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HIGHWAYS AND TRANSPORTATION

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Golden Jubilee Anniversary issue

The Institution of Highways and Transportation congratulates the Road Surface Dressing Association and its Members on its Golden Jubilee. The following pages illustrate the work of the RSDA during the last 50 years and show the advancements and achievements that have been made in this sector of the industry.
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Surface dressing – how it all came about

by Peter Distin, Chairman, Road Surface Dressing Association

Peter Distin is Managing Director of Johnston Brothers Ltd (Contractors) and Chairman of the Road Surface Dressing Association.

His career began in Local Government and after National Service he joined Wimpey Asphalt in 1953. He moved to Johnston Brothers (Contractors) in 1963 and was appointed to the Board in early 1978 and became Managing Director later that year. Over the years he has represented the surface dressing industry on a number of working parties and BSI Committees. He served on the RSDA’s Technical Committee from 1968 until 1981 and was Chairman of that committee for three years.

He joined the main Management Committee of the RSDA in 1977 and was elected to serve as Chairman of the Association in the years 1983-1984. Mr Distin has the honour of holding the office of Chairman of the RSDA in its Jubilee Year.

When cars first started to use roads in Great Britain, as well as heralding a new era in personal transport, it was soon apparent that they would bring environmental problems. The environmental problems caused by horses were at that time accepted as a fact of life, and most city streets had a very different aroma to that of petrol and diesel fumes from which we suffer today! The new problem was dust, and as many rural roads at that time had waterbound macadam surfaces, the passage of cars caused serious problems.

Engineers and “surveyors of roads” soon found that pouring crude tar from gas works and applying chippings onto the road’s surface, irrespective of the type of construction, not only ameliorated the problem of dust but that it also improved the general condition of road surfaces. This was followed by the use of refined tar and bitumens. Thus was born the surface dressing industry. In 1904, there were approximately 18,000 vehicles on the roads of this country. By 1910, the number had risen to 144,000 but by 1930, the figure had grown to 2.3m, and during the intervening years many miles of road had been surfaced with macadam or dressed with tar and chippings.

The Road Fund Report for 1934/5 showed that in the UK only 29% of the total road mileage was surfaced with asphalt or macadam, 58% consisted of water bound surfaces, the remainder being surfaced with either wood blocks, setts, natural stone or concrete. However, 62% of the total had been surface dressed with tar or bitumen – which is very similar to the position 58 years later.

The general improvement of the nation’s road network continued unabated by the great recession and was still in progress at the outbreak of the Second World War, when the country’s energies and financial resources were turned to other more urgent matters required to protect the freedom of the British people. Although during the war as much freight as possible was moved by rail, the national road network was required to carry a huge increase in traffic associated with the war effort and
Aubrey Watson and Britain's Premier Motorway

The company has seventy years experience in Civil Engineering and are founder members of the Road Surface Dressing Association. The surfacing division operates a modern fleet of bulk pressure sprayers and associated plant, specialising in all types of surface dressing contracts from driveways to motorways.
during this period funds available for road maintenance were so limited that patching and surface dressing was all that most roads received, irrespective of whether or not they were in a suitable condition for this type of treatment. There can be no doubt that hundreds of miles of roads with inadequate or failed foundations and deformed surfaces were surface dressed, giving a wholly unfavourable impression of this important maintenance technique. The need to improve this situation was recognised and in 1941 a wartime road note on surface dressing was issued.

Thus it was in July 1942 that representatives from 11 surface dressing contractors met in London and agreed to set up an Association of Road Surface Dressing Contractors, which two months later was incorporated as a limited company under the provisions of the Companies Act. At the first meeting of the newly-formed Association, Mr J M Johnston, father of the present Chairman of the Johnston Group of Companies, was elected Chairman and Mr J Duncan Ferguson, a chartered accountant, was appointed as Secretary. The Association flourished, and in 1948, Captain Douglas A Robinson MC, who had been discharged from the Army after a distinguished war record following injury received in action, was appointed as “Organiser”, a description to be altered to that of “Technical Director” when the name of the Association was changed to its present title of Road Surface Dressing Association in October 1962.

During the first 30 years of the Association’s life, substantial improvements in equipment and technique took place. Surface dressing which commenced in the early days using horse-drawn tankers accompanied by hand chipping or the use of pedestrian operated chipping machines, progressed to lorry-mounted pressure sprayers and self-propelled chipping machines, although the vast majority of chipping work was undertaken by lorries operating in reverse gear using tailboard chippers.

This period also saw the publication in 1965 of Road Note 1 by the then Transport and Road Research Laboratory which was entitled “Surface Dressing with Tar” and in 1968 of Road Note 38 “Surface Dressing with Bitumen”. These advice notes and the later introduction of a British Standard for a depot tray test to establish the satisfactory transverse distribution from spray bars and the production of Standards for both crushed rock and gravel allowed a much more scientific approach to the design of surface dressings, and the publication in 1972 of Road Note 39 encapsulated the advice given and experience gained over this important period.

The last 20 years of the Association’s life has perhaps seen even greater changes. Although these have included big improvements in the machinery used, the most

Horse drawn boiler and two man ‘pram’ gritter.
significant development has been in surface dressing binders, with a dramatic move away from coal tar based products to oil based bitumens and emulsions and the polymer modified materials which are available today.

This period has also seen the laying down of the national motorway network and traffic volumes unimagined at the birth of the Association in 1942, with 24.6m vehicles now licensed. In spite of this, the surface dressing industry, in the form of contractors, binder manufacturers, the roadstone industry and equipment producers, have responded to the demands placed upon them to the extent that surface dressing continues to be the single most widely used and cost-effective highway maintenance operation capable of satisfactory performance over the whole range of the road network, from the most heavily trafficked motorway to minor country lanes, and the process is now not only regarded as a road maintenance operation but an important method of restoring skid resistance in the fight against road accidents – how far removed from the need to suppress dust!

*Double Furnace Tar boiler with Waltham brooms, 1914.*

*Below: Night surface dressing of M25 concrete section, 1990.*
As a founder member of the RSDA May Gurney has many years experience in Road Surface Dressing. The company operates a large modern fleet including bulk pressure sprayers with expanding spraybars, and self propelled metered chipping spreaders.

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A review of recent developments in surface dressing

by Colin Underwood, Consultant Director, Road Surface Dressing Association

Although surface dressing as a maintenance operation is long-established in the UK, few would argue that the rate of development over the last ten years has been faster than ever before. Highway engineers and contractors have had to react positively to the changed circumstances represented by increases in volumes of traffic and increased weights and speeds of vehicles. These requirements have led to the development of surface dressing binders with improved initial adhesion and an increase in the range of temperatures over which these binders perform satisfactorily. It is this need to produce dressings which can withstand the stresses imposed by traffic during their early life, that has also led to the development of the "racked-in" system of surface dressing. Racked-in dressings now represent a substantial proportion of the work carried out on main roads and there can be no doubt that the mechanical interlocking which takes place between the larger and smaller aggregates does substantially reduce loss of chippings during the early life of dressings.

Colin Underwood trained in Somerset and, after experience in Hampshire and Surrey, was appointed as Senior Assistant County Surveyor, Leicestershire County Council, in 1967. In 1969, he was appointed Deputy County Surveyor, Derbyshire, and in 1973 County Surveyor, Chief Engineer of the Road Construction Unit and Civil Engineer to the East Midlands Airport. In 1983, he opened a practice as a highway and planning consultant and was in 1986 retained by the Road Surface Dressing Association as their Consultant Director. Mr Underwood has served as member and chairman on a number of British Standards Committees and is currently leader of the British delegation on the European Standards Committee considering surface dressing and slurry surfacing. He is a Fellow of the Institution of Civil Engineers, the Institution of Highways and Transportation and the British Institute of Management.

