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THE EFFECT OF AGGREGATE ON THE SKIDDING RESISTANCE OF BITUMINOUS SURFACINGS: FACTORS OTHER THAN RESISTANCE TO POLISHING

by

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THE EFFECT OF AGGREGATE ON THE SKIDDING-RESISTANCE OF BITUMINOUS SURFACINGS: FACTORS OTHER THAN RESISTANCE TO POLISHING

ABSTRACT

Resistance to polishing is the most important single characteristic of an aggregate in determining the resistance to skidding of a bituminous road surfacing.

This Report describes a study that has been made of other characteristics of aggregates that have been thought to influence resistance to skidding. The more important findings were:-

1. On average, quartzites and blast-furnace slags give a resistance to skidding equivalent to that given by other roadstones which are three units higher in polished-stone value. None of the other roadstone types studied (Basalts, Granites, Porphyries and Gritstones) showed an important departure from the average.

2. Provided that adequate road surface texture is maintained, reducing the nominal maximum size of an aggregate raises the resistance to skidding of a surfacing made with it.

3. There is some indication that the use of more nearly single-sized chippings in surface dressings gives a better surface texture.

4. Inadequate durability in an aggregate can affect the resistance to skidding of a road made with it.

5. Mixtures of two or more roadstones in a road surfacing yields a resistance to skidding and a depth of surface texture that are approximately equal to the means of those given by the constituents on their own.

1. INTRODUCTION

It has already been shown[1] that the most important single characteristic of an aggregate affecting the skidding resistance of bituminous road surfacings is its resistance to polishing as measured by the polished-stone value (PSV) determination[2]. The way in which PSV and traffic density affect the resistance to skidding of bituminous road surfacings forms the subject of a separate report[3], in which it is shown that a change of one unit of PSV makes a difference of one unit of sideway-force coefficient (sfc) at any given traffic density. However a number of other characteristics of aggregates have also been thought to affect resistance to skidding. These are:-

Geological group

Particle size

Single-sizedness of chippings

Durability

Differential wear of mixtures of two or more roadstones.

This Report gives an account of studies that have been made of these factors in order to obtain a fuller understanding of the role of aggregates in providing skide-resistant roads.

2. GEOLOGICAL GROUP

2.1 General

Although highly significant correlation between PSV and resistance to skidding has been found in a large number of road experiments, it has also been noted that aggregates of certain geological types appear to show a systematic departure from the general relationship. The experience of a number of materials engineers has also led to the same conclusion. In some instances the reason for the departure can be seen to be due to the poor durability of the aggregate, which has led to loss in texture and, in extreme cases, to the skidding measurements being made largely on the binder rather than the aggregate. This problem is dealt with later in this Report under "Durability". However, in other instances it has appeared that less obvious features of the geological groups of aggregates were influencing the skidding-resistance of the surfacings. Reports[4,5] have been published respectively suggesting that slags and quartzites give a higher resistance to skidding than would be expected from their PSVs; and, more recently, there has been a growing feeling that igneous rocks were showing the opposite tendency. It has not been possible to regard these departures as conclusive, because their relatively small magnitude (less than 5 units of PSV) is similar to the "experimental error" that can be expected in road experiments. However sufficient data are now available to allow statistical methods to be used to estimate the significance of any departure of a group from the general relationship.

2.2 Statistical analysis of data and results

In the course of research described in an earlier report (LR 504[3]) regression analyses were made of PSV and sideway-force coefficient (sfc) data from 20 full-scale road experiments. The opportunity was taken to calculate the "residual" for each observation, this is the difference between the actual and the calculated values based on the regression lines. The residuals required for the present investigation were those for PSV, i.e. when PSV was taken as the dependent variable, the values obtained being a measure of the degree to which the measured PSV failed to predict the sfc. The residuals for these 20 experiments were sorted into geological groups and then subjected to statistical analysis; the residuals for each group were first tested for equality of variance with the residuals for all of the groups together (using the Fisher's Ratio test) and then tested for equality of means (using the Student's t test). The results are summarized in Table 1.

2.3 Discussion of results and conclusions

The sfc/PSV data were only sufficient to allow worthwhile results to be obtained for six of the groups of aggregates: Basalt, Granite, Porphyry, Gritstone, Quartzite and Artificial (blast-furnace slag). The results show that only one group (Porphyry) had a variance that was significantly different from the overall variance (probably 2.5 per cent). This may be because the small number of different aggregates of this type used in the experiments failed to give a representative distribution of values. The t-tests showed that two groups (Quartzites and blast-furnace slags) gave a highly significant difference from "all groups" in their mean residual, and that the mean difference in each case amounted to about three units of PSV less than the general relationship. Apart from the Porphyry group, where the difference was barely significant and would have not been significant had the variances been equal, the only other group showing a significant difference in mean was the Gritstone group, which gave an average residual that was equivalent to one additional unit of PSV when compared with the overall figure.

It is concluded that the commonly believed anomalous behaviour of quartzites and blast-furnace slags is significant, but there is no justification for the belief that igneous rocks behave worse than their PSVs suggest. It is likely that this belief has arisen from the general use of high-PSV igneous rocks for the more heavily trafficked road sites, and that the failure to maintain the expected level of sfc is due to the heavier traffic (as described in LR 504[3]) rather than to the geological type of the aggregate.

It is also concluded that gritstones yield a slightly poorer performance than their PSV would suggest (possibly because of their softer nature), but that the magnitude of the effect (equivalent to a lowering of the PSV by only one unit) is small enough to be disregarded.

Thus the only anomaly of importance is that found with the quartzites and blast-furnace slags which, on average, behave as if their PSV were three units higher than their measured values.

3. PARTICLE SIZE

3.1 General

It has been observed at a number of sites that the smaller the size of the aggregate in a surfacing, the better was the resistance to skidding; an example is at Blackbushe[5], where rolled asphalts with 12.7 mm chippings gave a higher sfc than similar asphalts with 19.1 mm chippings. Further data are now available and this section of the present Report describes a general study that has been made of the effect of the nominal size of an aggregate on the resistance to skidding and texture depth of road surfacing materials.

3.2 Sources of data and results

Six full-scale road experiments provide data relating to the effect of aggregate size on skidding-resistance. Details are summarized in Table 2. The surfacings include chippings applied to rolled asphalt and rock 'non-skid' asphalt, bitumen macadams and surface dressings. Sfc_{50} measurements are available for each experiment and, additionally, measurements of sfc at 80 km/h and of texture depth (sand-patch method[6]) were made in some of the experiments. Results are summarized in Tables 3-8.

3.3 Discussion of results of road experiments

3.3.1 Streatham High Road

Table 3 gives the results obtained for an experiment that was begun in 1953 on the heavily-trafficked Streatham High Road[7,8]. The experiment included sections of hot-rolled asphalts and rock 'non-skid' asphalts with two sizes of coated chippings (25.4 mm and 12.7 mm nominal size). Sections of each were repeated with four types of chipping: a hornfels, a granite, a quartzite and a blast-furnace slag. Of the eight pairs of sections using the two sizes of chippings, seven gave a higher sfc for the smaller sizes, the average difference being 0.04 units higher for the rolled asphalts and 0.07 units for the rock "non-skid" asphalts. Thus there was an overall average improvement of nearly 0.06 units when the chipping size was halved.

