# ANTI-SKID ROAD SURFACING: A CONTRACTORS VIEW ON A RESIN/BAUXITE SYSTEM

P. B. Poulson and J. F. Wood, Prismo Universal Limited

The use of a bitumen-extended epoxy resin/calcined bauxite anti-skid surfacing has been demonstrated to be cost effective in reducing wet road skidding accidents. Over 1 million square metres of this type of surfacing have now been laid throughout the world. The excellent performance of the treatment results from the use of calcined bauxite aggregate, having high resistance to polishing and abrasion, bonded firmly to the road surface with a thermosetting resin, which prevents rolling or embedment. From the Contractor's point of view the material needs to be laid under carefully controlled conditions and this is achieved by the use of purpose built machinery designed to give precise proportioning and distribution of the components. The process has the advantage of fast application and does not require modification to existing markings or street furniture. With careful planning the contract can be carried out with minimum disruption to traffic flow. Different techniques are needed to achieve optimum adhesion to varying substrates which can be asphalt, concrete or steel. The paper illustrates the different types of traffic situation which can be successfully treated, including junctions, pedestrian crossings, bridges, tunnels, and rumble areas.

This paper is concerned with a particular anti-skid surfacing process, employing a calcined bauxite aggregate held in a bitumen extended epoxy resin binder. The most widely-used proprietary systems are Shellgrip and Spraygrip.

The process was developed as a result of a growing awareness of the poor skid resistance of road surfaces due to the polishing action of an increasing volume of traffic.

Studies over a number of years have clearly established the effect of traffic on the skid resistance of road surfaces. An extensive investigation by the British Road Research Laboratory (1) showed that the Sideways Force Coefficient (SFC), which is a direct measure of skid resistance, can be directly related to traffic volume and the polished stone value of the aggregate used (Fig.1). Their studies led to the introduction of recommended minimum SFC values for particular categories of site (2) (Table 1).

The resin/bauxite surfacing system was designed to provide an efficient anti-skid treatment for the most severe sites. The process has since been used on a wider variety of locations, including bends, bridge decks, toll booth approaches, tunnels and aircraft runways, where skidding problems have been met.

## Process Development

Development work on special surface dressing systems for sites where exceptional durability and performance are required began almost twenty years ago. Early problems with binder formulations, application techniques, and unsuitable aggregates were not resolved until the early 1960's when a series of reports (3) on TRRL trials were published.

Conventional treatments were not considered suitable for these difficult areas: burning-off the existing asphalt and replacing it with new material incorporating surface chippings was slow and costly, and the skid resistance of the new surface soon deteriorated. Mechanical roughening of the road surface produced very short term improvements in skid resistance, and normal surface dressing was not technically acceptable due to the severe traffic conditions.

The TRRL work proved that epoxy resin binders, used in conjunction with calcined bauxite aggregate, would provide a durable anti-skid road surface. Use of this type of surfacing was recommended at "decision areas", particularly traffic light approaches and junctions in urban areas with high traffic densities. These areas had been identified by accident records as requiring special treatment: the continuous turning and braking of vehicles had inevitably resulted in a highly polished surface.

The demand for the new surfacing system was therefore obvious and a number of early resin/bauxite contracts, employing hand application techniques, proved encouraging. More rapid progress was initiated by the Greater London Council (GLC) when studies indicated that 70% of the 55,000 personal injury accidents reported annually in London occurred at or within 20 metres of road junctions. Skid resistance at many junctions was found to be low despite careful choice of the aggregates used for surface application to hot rolled asphalt mixes.

Small scale trials were carried out in 1966 to examine the merits of a number of commercially available resins systems, and in particular to establish the following essential characteristics.

1. The binder to be suitable for spray application, with components mixed in approximately equal proportions.

2. A fast cure time to prevent undue traffic disruption during surfacing operations, but allowing sufficient time for application.

3. Adequate adhesion between the binder and the existing road surface under severe traffic conditions.

4. A combination of strength and flexibility to prevent displacement or embedment of the aggregate whilst avoiding binder failure due to brittleness.