The improved performance of dressings using these new binders and chipping systems have given those responsible for highway maintenance sufficient confidence to use surface dressings on sections of road where they would previously have been more likely to consider resurfacing rather than surface dressing. By adopting this process, it is possible to reduce the cost of providing safe road surfaces, to substantially reduce the inconvenience causes to road users, which is inevitably the result of maintenance operations, by minimising disruption, and to reduce the overall demand for high quality aggregates with good resistance to polishing, which are a finite national resource. An example of this

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A review of recent developments in surface dressing

Expanding spraybar with full width operating platform

improved confidence was demonstrated in 1990, when the DTP through its agents, Kent CC, asked one of the Association's members to surface dress a 8 km length of the west-bound concrete section of the M25 between Junctions 5 and 6. The success of that operation has led to the dressing of a number of lengths of other similarly heavily trafficked motorways, all of which look as if they will provide a safe running surface for many years to come.

The description “safe” surface leads us to one of the other significant developments in recent years, and that was the publication in 1987 by the DTP of Departmental Standard 15/87 “Skidding Resistance of In-Service Trunk Roads”, which effectively for the first time identified levels of skid resistance below which trunk roads and motorways of varying risk ratings should not, under normal circumstances, be allowed to fall. This initiative was taken as part of the Department’s mission to reduce by 33% road accident figures on motorways and trunk roads between then and the end of the century. The skidding levels which the DTP identified were not exceptionally high and for that reason it was all the more surprising and worrying to note the proliferation of slippery road signs erected on trunk roads awaiting surface treatment following routine skid resistance surveys. High performance surface dressing has been the preferred option to remedy this situation although understandably, not all these sections of road have since been surface dressed, many of them having been resurfaced because of other deficiencies such as rutting or because the existing asphalt or macadam surface was allowed to deteriorate to a condition where very extensive patching would have been necessary before a satisfactory dressing could be carried out.

The tendency to allow road surfaces to deteriorate to the position where extensive patching is necessary continues to be a source of concern and may, in part, result from the fact that hard-pressed maintenance engineers allow themselves to rely too heavily on the results of CHART and MARCH condition surveys. Because these assessment surveys only record defects, road surfaces which do not display defects but are nevertheless in the optimum condition for the
A review of recent developments in surface dressing

ARM sprayer – back end. Note air conditioned cab.

application of a surface dressing are not identified for early treatment until one or two years later, by which time the cost of patching can amount to as much or more than the cost of surface dressing, not to mention the disruption caused to traffic while the patching takes place. This is a classic example of where the skills of the Divisional Surveyor cannot be replaced by a computer system which relies on visual assessments undertaken in accordance with a formal system by inexperienced personnel and perhaps supported by the reluctance of accountants to recognise that, useful as they are, road condition surveys cannot be a substitute for engineering experience.

Another reason why surface dressing is not sometimes the selected method of returning road surfaces to a satisfactory condition is that occasionally the SCRIM survey shows that there is an urgent need to restore skid resistance to a road which requires work to be undertaken outside the surface dressing season – September to April inclusive. There is little doubt that the binder manufacturers are aware of this limitation, but as far as I am aware, binders suitable for use at road and ambient temperatures little above freezing are not under development.

A more recent trend has been a move away from the traditional recipe type specification in contracts let by highway authorities to contracts which are, at least in part, based on the end-performance of the dressing. A major disadvantage of this type of contract is that the responsibility for the success or failure of any particular dressing rests squarely on the contractor, thus avoiding acrimonious arguments about who is going to pay for the repair of any unsatisfactory work.

Because this type of contract puts the onus of design on to the contractor, a situation which is common in many other EEC countries, it should lead to a concentration of expertise and a reduction in the number of unsatisfactory dressings, many of which regretfully result from inappropriate specifications by often inexperienced client authority staff. End-performance specifications also allow for the development of new binders and techniques which, under the old system, would rarely be specified other than by a small number of progressive highway authorities prepared to take a risk with a new material or technique. It now seems almost certain that European Standards for surface dressing will be based on end-performance requirements which will probably result in the adoption of this system throughout Europe.

End-performance specifications, undertaken by quality assured contractors employing highly trained personnel, should prove to be a potent force for improvement in the quality of surface dressing, which will serve to highlight the excellent value for money which this process represents.

However, client engineers must appreciate that the use of end-performance specifications will cause contractors to be much more concerned with the condition of the road to be dressed. A long term uniform texture is not easily achieved over a section of road which has a widely variable texture prior to dressing and unreasonable expectations in this respect may result in contractual disputes involving senior management which will not be acceptable to either the engineer or the contractor.

1991 saw the publication of the Road Surface Dressing Association’s Code of Practice for Surface Dressing, which is
A review of recent developments in surface dressing

A document containing practical advice on the way to carry out surface dressing both effectively and efficiently, and the document is now referred to in many quality assurance schemes and contractual agreements.

The latest edition of Road Note 39, published this year, and the publication of Chapter 8 of the Traffic Signs Manual last year, are both significant for the surface dressing industry. The third edition of Road Note 39 replaces the earlier edition which had been in circulation for 11 years. Because of the substantial increase in vehicle weights and speeds, there was a widely held view that following the rates of spread of binder given in the 1981 edition of the Road Note would, in some instances, almost guarantee a failure due to the application of insufficient binder. This was a view particularly held as far as the advice given with regard to suitable rates of spread of bitumen emulsion on lightly trafficked roads.

The new Road Note addresses this deficiency and has, in some cases, increased the binder rate of spread by as much as 15%. Table 9 of the Road Note, which makes recommendations for variations in the binder rate of spread from the averages suggested in Table 8, is of particular importance. If Table 9 is ignored, the results can be disastrous as in extreme conditions the average rates of spread given in Table 8 may be as much as 1 litre/m² more, or less, than is necessary for a particular section of road.

Whereas the earlier edition of the Road Note dealt almost exclusively with the design of single spray single chip dressings, the new edition of the Road Note also considers raked-in dressings, double dressings and sandwich dressings. Additional design parameters in the form of minimum radii, altitude and total traffic volumes, as opposed to heavy commercial vehicles, are now taken into account when choosing the appropriate type of dressing and its design, and if the advice given in this publication and the RSDA Code of Practice is fully taken into account, the quality of surface dressings should improve significantly.

Safety is paramount, and the advice contained in Chapter 8 of the Traffic Signs Manual, which had undergone a gestation period of some four years since the time when consultation on proposed changes was undertaken, has raised unexpected difficulties for the surface dressing industry. This is particularly surprising when it is recognised that the advice given with regard to surface dressing in the former edition amounted to less than 30 words, while the new edition contains both written advice and a suggested layout and signing system for use when surface dressing single carriageways. In order to comply with the advice regarding the approved distance between workmen and moving traffic, total road closures would be required whilst surface dressing and surfacing work were undertaken, even on 7.3m carriageways. If this principle was widely adopted, the results of Chapter 8, far from reducing the number of accidents associated with surface dressing activities—which thankfully are not in any case high—would probably result in an increase in the number of accidents due to the passage of traffic along diversionary routes totally unsuitable for the type of vehicles involved. For this reason, the emphasis has focussed on the need to ensure that the speed of traffic passing operatives of a surface dressing train does not exceed 10 mph, and this is significantly more difficult than it sounds!
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Enquiry Number: 229
The development of end product performance specifications for surface dressing in Buckinghamshire

by Richard Rivett and David Frankland

Surface Dressing contractors can be given a high degree of pre-tender information, freedom of design choice and feedback of performance data in exchange for guaranteed measured performance during a two year period. End Product Performance Specifications (EPPS) are entirely different in concept to Method Specifications. Using method specification the client takes responsibility for choosing materials and method; his contractor simply follows these instructions. This can frequently lead to conflict between client and contractor on questions of who is responsible for failure or remedial works. EPPS on the other hand requires the client to specify only the performance he wants for each site to be included in the contract. The tenderer should then visit each site and give his proposed treatment for that site to meet all of the clients specification requirements. Once a contract is let, the contractor is responsible for all aspects of successfully implementing his own proposals. This arrangement ensures very clear demarcation of responsibilities. This paper describes how and why this form of contract for surface dressing was conceived and how it has developed since 1986 when a first trial was carried out.

