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French experience with grave-bitume a dense bituminous road base

by

C. E. Hingley (Tarmac Roadstone Holdings Ltd.)
K. R. Peattie (Asphalt and Coated Macadam Association)
and
W. D. Powell (TRRL)

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FRENCH EXPERIENCE WITH GRAVE-BITUME
A DENSE BITUMINOUS ROAD-BASE

Authors C E Hingley, K R Peattie and W D Powell

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Grave-bitume, a dense-graded bituminous material similar in some respects to the dense bituminous macadam used in the United Kingdom, but incorporating a stiffer binder, has been developed in France over the last decade primarily to overcome deformation problems which were widespread on heavily trafficked roads. Its reported success was of particular interest to the co-operative research group formed in 1975 by the Asphalt and Coated Macadam Association, the British Tar Industry Association, the Refined Bitumen Association and the Transport and Road Research Laboratory to carry out research to improve the performance of bituminous roadbase and basecourse macadams in relation to their cost. A visit was made by the three authors, all members of the Steering Committee of the research group, to make a detailed assessment of the potential of grave-bitume for use in its present form as a roadbase material in the UK or, to provide ideas of possible use in the development of improved dense coated macadams in the programme of the research group.

The Report provides background information about the development of grave-bitume including details of the standard tests used for determining composition. Laboratory studies were used in the development of grave-bitume to determine the structural properties considered to be related to pavement performance. These properties included dynamic modulus, resistance to deformation and fatigue. Grave-bitume is considerably superior to asphaltic concrete in its load-spreading ability and resistance to deformation but there is an apparent reduction in fatigue resistance when stiffness effects are ignored. The manufacture, laying and compaction of grave-bitume is discussed and attention is drawn to the special techniques required; for example segregation can be a major problem and satisfactory compaction may be difficult to achieve with construction techniques conventionally employed in the United Kingdom.

Grave-bitume was developed for use as a roadbase, sub-base and overlay material. Several sites were visited where grave-bitume had been laid and construction details are given.

Conclusions

1. Traffic, very heavy in terms of both number and magnitude of loads, was partly responsible for the severe deformation occurring in bituminous roadbases in France about 15 years ago. An additional contributory factor was the extensive use of river gravel which did not have the same resistance to deformation expected with crushed rock or crushed gravel itself. The primary objective in developing grave-bitume was to give high resistance to permanent deformation under traffic; this was achieved by providing a strong stone skeleton coated with a hard binder. Binder contents were lower than alternative French bituminous materials.

2. The major difference between construction techniques used for grave-bitume in France and those for dense coated macadam in the UK is in the compaction plant used. Considerable emphasis is placed on the high level of compaction of grave-bitume necessary to obtain satisfactory performance from grave-bitume and 8-10 Mg smooth-wheeled deadweight

rollers are considered unsuitable for compacting this material; the compaction plant used is considerably more powerful and expensive than that normally used in the UK.

3. It appears that grave-bitume is used at the same design thicknesses as the type of roadbase used previously, usually a continuously graded bituminous material or possibly a cement-bound material.

4. The direct adoption of grave-bitume using the compositions employed in France would certainly not result in any reduction in cost in the UK. The grading and binder content of grave-bitume base material are substantially those of dense bitumen macadam used in this country but a harder bitumen and, in practice, a higher filler content are used. Neither of these differences would in themselves directly result in a reduction in cost, indeed there would probably be a small increase. Nevertheless there is evidence that the stiffness is increased significantly without too great a reduction in resistance to fatigue. It therefore appears worthwhile investigating the structural performance of dense coated macadam incorporating these two features to determine whether a reduction in design thickness is possible. The actual cost per unit thickness of this material might be only slightly higher than conventional dense bitumen macadam and there is therefore possibility of an overall reduction in cost.

5. The approach to the specification of grave-bitume in France is considerably different from that of dense bitumen macadam in the United Kingdom; French engineers have considerable freedom to modify the recommended gradings and compositions given in a centrally issued Directive[1], to suit local materials and traffic conditions. The Directive is not in fact a "specification" but is more a "guide" to the types of mixes that will give satisfactory performance. Within the limits set down in the Directive engineers select the particular composition which will behave most satisfactorily with local materials and traffic conditions. At the start of large jobs this would require a selection of mix composition and testing of the materials by the Duriez test to establish that a proper balance had been obtained between performance requirements, ease of manufacture, and low cost. Once the composition has been so selected the control of the material appeared to be certainly no more onerous than in the United Kingdom and indeed was possibly less. This difference in approach to some extent appears to be a result of the range of climates and materials that exist throughout a country the size of France. However, it also appears to be partly a result of the greater involvement of Departmental (ie County) engineers in the choice and specification of materials and techniques within their particular locality.

REFERENCE

1. MINISTERE DE L'AMENAGEMENT DU TERRITOIRE DE L'EQUIPEMENT, DU LOGEMENT ET DU TOURISME. Directive pour la realisation des assises de chaussées en grave-bitume et sables-bitume, 1972.

The study tour described in this Report formed part of the programme of co-operative research between the Pavement Design Division (Highways Department) of the Transport and Road Research Laboratory, the Asphalt and Coated Macadam Association, the British Tar Industry Association and the Refined Bitumen Association.

If this information is insufficient for your needs a copy of the full report, SR 242, may be obtained on written request to the Library, Transport and Road Research Laboratory, Old Wokingham Road, Crowthorne, Berkshire.

TRANSPORT and ROAD
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SUPPLEMENTARY REPORT 242

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K R Peattie (Asphalt and Coated Macadam Association)
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ABSTRACT

The Report gives background information about the development in France of grave-bitume, a roadbase material with high resistance to permanent deformation under traffic. The required properties are obtained by providing a strong aggregate matrix coated with a hard binder. The quantity of binder used is less than that for alternative French bituminous materials. The method of determining the mixture composition is described and the techniques involved in laying and compacting grave-bitume discussed; in France considerable emphasis is placed on the high level of compaction necessary to obtain satisfactory performance and the compaction plant used is considerably more powerful and expensive than that normally used in the United Kingdom.

