfc value used in the analysis was an average of mean summer values, recorded on 3 consecutive years. Traffic figures for these sites were obtained from the DOE census (in the case of trunk roads and motorways) and from the TRRL 1300-point traffic survey. If the required information could not be obtained from any of these sources, an approach was made to the appropriate county authority or, in a few cases, a special traffic count was taken by TRRL staff.

One hundred and thirty-nine different sections of road were found to provide suitable data. These sites included mainly full-scale experiments (already listed in Table 1) for which detailed records of surfacing material were available and which conveniently provided a variety of aggregates of different PSV. Other sites comprised longer lengths of non-experimental roads, including motorways. In order to preserve equiprobability in statistical treatment of the data, a few sections which were longer than 1 km were subdivided into units, 1 km long, each unit being considered as a separate observation in the final analysis. The range of conditions covered in the survey is given in Table 3.

The aggregates in 130 of the surveyed surfacings represented a cross-section of natural roadstone available today from over 30 different sources. The remaining 9 sections were surfaced with calcined bauxite.

5.2 Correlation between sfc, PSV and traffic

The analysis has been carried out using the following measurements from each site:-

1. Mean summer sfc (average value for 3 consecutive years)
2. Traffic expressed as
 - a) commercial vehicles
 - b) total vehicles
3. Polished-stone value of the chippings.

Using a computer, the following highly significant correlation (correlation coefficient 0.92 for the 139 sets of observations) has been obtained:-

$$\text{sfc} = 0.033 - 0.664 \times 10^{-4} q_{\text{cv}} + 0.98 \times 10^{-2} \text{PSV}$$

where q_{cv} is the traffic flow in commercial vehicles per lane per day.

This estimate of the regression coefficient for PSV (0.98×10^{-2}) agrees with the estimate (1×10^{-2}) made for the sites where a range of aggregates have been used (Section 3), showing that the data are representative with respect to PSV. If the coefficient is rounded off to the more convenient value of 1×10^{-2} , the significance of the correlation is only slightly reduced (correlation coefficient = 0.91) and the formula becomes:-

$$\text{sfc} = 0.024 - 0.663 \times 10^{-4} q_{\text{cv}} + 1 \times 10^{-2} \text{PSV}$$

Alternatively if the correlation is linked with traffic expressed as total vehicles per lane per day (q_{tv}), the equation becomes:-

$$sfc = 0.024 - 0.15 \times 10^{-4} q_{tv} + 1 \times 10^{-2} PSV$$

In this case the multiple correlation coefficient is only 0.84 and therefore the use of this formula is not normally recommended.

The importance of these correlations is that it is possible to predict the level of skidding resistance on any site (surfaced with material in good condition, presenting a continuous mosaic of coarse aggregate to the tyre) from a knowledge of PSV of the surface aggregate and an estimate of traffic carried. The results should serve as a guide in the selection of material required to provide the necessary standards of skidding resistance on roads. Values of skidding resistance obtained on aggregates of different PSVs under a range of traffic conditions are shown in Fig. 6.

6. ACKNOWLEDGEMENTS

This Report was prepared in the Materials Division (G.F. Salt, Division Leader) of the Highways Department of the Laboratory.

The Authors wish to acknowledge the valuable assistance given by the officers of the many County Authorities concerned, and in particular those of Hampshire and Kent, who allowed the use of data obtained from their own road experiments.

7. REFERENCES

1. GILES, C G. The skidding resistance of roads and the requirements of modern traffic. *Proc. Inst. Civ. Eng.* 6, 216 - 249, (February 1957).
2. MINISTRY OF TRANSPORT. Specification for road and bridge works. London, 1969. (H.M. Stationery Office).
3. The Report of the Committee on Highway Maintenance, London 1970 (H.M. Stationery Office).
4. WELLER, D E and D P MAYNARD. "The influence of materials and mix-design on the skid resistance value and texture depth of concrete". *Ministry of Transport, RRL Report No. LR 334*, Crowthorne 1970 (Road Research Laboratory).
5. GILES, C G, BARBARA E SABEY and K H F CARDEW. Developments and performance of the portable skid-resistance tester *D.S.I.R. Road Research Laboratory Technical Paper No. 66*, London, 1964. H.M. Stationery Office.
6. ROAD RESEARCH 1965-66. The Report of the Road Research Board with the Report of the Director of Road Research, p.24. London 1967 (H.M. Stationery Office).
7. DUNN, J B. Traffic census results for 1969. *Department of Environment, RRL Report No. LR 371*, Crowthorne, 1970 (Road Research Laboratory).