3.3.2 Harmondsworth

This experiment, begun on Trunk Road A4 in 1954 at Harmondsworth[9], included four sections of bitumen macadams with hornfels coarse aggregates of maximum nominal size ranging from 19.1 mm down to 6.3 mm. A fifth size "3 mm macadam" was obtained by laying a section of fine cold asphalt made with the same hornfels aggregate. The results (Table 4) show a small, but fairly consistent, improvement of sfc as the nominal size becomes smaller, averaging about 0.02 units of sfc for a halving of the nominal size.

3.3.3 Blackbushe

This experiment, begun on Trunk Road A30 at Blackbushe in 1962[5], consists of sections of a wide range of flexible road surfacings and types of aggregate. The experiment includes duplicate sections of rolled asphalts with chippings of two sizes (19.1 mm and 12.7 mm) from six sources. The results (Table 5) show a small, but consistent, improvement in sfc with the smaller-sized chippings, which averaged about 0.04 units for the reduction by one-third of the nominal size. The results also show that the texture depth given by the two sizes of chippings was virtually the same.

3.3.4 Maidenhead Thicket

Two 1.6 km lengths of the M4 Motorway at Maidenhead Thicket (now A423 (M)) have been subjected to sfc measurements over the last two years. Both were surfaced dressed in 1968 with chippings from the same gritstone quarry, one length with nominal 9.5 mm chippings and the other with nominal 12.7 mm chippings. The results (Table 6) show that the smaller chippings are giving considerably higher sfc's at both of the speeds (50 and 80 km/h), the difference being about 0.08 units for the reduction in nominal size by one-third.

3.3.5 Swanley By-Pass

This experiment, begun on Trunk Road A20 at the Swanley By-Pass in 1970[10], includes two sections of surface-dressed concrete that are identical with the exception of chipping size. The chippings, from the same gritstone quarry, are respectively of 6.3 mm and 9.5 mm nominal size. Test results (Table 7) show that the smaller chippings gave a higher sfc at 50 km/h in each of the traffic lanes, the difference averaging about 0.06 units for the one-third reduction in size. However, at the higher speed of test (80 km/h), the improvement in sfc with the smaller chippings was less (averaging only 0.02 units). This loss in resistance to skidding at a higher speed is consistent with the lower texture depth that was observed with the smaller chippings (average 0.14 mm less).

3.3.6 Stonebridge

This experiment, begun in 1970 on Trunk Road A45 at Stonebridge[11], consists of a number of sections of bituminous macadam. Two pairs of the sections are identical except for the nominal size of the aggregates used, which were 19.1 mm and 9.5 mm respectively. Table 8 shows that in each case the sections with the smaller-sized aggregate have given higher sfc values, the average difference being about 0.05 units for the halving of the nominal size.

3.4 General discussion and conclusions

In each of the six experiments the sfc's at 50 km/h were appreciably higher for the sections using smaller-sized aggregates, the average difference varying from 0.03 to 0.08 units (overall average 0.04) for one step in chipping size in the usual "$\sqrt{2}$" series (25.4 mm, 19.1 mm, 12.7 mm, 9.5 mm, 6.3 mm ....). The effect was less noticeable with the macadams where the average difference was 0.03 units for a halving of the maximum nominal size. This is probably because of the greater range of aggregate particle size and the greater part played by the binder in providing resistance to skidding in this type of surfacing.

Similar differences were found for the sfc measured at 80 km/h at Maidenhead Thicket, but at Swanley the effect was rather less, probably because of the smaller texture depth of the sections using smaller chippings.

The effect of aggregate size on texture depth was less clear. Experience would suggest that a poorer texture is more likely with smaller aggregate and that any resulting loss in high-speed skidding-resistance must be balanced by the gain at lower speeds resulting from the use of smaller aggregate. Results are available for only two sites. At Blackbushe there was no appreciable lowering in texture with the smaller chippings, yet at Swanley there was an average difference of 0.14 mm.

4. SINGLE-SIZEDNESS OF CHIPPINGS

4.1 General

Two full-scale experimental surface dressings were laid in the summer of 1969 with the primary object of studying the effect of variations in the grading of chippings on the subsequent performance of surface dressings on heavily-trafficked roads[12]. One experiment was on Trunk Road A4 at Littlewick Green, Berkshire, and the other on Trunk Road A31 near Cadnam, Hampshire. At each site, three gradings were used all of the same nominal size, but planned to be respectively well within, just on the limit and well outside the limits laid down in BS 63:1951[13]. Target gradings (and the gradings actually achieved) are given in Table 9; two sections were laid with each grading at each site.

4.2 Results and discussion

A summary of the results of sideway force coefficient (sfc) measurements at two speeds (50 km/h and 80 km/h) and texture-depth measurements (sand-patch method) is given in Table 10. The sfc results show no significant differences for the different gradings, but the texture-depth results show some appreciable differences; these are more clearly shown in Fig. 1. This shows that the more single-sized chippings (Grading B) gave a greater texture depth than the chippings just complying with BS 63:1951. Similarly the less single-sized chippings (Grading C) gave a correspondingly lower texture. If measurements on the freshly laid material are ignored, the average differences were:-

an increase of 0.15 mm for Grading B

a decrease of 0.05 mm for Grading C.

The overall difference is thus about 0.20 mm for gradings where the percentage of nominal size varied from about 40 per cent to about 70 per cent.

5. DURABILITY

5.1 General

A number of quite different properties can affect the durability of an aggregate in a road surfacing; of these, resistance to abrasion, compressive and tensile strength, and resistance to mechanical and chemical decomposition, are the most important. Apart from reducing the life of a road surfacing, lack of durability in the aggregate used can also be expected to affect texture depth and resistance to skidding through excessive wear, degradation and loss of stone from the surfacing. Little systematic information is available which relates to the effect of these properties on the texture and skidding-resistance of roads, but a number of cases have been reported of defects in road surfacings being attributed to one or more of these factors. Examples are given in the following paragraphs.

5.2 Examples of lack of durability affecting resistance to skidding

5.2.1 Low abrasion resistance and strength

Evidence of the results of low resistance to abrasion and strength was obtained from the surface-dressing experiment[14] begun on Trunk Road A40 at West Wycombe in 1955. Thirteen different roadstones were used as nominal 12.7 mm single-sized chippings in tar surface dressings on this heavily trafficked (11,000 vehicles per day) road. It was reported that "the roadstone with the poorest (aggregate) abrasion and crushing values (17 and 28 respectively), was rapidly broken down by traffic wear and became too smooth". Correlation was also found between the aggregate abrasion value of the chippings and the texture depth of the surfacing, a difference of one unit of AAV being equivalent to a difference of about 0.05 mm in texture depth after nine years of heavy trafficking.