Details are given of the construction at three sites where grave-bitume was used as a roadbase or overlay material. The cost per unit thickness of grave-bitume is certainly not less than that of dense roadbase macadam used in UK but there is evidence from laboratory studies to suggest that its structural performance may be better; there is potential for incorporating some of the essential features of grave-bitume in the development of improved dense coated macadams.

1. INTRODUCTION

Grave-bitume, a dense-graded bituminous material similar in some respects to the dense bituminous macadam used in the United Kingdom, but incorporating a stiffer binder, has been developed in France over the last decade primarily for use on heavily trafficked roads. Its reported success was of particular interest to the co-operative research group formed in 1975 by Asphalt and Coated Macadam Association, British Tar Industry Association, Refined Bitumen Association and the Transport and Road Research Laboratory to carry out research to improve the performance of bituminous roadbase and base-course macadams in relation to their cost. Because it proved difficult to obtain a proper appreciation of the characteristics and performance of grave-bitume from the limited published literature alone a visit was made to France by the three authors, all members of the Steering Committee of the research group; the aim of the visit was to make a more detailed assessment of the potential of grave-bitume for use in its present form as a base material in the United Kingdom or to provide ideas of possible use in the development of improved dense macadams in the programme of the research group.

The visit included a meeting with staff of Laboratoire Central des Ponts et Chaussées (LCPC) at Orly, Paris, and bituminous construction involving grave-bitume was observed at several sites.

2. CHARACTERISTICS OF GRAVE-BITUME

During the meeting with LCPC staff, background information was obtained about the development of grave-bitume including details of determining the composition of the mixture; the techniques involved in laying and compacting grave-bitume were then discussed.

2.1 *The development of grave-bitume*

One of the main points of interest of the study visit was the reason for creating grave-bitume. In the early sixties bituminous roads in France were in a critical condition because of the occurrence of ruts; deformation of the bituminous surfacing contributed to these ruts but the main cause was deformation in the bituminous roadbase. At that time, the bituminous bases designed using the Duriez test[1] contained about 5 per cent to 5.5 per cent bitumen of 80/120 penetration and had a filler content of 3 per cent to 4 per cent. Rutting occurred with all types of aggregate but was particularly severe with the commonly used uncrushed gravel aggregate. The large amount of deformation was attributed to two causes; the use of bituminous materials to a much greater depth than was previous practice and a considerable increase in traffic loading and its intensity. There is considerable difference in statutory axle loadings between France and the UK but it is doubtful if this would be enough to account for the apparently much greater difference in the traffic damaging effect. There is however a greater loading of the French vehicles[2]; over some 30 weighbridges in France the loading is equivalent to about 152 standard 80 kN axles per 100 commercial axles compared with a typical figure of about 50 for motorways in the UK.

During this period when bituminous roads in France were in a critical condition roadbases of cement-bound aggregate and aggregate containing granulated slag were also used and both these materials gave pavements substantially free from rut formation. Consequently, by about 1967 most of the roadbases being constructed in France were of these two materials; efforts were then concentrated on developing an acceptable alternative base of bituminous material.

In developing the material first priority was therefore given to ensure adequate resistance to deformation; other requirements were good resistance to fatigue and the ability to lay the material satisfactorily using existing techniques. Factors that were found important in improving resistance to deformation in relation to materials then in current use were:

A lower bitumen content of about 3.5 per cent.

A greater proportion of crushed aggregate in the mix; uncrushed gravel aggregate was previously employed.

A higher filler content of about 7 per cent.

A harder bitumen of 40/50 penetration.

LCPC, having determined as a result of laboratory tests that grave-bitume was capable of giving adequate resistance to deformation and to fatigue, then carried out a series of field trials to ensure that grave-bitume to the compositions determined could be satisfactorily manufactured and laid under conventional conditions.

When these field trials had been successfully completed grave-bitume was used increasingly in France and by 1973 some 10 M tonnes had been laid as bases in new construction and also in overlays for strengthening purposes. The grave-bitume is almost always covered with a layer of asphaltic concrete wearing-course.

2.2 *Composition of grave-bitume*

The composition of suitable mixes is described in the Directive[3] which is not a contractual document in the sense that British Specifications usually are; it gives guidance to the engineer (usually a member of the French Roads Administration) responsible for determining a suitable composition to use, having regard to the materials that are locally available. There is considerably more variation in the type of contract specifications employed in France than in the United Kingdom. At one extreme the Administration draws up a mix composition with which the contractor must comply and for which he is often supplied with, not only all aggregates, but also binders. At the other is the specification in which the Administration lays down certain final mechanical and physical properties that the material on the road must have; the selection of the materials and the determination of their combination are then left to the contractor.

The range of material composition given in the Directive was determined from the results of laboratory experiments and road trials. The 'optimum' composition for a particular contract is determined primarily by results obtained with a simple mechanical test, but some consideration is also given to more fundamental laboratory tests; these are described later. It is claimed that this approach enables better use to be made of local aggregates to suit local conditions. The main features of the composition of the material described in the Directive are given below.

2.2.1 Aggregates: Grave-bitume may contain gravel aggregate or crushed rock. However a high proportion of the aggregate must be crushed, the exact amount depending on the amount of traffic; the maximum size of aggregate is normally 20mm but can be 31.5mm when crushed rock is employed or when the layer thickness exceeds 200mm. Aggregate of maximum size 40mm is only considered when grave-bitume is laid as a sub-base.