For many years the form of Contract used for surface dressing was the County Surveyor’s Society document (now HASTD). The document was multi-purpose and had become somewhat cumbersome by trying to provide a Specification for everyone. It was, and still is, usually modified by individual Counties and this can lead to an inconsistent response from tenderers.

The document allowed for permutations of three basic parameters:

i) Contract Type—five different types
ii) Road Category—three different groups plus footways
iii) Supply Area—up to fourteen different area prices.

Some tender prices were expressed as a rate per square metre but “supply only” materials were at a rate per tonne. Tenderers were given only limited details of proposed programmes and certainly no details of individual sites. The Client was usually responsible for the purchase of chippings but it was often difficult when bulk purchasing to have regard to the need of individual sites.

There were many areas where conflict could occur because up to four different organisations could be involved in the work: The Client, Chipping Supplier,

Richard Rivett MICE MIHT

Divisional Surveyor at High Wycombe in 1976 and transferred to headquarters at Aylesbury in 1988 as Group Engineer Maintenance. He has been a member of various National Working Parties involved in Chapter 8, New Roads and Street Works Act and BSI representing the County Surveyors Society and the Association of County Councils. He is particularly interested in performance specifications and adapting the philosophy to highway maintenance. He currently holds the position of Acting Assistant County Engineer Maintenance.

David Frankland BA MIHT

London Council. In 1973 he joined WDM Ltd to lead their first venture into a deflectograph testing service. He returned to local government in 1976 and has now been the Materials Engineer of Buckinghamshire CC for seven years.

He represents the Institution on a BSI Committee working on the European Standard of Aggregates for Bituminous Mixtures. Currently, his main interest is in identifying practical ways in which the philosophy of performance specification can improve the way in which all highway materials and processes can be purchased and monitored.

Richard Rivett began his career with Essex CC. In 1968 he joined Buckinghamshire CC where he pursued his career in Highway Maintenance. He took up the position of
Binder Supplier and Surface Dressing Contractor.
the limitations of this traditional approach to the work became clear by the mid 1970's. Proprietary systems and products were being promoted by industry, and these appeared to be the way forward.

Main road surface dressing

Surface dressing of main roads in the county started to become desirable in the early 1970's when highway maintenance budgets were under threat and the need for better skidding resistance was being recognised. Some success was found for a while with high viscosity and PVC modified tar binders, but the availability and use of tar declined except in Tar/Bitumen blends.

Another early type of “better performance” proprietary surfacing dressing was the Johnston Hot Chip Process with which successful work was carried out. The use of heated chippings enables a very viscous bitumen to be brushed onto the road giving good adhesion and early stability.

Europe also began to make its mark with the introduction from France of the “Racking In” and “Bichoche” processes in the late 1970's. All these improvements were only as good as the toughness and tenacity of the binder however, and it was not until polymer modified binders started to appear in the mid seventies that the most highly stressed sites could be tackled with confidence.

A major breakthrough came in 1985 with the Colas concept of “Blue Chip” surface dressing. All the developments in polymer binders coupled with parallel improvements in plant had given Colas the confidence to offer an all-in contract in which a two year performance guarantee would be given, provided the choice of all materials was theirs.

The Buckinghamshire specification

Buckinghamshire CC had, until 1986, watched with interest the advent of polymer binders. Apart from a few unsuccessful trials however, no real use had been made of them. A fair trial to compare all seventeen products in a “high stress” situation was considered, but complexity of this would have been too great. Even the then TRRL found many difficulties in organising such a trial of eleven binders on the A34 at Newbury in July 1986 despite this site being a straight dual carriageway.

The weakness of comparative trials is that it is difficult to carry out on identical sections of carriageway. In practice this often means a straight dual carriageway of low stress, thus these trials tend to measure endurance and effective life rather than performance under high stress conditions.

Still baffled by the choice and yet still wanting to tackle surface dressing of difficult high stress sites, Buckinghamshire saw merit in the Colas “Blue Chip” idea, provided it could be opened up to fair competition. To do this, an end product performance criterion was needed but the Colas guarantee had not mentioned any objective measurements of performance; merely subjective visual assessment had been implied.

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Surface dressing in Buckinghamshire

dressing is judged. The function of waterproofing can be taken for granted and the function of microtexture (the primary component involved in skidding resistance) can very simply be specified in terms of aggregate Polished Stone Value (PSV).

It was therefore decided in 1986 to attempt the use of laser sensor measured texture depth (SMTD) as a performance criterion for surface dressing works. This decision coincided with a move by surface dressing contractors Clugston Asphalt Ltd to offer a two year guarantee on work using the proprietary binder “Novlastic”. A trial of this concept was carried out forthwith. The sites were three roundabouts and a 100m length of dual carriageway linking two of them, all situated in Milton Keynes, and carrying about 700 commercial vehicles per day.

The contractor’s approach to this rather different level of responsibility was in marked contrast to anything previously experienced in typical method specified work. This refreshing change created a desire for more and so, given that the Milton Keynes trial looked very promising, drafting of documents commenced for a full scale contract in 1987.

Although it was useful to retain some standard clauses from the CSS documents, a completely new concept was needed. A first draft was produced as a client team effort and then improved through informal consultation with a number of specialist surface dressing contractors.

A specification evolved in which tenderers would be given as much information as the Engineer could possibly give. For individually named sites, a thorough description of the existing surface with any relevant history, and commercial vehicle traffic flow, followed by the PSV and SMTD required from the new dressing. The exact “PSV” for any quarry had always been a potential source of disagreement and so a schedule of approved sources complete with accepted PSV was incorporated in the contract to avoid argument. SMTD was to be monitored by the Engineer using the laser texture meter, not over the whole site, but initially restricted to 50m test lengths. These lengths were pre-defined on 1:1250 scale site plans forming part of the tender documents, and subsequently to be marked on the dressed sites with steel road studs. By deliberately placing some of these test lengths at the areas of greatest stress, a typical site of say 10,000m² would need only about four test lengths.

In order to set feasible criteria, some measurements of SMTD were studied for surface dressings of various ages. Although macrotexture was being used as a (perhaps arbitrary) measure of chipping embedment, it is of course important in its own right, and so traffic speed also needed consideration in setting the SMTD requirement for each site.

Table 1 gives guidelines which have since evolved on account of experience and also SFC performance measured by SCRIM. It must be noted however, that the contractor was not to be made responsible for microtexture (SFC) performance, only macrotexture. This seemed logical on the basis that macrotexture could be a direct measure of chipping embedment — the central principle of surface dressing design within Road Note 392. The objective was thus to encourage contractors to improve their design skills rather than become confused by the variables of SCRIM surveys.

**Buckinghamshire guidelines for specifying performance of surface dressing**

Specifying texture alone would not have been enough. Stripping has always been a common mode of failure and this had to be guarded against. Although the texture measurement would cover complete and total stripping, the more likely problems of stripping from limited small areas or uniform chipping loss overall needed a different approach. Performance in respect of stripping had to be defined in terms of the maximum permissible proportion of chippings which

<table>
<thead>
<tr>
<th>Class of Road</th>
<th>Traffic Speed</th>
<th>Texture Depth after 2 Years (SMTD)</th>
<th>Minimum PSV of Chippings</th>
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WHAT can seal the road surface and restore skid resistance quickly and economically?

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Surface dressing in Buckinghamshire

could be lost from a given area. After inspecting typical failure sites and comparing with laboratory scale models having varying degrees of loss, a criterion of 25% loss from any area of one square metre was adopted. It was important to also define the starting point for any such loss: it should not include any excess chippings when first laid and so the definition... lost from the original continuous mosaic pattern was made.