5.2.2 Decomposition

In the Derby Ring Road experiment[15] fuller details of which are given in 6.3.3 below, loss of stone from a section where basalt chippings had been used was attributed to the decomposition of some of the aggregate particles. This did not appear to affect the sfc of the surfacings and the texture depth appeared to be improved. In the Blackbushe experiment[5] a similar effect was observed with another stone in the Basalt group, but in this case there was an appreciable loss of both sfc and texture depth.

A study of unsound aggregates[16] has shown that other basic igneous rocks (all from overseas) can fail in service in the same way as the examples given above. Standard (BS 812:1967[2]) roadstone aggregate tests are not able to detect this weakness, but some tests, such as the sodium-sulphate soundness test, can do so.

5.3 Discussion and conclusions

The examples illustrate some of the ways in which lack of durability of an aggregate can affect the texture depth and resistance to skidding of road surfacings made with them. There are too few data to be able to draw any firm conclusions, but lack of durability is a factor that should be borne in mind when selecting aggregates for use in road surfacings and when searching for an explanation of any anomalies in performance.

6. MIXTURES OF ROADSTONES

6.1 General

Interest in the use of mixtures of roadstones has been renewed following a report[17] that the road-surfacing material developed by Dr G Lees of the University of Birmingham and Messrs Dunlop makes use of the differential wear of mixtures of aggregates of different hardness in order to maintain a coarse macro-texture.

Similar mixtures have been used in traditional road surfacing materials for many years, but, although still commonly seen in many of our major cities, their popularity has waned over the last decade or two. The British Standard Specification for compressed natural rock asphalt[18], in fact, specifies the chippings as follows:-

"Two-thirds of these shall be hard igneous rock 1-in (25.4 mm) in size and one-third of a slightly less hard igneous rock ¾-in (19.1 mm) in size, the two qualities of rock being selected so that there shall be a differential wear in service."

A number of full-scale road experiments conducted by the Laboratory have included sections of mixed roadstones, but the results (e.g. at the Derby Ring Road[15]) have shown no conclusive evidence that the additional cost of mixing is justified by improvement in the surfacing. A possible exception has been a recent experiment[19] at Kennington Lane in which 50:50 mixtures of calcined bauxite (RASC grade) and a conventional aggregate used in "Shellgrip" surfacings have shown some indication of giving a better skid-resistance than the average of that given by the two constituents used separately. However the results of this experiment were not conclusive, because of its premature failure as a result of poor laying conditions. A similar experiment has since been carried out at Brixton, the results from which, together with results from five other experiments where mixtures of aggregates have been used, form the subject of this chapter of the Report.

6.2 Sources of data and results

Six road experiments provide data relating to the effect of mixing different types of roadstone in a road surfacing. Details are summarized in Table 11. The surfacings include bitumen macadams, chippings in rolled asphalt and rock 'non-skid' asphalt, surface dressings and nominal 3 mm grit in resin-bound surfacings. Tests were made of sfc at 50 km/h at four of the sites and of skid-resistance value[6] (SRV) at the remaining two. Texture-depth measurements were made at three of the sites and braking-force coefficients at 130 km/h were measured at one. The results are summarized in Tables 12 to 17.

6.3 Discussion of results of road experiments

6.3.1 Bituminous macadams in Middlesex

An examination was made in 1954 of 31 sites in Middlesex where bitumen-macadam surfacings had been laid on heavily trafficked roads. Sfc_{50} measurements were made at the same time. The surfacings included mixtures of basalt, limestone and hornfels roadstone as well as of a number of roadstones on their own. It was noted at the time that the wide variation in results with the mixtures of the three roadstones (basalt, limestone and hornfels) could have been partly caused by the observed poor blending of the constituents. It was also noted that the surfacings with mixed roadstones were exhibiting a "medium-smooth texture" after the six-to-seven years of trafficking.

A proper comparison of the skidding measurements is not possible because of the difference in nominal maximum size of the mixed-aggregate surfacings (their smaller size would be expected to yield a rather higher sfc*) and because there are no figures for surfacings made with the basalt or the limestone aggregates on their own. Nevertheless, this work shows that mixtures of aggregates were in common use at the time (1954) and that the skid-resistance of the mixture was inferior to that of a slag on its own. It also showed that the textures of the surfaces using the mixture of aggregates were disappointingly smooth in view of the fact that they included one of the hardest of road-surfacing aggregates (hornfels with an aggregate abrasion value (AAV) of 2) and one of the softest (limestone with an AAV greater than 10).

6.3.2 Streatham High Road

Details of this experiment are given in 3.3.1 above. The mixtures were of equal proportions of hornfels and granite, and hornfels and blast-furnace slag. There were also sections of hornfels, granite and blast-furnace slag on their own, and additional sections of quartzite. The results (Table 13) show that the rolled asphalts with mixed chippings yielded rather poorer sfc's than the mean sfc of asphalts with the individual chippings on their own, whereas the reverse was true for the rock 'non-skid' asphalts. Much of this difference appears to result from the exceptionally low sfc's (average 0.33) given by the section of 25.4 mm hornfels chippings in rock 'non-skid' asphalt which, being close to the traffic-light-controlled junctions of the A23, A214 and A216, would be subjected to a greater polishing action by traffic than the remainder of the experimental site. No firm conclusions can therefore be drawn as to the effect of mixing two types of chippings on resistance to skidding; but the evidence suggests that the benefit (if any) is likely to be small and that the use of a more polishing-resistant roadstone such as the quartzite is more effective.

6.3.3 Derby Ring Road

This experiment, begun on the Trunk Road A5111 at Derby in 1953, consisted of sections of different 19.1 mm coated chippings applied to rolled asphalt. Full results have been published in LR 63[15], and a summary of those relevant to the present study are given in Table 14.

These results show that the sfc's of the sections with mixed chippings were very close to the mean values given by the corresponding aggregates on their own. Two were, in fact, equal and the other two were respectively 0.02 and 0.03 units lower than the mean. The skid-resistance values also showed little differences; two were slightly higher than the mean values and two were lower. These results suggest that the differences are of a random nature and only reflect the variability of the test methods. The results of the surface-texture measurements for two of the sections were also very close to the calculated values, but the other two were considerably lower (0.41 mm and 0.28 mm difference respectively). However reference[15] to the recorded rate of spread of the chippings shows that the two mixtures giving a lower texture depth were more lightly chipped than the other sections. On balance the results of this experiment show that the mixtures of chippings of two types in rolled asphalts gave a skidding resistance and a texture depth that was very close to the mean of the two types used on their own.

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* See Chapter 3.

6.3.4 High Wycombe By-Pass

This experiment[20] was begun in 1967 on the High Wycombe By-Pass (M40). The results that are relevant to the present Report are given in Table 15. They show that there is only a slight difference in sfc_{50} between the measured and calculated (from the results for single types of chippings) values for the mixtures of basalt and calcined-bauxite chippings. This small difference is probably not significant; the actual values are lower than the calculated values.