The aggregate gradings are shown in Figures 1 and 2 for 31.5mm and 20mm maximum-size grave-bitume base material. There are two gradings for each size, 'grenue' and 'semi-grenue'. The layer thickness determines the selection of the appropriate grading; the grenue grading, the coarser of the two, is not recommended for layers thinner than 150mm which are typical of those laid in the UK. Figures 1 and 2 also show gradings for 28mm dense bitumen macadam base[4] and 20mm dense bitumen macadam base-course[4] respectively for comparison with the grave-bitume gradings. The semi-grenue gradings, used for layers thinner than about 150mm, are close to the corresponding dense coated macadam gradings but a much narrower range of filler content is permitted. In the UK the filler content of dense coated macadam would normally be less than that permitted for grave-bitume roadbase material. When comparing grave-bitume with British materials it must be remembered that the curves shown in Figures 1 and 2 for grave-bitume do not correspond to grading envelopes but indicate the range within which the target or 'optimum' grading should be.

2.2.2 Bitumen: A hard bitumen, 40/50 penetration, is normally used although for layers of thickness less than 150mm a 60/70 penetration binder can be used in relatively cold conditions and when traffic is light.

The binder content, determined using a standard laboratory test, is normally about 3.5 per cent for layers of thickness greater than 200mm but for layer thicknesses typical of those in the UK (less than 100mm) the binder content may be increased by about 1 per cent. The binder content is increased by about 10 per cent when the aggregate is slag.

The acceptable range of binder content for a particular aggregate grading is determined by calculating the specific surface of the aggregate and relating binder content to this by a standard formula. The 'optimum' value is selected after considering the results of a standard laboratory test described below.

2.2.3 Standard laboratory test for determining mixture composition: The exact composition of the mixture to be used is determined with the aid of a simple mechanical test the basis of which is the Duriez test[1]. To use this test with aggregates of maximum size 20mm or greater the dimensions of the standard cylindrical mould are increased by 50 per cent so that the diameter and height are then 120 and 150mm respectively. Samples are compacted by a press in which a pressure of 16 kN/m^2 is maintained on the sample for 5 minutes. The resistance to axial deformation is then measured on two sets of samples, the second set after immersion in water at room temperature. The samples are compressed at a constant rate of deformation and the maximum load applied indicates the resistance to deformation. Adhesion of binder is indicated by the ratio of resistance to compression before and after immersion.

The exact composition of material is selected after considering the results of the Duriez test. Requirements are laid down for resistance to compression and immersion-compression ratio and the maximum acceptable void content of the Duriez samples is 12 per cent. The degree of compaction on site would normally exceed that of laboratory prepared samples and the void content should then be less than 10 per cent; most dense coated macadam materials laid in the UK would comply with this requirement[5]. According to the Directive this method of selecting the mix composition should guarantee a material of good quality but account may also be taken of results of more fundamental laboratory studies described later; however numerical requirements have not as yet been established for the test involved in these studies.

2.3 *Laboratory studies*

Laboratory studies were used in the development of grave-bitume to determine the structural properties considered to be related to pavement performance. The following is a brief description of some of the laboratory tests that were used.

2.3.1 Laboratory compaction using the gyratory compactor: The equipment is a modified version of that designed by the Corps of Engineers at Vicksburg USA[6]. This compactor simulates the kneading effect of pneumatic tyres often used for compaction on the material and it enables the changes in void content to be related to compactive effort applied in order to give a laboratory measure of the compactability of the material.

The cylindrical sample is subjected to vertical and shear stresses simultaneously in the machine and the axis of the sample describes the shape of a truncated cone with an angle of tilt of 1^{o}. Angles of tilt greater than this can be used in the original Vicksburg machine but were found to give excessive shear action in the mixture. The vertical load applied is 600 kN/m^2. There is a linear relation between level of compaction, defined as (1 - void content/100), and the logarithm of number of rotations. Both this relation and that between the shear resistance and level of compaction are determined in the test.

2.3.2 Resistance to deformation: Although the usual role of grave-bitume is not that of a wearing-course material its resistance to wheel tracking is nevertheless considered important. This is tested on slabs of surface area 500mm x 180mm trafficked by a pneumatic wheel at a rate of 1 pass/sec. The wheel load is maintained at 5 kN with a tyre pressure of about 600 kN/m^2 and up to about 300,000 passes are made at a standard temperature of 50°C. It is possible to vary the type of wheel, the tyre pressure, the applied load, the test temperature and the stiffness of the supporting layer.

Typical results obtained in an earlier test made at 35°C are shown in Table 1. Serious deformation took place in the basecourse consisting of typical asphaltic concrete material after it was laid in 1963. Laboratory tracking tests made on this asphaltic concrete material and on typical grave-bitume roadbase material reveal the superior resistance to deformation of the latter material; at a test temperature of 35°C the number of passes of the wheel to produce a 3mm rut was 200 times greater for grave-bitume than for asphaltic concrete.

TABLE 1

Comparison of rates of deformation of grave-bitume and asphaltic concrete at 35°C

	Asphaltic concrete (basecourse laid in 1963) at heavily trafficked site	grave-bitume (laboratory compacted specimens)
Bitumen content (per cent by weight)	4.6	3.8
Filler content (per cent by weight)	4	7
Angularity of gravel aggregate	partly crushed	well crushed
Bitumen penetration	80/100	40/50
Thickness	120mm	120mm
Surface rut depth	9mm after 1 year 2mm/year thereafter (basecourse accounted for 2/3 of this)	-
Number of passes in tracking machine to produce 3mm deformation	1500 passes	300,000

2.3.3 Resistance to fatigue: Flexural loading, sinusoidal in form and of frequency 30 Hz, is applied to trapezoidal specimens at a temperature of 10°C. The specimens are 250mm in length and varying in width from 75mm at the base, which is fixed, to 25mm at the point of load application. They are prepared by slicing laboratory-compacted slabs 1m x 0.5m x 70mm. Three machines can operate simultaneously, each containing 4 trapezoidal specimens driven by one motor. The bulk of the testing is done at a constant level of strain, the failure point being defined as that at which the force necessary to maintain the constant displacement has fallen to half its original value. To establish a strain/fatigue-life relationship, 10 specimens are tested at each of 3 levels of strain. Typical results given in Figure 3 show that the compaction of grave-bitume is critical; Curve 1 material (grave-bitume) with 8 per cent voids has a markedly superior resistance to fatigue than Curve 3 material with 14 per cent voids. Curves 8 and 9 show the results for typical asphaltic concretes. The resistance to fatigue is considered by LCPC to be normally lower for grave-bitume than asphaltic concrete as suggested by the results shown in Figure 3 but absence of information about composition and level of compaction of the "typical" asphaltic concrete specimens precludes detailed comparison.