As a guide for measuring stripping thus defined, a half square metre clear perspex sheet engraved with either a 10mm or 14mm grid pattern could be used. In practice, any idea of literally counting every missing chip space does not work, but the grid does serve as a broad guide and, in the rare case of dispute, any attempt at objective assessment is better than none at all.

A maintenance period of two years was set, on the premise that if a dressing could stay within a high standard of performance through two winters, its total life was then quite likely to be at least three or four years more.

Contracts awarded 1987-91

The first full scale contract in 1987 was carried out on twenty specially selected sites which included four roundabouts in Milton Keynes.

The contract was first called "High Stress Surface Dressing" because the intention was mainly to treat difficult sites. However, some long lengths of heavily trafficked principal roads were included where a higher standard of performance was required. This made the overall contract more attractive to Tenderers and helped to keep the costs down. It soon became clear that the performance of these dressings was far superior to "conventional" dressings using traditional binders and the annual contract size increased from around 100,000m² to over 600,000m² as shown in Fig 1. The rates per square metre have dropped from around £1.80 to £1.50 during this period. With this development of its purpose, the contract was renamed "High Performance Surface Dressing" and now is used on all classes of road where traffic conditions demand a higher performance from the dressing. One third of the Principal Road network in Buckinghamshire will have been surfaced dressed using this type of contract by the end of 1992.

An interesting development each year since 1988 has been the cautious introduction of a very high PSV requirement (viz Calcined Bauxite) on a very small number of short straight sites. Provided this is done very carefully, and with a polymer modified binder, a cheaper alternative to the conventional epoxy resin binder system appears feasible for at least the easy straight approaches to Pelican Crossings.

In 1991, encouraged by the High Performance contracts, this concept was introduced for all remaining surface dressing on lower category sites, but with less stringent standards more appropriate to them.

Contractors' response

The success of this concept has been largely due to increased professionalism on the part of the contractor. A greater investment has been made in modern equipment and skilled operatives. Design skills have been demonstrated in selecting materials which were well suited to individual site requirements.

The only major criticism from contractors has been the foreseeable problem of "impossibly high" targets of macrotexture being set for soft sites. The tenderer is deemed to have visited all sites and assessed them for hardness, but in practice when tendering in winter or spring, he is probably unable to actually measure hardness. This dilemma now has to be acknowledged by the client in two ways. Firstly, the contractor should be allowed to change his proposal for chipping size (but not price) once he is able to measure surface hardness. Secondly, if

Fig 1. Growth of High Performance Surface Dressing in Buckinghamshire since 1986.
a site is proved to be soft, and the contractor can demonstrate that he has followed Road Note 39 design, then his liability for macrotexture performance must be relaxed if this should fail due to embedment.

**Monitoring of performance**

Monitoring of actual performance is essential for two reasons, one old, and one new. Firstly to check, in time-honoured legalistic fashion, that the purchaser actually gets all of what he is committed to pay for.

Secondly, the test results are invaluable to both Client and Contractor for the distinct purposes of improving specification/criteria and design/construction skills respectively. This concept of feedback is of fundamental importance in EPPS. In the case of Recipe or Method checking, both parties simply have to trust a learned body of specification writers; learning, innovation and improvement are unlikely to flow out of routine compliance checking. For EPPS on the other hand, compliance checking must be its very life blood. The contractor, having been given freedom to design and construct, must see himself on a learning curve and make full use of the feedback.

This appears to present a good case for the contractor to do his own testing, but in fact the Client’s need for close and continuing involvement with performance monitoring is even greater. This is because the client should continue monitoring for years after any contractual liability has ceased. He should be constantly re-evaluating and improving his specification criteria against a background of whole life costing and maintenance intervention levels.

An ideal timetable for monitoring a surface dressing two year performance contract requires a full assessment and report within two months after completion of the dressing. Unless any immediate failures can be remedied within the same season they, and any borderline or winter damaged sites, should be given a repeat assessment in the following March. This then allows any remedial works to be planned early in the next season. A final assessment of all sites should be made in the second March, again to allow early planning on remedial work before the two year period expires. The total cost of this monitoring is of the order of two per cent of the contract value.

The above frequency is clearly the minimum for effective enforcement, but even this can be quite demanding on resources in March. Marking of test lengths and use of the MTM at walking pace are two limitations which could be removed if the TRL High Speed Texture Meter (HSTM) could now be used in place of the MTM. A Buckinghamshire trial of this concept is underway in 1992.

Use of the HSTM would obviously give a near complete picture of contractual performance, but the merit of this idea could go well beyond just a surface dressing contract, in the light of TRRL Research Report 296. This work has shown a relationship between macrotexture and accident rate. Longer term studies of accident statistics on surface dressed sites having known macrotexture history would be extremely valuable, in reassessing the performance criteria specified. A new level of accountability would then have been reached for any such criteria.

**Performance achieved**

The vast majority of sites have been generally satisfactory but nevertheless some problems were encountered. Contractors were asked to carry out remedial works on a few sites in most of the contracts, and their responsibility for such work has rarely been disputed. In some cases, remedial work was completed without even waiting for a formal request.

Out of 210 high performance sites dressed between 1986 and 1991, only six have needed to be re-dressed at the client’s expense to date, and they represent only about two per cent of the total area treated. One site had always been rather soft, and the others were relatively short lengths being overlapped by subsequent longer ones.

The main technical problem encountered was that of stripping in the innermost wheel path of some roundabouts. Clearly this is the area of greatest stress and the problem appeared to be that of the binder not adhering to the existing surface due to a build up of rubber deposit. In subsequent contracts this was drawn to the contractors attention with a suggestion that they might like to consider some preparatory abrasive treatment to remove any deposit from the existing surface.

**Conclusions**

One of the oldest and wisest rules in the business of specifying materials is “If you can’t measure something—don’t specify it!” This must also apply to specifying an end product or functional characteristic thereof. The experience described in this paper demonstrated quite clearly that it is possible to measure performance of surface dressing in terms of macrotexture and limited stripping defects. Success has also been demonstrated in implementing the principle within full scale contracts over a six year period involving over two million square metres of surface dressing.

The wise rule given above has an even wiser corollary: “If you specify something measurable—be seen measuring it!” Monitoring of actual performance is not an optional extra. Only a clear assurance of intended monitoring can ensure that tenderers enter into completely fair competition. It is also essential that only reputable contractors with a proven track record are used and that new contractors are included only after they have demonstrated that they can perform the type of work required.
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The greatest single disadvantage is simply that of change. Whilst contract documents can be changed very easily, both client and contractor have to change their roles and learn new skills, a process which takes time. The contractor has to develop design skills, and the client has to establish new procedures for preparing efficient programmes and informative tender documents, for instigating performance monitoring and reporting systems, for coordinating programmes of remedial work, and ultimately to monitor whole life costings.

Provided such changes in philosophy are managed in a professional way, there is much to be gained from the "End Product Approach" for all concerned with surface dressing, particularly for the real end-users - the motoring public.

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1. Hosking J R; Roe P G and Tubey L W; Research Report 120; Transport and Road Research Laboratory 1987.

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The Institution and Editor thank all the authors who have contributed to this special RSDA issue.

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Latex-modified bitumen for improved resistance to brittle fracture

By Dr A N S Beaty

The advantages of rubber-modified bitumen in road construction are discussed. The characteristics of rubber and the modifying effects resulting from the addition of small quantities of rubber to bitumen are briefly presented. A programme of laboratory testing on an 85/100 penetration grade bitumen modified by the addition of up to five per cent latex by mass of bitumen is described. Test methods used to measure changes in the behaviour of bitumen with temperature are reviewed and their relevance to the testing of rubberised bitumen is discussed. Laboratory test results are presented and compared with data reported by others. A linear relationship was found to exist between latex content and the ring-and-ball softening point. It was observed that a low temperature ductility test is more likely to provide a useful indication of the brittle behaviour of bitumen than is the Fraass test. It is concluded that the addition of three to five per cent of latex by mass of bitumen results in an appreciable improvement in the brittle behaviour of bitumen.