The bfc figures at 130 km/h showed a larger difference, the actual values again being lower than the calculated. This difference, on average 0.02 units for the chipped rolled asphalt and 0.07 for the surface dressings, was probably due to the difference in texture depth (see below) which affects the higher speed measurements.

The results show a considerably poorer texture depth for the mixture compared with either of the constituents on its own, the mean figures for the constituents alone being respectively 0.34 mm and 0.15 mm more than those of the mixture. This difference may reflect the difficulty of obtaining a good texture depth when the constituents of a mixed roadstone chippings are of different average least dimension* (although still within the grading and shape tolerances of the appropriate specifications[13,21]). This is consistent with the findings of Chapter 4, which indicate that a rather better texture depth is given by more highly single-sized aggregates of the same flakiness.

6.3.5 Kennington Lane

This experiment, carried out in co-operation with the Greater London Council, was begun in 1969 on a very heavily trafficked bend in the Inner London Ring Road at the junction between Kennington Lane and Wandsworth Road. It consisted of a number of sections of different aggregates of 3 mm nominal size in a resin binder. The whole experiment was abandoned early in 1970 because of adhesion failure of the binder to the road surface as a result of unsatisfactory weather conditions at the time of laying.

This experiment is fully reported in LR 466[19], but relevant results are summarized in Table 16. With each of the mixtures the SRV results were considerably higher than would be expected from the mean SRV of the two constituents on their own, the Craig-yr-Hesg/RASC-bauxite mixture giving the same results as the bauxite alone, and the Synopal/RASC-bauxite giving a mean SRV of 71 instead of about 63 which would be expected from the mean. Although encouraging (bauxite is very expensive) these results were not conclusive, because of the short life of the experiment. In view of this a similar comparison was subsequently included in another experiment at another site (see 6.3.6. below).

6.3.6 Brixton

Following the encouraging results from Kennington Lane, a further more comprehensive experiment with mixtures of aggregates in resin binders was included in a trial in 1971. The site is at a sharp bend in Effra Road, Brixton, and the work was again in co-operation with the Greater London Council. It included sections of calcined bauxite with two other roadstones in a number of different proportions. Results (Table 17) show that the SRVs for the mixtures were close to the calculated values based on the proportions of the two constituents, the mixtures of the calcined bauxite and gritstone giving SRVs which averaged about 1 unit better than the calculated values, and the mixtures of bauxite with basalt averaging about 2 units better. Proportionately larger differences were observed for the texture-depth measurements, the bauxite/gritstone mixture giving an average texture depth that was 0.05 mm less than the calculated values and the bauxite/basalt mixture giving 0.10 mm more than the calculated depth. Neither set of measurements (SRV and texture depth) shows any definite trend over the period of trafficking other than a general overall fall in SRV and texture depth. This suggests that the behaviour of the mixtures was not greatly affected by differential wear, and that the differences are more likely to be the result of experimental error.

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* Although the gradings were similar there was a large difference in the flakiness of the chippings, the indices being 29 and 3 respectively.

6.3.7 Other experiments

Further indirect evidence that mixtures of different aggregates give only the average skid-resistance of their constituents was obtained from two other experiments with resin binders. These were started in 1970 at Kennington Lane and Guildford respectively and are fully described in a separate Report[22]. In these experiments, seven different constituents of RASC calcined bauxite (which has a complex structure) were separated and laid in a resin binder beside the normal mixed material. Three of these constituents behaved rather better than the mixture, one was the same and two were poorer. If there was any special advantage for a mixture, the mixture would be expected to be better than the constituents on their own, rather than to give results that were close to the "weighted average" as was the case.

6.4 General discussion and conclusions

On balance the results from all the experiments where mixtures have been used have failed to show that the mere mixing of two aggregates has given a significant advantage either in resistance to skidding or in texture. On the other hand the work suggests that, apart from the higher cost of preparing a mixture, there could be two possible disadvantages of such mixing. The first is that mixtures could lead to less uniform road surfaces and the second is that surface texture might be lowered when applying chippings with a wide range of average least dimension.

7. SUMMARY OF CONCLUSIONS

It has already been shown that the resistance to polishing of an aggregate can affect the skidding-resistance of a bituminous road surfacing made with it. The present study of the effect of other aggregate characteristics shows the following:-

1. On average, quartzites and blast-furnace slags give a resistance to skidding equivalent to that given by other roadstones which are three units higher in PSV. None of the other roadstone types studied (Basalts, Granites, Porphyries and Gristones) showed an important departure from the average.

2. Providing adequate road surface texture is maintained, reducing the nominal maximum size of an aggregate raises the resistance to skidding of a surfacing made with it. Over the range of sizes studied (3 mm to 25 mm nominal sizes), halving the size of aggregates used as chippings increases sfc by about 0.08 units: in the case of macadams the corresponding increase is about 0.03 units.

3. There is some indication that the use of more nearly single-sized chippings in surface dressings will give a better surface texture.

4. Inadequate durability (resistance to abrasion, cracking and weathering) in an aggregate can affect the resistance to skidding of a road made with it.

5. The use of mixtures of two or more roadstones in a road surfacing yields a resistance to skidding and a depth of surface texture that is approximately equal to the means of those given by the constituents on their own.

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TABLE 1

Results of statistical tests on the 'residuals' for different roadstone groups (from PSV/sfc correlations) for 20 full-scale experiments

Roadstone group	Number of observations	Average residual	Standard deviation	Test for equality of sample with whole population (t-test)		F-Ratio test for equality of variances (probability - per cent)
				t-value	Probability* (per cent)	
Basalt	34	0.2	2.86	-0.24	> 5	> 5
Granite	25	–0.6	3.31	0.97	> 5	> 5
Porphyry	30	1.0	2.47	1.60	> 5**	2.5
Gritstone	84	1.4	3.07	2.10	< 5	> 5
Quartzite	18	–3.3	3.01	4.21	< 1	> 5
Blast-furnace slag	20	–2.7	3.56	3.68	< 1	> 5

* Probability of the t-value being further from zero.