Tests are also occasionally conducted at constant stress. Research is continuing into the effect of type and quantity of filler on fatigue performance.

2.3.4 Dynamic modulus: Repeated-loading tests, in flexure, have been employed to evaluate the dynamic modulus of grave-bitume in relation to the dynamic modulus of asphaltic concrete. Tests were made over a frequency range of 1 to 30 Hz and temperature range of - 10°C to 40°C; results are shown in Figure 4 where the stiffness modulus is plotted against reduced frequency at 10°C. Linear visco-elastic behaviour allows the use of a shift factor 'a' to transfer the reduced frequency scale from 10°C to any other temperature.

At low temperatures there is little difference between the moduli of grave-bitume and asphaltic concrete whereas at higher temperatures the modulus of asphaltic concrete is markedly lower than that of grave-bitume. The dynamic modulus of dense bitumen macadam measured[7] by uniaxial loading at 25°C and 1 Hz is about 5 times smaller than the corresponding value for grave-bitume; this difference may be expected because of the lower penetration of bitumen in grave-bitume. Another interesting feature about the results in Figure 4 is the effect of void content shown by Curves 5(1) and 5(2); this is in good agreement with the effect of void content on the dynamic modulus of dense bitumen macadam[7].

2.4 *Structural implications of the laboratory performance data*

Simple calculations characteristic of the pavement as a simple two-layer linear elastic system have been made to compare the relative thicknesses of grave-bitume and asphaltic concrete necessary to give the same values of indicators generally considered as being related to structural performance: vertical stress at formation level defining the load-spreading ability of the pavement, horizontal tensile strain at the bottom of the bound pavement layer as the parameter generating fatigue. These calculations suggest that a roadbase of grave-bitume should be considerably thinner than an asphaltic concrete roadbase whichever failure criteria applies: 40 per cent thinner from vertical stress considerations at formation level and 20 per cent thinner if fatigue performance is critical. In substituting grave-bitume for asphaltic concrete, the consequence of stiffening in reducing the strain level more than offsets the apparent reduction in resistance to fatigue indicated by the change in the strain/fatigue-life relationship. Many assumptions are made in these calculations and details of the composition and compaction of the materials concerned are not known; the results of the calculations must therefore be treated with caution. No comparison of relative deformation behaviour was possible other than the general indications provided by the wheel-tracking tests described in 2.3.2.

A more detailed comparison between the dense coated-macadam roadbase materials currently specified in the UK and the grave-bitume type of material containing a harder binder would clearly be useful but data of the stiffness, fatigue and deformation behaviour of these materials, which can be directly compared, are first required. The little evidence currently available suggests that the stiffness of dense bitumen macadam to the present specification is similar to that of asphaltic concrete and it would therefore be considerably less stiff than grave-bitume.

3. MANUFACTURE, LAYING AND COMPACTION

3.1 *Mixing*

The aggregate of grave-bitume is rather more difficult to coat because of the relatively high filler content, low binder content and hard bitumen. A higher mixing temperature is used to compensate for the harder bitumen but the temperature of 40/50 pen material when leaving the plant must not exceed 160°C. It is considered that the use of this grade of binder may rule out manufacture on batch-heater units and mixing would probably be confined to hot asphalt plants.

3.2 *Segregation*

In laying the material, segregation can be a major problem and for this reason the maximum size of aggregate is normally 20mm. The following modifications have sometimes been made to the paving operations:

(a) a modified screw is used on some paving machines to reduce the tendency of larger material to be displaced to the edges of the laid width;

(b) a baffle is positioned ahead of the screw to prevent larger material dropping to the bottom of the layer;

(c) the sides of the paver hopper are lifted as infrequently as possible because this has been found to give badly segregated areas.

3.3 *Thickness of lift*

The customary lift-thickness of grave-bitume is much greater than the lift-thicknesses employed for base materials in the UK; the thickness of grave-bitume is often 200mm or more. The main advantage of thick-lift construction is considered to be the better final compaction achieved and this outweighs problems of poor level-control sometimes associated with this type of construction. A high production capacity is essential even for a low spreading rate of 1m/min. If thin lifts are laid, the compaction may be poor and consequently the riding quality deteriorates through further compaction under traffic; British experience with thick-lift construction[8] has been quite different but great emphasis is placed by the French on the difference between grave-bitume and other bituminous materials. Evidence is available which shows that an increase in thickness from 170 to 220mm of grave-bitume results in a 2 per cent increase in compaction.

The slower rate of cooling of thick lifts enables the normal period of laying to be extended so that grave-bitume can be laid, say, between 15 February and 15 December unless extreme weather conditions occur. The minimum thickness of grave-bitume normally laid is about 100mm. Thin layers of grave-bitume are however sometimes used; they require a higher binder content, the use of the 'semi-grenue' grading and possibly 60/70 pen bitumen in cold weather.

3.4 *Longitudinal joints*

To avoid difficulties with longitudinal joints LCPC recommend the use of a paver capable of laying the full width in one pass wherever possible. This can, of course, give rise to difficulties in supplying sufficient quantities of material to keep the paver moving at a satisfactory speed. This is particularly true for construction in thick lifts. Where the laying has to be done in two widths, the use of two pavers operating in echelon is recommended so that a roller can compact the material in the joint as rapidly as possible. When this is not possible, the method employed is to lay material with one pass of the paver for a length of some 200m and then to return to the start of that section and lay the adjoining width of material while the material at the joint is still hot. A primer is applied to joints.

