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ADVANCES IN FOAMED BITUMEN TECHNOLOGY

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Abstract

Stabilising roads with foamed bitumen is now an old technique that has generally been applied to fine, poorly graded materials in many parts of the world including South Africa. In the U.K. two new techniques using foamed bitumen have been introduced - FOAMSTAB in situ recycling, FOAMSPRAY surface dressing.

The paper will describe what these techniques are, how they have been introduced, the design procedure, and the benefits and problems that have occurred in use in the U.K.

FOAMSTAB recycling has the ability to produce in-situ full depth bituminous pavements of equivalent strength to new hot mix pavements without the need for removal and replacement of any existing material.

In the U.K. roads have been renewed by FOAMSTAB recycling to save up to one half the cost, two thirds the time and three quarters of the energy needed for traditional remove and replace methods.

FOAMSPRAY applies hot penetration bitumen directly to the road without the need for cut back or emulsified bitumens and has been used in surface dressing in the UK and France with cost and performance benefits.

The Process

The Mobil patented foamed bitumen process involves the injection of cold water under controlled conditions and with certain additives into hot penetration grade bitumen before application through specially designed nozzles and spray bar. The foamed bitumen expands from 10 to 15 times its original volume and when sprayed and mixed into cold moist aggregate a unique mixture is produced. This mix will remain soft and brown until compaction and water migration, after which it becomes harder and blacker and ultimately reaches strengths comparable with hot mix bituminous materials.

The foamed bitumen process had been used for base stabilisation (FOAMSTAB) in the USA, Australia[1], South Africa[2], Norway and now in the UK[3,4].

Based on this experience, the process appears to have many economic environmental and engineering advantages for recycling and reconstruction. It has a wide range of applications from in situ rehabilitation of failing roads through providing new low cost asphalt bases and sub bases to stabilising waterproof working platforms for all classes of road and other paved areas.

FOAMSTAB recycling restores in-situ the structural integrity to road pavements, is rapid in execution and permits early reopening to traffic thus minimising traffic delays. The process also conserves available resources by re-utilising existing road materials and is very energy efficient.