8. CURRER, E W H and P D THOMPSON. The classification of traffic for pavement design purposes. Paper to 3rd International Conference on the Structural Design of Asphalt Pavements, London 1972.
9. DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH. Road Research 1963. The report of the Road Research Board with the report of the Director of Road Research. London, 1964 (H.M. Stationery Office), p.16.
10. MINISTRY OF TRANSPORT. Road Research 1964. The report of the Road Research Board with the report of the Director of Road Research, London, 1966 (H.M. Stationery Office) pp.13-14.

8. APPENDIX

ESTIMATION OF NUMBER OF VEHICLES IN TRAFFIC LANES

A difficulty may arise in connection with a reliable estimate of traffic flow per lane when figures for individual lanes are not available. Traffic estimates are usually quoted in the form expressing the number of vehicles passing at a given point on all lanes in both directions. There will be no problem in the case of a 2-lane single carriageway as each lane can usually be assumed to carry half of the total flow.

On dual carriageways, however, each lane will carry a proportion of the total flow and the distribution of vehicles between lanes will vary according to traffic density. As traffic increases, the proportion of vehicles in the left-hand lanes decreases with corresponding increase in the proportion in the other lanes.

Recently an investigation⁸ was carried out by TRRL into the distribution of commercial traffic on a motorway. Earlier work^{9,10} by Coburn has provided relationships between traffic flows in individual lanes of dual carriageways, in terms of all motor vehicles. The information from these two sources was used to produce the data given in Tables 4 and 5. From the knowledge of a normal traffic count of either commercial or total motor vehicles on any particular site, approximate traffic figures can be obtained for any lane, by referring to the appropriate Table.

As the number of vehicles on roads tends to increase from year to year, this should be allowed for when considering sfc levels in the future. Present trends indicate⁷ a continued increase of the number of cars, but only a negligible increase in commercial traffic over the last 5 years.

TABLE 1

Results of regression analyses made on data from the full-scale road experiments

Site	Chippings		Lane	Traffic intensity (commercial vehicles per lane per day)	Age at last test (yrs)	Regression line $sfc\ 50 = a + b(PSV)$		Significance level (%)	Range of PSVs	Number of different aggregates
	Nominal size (mm)	Method of use				a ($\times 10^{-2}$)	b ($\times 10^{-2}$)			
Blackbushe Derby	19.1	Chippings in asphalt	-	2100	9	0.3	0.815	< 1	49 - 62	5
	19.1	Chippings in asphalt	-	.*	9	12.2	0.699	< 1	32 - 58	16
	19.1	Chippings in asphalt	-	860	3	- 6.8	1.029	< 2	58 - 71	7
	19.1	Chippings in asphalt	-	660	4	24.3	0.539	< 5	47 - 65	10
Blackbushe	12.7	Macadam	-	2100	9	- 6.6	1.063	< 1	49 - 69	6
Blackbushe High Wycombe	12.7	Chippings in asphalt	-	2100	9	-20.5	1.258	< 0.1	49 - 75	7
	12.7	(Chippings in asphalt) (and surface dressings)	F S	38 910	4 4	- 6.3 -27.7	1.102 1.372	< 0.1 < 0.1	55 - 75 55 - 75	5 5
Blackbushe West Wycombe Darent Hill Potters Corner	12.7	Surface dressings	-	2100	9	-10.1	1.110	< 0.1	49 - 75	6
	12.7	Surface dressings	-	1490	9	- 9.0	1.030	< 1	45 - 72	7
	12.7	Surface dressings	-	2520	2	- 3.7	0.809	< 10	53 - 61	6
	12.7	Surface dressings	(F (S	37 890	3 3	23.8 7.9	0.629 0.830	< 2 < 0.1	45 - 70 45 - 70	10 10
Shorne Cross Stelling Minnis Roman Galley Hook Swanley	12.7	Surface dressings	-	.*	2	5.2	0.770	< 1	57 - 70	12
	12.7	Surface dressings	-	.*	2	-11.9	1.380	< 1	39 - 54	5
	12.7	Surface dressings	-	800	3	- 1.0	0.968	< 10	54 - 61	6
	12.7	Surface dressings	-	400	3	- 4.5	1.080	< 0.1	49 - 64	15
	9.5	Surface dressings on concrete	(F (C (S	1 180 1780	2 2 2	-24.4 -23.4 -35.2	1.399 1.321 1.466	< 1 < 1 < 0.1	62 - 75 62 - 75 62 - 75	3 3 3
Average										1.03

* No traffic figures available.