** Assuming equality of variances.

TABLE 2

Summary of details of experiments where different sizes of chippings have been used

Experiment	Date of laying (and reference)	Traffic intensity (cvd)	Tests	Dates of testing	Details of surfacings
Streatham High Road (A23)	1953 (7,8)	Heavy (–)	sfc 50	1955 to 1957	4 different chippings plus two mixtures. 10 30-metre sections of rolled asphalt with 12.7 mm (at 10 kg/m^2) and 25.4 mm (at 17 kg/m^2) coated chippings. 10 30-metre sections of rock-asphalt powder on mastic asphalt with 12.7 mm (at 24 kg/m^2) and 25.4 mm (at 37 kg/m^2) coated chippings.
Harmondsworth (Trunk Road A4)	1954 (9)	Heavy (–)	sfc 50	1956 to 1957	One aggregate (hornfels) used throughout. Four sections of bitumen macadam of 19.1 mm, 12.7 mm, 9.5 mm and 6.3 mm nominal size to BS 1621, also one section each of fine cold asphalt and surface dressing. 400 metres length overall.
Blackbushe (Trunk Road A30)	1962 (5)	Heavy (2,500)	sfc 50 Texture depth	1963 to 1971	Eight different aggregates. 60-to 100-metre lengths of surface dressings, chippings in rolled asphalts, dense tar surfacings, and open- and close-textured bitumen macadams.
Maidenhead Thicket (M4 Motorway)	1968 (–)	Very heavy (–)	sfc 50 sfc 80	1970 to 1971	Gritstone chippings in two sizes (12.7 mm and 9.5 mm) in 1.6 km lengths of surface dressing.
Swanley By-Pass (Trunk Road A20)	1970 (10)	Heavy (2,000)	sfc 50 sfc 80 Texture depth	1970 to 1971	13 150-metre sections of two gritstones and calcined bauxite chippings in surface dressings on concrete. The experiment includes two sizes of chippings from one source and additionally a resin-bound surfacing.
Stonebridge (Trunk Road A45)	1970 (11)	Heavy (–)	sfc 50	1970 to 1971	Lengths of six pervious surfacing materials (macadams) using two sizes of coarse aggregate.

TABLE 3

Results from the Streatham experiment

Section	Chippings	Nominal chipping size (mm)	Mean summer sfc 50			
			1955	1956	1957	Mean
Hot rolled asphalts:-						
1	Hornfels	25.4	0.38	0.35	0.40	0.38
7	Quartzite	25.4	0.52	0.51	0.52	0.52
9	Granite	25.4	0.41	0.39	0.41	0.40
15	Slag	25.4	0.39	0.40	0.39	0.39
Average of the four						0.42
3	Hornfels	12.7	0.37	0.35	0.37	0.36
5	Quartzite	12.7	0.51	0.51	0.56	0.53
11	Granite	12.7	0.47	0.46	0.47	0.47
13	Slag	12.7	0.47	0.47	0.47	0.47
Average of the four						0.46
Rock "non-skid" asphalts:–						
2	Hornfels	25.4	0.32	0.31	0.36	0.33
10	Quartzite	25.4	0.57	0.57	0.61	0.58
8	Granite	25.4	0.39	0.40	0.43	0.41
16	Slag	25.4	0.38	0.40	0.45	0.41
Average of the four						0.43
4	Hornfels	12.7	0.38	0.39	0.42	0.40
12	Quartzite	12.7	0.56	0.58	0.64	0.59
6	Granite	12.7	0.49	0.50	0.49	0.49
14	Slag	12.7	0.49	0.51	0.55	0.52
Average of the four						0.50

TABLE 4

Results from the Harmondsworth experiment

Maximum nominal size of aggregate in bitumen macadam (mm)	Mean summer sfc 50		
	1956	1957	Average
19.1	0.38	0.40	0.39
12.7	0.41	0.41	0.41
9.5	0.40	0.44	0.42
6.3*	0.41	0.43	0.42
3**	0.45	0.52	0.49

* Mean of two sections

** Fine cold asphalt

TABLE 5

Results from the Blackbushe experiment

Section	Aggregate	Size (mm)	Mean summer sfc 50										Mean texture depth (mm)			
			1963	1964	1965	1966	1967	1968	1969	1970	1971	Mean	1965	1968	1971	Mean
Rolled asphalts with 7.4% bitumen:																
16	Corby	12.7	.43	.44	.45	.48	.44	.45	.47	.43	.47	0.45	1.22	1.19	1.45	1.29
15	Penmaenmawr	12.7	.41	.43	.43	.45	.40	.40	.45	.41	.44	0.42	1.19	1.19	1.33	1.24
22	Groby	12.7	.42	.43	.44	.44	.42	.40	.46	.40	.43	0.43	1.24	1.29	1.51	1.35
21	Hartshill	12.7	.46	.49	.48	.53	.48	.47	.54	.49	.52	0.50	1.27	1.24	1.62	1.38
24	Triscombe	12.7	.51	.54	.55	.56	.50	.49	.57	.50	.53	0.53	1.22	1.32	1.48	1.34
23	Spring Grove	12.7	.45	.48	.48	.52	.46	.46	.52	.47	.51	0.48	0.91	0.94	0.99	0.95
Average			.45	.47	.47	.50	.45	.45	.50	.45	.48	0.47	1.18	1.20	1.40	1.26
30	Corby	19.1	.42	.42	.43	.45	.38	.40	.43	.39	.43	0.42	1.27	1.22	1.47	1.32
31	Penmaenmawr	19.1	.40	.41	.41	.41	.36	.42	.42	.39	.40	0.40	1.17	1.19	1.42	1.26
32	Groby	19.1	.39	.41	.40	.41	.37	.38	.42	.38	.40	0.40	1.27	1.37	1.44	1.36
37	Hartshill	19.1	.43	.46	.47	.48	.44	.45	.50	.47	.50	0.47	1.22	1.27	1.44	1.31
35	Triscombe	19.1	.46	.49	.50	.52	.47	.49	.53	.51	.51	0.50	1.14	1.35	1.53	1.34
42	Spring Grove	19.1	.43	.44	.42	.41	.38	.38	.44	.39	.43	0.41	1.12	1.11	1.26	1.16
Average			.42	.44	.44	.45	.40	.42	.46	.42	.45	0.43	1.20	1.25	1.42	1.29
Rolled asphalts with 8.4% bitumen																
18	Corby	12.7	.43	.44	.45	.46	.43	.44	.46	.43	.45	0.44	0.86	0.86	1.04	0.92
17	Penmaenmawr	12.7	.42	.44	.43	.44	.40	.40	.47	.43	.45	0.43	0.97	0.94	1.06	0.99
20	Groby	12.7	.42	.42	.42	.42	.40	.40	.44	.40	.42	0.42	1.09	1.07	1.31	1.16
19	Hartshill	12.7	.46	.50	.50	.53	.50	.49	.55	.51	.53	0.51	0.97	1.04	0.94	0.98
26	Triscombe	12.7	.45	.52	.53	.55	.51	.51	.57	.52	.53	0.52	0.81	0.81	1.06	0.89
25	Spring Grove	12.7	.43	.45	.46	.49	.45	.46	.52	.48	.47	0.47	0.69	0.61	0.77	0.67
Average			.44	.46	.47	.48	.45	.45	.50	.46	.48	0.47	0.89	0.89	1.03	0.94
28	Corby	19.1	.41	.43	.42	.44	.39	.40	.43	.49	.42	.41	0.94	0.91	1.17	1.01
33	Penmaenmawr	19.1	.39	.41	.42	.43	.38	.39	.43	.42	.42	.41	0.84	0.94	1.04	0.94
34	Groby	19.1	.37	.42	.40	.42	.38	.39	.44	.40	.41	.40	0.94	0.99	1.23	1.05
38	Hartshill	19.1	.41	.47	.46	.47	.45	.45	.50	.46	.48	.46	0.89	0.99	0.91	0.93
36	Triscombe	19.1	.41	.48	.48	.52	.49	.48	.54	.49	.50	.49	0.84	0.99	1.17	1.00
40	Spring Grove	19.1	.39	.43	.42	.42	.39	.41	.45	.41	.43	.42	0.76	0.76	0.91	0.81
Average			.40	.44	.43	.45	.41	.42	.47	.43	.44	.43	0.87	0.93	1.07	0.96