The trials identified a resin system able to meet these criteria and the GLC then initiated, in 1967, full scale trials, using spray application techniques. Five experimental sites were selected on the basis of the number of wet road accidents, expressed as a percentage of the total accidents. The number of accidents involving skidding in the 12 months prior to and after treatment were recorded, and are summarised in Table 2.

These encouraging statistics, and evidence of a satisfactory cost/benefit relationship resulted in a significantly increased programme of full scale experiments in 1968. The success of this early work was recorded in detail (4, 5) and to date over 700 London sites have been treated with a resin/bauxite process. A report issued by the Greater London Council in 1970 on the economic considerations influencing the use of this process showed that if the treatment lasted two years and one accident per year was prevented, then the cost would be justified. In fact there is evidence that many sites are effective in reducing accidents for at least 7 years.

Use of resin/bauxite materials has developed to the extent that over 600,000m$^2$ of carriageway area is surfaced annually in Great Britain including junctions and roundabout approaches on high speed roads.

A TRRL report (7) on a 1968 trial on the A1 Trunk Road in Bedfordshire indicated the potential for resin/bauxite treatments on motorways and trunk roads. Motorways are designed in such a way as to minimise hazardous conditions, but interchanges, toll booths, and slip roads inevitably produce conditions where skidding may occur. Trunk roads, due to lower design standards or earlier construction, may contain a higher number of hazard sites demanding special anti-skid treatment.

## Materials

The successful anti-skid surfacing process comprises a highly polish-resistant aggregate, calcined bauxite, bound firmly in a rigid thermo-setting bitumen extended epoxy resin binder: both materials are considerably more expensive than conventional road surfacing aggregates and binders, but the premium performance which results more than justifies the extra cost.

### Aggregates

The choice of these materials stems from the work, previously mentioned, carried out by the Road Research Laboratory. Their road tests included a range of natural stones of good polishing resistance together with selected artificial abrasives, such as calcined bauxite, corundum and silicon carbide. The results of these tests showed that calcined bauxite gave the highest resistance to skidding and that this was maintained for far longer periods than the best natural stones, which had only a limited period of effectiveness.

The differences in road performance between various aggregates have been found to correlate well with laboratory measured parameters such as polished stone value and aggregate abrasion value. On the basis of this work, TRRL have recommended that aggregates used in this type of surfacing should have a minimum polished stone value of 70 and a maximum aggregate abrasion value of 5 (8).

Bauxites from a number of different sources have been investigated and the most effective material found so far is that from Guyana (9). Other bauxites from China, Australia, Ghana and Northern Ireland gave satisfactory performance in road tests though were not quite as effective as the Guyanan material.

No natural stones have been found which give a performance matching that of calcined bauxite, particularly in terms of length of life. Several grit-stones have the necessary open textured granular surface and give high polished stone values, but their abrasion resistance is low presumably because of a weak cementing phase. Those natural stones which have good abrasion resistance, such as granites, generally do not have good polishing resistance.

For successful use in anti-skid surfacing the aggregate must be largely single-size in order to give the smooth overall texture to the surfacing which ensures maximum contact area with the tyres of traffic. The size generally used is 2 - 3 mm as this has been found sufficient to give the necessary level of texture depth. The initial value for the treatment is about 1.5 mm but this reduces to about 1.0 mm as the more loosely bound particles are removed by traffic. The reduction in texture depth thereafter is very slow because of the high resistance to abrasion of the calcined bauxite.

A full specification for a widely used grade of calcined bauxite is given in Table 3.

### Binder

In order to gain the maximum benefit from the high performance of the calcined bauxite it is necessary to use a thermo-setting resin binder rather than conventional surface dressing binders which are thermoplastic. Only a thermo-setting resin would hold the aggregate firmly in place and prevent rolling. Various thermo-setting systems have been tried such as epoxy, polyester, polyurethane but the epoxy resin systems are preferred on grounds of proven performance.

A wide range of epoxy resin systems can be formulated using a variety of curing agents. Those systems which have been used widely in surfacing are extended with bitumen which reduces the cost and gives a high level of flexibility to the cured binder. The formulation has to be very finely balanced in order to give optimum performance. This is derived by the use of phenolic accelerators and organic acids which apart from their usual functions, increase the compatibility of the bituminous extender with the epoxy resin.