3.5 *Compaction*

For compaction of grave-bitume conventional smooth-wheeled deadweight rollers are considered by the LCPC to be unsuitable; vibrating rollers, pneumatic-tyred rollers or a combination of these two are normally used. A high level of compaction is considered absolutely essential and this is used to justify the use of more powerful and expensive plant than normally employed in the UK.

The use of pavers equipped with heavy vibrating screeds is recommended; the following are typical weights of rollers that are used: 3 to 5 Mg per wheel for pneumatic-tyred rollers and 3 to 5 Mg/m width of vibrating roll. The exact details of equipment used depends on circumstances eg the degree of crushed aggregate used and the thickness of layer. Research is in progress at the Centre d'Etudes Techniques de l'Equipement de Rouen, to determine the optimum modes of operation of vibrating rollers.

To allow for the higher viscosity of binder in grave-bitume, the laying temperatures are correspondingly higher than those for dense bitumen macadam containing 100 pen bitumen; this has not produced difficulties in practice.

3.6 *Workability*

In all bituminous materials there is always a balance to be struck between workability and resistance to deformation. The French consider that the balance is particularly critical in the case of grave-bitume. A high level of compaction is essential if adequate resistance to rut formation is to be obtained. However, if an attempt is made to achieve high stability by the use of hard bitumens, high filler contents and large quantities of crushed aggregate, this can lead to a mix which cannot be laid and adequately compacted. On the other hand, mixes having good workability which can readily be compacted to a high density may have inadequate resistance to deformation. The emphasis placed by the French on good compaction of grave-bitume stems from their views on this critical balance.

3.7 *Contractual operations*

The Directive is essentially a guide to the LCPC engineers carrying out the design of mix. At the start of the contract they establish a suitable composition having regard to the aggregates and binders which they supplied or which the contractor had available; thereafter the composition of the mix is unchanged during the contract. At the beginning of the operations, a test section several hundred metres long is laid using the equipment which the contractor proposes to employ. Checks are made of the density obtained in this material and this enables the LCPC to prescribe the laying and compaction procedure to be followed. Primary control is then obtained by checking the methods employed, with only a small amount of end-result checking, normally done with nuclear instruments. Control of quality of the mixture is achieved by checking the supply of materials at the plant and ensuring satisfactory operation of the plant.

4. THE USE OF GRAVE-BITUME

Grave-bitume was developed for use as a roadbase, sub-base and overlay material. During the visit to France several sites were visited where grave-bitume had been laid. Details of these sites are as follows.

4.1 *New construction on Autoroute A11 at Illiers between Chartres and Le Mans*

This section of autoroute is being constructed by SRC (Colas), a company appointed by COFIROUTE who were responsible for providing an autoroute giving satisfactory service for 35 years. The choice of design, the composition and the construction methods are therefore largely the responsibility of COFIROUTE and its appointed companies.

Grave-bitume was supplied from a 350 Mg/hr continuously operating plant and laid to a thickness of about 180mm in a single lift over a stabilised sub-base. The grave-bitume consisted largely of crushed flint-gravel aggregate, 0/25mm size, with 4 per cent bitumen, 40/50 penetration. The filler content, 4.5 per cent, was lower than that recommended in the Directive; this indicates the freedom that French engineers have to modify the composition of the material to suit local conditions. The material was laid to a width of 8m with a Titan 410S paver equipped with vibrating screed. There was little lateral movement at the edges of the lift when rolled by a Ray Go 404 vibrating roller (9Mg) followed by an Isopactor pneumatic tyred roller (25Mg overall weight). The temperature of the material on leaving the paver was high, about 150^{o}C, but apart from the grade of bitumen the material was very similar to a British dense coated macadam. It was noticeable that the flint-gravel aggregate was not particularly well coated but this was claimed to be satisfactory for roadbase layers. Asphaltic concrete was laid as surfacing material. Deflection measurements were made on top of each layer during construction.

4.2 *Overlay on D39 road at Beaumont, 26km north of Le Mans*

A section of the D39 road leading out of Beaumont was being widened and overlaid with grave-bitume. The surface of the old road was cracked and somewhat deformed in places. It was being strengthened and widened to restore it to a satisfactory condition and to provide an alternative route for traffic on the RN138 while that road was being repaired. The traffic anticipated under the by-pass situation was about 4,000-5,000 vehicles per day in both directions with about 25 per cent commercial vehicles (commercial vehicles in France are defined as those with a pay-load of 5 Mg or more).

The grave-bitume used crushed-rock aggregate of 14mm size. In this area crushed rock from quarries is commonly used for road construction. The grave-bitume overlay was being laid to a compacted thickness of 70mm and a width of 3m. Binder content was 4.5 per cent and the filler content about 7 per cent. The relatively small size of the large aggregate was because of the limited thickness of overlay being applied. Binder grade was, as usual, 40/50 penetration.

Where widening of the road was required this was built up with 300mm of dry-bound aggregate and then a regulating course was applied to provide a suitable laying surface for the grave-bitume roadbase. This was again being laid at a temperature of 150/160°C and it was noticeable that coating of the crushed-rock aggregate was satisfactory. Compaction was being carried out by two rollers; one having one vibrating steel roll and pneumatic-tyred wheels on the second axle (14 Mg Richier CV 415), the other a smooth-steel-wheeled 8 Mg Richier roller used for finishing. The composite roller was being used with the pneumatic-tyred wheels next to the paver and the actual amount of vibration being employed was quite small, apparently because the overlay was so thin.

The actual rolling pattern had been established by laying a short test section, carrying out a series of tests and analysing the density of the materials obtained, this analysis being carried out by the Angers Regional Laboratory of Ponts et Chaussées. At the site at Beaumont some 20 passes of the large roller without vibration were applied, then 4 passes with vibration followed by the smaller finishing roller. The grave-bitume was being laid in two widths and sections of not more than 300-400m were laid on one side of the road before the paver returned to apply the layer in the adjacent lane. Emulsion tack-coat was applied to the existing road surface before the grave-bitume was applied.