TABLE 2

Mean summer values of sideways force coefficient recorded on different sites with one type of surfacing material (rolled asphalt with precoated chippings of PSV 58-60)

Road	Traffic in lane per day		sfc
	Total vehicles	Commercial vehicles	
M 1	9000	> 4000	0.31
A 12	14300	4000	0.34
M 4	16200	3900	0.34
M 4	9500	3100	0.36
A 2	17550	2500	0.43
A 4	10000	2400	0.42
M 40	3550	910	0.56
B 3053	5160	660	0.55
M 40	480	40	0.63

NOTE: Traffic estimates refer to the periods when sfc measurements were taken.

TABLE 3

Particulars of traffic and aggregate on sites included in the survey

Traffic lane No.	Number of Sections	Traffic per lane per day		Number of different aggregates	PSV range
		Commercial vehicles	Total vehicles		
1	1	4040	14300	1	59
2	6	3900	16200	1	59
3	4	3400	8400	1	58
4	9	3100	9500	1	59
5	6	2520	17550	6	53-61
6	1	2450	7300	1	61
7	1	2400	10000	1	55
8	2	2290	11740	1	71
9	1	2180	9050	1	71
10	16	2100	8700	7	55-75
11	3	1780	5850	3	62-75
12	1	1750	7280	1	71
13	1	1700	6160	1	51
14	6	1490	5240	6	49-71
15	4	1080	4650	1	58
16	1	1030	4260	1	71
17	2	920	4000	2	59-61
18	6	910	3550	3	57-75
19	9	890	5200	9	45-71
20	1	860	5100	1	70
21	5	800	4700	5	54-62
22	1	730	3200	1	55
23	13	660	5170	11	47-77
24	1	590	3090	1	55
25	14	400	2400	14	49-67
26	1	360	4250	1	71
27	3	180	3100	3	62-75
28	1	100	1000	1	58
29	6	38	490	3	57-75
30	10	37	1650	10	45-71
31	3	1	490	3	62-75

TABLE 4

Distribution of commercial traffic between lanes of a dual carriageway

Commercial vehicles in both directions per day	Commercial vehicles per lane per day (% of total commercial traffic in both directions)		
	Left hand lane	Centre lane (if 3 lanes)	or Right hand lane (if 2 lanes)
1000	49		1
2000	48		2
3000	47		3
4000	45		5
5000	43		7
6000	42		8
7000	41		9
8000	39		11
9000	38		12
10000	37		13
11000	35		15
12000	33		17

TABLE 5

Distribution of traffic, as total motor vehicles, between lanes of a dual carriageway

Total vehicles in both directions per day	Total vehicles per lane per day (% of total traffic in both directions)				
	Two-lane dual		Three-lane dual		
	LH	RH	LH	C	RH
1000	49	1	49	1	< 1
2500	48	2	47	3	< 1
5000	45	5	44	6	< 1
10000	40	10	38	11	1
20000	34	16	28	18	4
30000	31	19	23	20	7
40000	29	21	18	22	10
50000	27	23	14	23	13
60000	25	25	12	24	14