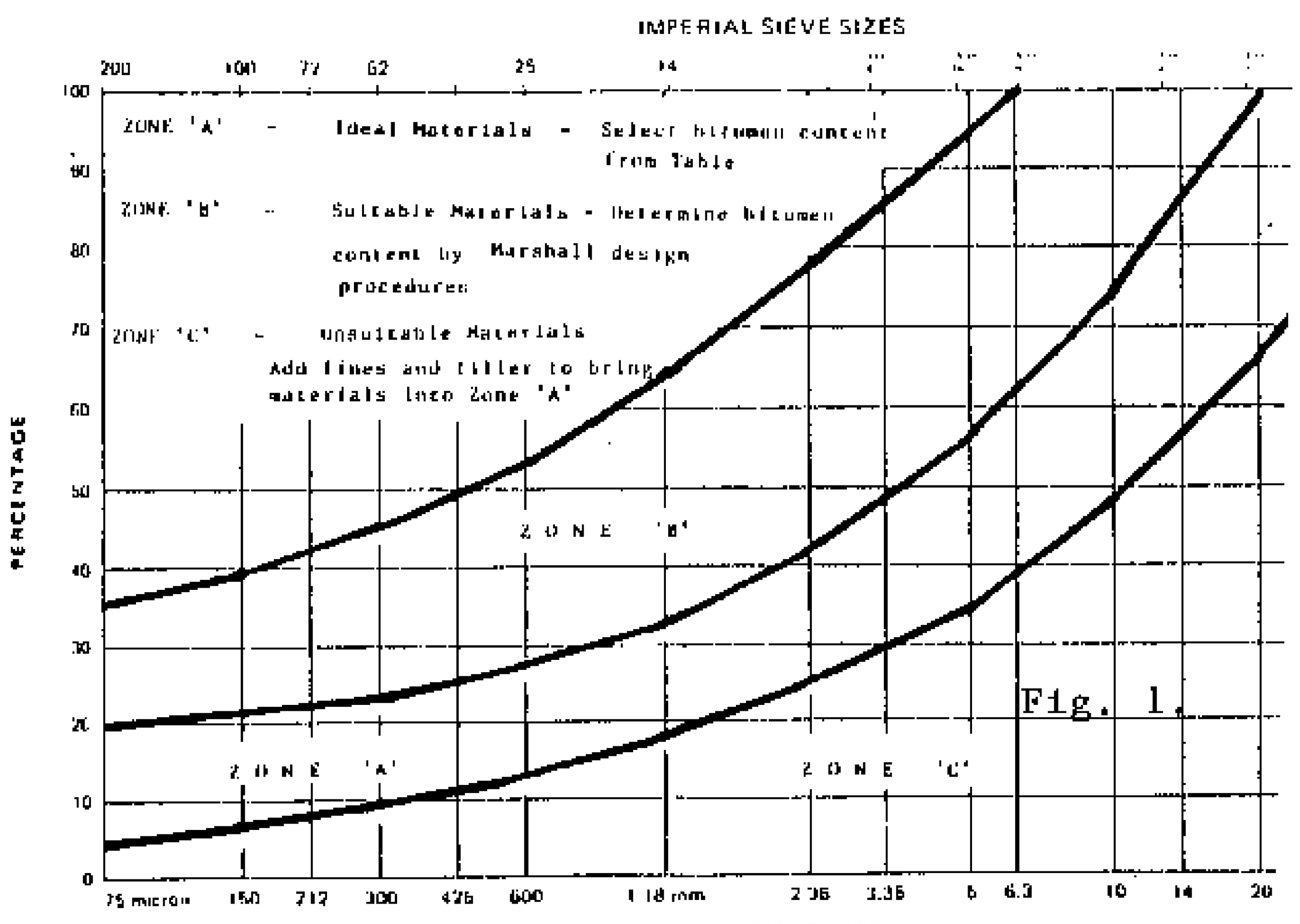

Fig. 1.

Materials

The existing material's suitability for FOAMSTAB can first be checked by reference to the Aggregate Grading Chart, Fig. 1. Materials whose grading after pulverising falls in Zone A have from experience and analysis proved suitable for FOAMSTAB. Zone B are fine graded materials which can be successfully stabilised as long as any clay fractions are modified by treatment with hydrated lime. Zone C are coarse materials lacking in fines and can only be used if selected fine material is added to bring the grading within Zone A particularly at the fine end. Pulverised fuel ash is a very economical material for this purpose if available.

A critical aspect of the grading is the amount passing the 75 micron sieve that is NOT clay. At least 5% and not more than 20% passing 75 micron are the recommended limits for acceptable FOAMSTAB. Where clay or excess moisture is present the addition of 1.0% of hydrated lime is very effective in reducing its influence.

Bitumen

The bitumen contents required for FOAMSTAB are generally proportional to the percentage mass passing the 75 micron sieve, and as a guide vary from 3.5% for materials with 5% passing the 75 micron to 5.0% for materials with 20% passing the 75 micron sieve size. Ideally a full mix design including Marshall Stability, Flow and Quotient, Immersion Strength and Voids in the Mix at various bitumen contents should be undertaken.

The optimum bitumen content is not as clearly defined in FOAMSTAB as in hot mix and good strengths can be obtained over a wide range of bitumen contents. Hence it is not as critical to be accurate with bitumen content and 3.75% ±0.75% would be a typical spec. Normally 200 pen bitumen is the basis of the special foamable bitumen and although other grades can be used it is rarely necessary. Existing bitumen in old recycled material is not considered to be totally active and is only partially included in the total bitumen content. A key element of the tests is measuring Marshall Stability after Immersion in water for 24 hours at 60°C to simulate performance in saturated ground. A Stability after Immersion of at least 3.5kN at 60°C and Marshall Quotients greater than 1.5kN/mm are current acceptance criteria.

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VALIDATION

The process was believed by the UK Department of Energy to be more energy efficient than conventional road maintenance techniques and consequently they awarded a grant to specialist contractors Road Recycling Limited under the Energy Efficiency Demonstration Scheme - a scheme designed to encourage the uptake of novel energy saving technology by awarding grants to offset the technical and commercial risk of being the first to use the new technology.