The performance of the binder is generally assessed by measuring the tensile properties to failure. Early road tests with varying formulations suggested that a minimum tensile strength of 7MN/m$^2$ was necessary in order to retain the aggregate securely. Further laboratory tests indicated that lower tensile strengths are adequate to hold the aggregate against slow shear forces but the position in the case of impact stresses is far harder to define and as a result it has been considered prudent to retain a minimum tensile requirement of 7MN/m$^2$ for the binder. This has limited the introduction of more highly extended epoxy resin binders.

The mechanical properties of bitumen-extended epoxy resin binders change significantly with temperature, as for all epoxy systems cured at ambient conditions. As the temperature increases so the tensile strength falls off rapidly, as illustrated in Figure 2. This is a further reason why more highly extended systems can not be adopted for use until adequately proved by road tests.

## Application Equipment

The aim of the process is to produce a monolayer of 2 – 3 mm calcined bauxite embedded in the epoxy resin binder. If insufficient binder is applied, the aggregate will only be loosely held and the surfacing will have a limited life. On the other hand too much binder will reduce the texture depth of the surfacing and may even cover the aggregate, thereby reducing the skid resistance. It is therefore essential that both materials should be distributed evenly and accurately. Undoubtedly much of the successful and trouble-free operation of the system stems from the attention given to the careful design of suitable applicators, particularly for the binder.

The epoxy binder, being thermo-setting, has two components and the chemical reaction, which leads to setting, begins when these components are mixed. The applicator machine must therefore blend the two components in the correct proportions, mix them thoroughly and then spray them evenly over the road. Proportioning is particularly critical in order to get optimum performance and a variety of mechanical devices have been used to ensure this.

In the earliest machine the two components were pumped on equal pressure circuits, the temperatures of the materials being so adjusted as to give equal viscosities and therefore equal rates of flow. Later machines used metering pumps to regulate the flow of the two ingredients and this type of equipment has been further refined by the use of automatic balancing devices. Other types of machine have also been developed using positive displacement reciprocating piston pumps with surge tanks to smooth the flow.

After proportioning and mixing, the binder is sprayed onto the road and it is essential that it is metered accurately and that the transverse distribution of the material is uniform. Conventional spray bars have been used but recent developments include the use of a multiplicity of independent spray jets separately fed from the mixer.

The binder components are heated for application to a temperature of about 50°C. Hot application gives several benefits such as better mixing of the components, improved flow-out on the road and an initial boost to the curing process. The temperature of the binder rapidly falls to that of the road after application and this helps to minimise run-off in the case of roads with any appreciable gradient. In the case of steep slopes or where a heavier coverage than usual is required a special thixotropic grade of binder is used.

The minimum rate of spread of binder is $1.35 kg/m^2$ when used on smooth road surfaces. A higher binder coverage is needed where there is any appreciable degree of texture on the road. Generally the required coverage rate can be gauged by an experienced operator on visual inspection but, where a more precise method is required, values for the binder coverage necessary for different texture depths have been found by experience and the relationship is shown in Figure 3.

Apart from surface texture the required coverage of resin will also depend upon the porosity of the surface. This is particularly important in the case of newly laid asphalt surfaces which are frequently very porous until compacted by the action of traffic.

On extremely rugous surfaces the binder will tend to drain off the peaks of the chippings leading to poor retention of the bauxite which will soon become detached at these points. Although the effectiveness of the anti-skid treatment may only be marginally reduced when the asphalt chippings show through, the visual appearance may not be acceptable. In such cases a two-fold application of binder, the first coat being allowed to set partly before the second is applied, will minimise the problem. The calcined bauxite aggregate is applied shortly after the binder is sprayed. Sufficient time is allowed for the binder to flow-out to an even film but care must be taken that too great a time should not elapse, otherwise gelation of the binder will begin and the bedding of the aggregate will be impaired.

Unlike conventional surface dressings the aggregate is applied in considerable excess – about 50% – and after curing this excess is removed by vacuum sweeping. This method is used in order to ensure that the maximum coverage of aggregate results. The aggregate is not rolled after application since this might cause some embedment of the bauxite in the underlying surface, which would reduce the effectiveness of the treatment, and also because rolling would tend to drag the binder over the surface and thereby reduce the skid resistance.