The work was experimental in the sense that, instead of applying the usual wearing-surface of asphaltic concrete, surface dressing only was to be applied.

4.3 *Recently constructed trial lengths of grave-bitume overlays on RN 158, south of Le Mans*

The traffic here was similar to that in Beaumont, ie about 5,000 vehicles per day in each direction with about 15 per cent commercial vehicles. Several sections had been overlaid in grave-bitume with thicknesses ranging from 120 to 200mm. The grave-bitume in some sections contained crushed-rock aggregate, which is normally used in that area, whereas in others a proportion of cheaper crushed gravel was used. The grading in both cases was typical of that shown in Figure 2 for 20mm 'semi-grenue' material and the bitumen content (40/50 penetration) was 4.3 per cent. In the particular sections that were inspected grave-bitume containing a proportion of crushed gravel had been laid 2 months previously and this had been sealed with an application of cut-back bitumen (0.5 ℓ/m^2) and 2-4mm aggregate (5 ℓ/m^2). These sections were shortly to receive a double surface dressing, as follows: 1.1 ℓ/m^2 of cut-back bitumen with 9 ℓ/m^2 of 10/14mm aggregate followed by 0.9 ℓ/m^2 of cut-back bitumen with 7 ℓ/m^2 of 4/6mm aggregate.

5. CONCLUSIONS

1. About 15 years ago severe deformation was occurring in bituminous road bases in France. Traffic, very heavy in terms of both number and magnitude of loads, was partly responsible. An additional contributory factor was the extensive use of river gravel which did not have the same resistance to deformation expected with crushed rock or crushed gravel itself. The primary objective in developing grave-bitume was to give high resistance to permanent deformation under traffic; this was achieved by providing a strong stone skeleton coated with a hard binder. Binder contents were lower than current alternative French bituminous materials.

2. The major difference between construction techniques used for grave-bitume in France and those for dense coated macadam in the UK is in the compaction plant used. Considerable emphasis is placed on the high level of compaction necessary to obtain satisfactory performance from grave-bitume and 8-10 Mg smooth wheeled deadweaight rollers are considered unsuitable for compacting this material. The compaction plant used is considerably more powerful and expensive than that normally used in the UK.

3. It appears that grave-bitume is used at the same thicknesses as the type of roadbase used previously, usually a continuously graded bituminous material, or possibly a cement-bound material.

4. The direct adoption of grave-bitume using the compositions employed in France would certainly not result in any reduction in cost if applied in the UK. The grading and binder content of grave-bitume base material are substantially those of dense bitumen macadam used in this country but a harder bitumen and, in practice, a higher filler content are used. Neither of these differences would in themselves directly result in a reduction in cost, indeed there would probably be a small increase. Nevertheless there is evidence that the stiffness is increased significantly without too great a reduction in resistance to fatigue. It therefore appears worthwhile investigating the structural performance of dense coated macadam incorporating these two features to determine whether a reduction in design thickness is possible. The actual cost per unit thickness of this material might be only slightly higher than conventional dense bitumen macadam and there is therefore a possibility of an overall reduction in cost.

5. The approach to the specification of grave-bitume in France is considerably different from that of dense bitumen macadam in the United Kingdom; French engineers have considerable freedom to modify the recommended gradings and

compositions given in a centrally issued Directive, to suit local materials and traffic conditions. The Directive is not in fact a 'specification' but is more a 'guide' to the types of mixes that will give satisfactory performance. Within the limits set down in the Directive engineers select the particular composition which will behave most satisfactorily with local materials and traffic conditions. At the start of large jobs this would require a selection of mix composition and testing of the materials by the Duriez test to establish that a proper balance had been obtained between performance requirements, ease of manufacture, and low cost. Once the composition has been so selected the control of the material appeared to be certainly no more onerous than in the United Kingdom and indeed was possibly less. This difference in approach to some extent appears to be a result of the range of climates and materials that exist throughout a country the size of France. However it also appears to be partly a result of the greater involvement of Departmental (ie County) engineers in the choice and specification of materials and techniques within their particular locality.

6. ACKNOWLEDGEMENTS

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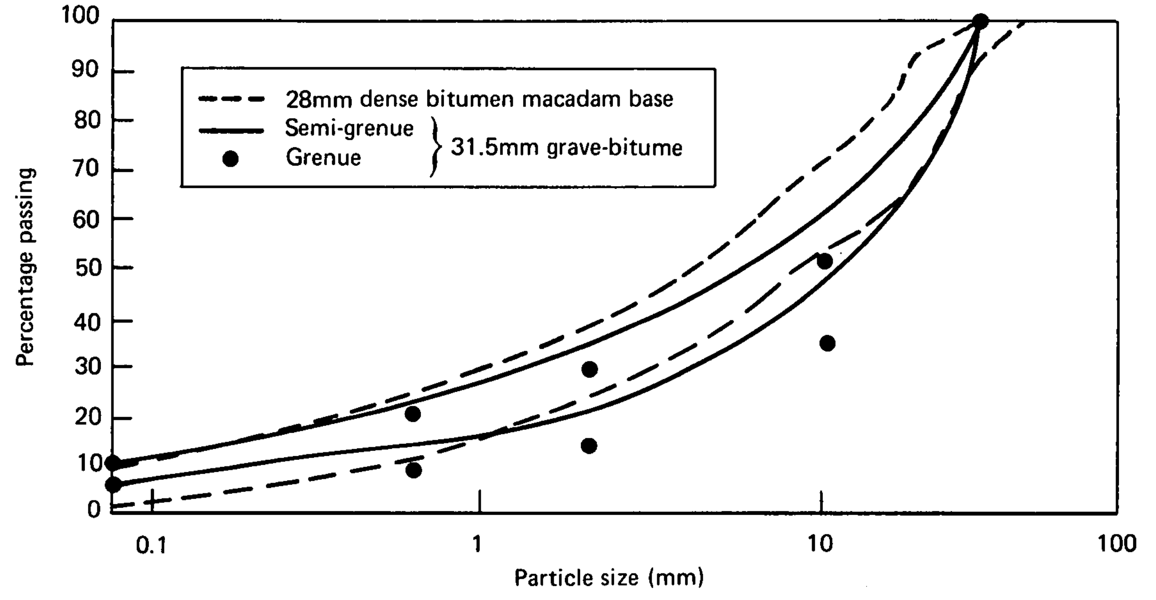