In order to compare the behaviour of recycled road against conventional reconstructed road, two sections were repaired by excavation and the laying of conventional materials. The monitoring of the trial on Lunedale Road at Dartford in Kent was carried out by W S Atkins Management Consultants, which was responsible for examining the energy saving aspects, and by TRRL which measured the road quality before and after repair.

Monitoring of road quality

The compacted foamed bitumen roadbase had a uniform density (95% of maximum achievable density) throughout the site with only minor variations with depth.

Foamed bitumen cores exhibited a high deformation resistance in universal creep stiffness tests, the measured values being 130% higher than those for HRA cores from the control sections. An early life traffic trial using an 8,160kg "standard axle" confirmed that high deformation resistance. The road rutted to a depth of 1.5mm after 300 passes in 4 hours.

Deflectograph and falling weight deflectometer results were used to determine the effectiveness of the repairs. The results are given in Table 1. It should be noted that after reconstruction the deflections are influenced by the strength of the foundation which becomes progressively stronger from section 1 to section 4. The strength of the foundation also influences the predicted remaining life.

Using an equivalent foundation modulus of 76 MPa as a "standard" foundation, TRRL estimated the expected life of the bound pavement layers to give a true comparison of the effectiveness of recycling as a maintenance treatment. These figures are also presented in Table 2.

Interim Design Curve

Performance data for roads recycled using foamed bitumen are still scarce. Therefore, until more data becomes available TRRL has suggested using the 200 pen life/thickness curve (Figure 2) as an interim design curve for foamed bitumen road bases. The present pulverising limit is 300mm deep and this, when associated with reasonable extrapolation of current data, suggests an overall limit of 2 Msa cumulative traffic. However sections of road carrying the equivalent of 20 MSA and even 50 MSA have been processed and so far are performing satisfactorily.