During the early development of the process, special gritting machines were used having low overall weight and low pressure tyres so as to minimise disturbance of the calcined bauxite aggregate as the vehicle moved over the newly laid treatment. Subsequent experience has shown that conventional gritting lorries can be used providing they are adjusted to handle 2 – 3 mm aggregates. The excess of aggregate tends to minimise disturbance of the final layer next to the road surface.

## Quality Control

Experience has shown that the performance of the system is dependent upon the properties of the resin binder which in turn rely on the material being proportioned and mixed correctly. In order to provide assurance on these aspects a continual check is maintained on the relative volumes of the two components consumed and samples of cured resin are regularly taken and tested in the laboratory for tensile properties. These tests provide a second check on the quality of the resin components, which will have been pre-tested in manufacture, and also show whether there is any regression in the proportioning performance of the machine.

## Surface Preparation and Adhesion

The majority of the work carried out has been on hot rolled asphalt or asphaltic concrete and a very high success rate has been obtained. With asphaltic surfaces, experience has shown that provided the road is dry it is usually sufficient to sweep off loose dust and debris. Surfaces contaminated with oil will require additional preparatory treatment in the form of a weak detergent wash, accompanied by vigorous brushing, followed by hosing down with clean water.

The tolerance of the system on asphalt is probably derived to a large extent from the thermoplastic character of the road surface which enables the bond to be self-healing. Thus the action of traffic can "iron" the surface treatment into contact with the road surface, particularly in warm weather.

Adhesion of the binder to concrete is much more critical and has given rise to considerable problems in practice. Laboratory tests have shown that, in general, the bond of epoxy resins to concrete does not resist peeling forces even if the concrete is sound and free from laitance. The bond is further harmed by moisture and dust both of which are frequently present on concrete surfacings.

Moisture is particularly serious since it is not always evident on visual inspection. After rain a concrete surface can appear to dry out rapidly, particularly in light wind, but considerable moisture will be left deep in the pores. It is particularly important therefore that adequate time is allowed for the surface to dry out thoroughly and this could take many hours depending upon the ambient conditions.

In order to achieve successful application on concrete it is essential that the surface is first well prepared. The most convenient method is by exposing a fresh surface on the concrete. Grinding has been used for this purpose but is not particularly satisfactory since the full depth of the texture will not be treated. Grit-blasting is the preferred method since it naturally gives an even coverage of the surface.

The most effective method of improving the bond to concrete is by etching with hydrochloric acid but this is not usually a practical proposition since, apart from the hazards of using acid on public roads, it leaves the surface completely saturated with water which would take a considerable period to dry out before application could be made.

The bond strengths of the epoxy binder to both asphalt and concrete are illustrated in Table 4.

Apart from asphalt and concrete the resin/bauxite treatment has also been applied in a number of cases on steel, for example on fly-overs and temporary bridges. Again careful preparation is required to ensure success. The steel surface must be thoroughly grit-blasted to an even grey colour and the binder is applied shortly afterwards before 'rusting' can begin. In such treatments it is customary to make two successive applications of binder, the first being merely a skim coat. In this way the possibility of pinholes occurring is greatly reduced. Pinholes are undesirable since they provide a route through which water can penetrate and initiate rusting and detachment.

## Operational Procedures

In cities and other locations where high traffic densities are experienced it is normal for anti-skid surfacing to be carried out at night in order to minimise interruptions to traffic flow. The normal sequence of events is as follows:

### Site inspection/Contract Programming

The site will be inspected at Tender stage to establish the condition of the road surface, the volume and type of traffic and any particular specification or contract requirements. This inspection will determine the preparatory works required, the rate of spread of binder and the likely time scale involved in completing the resurfacing. Of particular importance is the rugosity of the surface, which will have a direct bearing on the amount of resin required, this being the single most expensive cost item.

Essentially the road surface must be hard, sound and impervious. Trench openings and weak areas in the carriageway must be satisfactorily reinstated in advance of the anti-skid treatment. Areas of reinstatement must be in hard, dense material; fine cold asphalt or bitumen macadam materials are generally unsuitable.