For more than a century, road-builders have sought to modify the properties of road bitumens through the addition of small quantities of rubber and other polymers. The broad aim is to improve the rheological properties of the binder without adversely affecting its handling properties. Numerous laboratory studies and sporadic full-scale field applications have demonstrated the benefits of rubber-modified bitumen. Nevertheless, broad acceptance that the improved road performance resulting from the use of rubberised bitumen is worth the extra cost and complexity has only been achieved very recently.

There are three principal sources of the rubber used to modify bitumen. These are natural latex, scrap rubber from used motor vehicle tyres and synthetic rubbers of the styrene-butadiene block copolymer type.

In rubber-producing countries such as Malaysia and Indonesia and also in Great Britain, interest has centred on the addition of natural latex to bitumen. In Australia and the United States, however, where the disposal of large numbers of used vehicle tyres presents environmental problems, research has been directed towards the use of scrap rubber as an additive to bitumen. More recently, the oil and chemical companies have become interested in the manufacture and supply of proprietary rubber-modified bitumens. These are mostly based on synthetic rubber, often in the form of a water-based emulsion or synthetic latex.

Over the last five years increasing quantities of bituminous materials incorporating rubber-bitumen have been used as surface dressings or in hot-mix asphaltic road surfacing.

Current interest in the behaviour of rubber-modified road surfacings can be traced to an extensive programme of full-scale road trials carried out in Great Britain by the Road Research Laboratory in conjunction with the National Rubber Producers' Research Association during the period 1953-1963. This demonstrated that the incorporation of small percentages of rubber in bituminous binders produced appreciable changes in the physical properties of the binder. In particular, compared to bitumen, rubberised bitumen shows decreased temperature susceptibility, with consequently improved resistance to deformation at high temperatures and reduced brittleness at low temperatures.

In a previous paper the advantages of hot rolled asphalt made with latex-modified bitumen were demonstrated for the conditions of high road surface temperature and heavy rainfall typical of wet tropical regions. In the present paper attention is focused on the behaviour of latex-modified bitumen at the low
temperatures associated with brittle fracture. These are typical of winter service conditions for roads in Canada and the northern United States. The potential benefits of using rubber-modified bitumen at low temperatures were seen to be important as long ago as 1951, but it has only been since the mid nineteen-eighties that road materials incorporating rubberised bitumen have begun to be used fairly widely in practice.

Enhanced behaviour of rubber-modified bitumen

A wide range of advantages of rubber-modified bitumen have been suggested, these include:
1. to improve low temperature ductility and hence the resistance of the bituminous mixture to brittle fracture
2. to improve the stiffness of the bituminous mixture at high temperatures so as to reduce permanent deformation and rutting under traffic loading
3. to improve the adhesion of the binder to the aggregate and thus improve resistance to stripping
4. to reduce the temperature susceptibility of the binder, i.e. to decrease the loss of viscosity at high temperatures and hence to reduce bleeding
5. to reduce, or prevent reflection cracking when the material is laid over a cracked pavement structure
6. to improve the fatigue resistance of the bituminous mixture
7. to increase the strength of the bituminous mixture
8. to improve the impact resistance of the bituminous mixture
9. to improve resilience and elastic recovery
10. to find a use for scrap rubber from vehicle tyres

In spite of the impressive number of benefits to be gained by the use of rubberised bitumen, its acceptance by the road construction industry was rather slow for a long time. This can be attributed to the following:
1. in the majority of road applications traditional bituminous mixtures have given satisfactory service
2. rubberised bitumen is more costly and, until comparatively recently, its use often required additional processing and modifications to traditional handling and laying techniques

However, as traffic intensities have increased and road authorities' budgets have been constrained, interest in enhanced material performance has grown and the major oil companies have had incentives to market commercially produced rubber-modified bitumens. The technology has now advanced to the point where most commercially available rubber modifiers can be used without modification to traditional handling and laying methods and equipment. As more bituminous surfacing incorporating rubber-bitumen have been seen to perform successfully in service, awareness of this technology and confidence in its application have begun to grow.

Characteristics of rubber

The essential characteristic of rubber is its property of high elasticity which allows it to undergo large deformations from which almost complete, instantaneous recovery is achieved when the load is removed. This property of high elasticity derives from the molecular structure of rubber. Rubber belongs to the class of materials known as polymers and is also referred to as elastomer. The characteristics of an elastomer are:
1. the molecules are very long and are able to rotate freely about the bonds joining neighbouring molecular units
2. the molecules are joined, either chemically or mechanically, at a number of sites to form a three-dimensional network. These joints are termed cross-links
3. apart from the cross-links, the molecules are able to move freely past one another, i.e. the Van der Waal's forces are small

Although, like bitumen, rubber is a thermoplastic, visco-elastic material, whose deformation response under load depends on both temperature and rate of strain, the deformation of rubber is relatively insensitive to temperature change and the material remains elastic at both low rates of strain and at temperatures well above the ambient. The wider range of elastic behaviour of rubber compared to that of bitumen largely results from the cross-linking of the long rubber molecules. Rubber is also much more ductile than bitumen at low temperatures and high loading rates.

Modifying effects of rubber

The dispersion of small concentrations of rubber through the bitumen confers on the bitumen some of the beneficial properties of the rubber. It is desirable to achieve these benefits without adversely affecting the handling characteristics of the binder.

It has been said, that for a polymer to be effective in improving the visco-elastic behaviour of a road binder, it should have the following attributes:
1. ready availability
2. resistance to degradation at asphalt mixing temperatures
3. be easily mixed with bitumen
4. improve binder flow at high road temperatures without making the binder too viscous at mixing and laying temperatures or too stiff or brittle at low road temperatures
5. be cost effective

Concerning resistance to flow, Fernando and Guirigis have shown that the addition of natural rubber to bitumen in a Kuwaiti asphalt not only increased the stiffness modulus of asphalt by as much as 100% at 45°C but also reduced the asphalt stiffness modulus at low temperatures, for example by 16% at 5°C. There appeared to be a transition temperature of about 13°C below which stiffness was reduced by the addition of rubber and above which it was increased. This means that the addition of natural rubber can improve both rutting resistance at high temperatures and resistance to brittle fracture at low temperatures.

In the words of another writer, the idealised modified bituminous binder would contribute:
(i) higher stiffness at high temperatures to reduce rutting and shoving
(ii) lower stiffness at cold ambient temperatures to reduce cracking
(iii) lower stiffness at processing temperatures to expedite spraying, pumping, mixing and compaction
(iv) improved adhesion of binder to aggregate in the presence of water and water vapour, to increase stripping resistance

Of these, the prime goal is to reduce the binder's cold-weather stiffness, thus lessening its tendency to brittle fracture.

Applications of rubber-modified bitumen

Rubberised bitumen can be used in all types of bituminous material including cut-backs and emulsions. The principal uses can be divided between surface seal coats and bituminous mixtures including asphalt. Rubber-modified bitumen can be used as the binder in densely graded mixtures, such as mastic asphalt and hot rolled asphalt, in open-graded mixtures such as bitumen macadam, in cut-backs typically used for surface treatments and in emulsions used for slurry seals.

Objective of the present research

The principal objective of the research described in this paper was to investigate the brittle fracture of rubberised bitumen at low temperatures.

Materials used

The bitumen tested was an 85/100 penetration grade bitumen typically used in road construction in southern Ontario. The rubber additive was in the form of latex, a water-based emulsion. The latex used had a dry rubber content of 68.1%.