TABLE 6

Summary of skidding measurements made at Maidenhead Thicket

Size of chippings (mm)	Year of test		
	1970	1971	Mean
Mean summer sfc at 50 km/h:-			
12.7	0.61	0.52	0.57
9.5	0.64	0.64	0.64
Mean summer sfc at 80 km/h:-			
12.7	0.51	0.53	0.52
9.5	0.61	0.59	0.60

TABLE 7

Results from the Swanley By-Pass experiment

Size of chippings (mm)	Year of test								
	1970			1971			Mean		
	Traffic lane								
	Off-side	Centre	Mean	Off-side	Centre	Mean	Off-side	Centre	Mean
Sideway-force coefficient at 50 km/h:-									
6.3	0.67	0.63	0.65	0.76	0.69	0.73	0.70	0.66	0.69
9.5	0.61	0.55	0.58	0.68	0.66	0.67	0.65	0.61	0.63
Sideway-force coefficient at 80 km/h:-									
6.3	0.60	0.61	0.61	0.72	0.62	0.67	0.66	0.62	0.64
9.5	0.61	0.60	0.61	0.67	0.58	0.63	0.64	0.59	0.62
Texture depth in mm (sand-patch method):-									
6.3	2.35	2.25	2.30	1.80	1.82	1.81	2.07	2.28	2.18
9.5	3.05	3.23	3.14	1.49	1.42	1.46	2.27	2.35	2.31

TABLE 8

Results from the Stonebridge experiment

Nominal maximum size (mm)	Binder	Year		
		1970	1971	Mean
		Mean summer sfc 50		
19.1	100 pen bitumen	0.46	0.56	0.51
9.5	100 pen bitumen	0.49	0.61	0.55
19.1	100 pen rubberized bitumen	0.45	0.55	0.50
9.5	100 pen rubberized bitumen	0.49	0.62	0.56

TABLE 9

Gradings of aggregates used in the surface-dressing experiments at Littlewick Green and Cadnam

Per cent by weight passing BS sieve*	Grading A (Just within BS63)**		Grading B (Well within BS63)		Grading C (Outside BS63)	
	Target spec	As delivered	Target spec	As delivered	Target spec	As delivered
A4 LITTLEWICK GREEN (Gilfach - gritstone)						
5/8 in BS sieve (15.9 mm)	100	99	100	100	100	98
1/2 in BS sieve (12.7 mm)	85	92	90	96	85	89
3/8 in BS sieve (9.5 mm)	30	45	15	23	45	55
1/4 in BS sieve (6.3 mm)	7	2.9	5	0.8	15	3.4
Flakiness index (on ½-in nominal-size) (12.7 mm)	20-30	18	20-30	16	20-30	18
A31 CADNAM (Gore - gritstone)						
5/8 in BS sieve (15.9 mm)	100	99	100	100	100	98
1/2 in BS sieve (12.7 mm)	85	87	90	91	85	86
3/8 in BS sieve (9.5 mm)	30	26	15	23	45	40
1/4 in BS sieve (6.3 mm)	7	2.5	5	2.0	15	6.7
Flakiness index (on ½-in nominal-size) (12.7 mm)	20-30	12	20-30	16	20-30	13

* These gradings were actually carried out using imperial BS sieves which are accordingly expressed in inches.

** BS 63:1951 Part 1.

TABLE 10

Sideway-force coefficients at 50 km/h and 80 km/h and texture-depth measurements made on the experimental surface dressings at Littlewick Green and Cadnam

Aggregate grading (see Table 9)	Section No.	Mean sideway-force coefficient						Texture depth (mm)		
		sfc 50			sfc 80					
		1969	1970	1971	1969	1970	1971	1969	1970	1971
		A4 LITTLEWICK GREEN (Gilfach Gritstone)								
A	1	0.46	0.56	0.46	0.47	0.54	0.43	1.35	0.75	0.46
	4	0.47	0.55	0.46	0.47	0.53	0.38	1.50	0.75	0.43
B	2	0.45	0.55	0.46	0.45	0.54	0.45	1.75	0.95	0.49
	5	0.48	0.55	0.53	0.47	0.54	0.46	1.95	1.10	0.58
C	3	0.48	0.56	0.43	0.47	0.48	0.37	1.15	0.60	0.39
	6	0.50	0.56	0.53	0.53	0.55	0.49	1.70	0.95	0.47
		A31 CADNAM (Gore Gritstone)								
A	4	0.44	0.50	0.51	0.40	0.49	0.49	2.95	1.75	1.75
	7	0.45	0.53	0.52	0.43	0.52	0.51	3.10	1.90	1.85
B	2	0.44	0.51	0.53	0.44	0.52	0.51	2.95	1.75	1.81
	5	0.41	0.49	0.53	0.41	0.51	0.51	3.25	2.15	2.02
C	3	0.44	0.52	0.52	0.41	0.50	0.50	2.90	1.75	1.73
	6	0.44	0.53	0.53	0.41	0.52	0.51	2.95	1.70	1.67

TABLE 11

Summary of details of experiments where mixtures of aggregates have been used

Experiment	Date of laying (and reference)	Traffic intensity (cvd)	Tests	Dates of testing	Details of surfacings
Bitumen macadams in Middlesex	1947-50 (–)	Heavy (–)	sfc 50	1953	31 different sites on heavily trafficked roads where macadam surfacings had been used. Two different aggregates and a mixture of three were used.
Streatham High Road (A23)	1953 (7,8)	Heavy (–)	sfc 50	1955 to 1957	See Table 2
Derby Ring Road (Trunk Road A5111)	1953 (15)	Fairly heavy (–)	sfc 50 SRV Texture depth	1954 to 1965	19.1 mm coated chippings from 17 sources were laid in rolled asphalt. Four 50:50 mixtures of some of the chippings were laid on additional sections.
High Wycombe By-Pass (M40 Motorway)	1967 (20)	Moderate (850)	sfc 50 bfc 130 Texture depth	1967 to 1971	30 135-m sections of different types of bituminous road surfacings. Four different aggregates plus a 50:50 mixture of two of them.
Kennington Lane	1969 (19)	Very heavy (–)	SRV	1970	A wide range of different nominal 3 mm aggregates in "Shellgrip" binder, including two sections of 50:50 mixtures.
Brixton (A23)	1971 (–)	Very heavy (–)	SRV Texture depth	1971	A wide range of different nominal 3 mm aggregates in "Shellgrip" binder, including sections of 25:75, 50:50 and 75:25 mixtures of calcined bauxite with each of two other aggregates.