In particularly difficult locations a meeting with the Police on site may be necessary. In this case suitable dates, times and operational procedures will be discussed including the need for traffic control, diversions or road closures. Occasionally public transport companies will be involved if, for example, bus routes are affected by the works.

### Site Operations

Contract planning in advance of the arrival of the surfacing crew on site should enable the works to be executed with the minimum disruption to traffic. Off-peak operations, normally between 2000 and 0600 hours, plus the experience and expertise of the contractor's crew will enable even the most difficult sites to be quickly and efficiently completed.

The first essential is always to erect adequate temporary road signs, and to cone-off the areas to be treated, as protection for the crew, equipment and works.

The two component binder is heated in the applicator whilst manhole covers, surface water drainage gullies and road markings are protected with adhesive tape and bituminous paper. The sequence of spraying and gritting is planned, and provision is made for hand application to any small areas inaccessible to the applicator unit.

After the whole area has been thoroughly swept the binder is sprayed onto the road surface; wherever possible more than one spray bar width is applied at a time in order to reduce the number of joints and overlaps in the finished surface. When the binder has cooled to road temperature the calcined bauxite is applied to excess in order to ensure complete coverage.

Following the application of the calcined bauxite the protective covering to street furniture is removed and the new surface remains closed to traffic during the curing period. The operations on site may cover a period of between four and eight hours depending on the area of treatment involved, the complexity of the road and traffic situation, and the ambient temperature. This latter consideration is important in assessing the time required for the binder to set sufficiently for traffic to be allowed to use the new surface. The variation of cure time with temperature is shown in Figure 4. In practice application is not made at road temperatures less than 5°C, since apart from the prolonged curing time there is the possibility of frost on the road impairing the adhesion.

When the binder is sufficiently cured the surplus chippings are removed using a suitably modified road vacuum sweeper and the road is re-opened to traffic. There will inevitably be some delay because of the curing time, and wherever possible, work is carried out on another site nearby, during the period between the bauxite distribution and the removal of surplus chippings on the first site. At times when the binder cure time is delayed due to low temperatures, and no other work is available, it is apparent that restricted output will result, with the obvious effect on costs. In the United Kingdom a crew involved in this type of process consists of six or seven men, but sites presenting difficult traffic control problems may necessitate additional labour. Taking a simple example of one pedestrian crossing, the normal procedure is to surface half of each approach in one shift, and the other half on a second visit as shown in Figure 5.

Road junctions present additional operational and traffic control problems; where a high proportion of mid-crossing collisions occur, the anti-skid treatment may be extended to include the centre of the junction. Figure 6 indicates a typical cross-road situation with right turns permitted in each case. It is apparent that a number of visits to the site will be necessary to complete re-surfacing to the junction centre area while maintaining traffic flow.

Where road closures or traffic diversions can be arranged work can be more efficiently completed and considerable cost savings affected. However high traffic volumes on city roads for almost 24 hours a day, together with the special problems created by public transport and commercial vehicles, usually prevent this luxury. The contractor must therefore be able to operate with the maximum efficiency under the most difficult traffic conditions.

## Other Uses for the Resin/Bauxite Process

### Bridges

A number of successful applications have been made on bridge decks, where a resin/bauxite treatment can offer distinct advantages over conventional materials in terms of low weight loading, speed of application, and durability.

The largest contract completed to date has been the whole of the mastic asphalt surface of the Severn Bridge, a total of 50,000m$^2$. The bridge was opened to traffic in 1966, and the increasing volume of traffic prompted trials in 1970 to establish the most effective skid resistant surfacing process able to meet the particular requirements of the Severn Bridge Engineers. A resin/bauxite process was chosen and contracts were let in 1971 for the slow lane resurfacing, and in 1972 for the outside lanes. On each occasion anti-skid treatment was also carried out to toll booth approaches. The excellent texture depth and abrasion resistance of the calcined bauxite aggregate have provided a safe and economic surface on this bridge which carries 10 million vehicles annually over the M4 Motorway link between England and Wales.

### Airports

At Belfast Airport a bauxite surface was used on the secondary runway to allow R.A.F. Phantom jets to land safely at high speed. The treatment allowed normal air traffic operations to be diverted to the subsidiary runway while the main runway was closed for reconstruction.