Blending of latex and bitumen

The blending procedure adopted was generally in accordance with road Note No 361. For each blending, approximately 500g of bitumen were heated, in a one litre container in an oil bath, to a constant temperature of 140 ± 5°C. In order to avoid foaming problems as the water in the latex turns rapidly to steam, the latex was added slowly in small quantities, each amount being allowed to remain on the surface of the bitumen for approximately 2 seconds so that the
water evaporated but without allowing the latex to coagulate and form a skin. The latex was then stirred into the bitumen. Once the required quantity of latex had been added to the bitumen in this manner, stirring was continued mechanically for a further 20 minutes, the temperature being maintained at 140 ± 5°C.

When latex is added to hot bitumen, it first disperses in the form of fine rubbery particles which then swell and begin to dissolve under the action of heat. Eventually they dissolve completely to produce a tough rubbery material called latex-bitumen; in this condition the changes in the physical properties of the bitumen are most marked. However, under prolonged heating the latex begins to degrade and its effectiveness is reduced. Care must be taken to ensure that the mixing time is sufficient to ensure complete dissolution, but not so long as to allow degradation. Thompson has recommended blending times at various mixing temperatures.

Testing programme
As a control against which to measure changes resulting from the addition of latex, tests were first carried out on the unmodified bitumen. Tests on rubber-modified bitumen were carried out at latex contents of 2, 3, 4 and 5% by mass of bitumen. The tests performed together with the relevant standards are shown in Table 1.

Penetration test
The standard 100g, 25°C, 5 seconds test was performed. Further 100g, 5 seconds tests were also carried out at temperatures of 30°C, 27.5°C, 15°C, 10°C, 7.5°C and 5°C in order to study temperature susceptibility. At each of the latex contents of 0, 2, 3, 4 and 5% by mass of bitumen linear regression analysis was used to determine the best fit straight line corresponding to the equation:

\[ \log(\text{Pen}) = A \cdot T^* + K \]

in which the slope A represents the temperature susceptibility of the logarithm of the penetration. Fig 1 shows the relationship between temperature and penetration for the range of latex content from 0 to 5%. Fig 2 shows penetration as a function of latex content for a range of temperatures from 5 to 30°C. From these two figures it can be seen that at low temperatures penetration increases with increasing latex content, whereas at high temperatures penetration decreases with increasing latex content. It can also be seen that, for the material tested, the transition temperature between the two states was found to be approximately 17°C at which the penetration is sensibly independent of latex content. This is consistent with the findings of Fernando and Guirguis who observed a transition temperature of about 13°C in terms of

<table>
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<tr>
<td>Ring and ball softening point</td>
<td>ASTM D36-86</td>
</tr>
<tr>
<td>Ductility</td>
<td>ASTM D113-86</td>
</tr>
<tr>
<td>Fraass breaking point</td>
<td>IP 80/53</td>
</tr>
</tbody>
</table>

![Fig. 1. Log Penetration versus Temperature](image)

stiffness, for a Kuwait 60/70 penetration grade bitumen.

Penetration index
A different way of looking at the temperature sensitivity of viscosity of bitumen has been given by Pfeiffer and van Doornmaal who have defined the penetration index (P.I.) according to the relation

\[ \text{P.I.} = \frac{20-500A}{1 + 50A} \]

where A is the slope of the log (penetration) versus temperature line. For latex contents from 0 to 5%, Table 2 gives the values of A, K and P.I. The penetration index has been found to be a measure of the deviation of a bitumen from Newtonian behaviour, that is to say behaviour characterised by a linear relationship between shear stress and rate of strain. Bitumens usually used in road construction have a penetration index lying in the range +1 to -1. Bitumens with a penetration index less than -2 exhibit substantially Newtonian flow behaviour and are usually characterised by brittleness at low temperatures. Bitumens having a penetration index greater than +2 are usually less brittle, show marked timed-dependent elastic properties and have a flow behaviour at high strain rates which shows considerable deviation from Newtonian behaviour.
to the liquid state at a fixed temperature, but rather pass progressively from one state to the other as the temperature increases. Consistency of bitumen can therefore be described either by direct measurement under prescribed loading conditions at a fixed temperature, as in the penetration test, or by measurement of the temperature corresponding to a given consistency as in the ring and ball softening point test. When the relationship of equation (1) is extrapolated to the temperature of the ring and ball softening point it is found that the penetration at that temperature is about 800 for all bitumens. Included in Table 2 are the measured values of the ring-and-ball softening point temperature and the corresponding value calculated from equation (1) at a penetration value of 800. It will be seen that these values are in good agreement.

The ring-and-ball softening temperature is said to be a measure of the hardness of the bitumen. It can be seen that, as the amount of latex added to the bitumen is increased, the ring and ball softening point also increases. Fig 4 shows a sensibly linear relationship between latex content and ring-and-ball softening temperature. Over the range 0-5% of latex content, for each one percent of latex added, the softening point temperature increased by 2.14°C. For a latex content of 4% an increase in softening point of 8.6°C was observed, which is comparable to the value of 8° reported by Fernando and Guiguis for a Kuwait 60/70 penetration grade bitumen, but somewhat less than the nine to eleven degree range reported by Smith for penetration grades of 55 and 120.

In Fig 3 the penetration index is plotted as a function of latex content. Within the limits of the experimental data it can be seen that an increase in penetration index of approximately 0.45 is obtained for each one percent of latex added. Knowing the penetration index of the natural bitumen this relationship can be used to determine the approximate amount of latex to be added in order to achieve a particular value of penetration index.

**Ring and ball softening point**

Bitumens do not change from the solid

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**Table 2. Penetration Index and Softening Point**

<table>
<thead>
<tr>
<th>% LATEX</th>
<th>A</th>
<th>K</th>
<th>PI</th>
<th>( T^+_{R+B} )</th>
<th>( T^+_{R+B} )</th>
<th>PENETRATION AT 25°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.0517</td>
<td>0.627</td>
<td>-1.614</td>
<td>44.0</td>
<td>46.0</td>
<td>83</td>
</tr>
<tr>
<td>2</td>
<td>0.0424</td>
<td>0.772</td>
<td>-0.385</td>
<td>50.1</td>
<td>50.3</td>
<td>68</td>
</tr>
<tr>
<td>3</td>
<td>0.0399</td>
<td>0.798</td>
<td>0.025</td>
<td>52.8</td>
<td>52.4</td>
<td>62</td>
</tr>
<tr>
<td>4</td>
<td>0.0391</td>
<td>0.823</td>
<td>0.147</td>
<td>53.2</td>
<td>54.6</td>
<td>63</td>
</tr>
<tr>
<td>5</td>
<td>0.0359</td>
<td>0.898</td>
<td>0.730</td>
<td>55.9</td>
<td>56.7</td>
<td>61</td>
</tr>
</tbody>
</table>

* calculated from penetration = 800 + measured
Fig 5. Log Penetration versus T (°C).

In Fig 5 the logarithm of penetration at 25°C is plotted against the ring-and-ball softening point temperature. Also shown in the same figure are lines representing penetration index values of 1, 0 and -1. It can be seen that the value of penetration index increases from approximately -1.6 for the natural bitumen to a value of 0.73 for bitumen containing 5% of latex.

**Ductility**

Ductility may be described as the ability of a material to remain coherent under large tensile strains. Typical road bitumens can be extended more than one metre in the standard (ASTM D113-86) test performed at 25°C. As such a strain is well in excess of strains experienced by bituminous materials in service in road pavements, there has long been a debate as to the relevance of ductility testing of road materials. However, at low temperatures where brittle failure is the principal concern, the ductility of a bitumen can be a useful indicator.