Fig. 1 RANGE OF TARGET GRADINGS OF 31.5mm GRAVE–BITUME COMPARED WITH THE GRADING ENVELOPE OF DENSE BITUMEN MACADAM

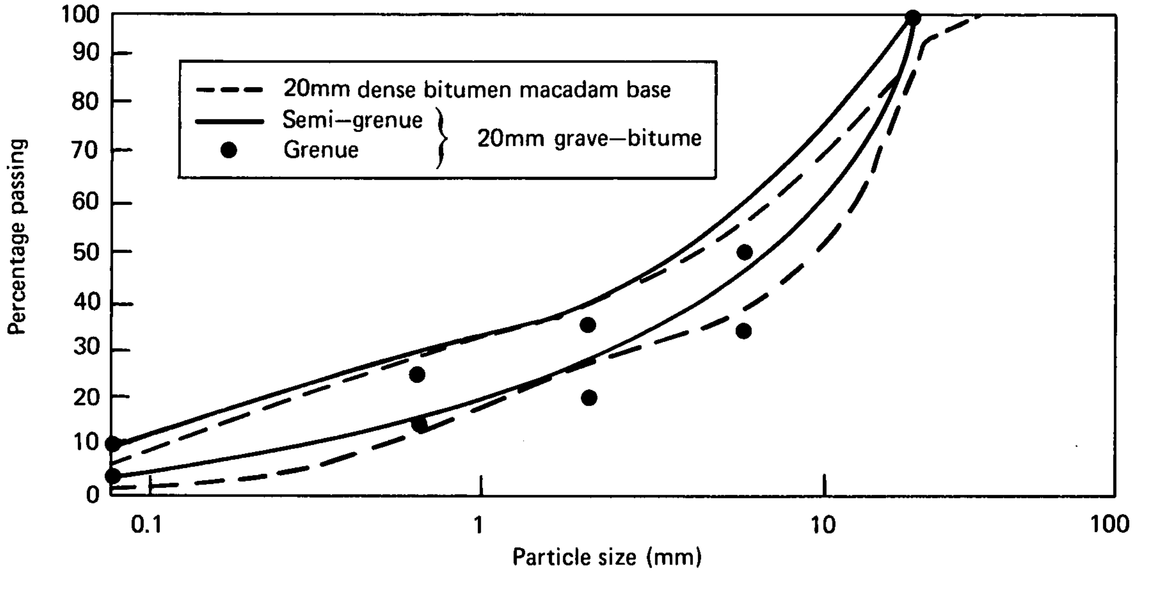

Fig. 2 RANGE OF TARGET GRADINGS OF 20mm GRAVE–BITUME COMPARED WITH THE GRADING ENVELOPE OF DENSE BITUMEN MACADAM

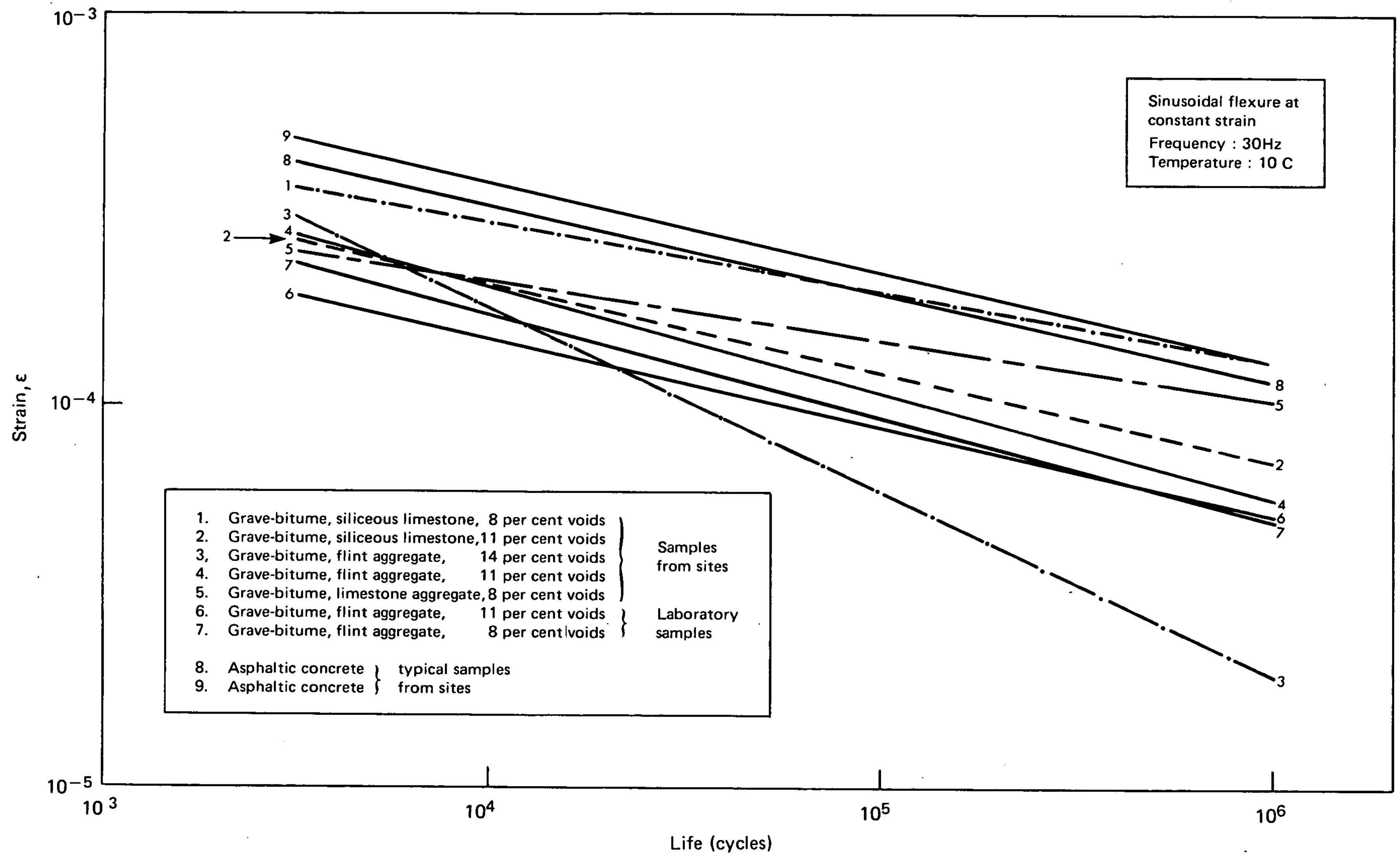

Fig. 3 FATIGUE PERFORMANCE OF GRAVE–BITUME AND ASPHALTIC CONCRETE

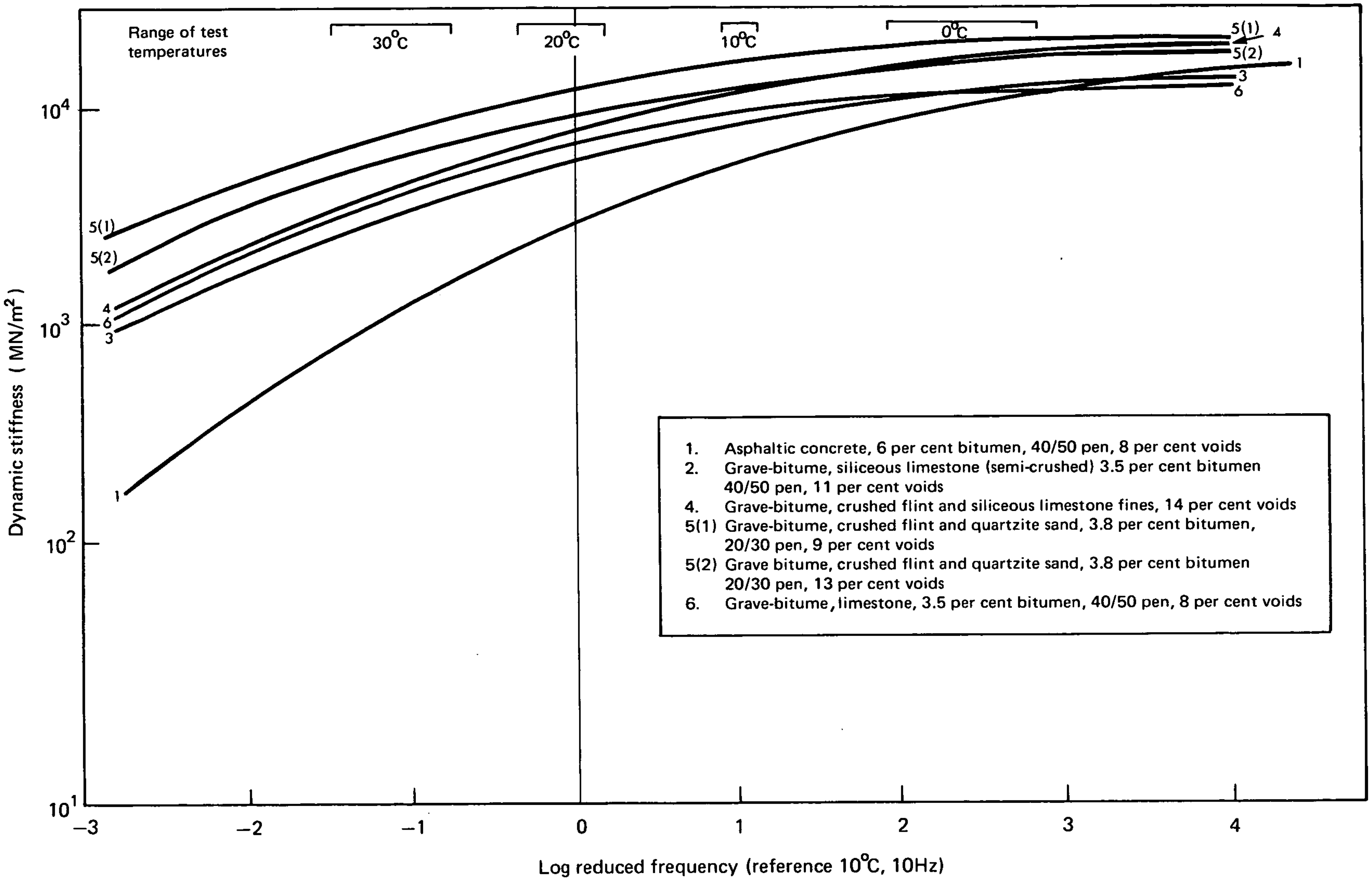

Fig. 4 VARIATION OF DYNAMIC STIFFNESS OF GRAVE-BITUME AND ASPHALTIC CONCRETE WITH REDUCED FREQUENCY

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ABSTRACT

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Details are given of the construction at three sites where grave-bitume was used as a roadbase or overlay material. The cost per unit thickness of grave-bitume is certainly not less than that of dense roadbase macadam used in UK but there is evidence from laboratory studies to suggest that its structural performance may be better; there is potential for incorporating some of the essential features of grave-bitume in the development of improved dense coated macadams.

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