The centre 500 metres of the runway, where braking occurs, was treated to avoid skidding and aquaplaning on the flat and often wet surface.

Another airfield treatment has been in providing traction for aircraft tugs. Faced with ever bigger and heavier aircraft to move, tugs often find the task difficult when the airfield pavement is wet. The texture depth provided by calcined bauxite aggregates produces an effective non slip surface to resolve this problem.

### Rumble Areas

An interesting additional use of bitumen extended epoxy resin binder has been in "rumble areas", which are used to persuade drivers to reduce speed at potentially dangerous locations (10). After a period of continuous high speed motorway travel a driver may easily under-estimate his speed when approaching a roundabout, bend or junction.

The rumble area consists of 13 - 19 mm stone held in the resin binder, and the effect is to produce a high noise level and a noticeable change in road surface texture. A number of areas are laid on the approach and are designed to promote a "rumble" sensation for approximately half a second duration every second.

On a typical site the percentage of vehicles travelling at or above 64 km/h was 21% before the rumble area was laid and 7% after treatment. The initial results have been sufficiently encouraging for extended trials to be carried out on a wider range of sites.

### Tunnels

Many successful resin/bauxite treatments have been carried out in tunnels, where an accident can cause additional hazards and considerable congestion because of the confined space.

In 1969 5,000 square metres of carriageway at the Blackwall Tunnel under the River Thames was surfaced with resin/bauxite materials. Similar work has since been completed at other locations including the Mersey and Wallasey Tunnels, with equal success.

### Winter Tyres

The resin/bauxite skid resistant process has been applied extensively in many European countries, U.S.A. and Japan, but in areas where studded snow tyres are used damage to the surface is inevitable. The degree of damage is normally directly related to the number of vehicles using studded tyres, but variable factors associated with weather conditions can also influence the situation. For example, on a mountain bend the surfacing may be protected by snow cover during at least part of the winter period.

The damage to resin/bauxite surfaces is caused by the crushing and levering action of the metal projections. Calcined bauxite has unique qualities of resistance to abrasion, but a relatively poor crushing strength; the peaks of the bauxite aggregate are ground down by the studs and the texture depth of the surfacing is consequently reduced.

These problems have not prevented a number of successful treatments being completed, notably on the Grand St. Bernard Pass in Switzerland, where accidents on a bridge and mountain bends have been drastically reduced.

Although a resin/bauxite treatment will have reduced life in areas where studded tyres are widely used and will therefore need regular renewal, it can nevertheless prove cost-effective in reducing accidents in hazardous situations.

## Conclusions

Anti-skid surfacing based on the use of calcined bauxite held in a bitumen extended epoxy resin is now well accepted as having proven road performance and an excellent cost/benefit relationship. The many advantages of the system allow it to make a significant contribution to accident reductions, particularly at high traffic density 'decision areas'. There may also be justification for a wider use of the process to include key sections of motorway and trunk roads in order to counteract an increase in skidding accidents.

The success of the process stems in part from the use of precision machinery to ensure that the components are laid in the correct proportions. Careful planning and the skill of the team of workers ensure that the treatment is applied with the minimum disruption to traffic.

The resin/bauxite system can be applied to most road surfacing materials, although specifications may vary to provide for suitable preparatory works and adjustments to binder usage rates.

This paper has deliberately avoided reference to driver behaviour, road layout and signing and other contributory factors in accident statistics. These considerations, together with improved road surfaces and tyre design will probably be discussed in more detail in other papers to this Conference.

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Table 1. Minimum* values of skidding resistance for different sites as proposed by TRRL.