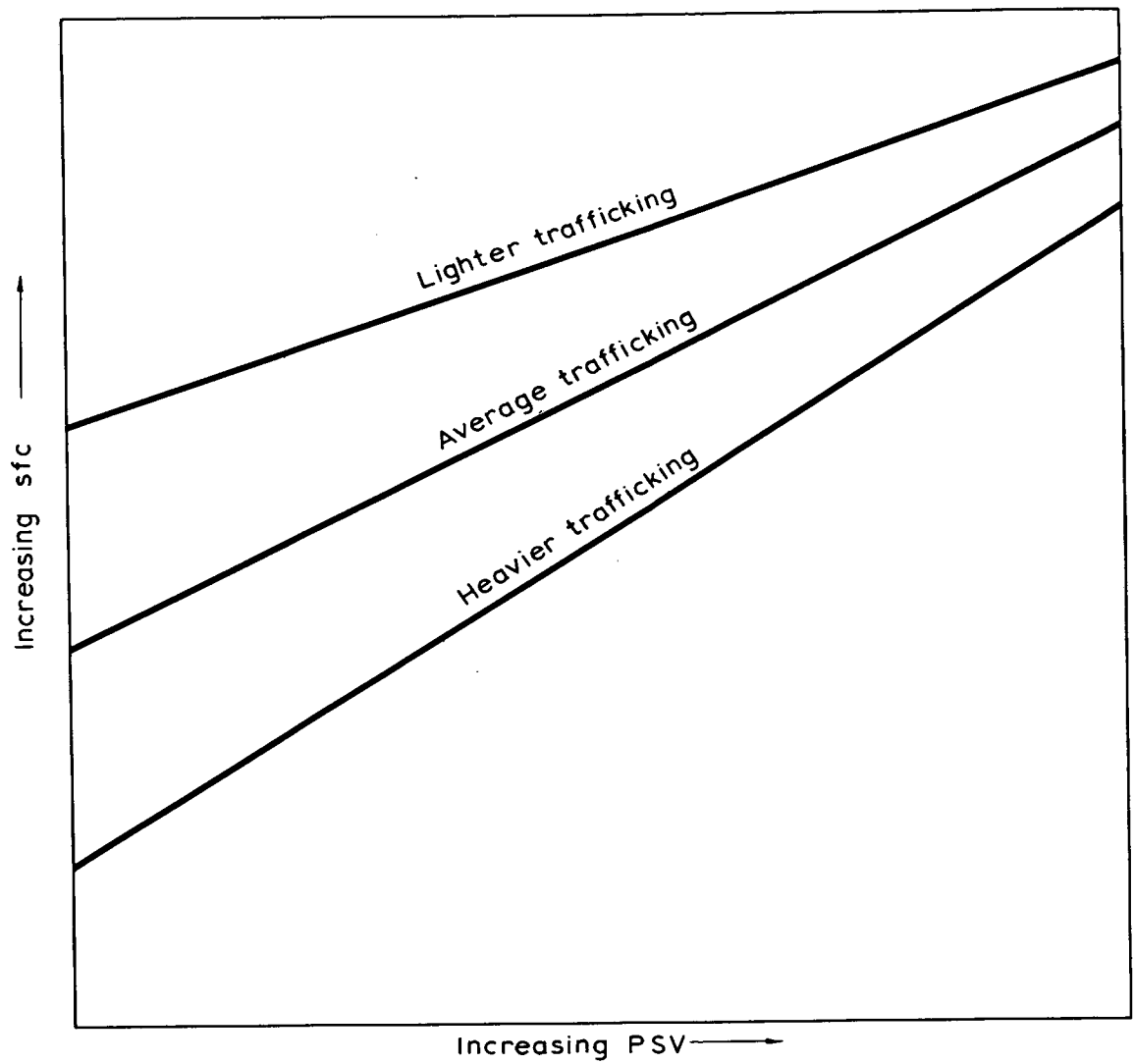


Fig.1. DIAGRAMMATIC RELATION BETWEEN sfc AND PSV FOR DIFFERENT DEGREES OF TRAFFICKING