Ductility depends on the hardness (ring-and-ball softening temperature) and the type (penetration index) of the bitumen. Saal\textsuperscript{18} reported the remarkable fact that all the bitumens which he tested exhibited a ductility of 100mm at about -45°C below their ring-and-ball softening temperature. He has also shown that the temperature of the specimen in the ductility test can be raised appreciably by the energy of stretching. This effect is most pronounced for small cross-sectional areas and leads to a decrease in viscosity and hence to an over-estimation of ductility. Applying Van der Poel’s concept of stiffness\textsuperscript{33} to the brittle behaviour of bituminous binders, Saal\textsuperscript{18} showed that for low ductilities, the ductility test is essentially a test for brittle fracture, the onset of fracture being determined by the stiffness (resistance to deformation) of the binder at the temperature and extension rate of the test, as well as by its breaking strength. In the case of failure after extension greater than 10mm, the elongation is principally dependent on the stiffness. The critical temperature of brittle fracture is that temperature at which the stiffness of the bitumen, at a loading time of 10 seconds, attains a value of 10\textsuperscript{7}N/m\textsuperscript{2}. At the standard ductility test deformation rate of 50mm/min this corresponds to a ductility of about 8.5mm. If the stiffness of the bitumen at 10 seconds is higher than 10\textsuperscript{7}N/m\textsuperscript{2} then brittle fracture will occur.

Saal\textsuperscript{18} considered that the ductility test is analogous to the Fraass test in which the temperature is determined at which the stiffness of the bitumen is ten times higher than that corresponding to brittle failure in the ductility test.

Fig 6 shows measured ductility at 5°C as a function of latex content. The natural bitumen exhibited brittle failure at an elongation of 72mm whereas for rubberised bitumen, containing 3% or more latex by mass of bitumen, ductilities in excess of 1.5m were observed. This is compatible with results cited by Epp\textsuperscript{11} for ductility tests, performed on a Californian bitumen at 3.9°C, in which ductility increased from 20mm for the unmodified bitumen to 1.5m for bitumen to which 5% synthetic latex had been added.

Ductility tests were carried out at 5, 10, 15, and 25°C. At 10°C and above, all samples extended to the limit of the ductility tank (1.5m) without failure. However, qualitative differences were...
observed in that at 10°C and at full extension, the threads of natural bitumen and bitumen containing less than 3% latex were of such small diameter as to be barely visible to the naked eye.

Smith7 observed that at -10°C ductility specimens of natural bitumen were very sensitive to shock and frequently broke during removal from the moulds, whereas the rubberised-bitumen specimens could be removed from the moulds without breakage even at -10°C. In the work reported in the present paper the specimens of natural bitumen were found to be so brittle even at 5°C that they frequently broke during attempts to remove them from the ductility moulds.

**Fraass breaking point**

An important factor in the liability to fracture of a bituminous road material is the brittleness of the binder itself. The Fraass breaking point test was developed20 in order to determine the temperature corresponding to the onset of brittle failure in bitumens.

The Fraass breaking point is the temperature at which a binder becomes brittle as indicated by the appearance of cracks when a thin film of binder 0.05mm thick, on a flexible metal plate, is cooled at a rate of 1°C per minute and flexed at a constant rate. Rigden and Lee24 have shown that, at the Fraass breaking point, binders have a constant viscosity, of the order of 4 x 10⁹ poises and that under conditions giving rise to brittle fracture, their tensile strength is of the order of 6 x 10¹⁰ N/m². Van der Poe22 has shown that brittleness in the Fraass test corresponds to a stiffness of 10¹⁰ N/m² for a loading time of 10 seconds, or ten times higher than the stiffness corresponding to brittle behaviour in the ductility test. He also showed that for bitumens of the same penetration index, but of different hardness, the difference between the Fraass breaking point and the ring-and-ball softening point is a constant.

Rigden and Lee24 analysed the behaviour of a bituminous film when subjected to the Fraass test. When the thin steel plate is flexed, the thin film of bitumen on the outside of the curve is stretched and the surface layers are subjected to a tensile stress which will normally be relaxed by viscous flow. As the temperature is progressively lowered the viscosity of the film will increase and a point will be reached where the tensile stress in the outside of the film will not be relaxed quickly enough to prevent it from reaching a value in excess of the tensile strength of the material. The film of bitumen will then crack. From the rate of bending and the tensile strength of the material, the viscosity at the Fraass point can be calculated. The apparent tensile strength of the bitumen falls to a constant value as the range of loading is increased and as the test temperature is lowered.

The region of constant value commences approximately at the Fraass brittle temperature; under the conditions of the test there is no flow of the material before it fractures.

In the present work the Fraass breaking point for the unmodified bitumen was observed to be -10°C. Although many tests were carried out on the latex-modified bitumen, the results are considered to be inconclusive.

The Fraass test is not an easy test to carry out consistently and in the work reported here, difficulties in observing the bitumen specimen were experienced due to fogging of the glass test tubes. Furthermore, although the point of brittle fracture of the unmodified bitumen was readily identifiable, the same was not true for the rubberised-bitumen samples. In fact, although minor cracks were observed, these tended to fill once flexing ceased. Observations led to the conclusion that either rubberised-bitumen does not exhibit clear brittle failure or that it does so, but at a temperature below the lower limit of the test temperature range (-20°C).

The Fraass test has been criticised on the grounds of limited reproducibility and sensitivity to film thickness which is difficult to control with the necessary degree of accuracy. Parker and Walker21 have indicated that, with rubber-modified bitumen, the difficulty in preparing satisfactory specimens is increased. These problems have been confirmed in the present work in which it was also found difficult to identify the point of brittle fracture of rubber-modified specimens.

However, Fernando and Guirguis10 reported that the addition of 4% latex to a Kuwait 60/70 grade bitumen depressed the Fraass brittle temperature from -21°C to -25°C. They made no mention of difficulty either in identifying the Fraass point for the rubber-modified material or with control of sample thickness or reproducibility of results.

**Other tests for brittleness**

Mason et al22 carried out simple extension tests for brittleness and remarked that the fracture surfaces of rubberised bitumen showed striking qualitative differences from those exhibited by the unmodified bitumen. The normal bitumen showed the characteristic features of glass-fracture surfaces, ie an area of ‘mirror’ surface bounded by a ‘frosty’ zone, whereas the specimens containing rubber had a matt surface with none of the glassy characteristics.

Hughes and Faris25 investigated the ability of bitumens to bend without breaking over a range of temperature from 0°C to -18°C. Two deformation rates were used, a high rate of 76mm/sec corresponding to loading by fast moving traffic and a low rate of 1.8mm/hour corresponding to the rate of expansion and contraction believed to result from ambient temperature changes during freezing and thawing. They concluded that the low deformation rate forces were the critical ones for pavement performance. It was found that deformation at failure at -18°C for the low deformation rate was half the corresponding high rate value and that deformation at failure was less for harder bitumens than for softer ones.

As has been discussed, neither the Fraass test nor the standard ductility test is entirely satisfactory for the measurement of brittle fracture behaviour of rubberised bitumen. Parker and Walker21 proposed an alternative low temperature brittleness test in which a rectangular specimen 50 x 25 x12.7mm was subjected to a low rate of tensile deformation (3.175mm/h), parallel to its least dimension, to failure or to 50% strain, at a temperature of -9°C. It was found that specimens containing 5% of modifier either failed at low strains or extended by the full amount. An interesting part of the work these authors reported consisted of blending bitumens of different hardness but from the same crude oil source so as to produce a series of materials which differed only in their penetration values. These were then subjected to the low temperature extension test at -9°C and the lowest value of penetration at 25°C, for which fracture at -9°C did not occur, was termed the ‘critical penetration’. It was however demonstrated that the penetration measurement did not enable a direct comparison to be made of the brittleness of materials of different composition.