| SITE | DEFINITION | SFC (at 50 km/h) Risk Rating | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| A1 (v difficult) | (i) Approaches to traffic signals on roads with a speed limit greater than 40 mile/h (64 km/h)<br>(ii) Approaches to traffic signals, pedestrian crossings and similar hazards on main urban roads | | | | | | 0.55 | 0.60 | 0.65 | 0.70 | 0.75 |
| A2 (difficult) | (i) Approaches to major junctions on roads carrying more than 250 commercial vehicles per lane per day<br>(ii) Roundabouts and their approaches<br>(iii) Bends with radius less than 150 m on roads with a speed limit greater than 40 mile/h (64 km/h)<br>(iv) Gradients of 5% or steeper, longer than 100 m | | | | 0.45 | 0.50 | 0.55 | 0.60 | 0.65 | | |
| B (average) | Generally straight sections of and large radius curves on:<br>(i) Motorways<br>(ii) Trunk and principal roads<br>(iii) Other roads carrying more than 250 commercial vehicles pr lane per day | 0.30 | 0.35 | 0.40 | 0.45 | 0.50 | 0.55 | | | | |
| C (easy) | (i) Generally straight sections of lightly trafficked roads<br>(ii) Other roads where wet accidents are unlikely to be problem | 0.30 | 0.35 | 0.40 | 0.45 | | | | | | |

* Minimum in this context does not refer to the lowest individual measurement taken but is defined in terms of the 'mean Summer SFC' (average of 3 readings taken during the months May - September) in a year of normal weather conditions.

Table 2. Accident reductions on 5 initial sites in London area.

| | Before | After | % change |
|---|---|---|---|
| total accidents | 73 | 35 | - 52 |
| total casualties | 88 | 42 | - 51 |
| number of wet road accidents | 24 | 8 | - 67 |
| number of dry road accidents | 49 | 27 | - 45 |
| number of skidding accidents | 18 | 4 | - 78 |

Table 3. Typical Specification for Calcined Bauxite - RASC grade.

| Characteristic | | Specified | Typical |
|---|---|---|---|
| Grading: | Passing 2.80 mm, B.S. sieve | 100% | 100% |
| | Passing 1.70 mm, B.S. sieve | 40% max. | 30% |
| | Passing 1.18 mm, B.S. sieve | 5% max. | 1% |
| | Passing 600 micron, B.S. sieve | 2% max. | Nil |
| Chemical Analysis | $Al_2O_3$ | 86% min. | 88% |
| | $Fe_2O_3$ | 2.5% max. | 2% |
| | $SiO_2$ | 7.5% max. | 7% |
| | $TiO_2$ | 4.0% max. | 3% |
| Calcining Temperature ($^{o}C$) | | 1500 min. | 1600 |
| Polished Stone Value | | 70 min. | 75 |
| Aggregate Abrasion Value | | 10 max. | 4 |

Table 4. Bond strength of Spraygrip to various road surfaces.

| Surface | Typical Bond strengths ($MN/mm^2$) |
|---|---|
| Asphalt (dry) | 0.8 - 1.0 |
| Asphalt (damp) | 0 - 0.2 |
| Concrete (dry) | 1.0 - 1.5 |
| Concrete (grit-blasted) | 1.5 - 2.0 |
| Concrete (damp) | 0 - 0.3 |
| Concrete (acid-etched) | 2.0 - 2.5 |

Figure 1. Effect of traffic on skidding resistance of a typical motorway-standard surfacing (rolled asphalt with precoated chippings of PSV 58-60).

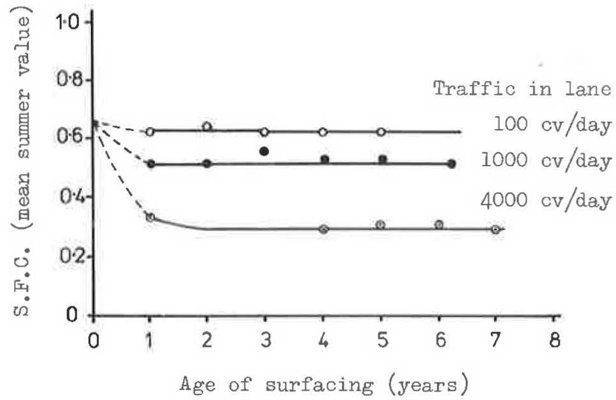


Figure 3. Required binder coverage rate for surfaces of varying texture depth.