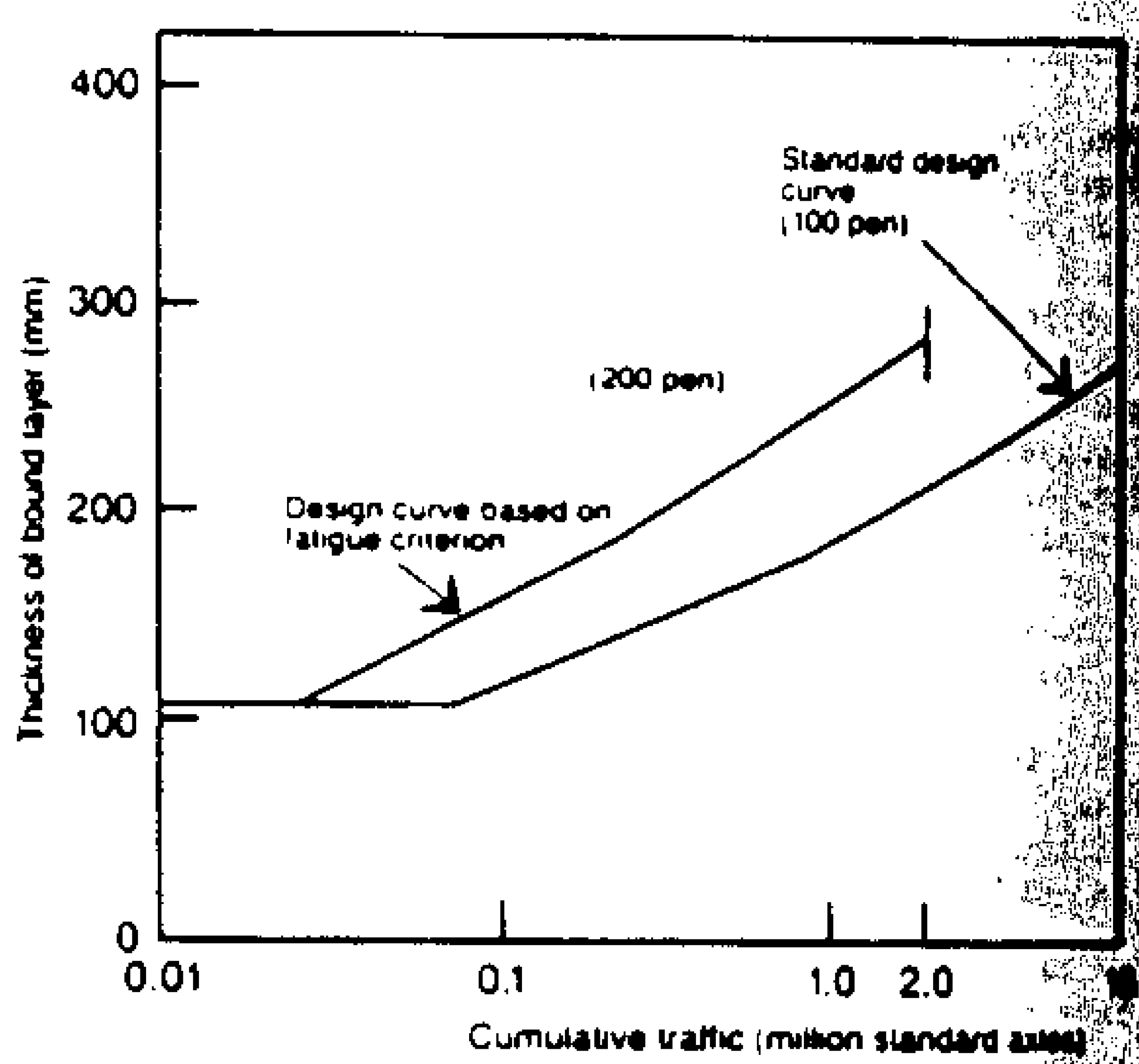


Figure 2.

TABLE 1 - PAVEMENT LIFE, STIFFNESS AND ESTIMATED REMAINING LIFE

Section	Details of Reconstruction and Foundation	Equivalent Foundation Modulus MPa	Equivalent Complex Modulus of Pavement Layers MPa	Deflectograph Before Reconstruction: Measured Deflection (mm)	Deflectograph Before Reconstruction: Remaining Life (msa)	Deflectograph After Reconstruction: Measured Deflection (mm)	Deflectograph After Reconstruction: Remaining Life (msa)	Estimated Remaining Life on standard Foundation 70 MPa (msa)
1	Foamed Bitumen roadbase no lime added strong Foundation	76	2,100	0.76	0.07	0.61	0.34	0.30
2	Foamed Bitumen roadbase lime added strong foundation	122	4,900	0.72	0.15	0.44	0.75	0.30
3	Foamed Bitumen roadbase [illegible]	177	3,300	0.64	0.34	0.29	3.5	0.33
4	HRA roadbase (control) very strong Foundation	185	8,700	0.61	0.50	0.24	7.9	0.3[illegible]

Note: The sections 1 to 4 are equal lengths of road running from east (Section 1) along its distance.

Benefits

When operating in urban areas the speed of construction is an important factor in minimising inconvenience and congestion. Lunedale Road was scheduled to take 8 weeks by conventional methods but was completed in 5.5 weeks. Hold ups were mainly due to under road services rather than the process and normally could have been completed in under 4 weeks. The cost was 75% of conventional repair and the process saved 60% of normal energy needs.

The recycled road has sufficient strength of support light traffic immediately after repair. Furthermore, traffic management is simplified because there is no great difference in level between the working area and the normal running area. Therefore both sides of the road are available to traffic for most of its length during repairs. Access to properties adjacent to the working area can be maintained for residents and emergency vehicles without additional difficulties.

Construction

The specialist plant that contractors Road Recycling Limited employ is a modified Bomag MPH100R Recycler. This machine has the stabilisation rotor blades suitable for loose fine grained materials replaced with a cold planing drum holding hardened steel picks. This drum is capable of pulverising old asphalt and cement treated materials up to an in-situ crushing strength of $15N/mm^2$ (15 MPa) and thoroughly mixing in the foamed bitumen. The machine has an on-board bitumen and water circulating system from which it is fed along a spray bar into expansion chambers which provide controlled conditions for the hot bitumen and the water to mix and foam. The plant is fully computerised to ensure accurate measurements of bitumen and water.