TABLE 12

Summary of results of the sfc measurements on the Middlesex macadams

Aggregate	Nominal maximum size (mm)	Number of sections	Age at test (years)	Ranges of mean sfc 50				Average sfc 50
				0.20-0.29	0.30-0.39	0.40-0.49	0.50-0.59	
				Number of sections in each range				
Hornfels	19.1	14	4 to 5	4	10	0	0	0.31
Slag	19.1	5	5	1	0	2	2	0.43
Mixture	12.7	12	6 to 7	1	5	6	0	0.38

TABLE 13

Results from the Streatham experiment

Section	Chippings	Nominal chipping size (mm)	Mean summer sfc 50			
			1955	1956	1957	Average
	<u>Hot rolled asphalts:-</u>					
1	Hornfels	25.4	0.38	0.35	0.40	0.38
7	Quartzite	25.4	0.52	0.51	0.52	0.52
9	Granite	25.4	0.41	0.39	0.41	0.40
15	Slag	25.4	0.39	0.40	0.39	0.39
17	Hornfels/granite (measured)	25.4	0.36	0.37	0.37	0.37
	Hornfels/granite (calculated)*	25.4	0.40	0.37	0.41	0.39
19	Hornfels/slag (measured)	25.4	0.35	0.35	0.38	0.36
	Hornfels/slag (calculated)*	25.4	0.39	0.37	0.40	0.39
	<u>Rock "non-skid" asphalts:-</u>					
2	Hornfels	25.4	0.32	0.31	0.36	0.33
10	Quartzite	25.4	0.57	0.57	0.61	0.58
8	Granite	25.4	0.39	0.40	0.43	0.41
16	Slag	25.4	0.38	0.40	0.45	0.41
18	Hornfels/granite (measured)	25.4	0.39	0.38	0.42	0.40
	Hornfels/granite (calculated)*	25.4	0.36	0.36	0.41	0.37
20	Hornfels/slag (measured)	25.4	0.42	0.41	0.44	0.42
	Hornfels/slag (calculated)*	25.4	0.35	0.36	0.41	0.37

* Mean of the respective sections with the different chippings used on their own.

TABLE 14

Results from the Derby Ring Road experiment

Section	Chippings	Mean summer sfc 50				Skid-resistance value (1965)	Texture depth (1965) (mm)
		1961	1962	1964	Average		
2	Corby blast-furnace slag	0.51	0.47	0.43	0.47	54	1.02
13	Furnace granite	0.45	0.39	0.39	0.41	48	0.76
5	Penlee hornfels	0.37	0.32	0.35	0.35	43	0.84
7	Cawdor limestone	0.38	0.32	0.37	0.36	50	0.41
14	Furnace/Penlee (measured)	0.42	0.36	0.36	0.38	44	0.79
	Furnace/Penless (calculated)*	0.41	0.36	0.37	0.38	46	0.80
19	Corby/Penlee (measured)	0.41	0.36	0.38	0.38	51	0.53
	Corby/Penlee (calculated)*	0.44	0.40	0.39	0.41	49	0.94
20	Furnace/Cawdor (measured)	0.42	0.38	0.36	0.39	51	0.61
	Furnace/Cawdor (calculated)*	0.42	0.36	0.38	0.39	49	0.59
15	Corby/Cawdor (measured)	0.42	0.37	0.40	0.40	49	0.43
	Corby/Cawdor (calculated)*	0.45	0.40	0.40	0.42	52	0.71

* Mean of the respective sections with the different chippings used on their own.

TABLE 15

Results from the High Wycombe By-Pass experiment

Surfacing	Aggregate	Year of test					Mean
		1967	1968	1969	1970	1971	
Sideway-force coefficient at 50 km/h:-							
Rolled asphalt with 12.7 mm chippings	Criggion	0.60	0.56	0.56	0.54	0.55	0.56
	RASC bauxite	0.75	0.76	0.79	0.77	0.83	0.78
	Criggion/bauxite (measured)	0.65	0.66	0.66	0.66	0.68	0.66
	Criggion/bauxite (calculated)*	0.68	0.66	0.68	0.66	0.69	0.67
Surface dressing with 12.7 mm chippings	Criggion	0.55	0.48	0.52	0.52	0.51	0.52
	RASC bauxite	0.75	0.72	0.76	0.76	0.78	0.75
	Criggion/bauxite (measured)	0.61	0.59	0.61	0.62	0.60	0.61
	Criggion/bauxite (calculated)*	0.65	0.60	0.64	0.64	0.65	0.64
Braking-force coefficient at 130 km/h:-							
Rolled asphalt with 12.7 mm chippings	Criggion	0.49	0.50	0.51	0.53	0.48	0.50
	RASC bauxite	0.62	0.56	0.58	0.68	0.53	0.59
	Criggion/bauxite (measured)	0.54	0.54	0.54	0.56	0.47	0.53
	Criggion/bauxite (calculated)*	0.55	0.53	0.55	0.61	0.51	0.55
Surface dressing with 12.7 mm chippings	Criggion	0.39	0.42	0.33	0.32	0.29	0.35
	RASC bauxite	0.69	0.60	0.63	0.61	0.62	0.63
	Criggion/bauxite (measured)	0.46	0.44	0.46	0.38	0.38	0.42
	Criggion/bauxite (calculated)*	0.54	0.51	0.48	0.47	0.46	0.49
Texture depth in mm (sandpatch method):-							
Rolled asphalt with 12.7 mm chippings	Criggion	1.81	1.92	1.78	1.97	2.04	1.90
	RASC bauxite	1.76	1.92	1.78	1.97	2.00	1.89
	Criggion/bauxite (measured)	1.46	1.53	1.41	1.65	1.74	1.56
	Criggion/bauxite (calculated)*	1.79	1.92	1.78	1.97	2.02	1.90
Surface dressing with 12.7 mm chippings	Criggion	1.62	1.26	1.21	1.10	0.98	1.23
	RASC bauxite	1.92	1.83	1.55	1.66	1.57	1.71
	Criggion/bauxite (measured)	1.62	1.36	1.12	1.28	1.20	1.32
	Criggion/bauxite (calculated)*	1.77	1.55	1.38	1.38	1.28	1.47

* Calculated values are the respective means for the two aggregates when used alone.