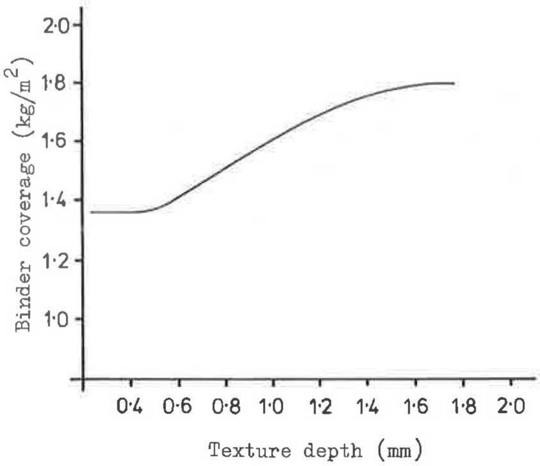


Figure 2. Effect of temperature on the tensile strength of bitumen-extended epoxy resin binders.

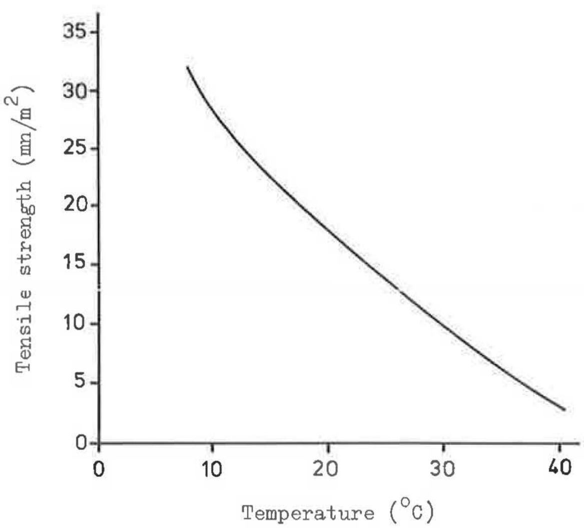


Figure 4. Spraygrip - variation of curing time with temperature.

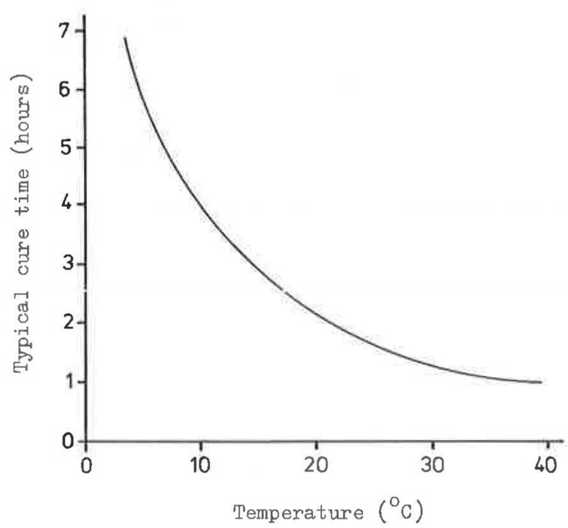

Figure 5. Anti-skid treatment of a typical pedestrian crossing.

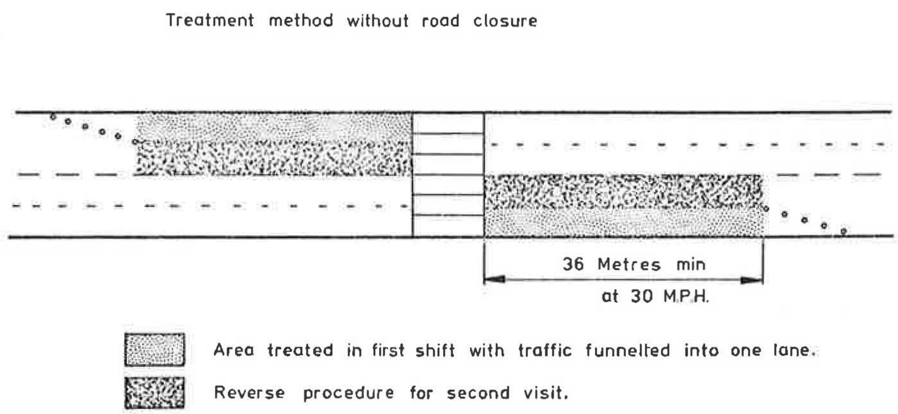


Figure 6. Anti-skid treatment of a typical cross-roads (right turns permitted).