The MPH100R Recycler can work to depths of up to 350mm in a single layer effectively pulverising together the blacktop, (if not recoverable for later hot mix) the roadbase and the subbase layers.

To date most FOAMSTAB layers have been 150mm and 200mm thick but 300mm layers have been successfully processed and compacted in a single layer on two very heavily trafficked road projects.

Following satisfactory compaction the surface can be opened to light traffic within hours on a temporary 'bitgrit' surface until the final wearing surface is constructed.

FOAMSTAB is an in situ recycling process of existing materials and as such the tolerances for quality control must of necessity be wider than those required for traditional methods.

Nevertheless it is a very tolerant material of variations. Its advantages over cement stabilisation is that it is flexible, waterproof and does not crack and the bitumen emulsion stabilisation alternative requires open graded aggregates with a minimum of fines to succeed. Even then excess moisture causes curing problems and the resulting material is less strong than hot mix.

FOAMSPRAY SURFACE DRESSING

This process applies a thick layer (10-20mm) of foamed bitumen to the road collapsing to a 1-2mm layer of bitumen and chippings are applied before full collapse occurs (usually several minutes later).

There is a rapid increase in binder viscosity as the foam collapses thus giving early grip and stability to the layer. It is usually specified as a racked in process where smaller chippings are spread over the main layer of chippings before rolling, thus developing a tight mosaic (e.g. 14mm racked in with 6mm).

Experience has also shown that like other surface dressing binders Foamspray does not work well if the chippings are very dusty. Hence lightly coated (with bitumen) chips have been specified but now Mobil has developed a new chipping treatment called HYDROCHIPS to overcome both dusty and sticky chips.

Design

It was also discovered during the introduction of Foamspray that as many clients wanted the process to replace more expensive hot mix on heavily trafficked roads the existing UK surfacing dressing specifications were inadequate for such locations.

Peter Groth (ex Natal Materials Engineer) working as a consultant to Mobil, developed some more scientific approaches to surface dressing encompassing his South African experience and that of the author. After extensive performance studies a new UK design method was developed with a number of new and previously neglected factors.

These include:

1. Traffic Concentration Factor - Table 2.
2. Chipping Orientation Factor - Figure 3.
3. Traffic Speed/Load Factor - Figure 4.
4. Embedment Factor/ Net Spray Rate - Figure 5.

Figure 5 relates the embedment of a 19mm ball by 3 blows of a Marshall hammer (which is equivalent to the standard UK Coal Tar Association needle probe value) to the net spray rate for 10 mm chips (Ald 6.0 mm) for different traffic counts. The traffic counts are adjusted by the above factors.