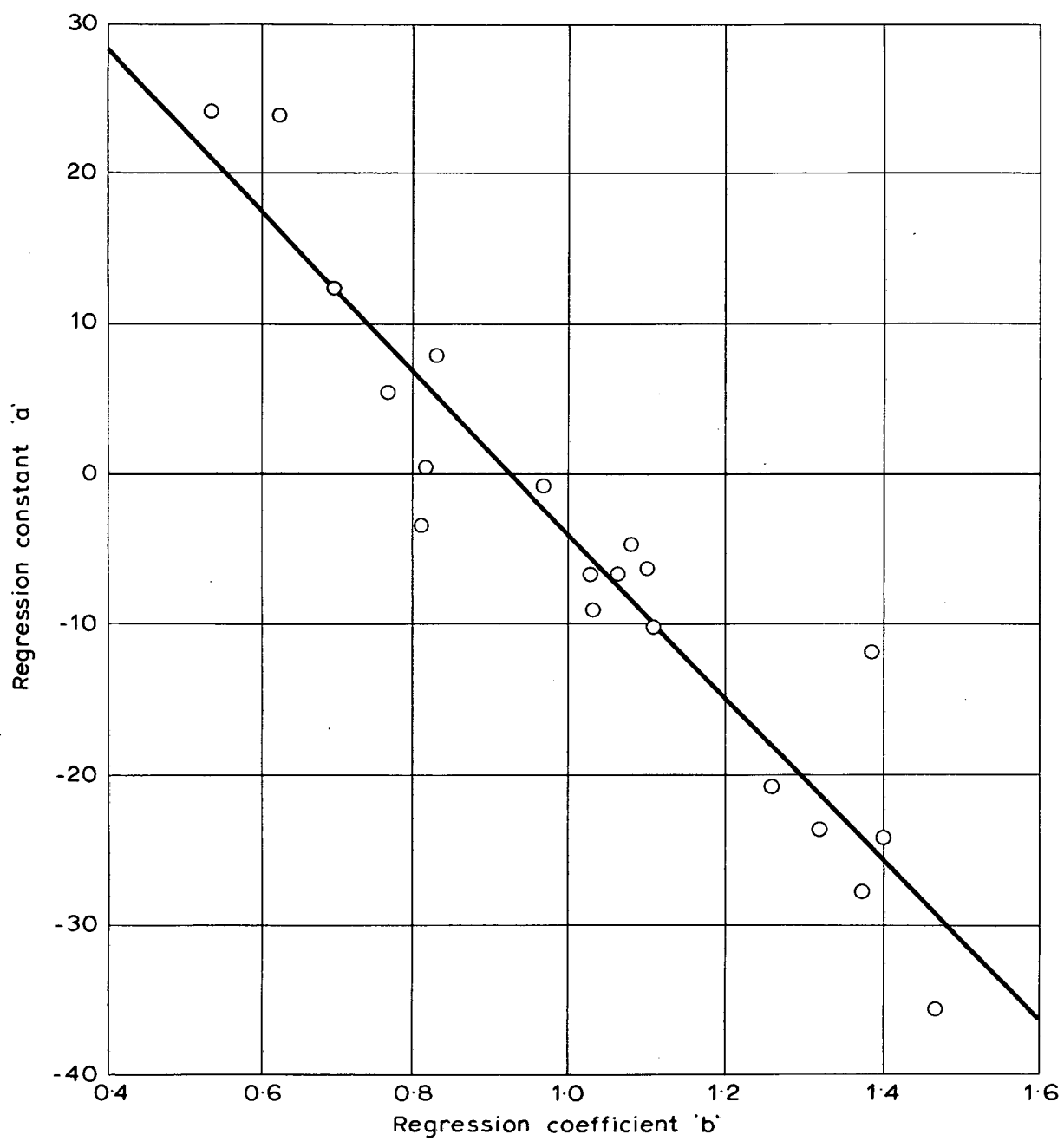


Fig. 2. RELATION BETWEEN REGRESSION COEFFICIENT AND CONSTANT FOR
sfc₅₀ / PSV RELATIONSHIPS

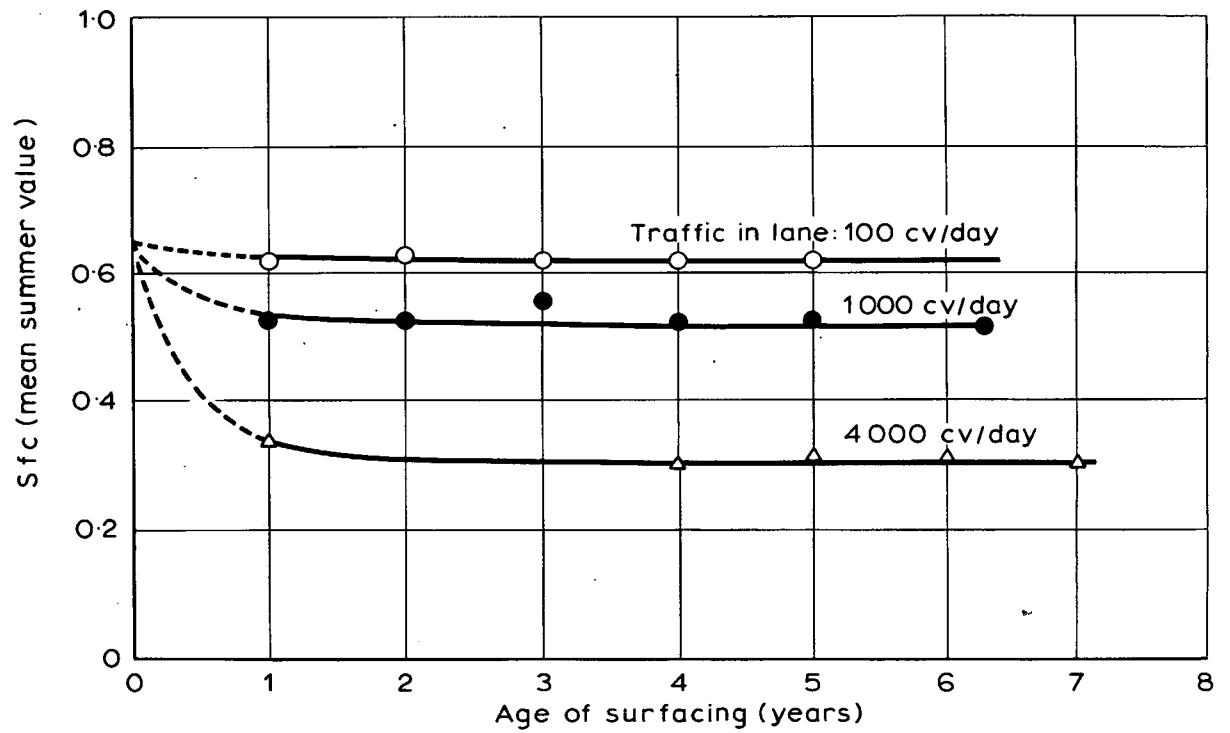


Fig. 3. EFFECT OF TRAFFIC ON SKIDDING RESISTANCE OF A TYPICAL MOTORWAY-STANDARD SURFACING (ROLLED ASPHALT WITH PRECOATED CHIPPINGS OF PSV 58-60)