Oliver and Dickinson11 have suggested that standard tests for bitumen may not be appropriate for testing rubber-modified bitumens. They have expressed the view that the difficulty in interpreting the results of standardised, empirical bitumen tests, arises because rubberised bitumen is, in effect, a new material for which new tests, appropriate to its fundamental properties and particular behaviour, should be devised. This view is supported by Fernando and Guirguis10 who believe that there is a need to specify mechanical properties and visco-elastic behaviour of rubberised bitumen in terms of fundamental measurements rather than the arbitrary, empirical bitumen tests currently used.

The laboratory data reported in this paper also lend support to these views, concerning the characterisation of brittle behaviour. The Fraass test seems not to be appropriate. However, it is felt that the measurement of ductility values over a range of temperature can give useful information concerning the onset of brittle behaviour and the effects of the rubber additive on that threshold.
Epps\textsuperscript{1} has also expressed the view that current test methods are not representative of the loading and environmental conditions expected in service in the road pavement. He has also pointed out that current flexible pavement design methods are unable to take into account the performance improvements which can accrue from the use of rubber-modified bitumen. In addition to devising new tests for this new class of materials, material specifications need to be changed so as to reflect the properties of the modified binder rather than those of the modifier itself. Modifiers are known to react differently with bitumens from different sources. Performance of bituminous mixtures incorporating modified binders needs to be defined in such a way that life-cycle costs can be determined and compared with those for a comparable pavement made with a conventional binder. Such an analysis has recently been attempted in Alaska\textsuperscript{2}.

It seems clear that the brittle behaviour of rubberised bitumen is significantly different from that of unmodified bitumen and that the development of a new test conceived specifically to measure the brittle behaviour of rubberised bitumen would be highly desirable.

Conclusions
1. It has been shown that the addition of small quantities of latex to a penetration grade bitumen results in an increase in penetration values at low temperatures and a decrease in penetration values at high temperatures. The magnitude of these changes in penetration increases with increasing latex content in the range 2.5\% to 5\% by mass of bitumen.
2. For the 85/100 penetration grade bitumen tested, the transition temperature between increasing and decreasing penetration was observed to be approximately 17\°C.
3. The penetration index of the rubber-modified bitumen was found to increase linearly from 1.6 for the natural bitumen to a value of 0.73 for 5\% latex content. This indicates that the addition of small quantities of latex reduces the temperature susceptibility and the brittleness of bitumen.
4. A linear relationship was observed between ring-and-ball softening point temperature and latex content. For a latex content within the range 0-5\%, the ring-and-ball softening point temperature was found to be given by the relationship $T = T_r + \beta L = 46 + 2.14L$, where $T_r$ is the softening point of the asphalt, and $\beta$ is a constant.
5. The ductility test conducted at low temperature was found to be a useful indicator of brittle behaviour of bitumen. Latex contents in the range 3 to 5\% were found to result in non-brittle behaviour in the ductility at 5\°C whereas the unmodified bitumen failed by brittle fracture in the same test.
6. The addition of 3 to 5\% of latex by mass of bitumen to an 85/100 penetration grade bitumen in the laboratory was observed to bring about an appreciable improvement in the brittle behaviour of the bitumen.

Acknowledgements
The work described in this paper was carried out in the laboratories of the Royal Military College of Canada. The assistance of Miss Susan Chambers is gratefully acknowledged. The views expressed in the paper are those of the author and do not necessarily reflect those of the Canadian Department of National Defence.

References
ARM undertakes five day job for its Armacote process

Specialist road maintenance contractor Advanced Road Maintenance has used its Armacote surface dressing process to resurface an eight kilometre section of the busy A121 at Loughton in Essex.

The eight day job, part of which was performed over a weekend to minimise congestion in the Loughton High Street, involved ARM applying the Armacote surface dressing process to 61,000m² of the single carriageway road that runs through the Essex town. It was carried out for clients, Epping Forest District Council using one of ARM’s two Marius Pedersen programmable binder distributors.

The Danish machines, the second of which was purchased earlier this year, benefit from the latest microprocessor technology that makes them the most advanced units of their type for the controlled distribution of surface dressing binder. Costing over £300,000, each unit features a large capacity (19,000 or 25,000 litres) storage tank and telescopic spray bars that can distribute the binder over varying widths from 300mm up to 6.0 metres.

On-board computers can be pre-programmed with the design information applicable to each section of the road to be dressed. This ensures that the spread rate of the BP Armacote binder is matched exactly to application requirement. Spread rates can for instance be reduced in the highly trafficked areas of the road such as the wheel tracks and increased in the more lightly used areas such as the slip lanes, crown and channels.

ARM has further improved the performance of its Marius Pedersen binder distributors by equipping both machines with telephone modem links. This allows the manufacturer’s engineers to interrogate the two machines’ microprocessor functions directly from its headquarters in Denmark. The modem link has been added to help ARM ensure that the two machines are always achieving optimum performance. It will also be used to assist ARM’s site engineers in tracing and correcting a system malfunction, so minimising downtime.

The Marius Pedersen binder distributor was one of 13 machines from ARM’s specialist road surfacing fleet on the A121 contract. Also on site were the company’s Phoenix self-propelled chipping spreader, two Johnson 600 suction sweepers, a 10 tonne Caterpillar . PF-200 pneumatic roller and a 6.7 tonne Dynapac CA151R rubber coated drum vibratory roller.

As with all ARM projects, an extensive site survey was conducted prior to the start of the contract to establish the condition of the existing road surface and other important design criteria. All the information gathered was then fed into the company’s computer so that an accurate job specification could be prepared. The new road surface was laid down using lightly coated 14mm high PSV Grimestone chippings raked in with very clean granite chippings. The rate of spread was varied throughout the job to allow for such factors as the existing substrate hardness, varying traffic density and the differences in ambient temperature where the road passes through heavily wooded areas of Epping Forest.

Safe roads in Manchester and Uckfield

The Fibrescreeed Group of companies recently won a contract put out to tender by the City Engineer of Manchester, for the surface re-texturing on various roads in urban areas of the city.

Fibrescreeed’s Roadtex division, roadially commissioned to treat hazardous areas at four sites, was subsequently instructed to effect repairs at four further sites.

The project is part of an anti-skid programme which is being co-ordinated by the city’s Traffic Accident Investigation Unit. The team has successfully identified several hazard areas in Manchester’s road network and is responsible for raising the level of safety – in this instance by reducing stopping distances. The most dangerous areas are junctions, approach to junctions, roundabouts and bends.

Not long after the job in Manchester, a Roadtex machine could be seen providing the very same safety treatment right on its own doorstep in Uckfield High Street! The occurrence of potentially hazardous, smooth road surfaces is not limited only to heavily used city streets of somewhere like Manchester but will just as easily be found in a comparatively small town like Uckfield. The process is a mechanical and thermal one whereby both the micro and macro-textures are improved to increase the skid-resistant qualities of road surfaces which have been worn smooth by heavy traffic and can lead to dangerous situations.

SLIP SLIDING AWAY

Jimi-Heat heat tracing specialists has developed an innovative solution to dangerous ice and snow accumulation on sloping road surfaces.

The Jimi-Heat Thermocable, JSP/BRP is a braided heater cable which, when embedded into the concrete base, ensures an even heat supply to the road surface, eliminating any build up of snow or ice, says Jimi-Heat.

Normally positioned at least 50mm beneath the road surface, the Thermocables are spaced apart by Jimi-Heat PVC Spacer Strips, specially designed to ensure regular 100/150mm spacing intervals.

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Site safety from Colas

Colas has fitted a reversing anti-collision system to an eight-tonne double drum vibrating road roller used during their deep mix recycling operations in an effort to increase site safety.

The system, known as Ogden VMS Tadar, is activated by detectors fitted at the front and rear of the vibrating roller. When a potential collision risk is detected, the vehicle’s brakes are automatically applied.

Developed by Ogden Safety Systems, VMS Radar is a precisely defined beam that gives full coverage across the width of the roller and accurately determines its distance from a target irrespective of the size of the target.

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