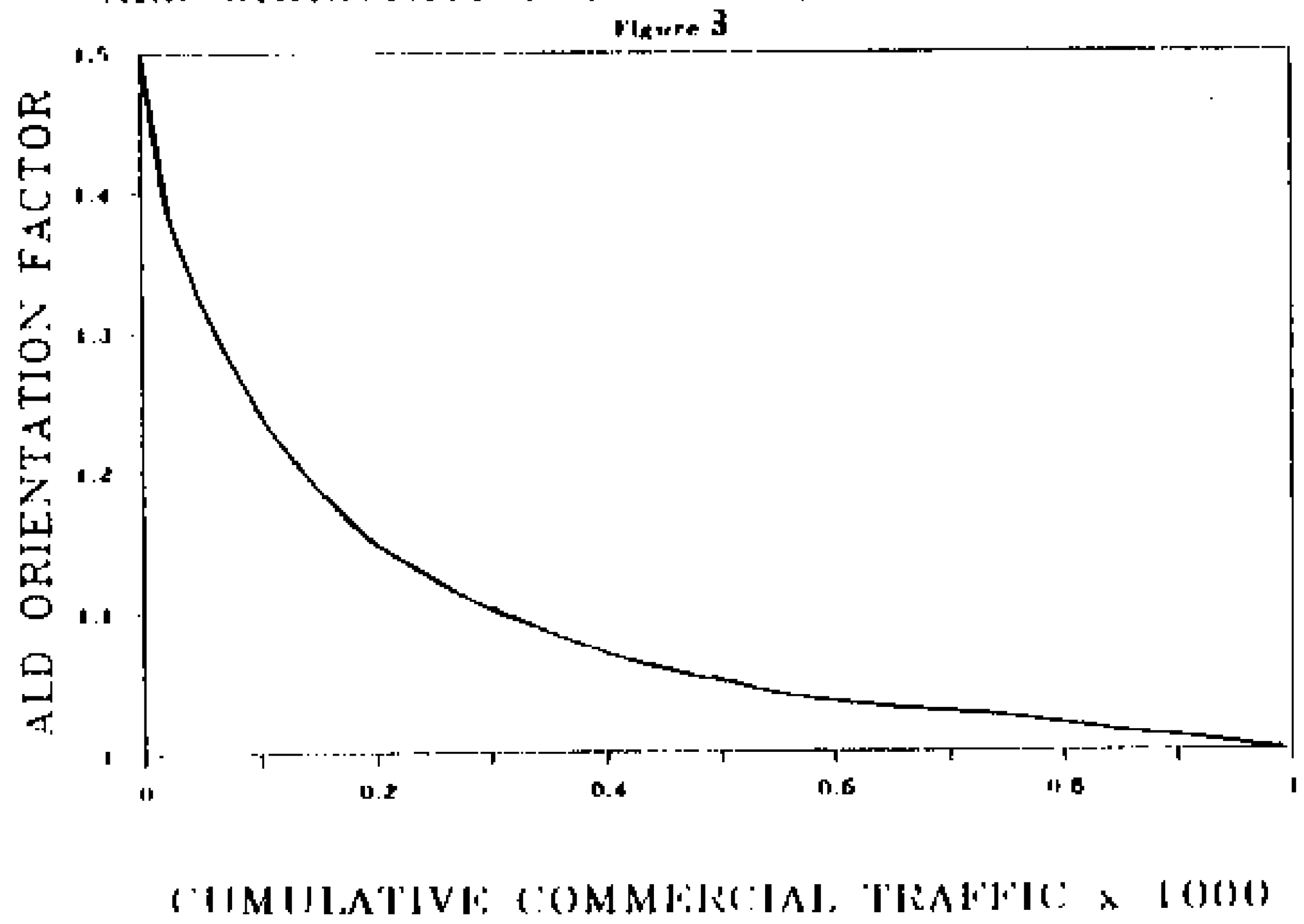
TABLE 2

Lane Width (Metres)	Traffic Concentration Factor	Recommended Factor
2.4	1.41	
2.7	1.33	1.2 max
3.0	1.16	1.15
3.35	1.00	1.00
3.7	0.87	0.87
4.0	0.77	0.77 min
4.3	0.68	
4.6	0.61	