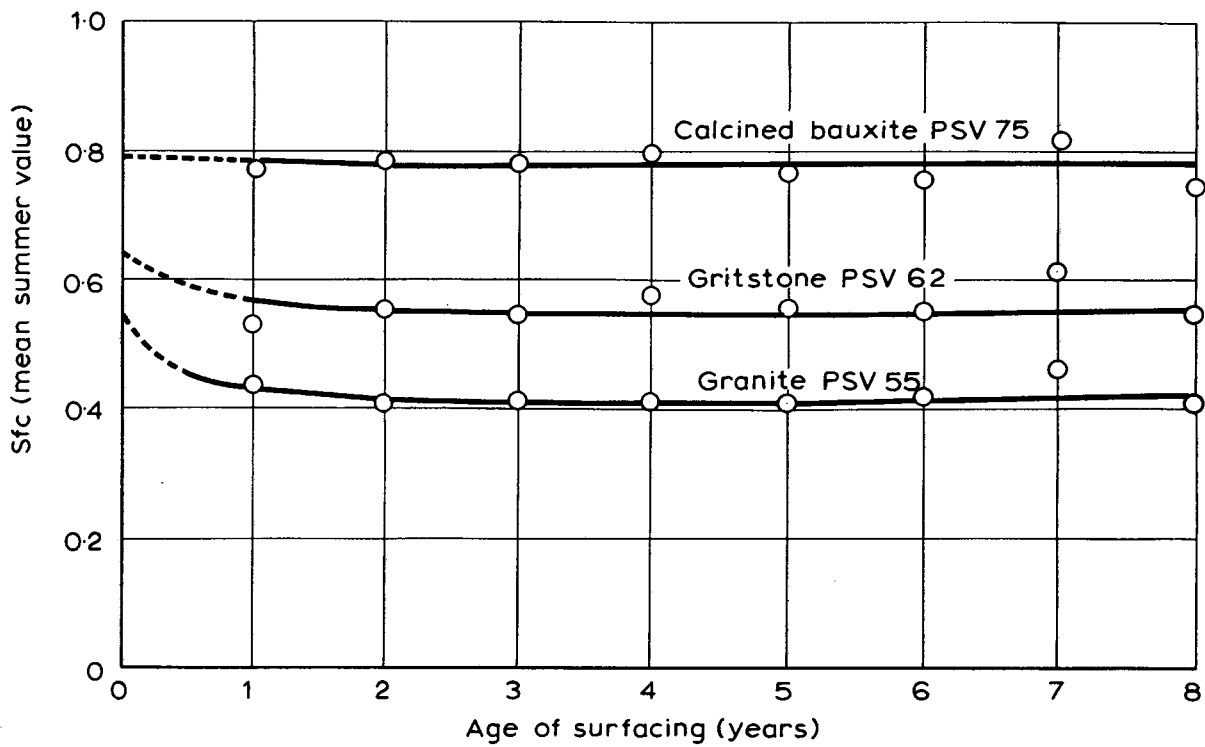


Fig. 4. LEVELS OF SKIDDING RESISTANCE RECORDED ON DIFFERENT SECTIONS OF THE SAME ROAD (SURFACE DRESSING USING 13mm CHIPPINGS. TRAFFIC IN LANE : 2100 COMMERCIAL VEHICLES PER DAY)

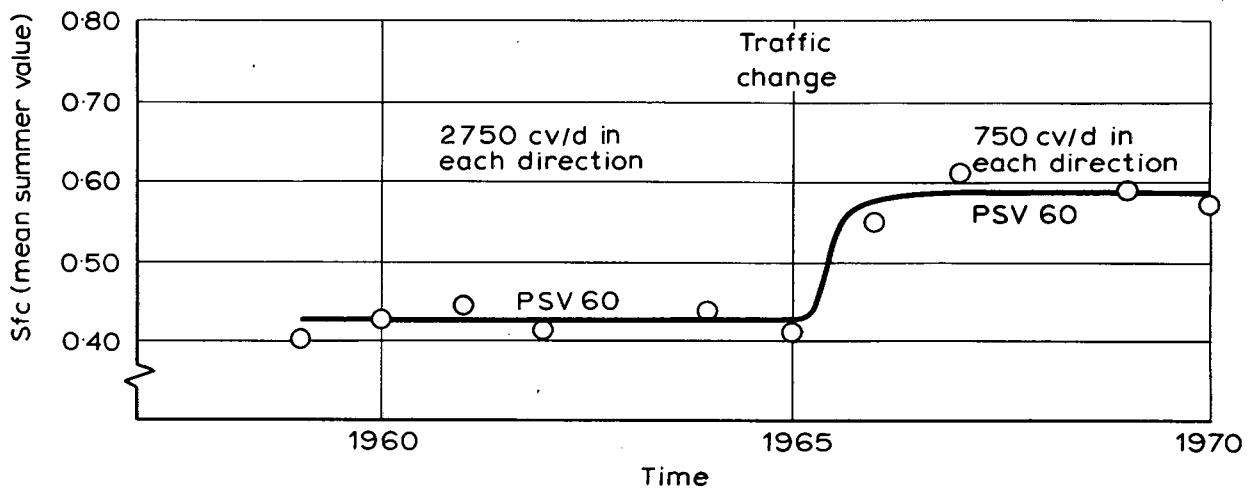


Fig. 5. AN INCREASE IN THE LEVEL OF SKIDDING RESISTANCE RECORDED ON TRUNK ROAD A4, COLNBROOK BY-PASS, WHEN TRAFFIC DECREASED DUE TO THE OPENING OF A MOTORWAY