TABLE 16

Results from the Kennington Lane experiment

Aggregate	Skid-resistance values after 49 days		Skid-resistance values after 140 days	
	Wheel track			
	Left-hand	Right-hand	Left-hand	Right-hand
Calcined bauxite (RASC)	79	74	78	75
Synopal	47	49	44	52
Craig-yr-Hesg	65	70	66	70
Bauxite/Synopal (measured)	69	74	69	72
Bauxite/Synopal (calculated)*	63	62	61	64
Bauxite/Craig-yr-Hesg (measured)	77	75	78	75
Bauxite/Craig-yr-Hesg (calculated)*	72	72	72	73

* Mean of respective values for the separate sections of the aggregates

TABLE 17

Results from the Brixton 1971 experiment

Proportions of the two aggregates	SRV measurement (mean of two wheel tracks)						TEXTURE DEPTH measurements (mean of two wheel tracks) (mm)					
	August 1971		March 1972		May 1972		August 1971		March 1972		May 1972	
	A*	C*	A	C	A	C	A	C	A	C	A	C
Haughmond gritstone: RASC calcined bauxite:-												
100 : 0	72	-	65	-	60	-	1.24	-	-	-	0.74	-
75 : 25	76	76	70	69	65	64	1.06	1.24	-	-	0.69	0.76
50 : 50	80	80	77	73	68	67	1.18	1.23	-	-	0.81	0.77
25 : 75	81	83	77	76	72	71	1.20	1.23	-	-	0.76	0.79
0 : 100	87	-	80	-	74	-	1.22	-	-	-	0.80	-
Criggion basalt: RASC calcined bauxite:-												
100 : 0	64	-	57	-	50	-	1.07	-	-	-	0.62	-
75 : 25	76	70	65	63	58	56	1.29	1.11	-	-	0.83	0.67
50 : 50	76	76	71	69	65	62	1.31	1.15	-	-	0.71	0.71
25 : 75	80	81	77	74	71	68	1.16	1.18	-	-	0.88	0.76
0 : 100	87	-	80	-	74	-	1.22	-	-	-	0.80	-

* A Actual results

* C Calculated results (proportioned from results for the sections of unmixed aggregates).

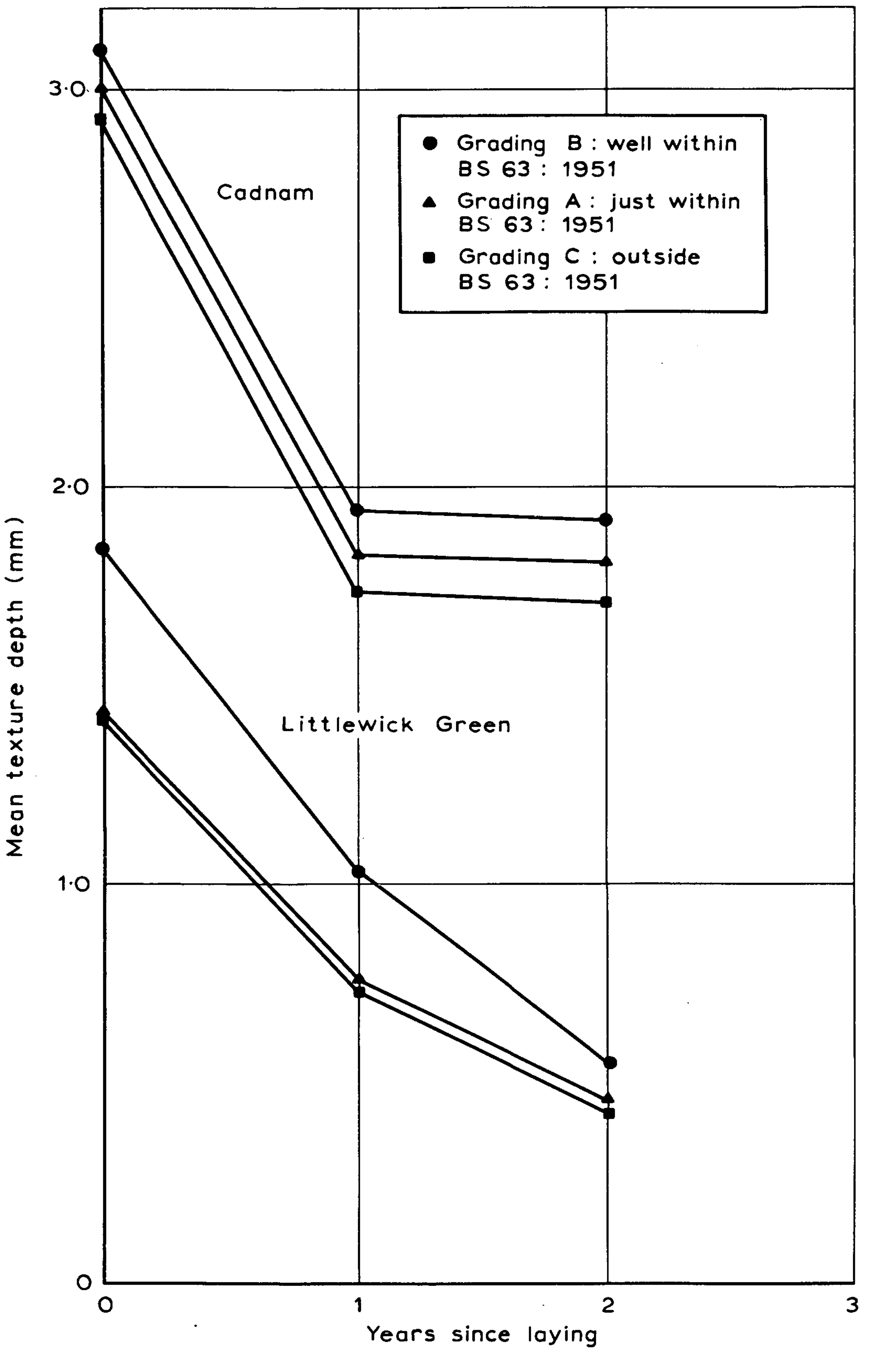

Fig. 1. CHANGES IN THE TEXTURE DEPTH OF EXPERIMENTAL SURFACE DRESSINGS AT LITTLEWICK GREEN AND CADNAM

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ABSTRACT

The effect of aggregate on the skidding resistance of bituminous surfacings: factors other than resistance to polishing: J R HOSKING MSc, ACSM, AIMM: Department of the Environment, TRRL Report LR 553: Crowthorne, 1973 (Transport and Road Research Laboratory). Resistance to polishing is the most important single characteristic of an aggregate in determining the resistance to skidding of a bituminous road surfacing.

This Report describes a study that has been made of other characteristics of aggregates that have been thought to influence resistance to skidding. The more important findings were:-

1. On average, quartzites and blast-furnace slags give a resistance to skidding equivalent to that given by other roadstones which are three units higher in polished-stone value. None of the other roadstone types studied (Basalts, Granites, Porphyries and Gritstones) showed an important departure from the average.

2. Provided that adequate road surface texture is maintained, reducing the nominal maximum size of an aggregate raises the resistance to skidding of a surfacing made with it.

3. There is some indication that the use of more nearly single-sized chippings in surface dressings gives a better surface texture.

4. Inadequate durability in an aggregate can affect the resistance to skidding of a road made with it.

5. Mixtures of two or more roadstones in a road surfacing yields a resistance to skidding and a depth of surface texture that are approximately equal to the means of those given by the constituents on their own.

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