Effective Traffic Count = Heavy Vehicle Lane Count x Concentration Factor

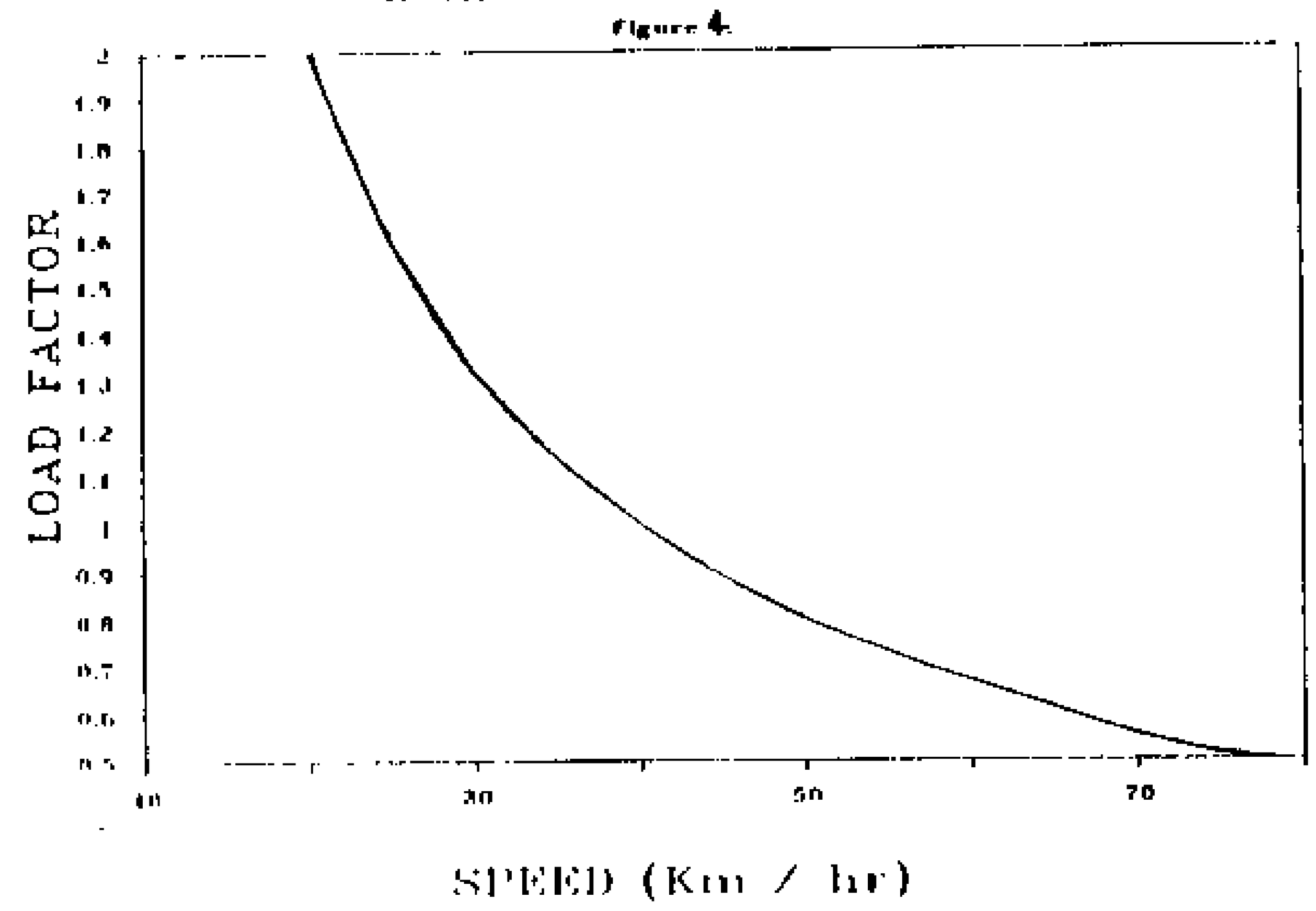
ALD ORIENTATION FACTOR / TOTAL TRAFFIC

Figure 3



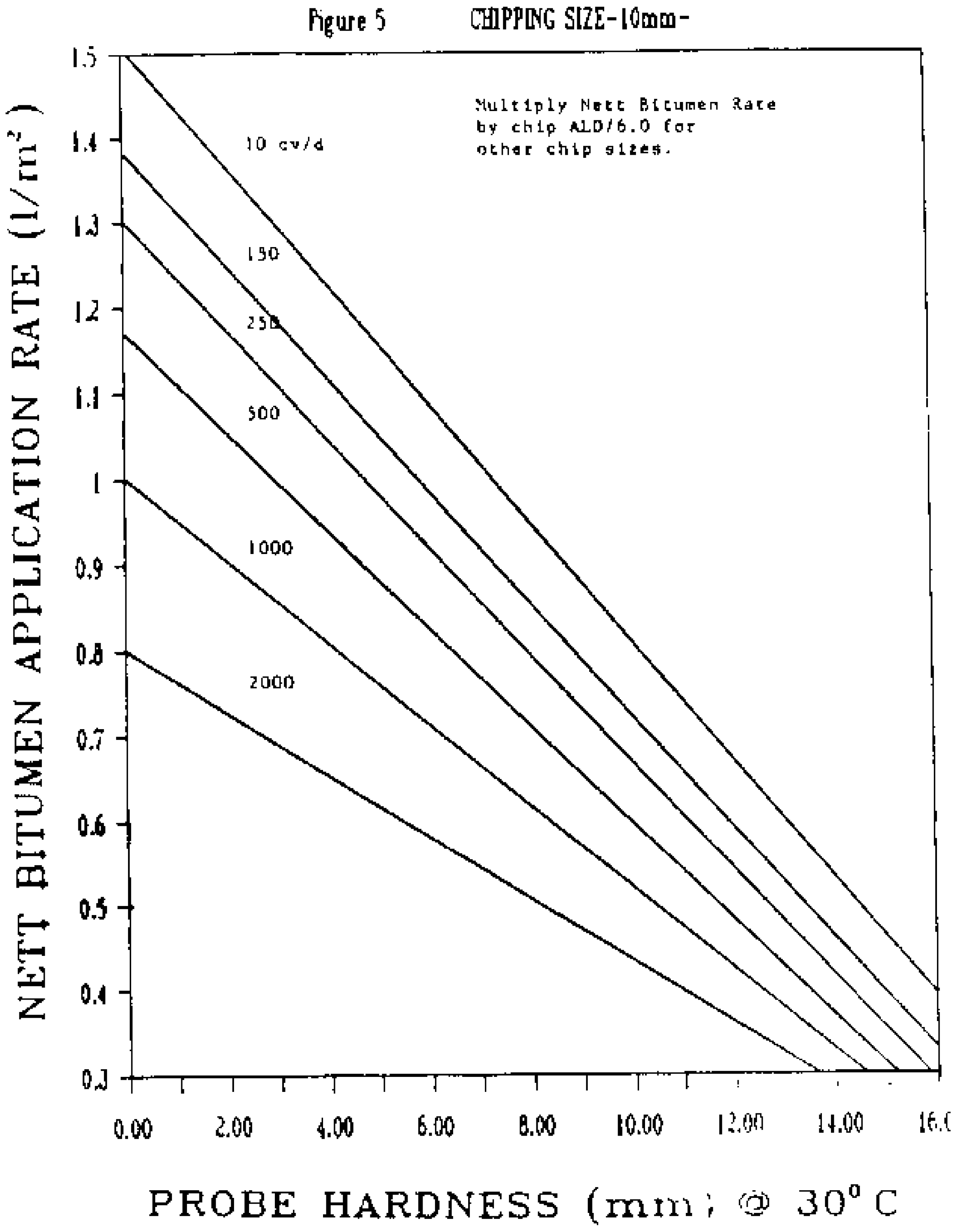
LOAD FACTOR / SPEED

Figure 4



SPRAY RATE / HARDNESS / TRAFFIC COUNT

Figure 5 CHIPPING SIZE-10mm-



Construction

Normal bitumen distributors are converted to Foamspray by connecting the special patented spray bar and adding a small water feed system.

All the procedures for good surface dressing construction should be followed because there is a tendency when clients are offered improved binders to expect them to work miracles. They will only give superior performance to traditional binders if they are all applied to the same level of quality.

Over 3000te of Foamspray were applied to roads in the South of England in 1982-85 of which over 95% was successful. The problems arose in some earlier work from heavy channelised traffic, loss of dusty chippings and soft surfaces leading to fatty conditions. No further problems have been experienced since the new design procedures were introduced, but work is now in abeyance because Mobil's staff resources are concentrating on the greater opportunities offered by the Foamstab process. In France there have been 5 Foamspray distributors operating in 1988 applying over 2500 te of bitumen in successful surface dressing.

CONCLUSION

The foamed bitumen process has been around for some time and it has not always found the favour that it deserves. This is partly because of its unusual and unique behaviour. However we are demonstrating in the U.K. that it continues to have several original and economic applications and that it works even in our damp temperate climate.

DEDICATION

This paper is dedicated to the memory of the pioneer of foamed bitumen in South Africa, the late Pete Faure who the author was privialeged to work with for several years and whose foreward thinking in asphalt technology was a revelation to all associated with him.

ACKNOWLEDGEMENTS

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