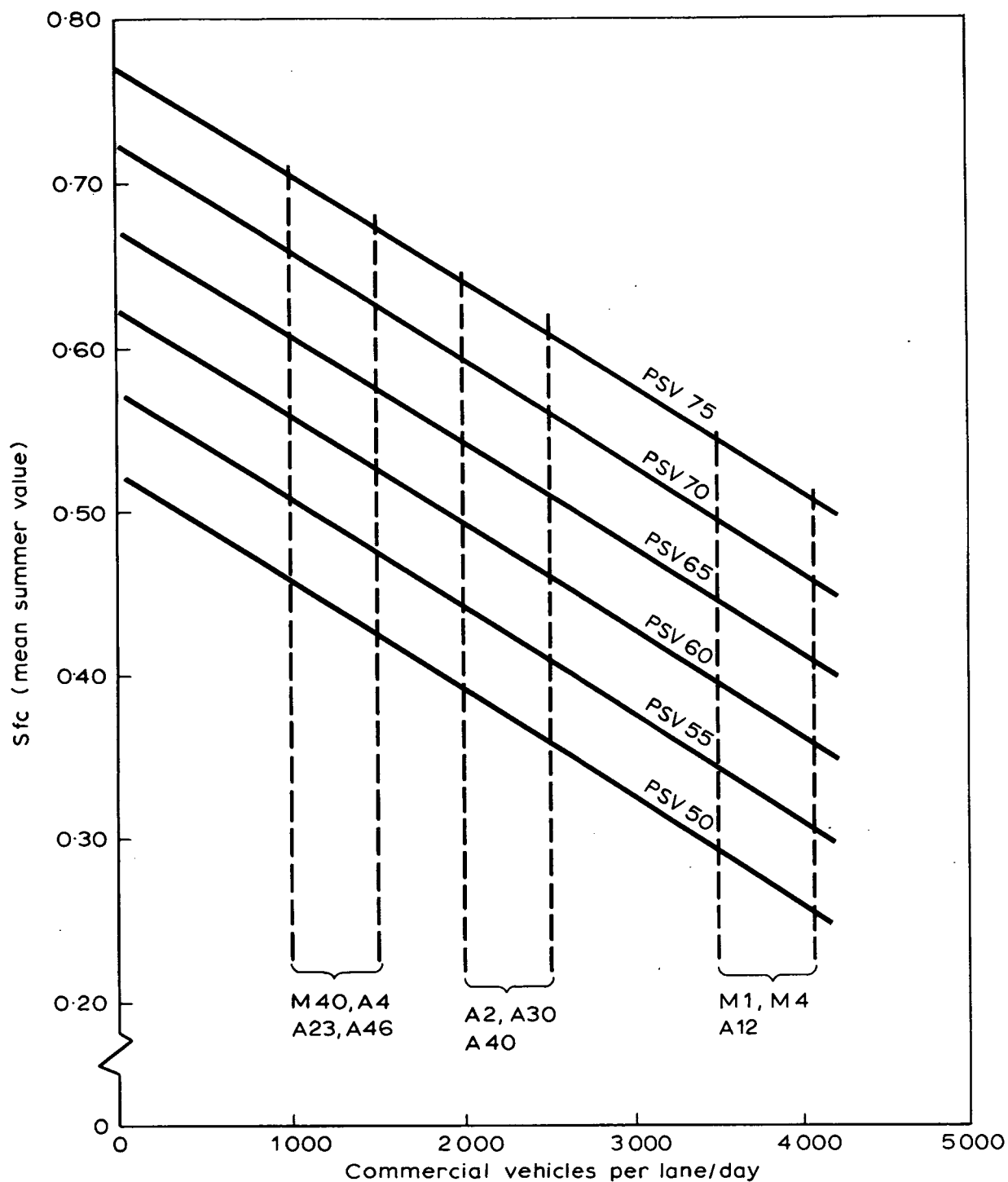


Fig. 6. SKIDDING RESISTANCE ACHIEVABLE ON BITUMINOUS SURFACINGS
(SURFACE DRESSING OR ROLLED ASPHALT WITH CHIPPINGS OF GIVEN PSV)
UNDER DIFFERENT TRAFFIC CONDITIONS

ABSTRACT

The effect of traffic and aggregate on the skidding resistance of bituminous surfacings: W S SZATKOWSKI, B.Sc., and J R HOSKING, M.Sc., A.C.S.M., A.I.M.M.: Department of the Environment, TRRL Report LR 504: Crowthorne, 1972 (Transport and Road Research Laboratory). The polishing characteristics of the aggregate used in a bituminous road surfacing are a major factor in determining its resistance to skidding. The amount and weight of traffic is also a determining factor on heavily trafficked roads. Analysis of measurements made on roads over the last 10 years has shown a direct correlation between traffic intensity and the skidding characteristics of the wet road surface, a correlation that varies consistently with the polishing characteristics of the aggregate. Thus it has been possible to derive an empirical formula which indicates the expected resistance to skidding of the surfacing from a knowledge of the polished-stone value of the aggregate and the expected traffic on the road. This formula will be of use to engineers in selecting aggregate to obtain surfacings of a required resistance to skidding under given circumstances. It applies only to surfacings which present a continuous mosaic of coarse aggregate to the motor tyre, i.e. to bituminous surface dressings and to bituminous premixes with a substantial proportion of exposed aggregate in the surface.

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