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SURFACE COURSES OF BITUMINOUS MATERIALS

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Abstract

The surfacing plays a special role in the pavement because it is directly subjected to vehicle movement. Therefore it must

- offer a suitable surface for vehicle movement that is safe and comfortable (properties of skid-resistance and riding quality)
- resist the forces imposed by traffic (vertical and horizontal forces)
- resist the attack of agencies other than traffic (sun, oxygen, water, temperature)

Two principle techniques are used in the construction of surface courses

- surface dressings
- premixed bituminous materials

Surface dressing an old established technique with certain advantages and disadvantages. Two of the disadvantages (sensitivity to technique of application, unsatisfactory durability under heavy traffic) have led to some decline in use. With regard to the advantages, important studies have just been made on the question of adhesivity/cohesivity of the binder and on treatments for the stone chippings.

Bituminous premix materials, a more recent technique with also its advantages and disadvantages. At the formulation stage there are means available to optimise behaviour for different applications. For heavy lorry traffic in hot climates attention must be paid to the problem of rutting in the wheel-tracks. Means exist for overcoming the problem by using hard bitumens and/or crushed aggregate, but these require appropriate construction techniques (compaction, thick layers etc). Equally attention must be paid to fatigue resistance having, of course, regard to the structure of the pavement.

It is, in addition, possible to combine the use of bituminous premixed material and surface dressings.

SURFACE COURSES OF BITUMINOUS MATERIAL

The role of the surface layer.

The surface layer plays a particular part in the road. It is not, perhaps, pointless to remember one fact: we construct roads in order to permit the passage of vehicles under acceptable conditions.

Thus the wearing course represents the ultimate aim of road technology; all the other layers are only justified if they allow the wearing course to perform its task effectively which does not, on the other hand, diminish the importance of the lower layers. It is through the intermediary role of the wearing course that the road user will come into contact with the road and by which he will judge it.

Consequently, the design and the construction of wearing courses have become the subject of particular attention and are not to be considered, as is sometimes the case, as accessories which we provide at the end of the job, ie at a time and under conditions which are determined by the more or less satisfactory construction of the preceding stages and with the available funds remaining.

It is therefore indispensible, if a correct solution is to be found, to commence by stating the problem properly, and for that we must analyse the role which they (wearing courses) have to play as exactly as possible:

A. The wearing course must offer, for the passage of vehicles, a surface which is acceptable both for safety and for comfort; thus we see anti-skid and riding quality problems arising. With respect to anti-skid properties, and without making an exhaustive treatment of the subject, we must note that:

- for a wet road and high speeds (greater than 80 km/h), acceptable anti-skid properties can only be obtained by the use of chippings resistant to polishing and capable of retaining their angular faces (the property of micro-texture) and by the existence of a certain geometric roughness, as measured by the "sand-patch test" (the property of macro-texture).

The importance ascribed to this anti-skidding problem will be directly related to climatic conditions. The overall risk of accidents due to skidding, can be considered in terms of the ratio:

$$\frac{\text{Accidents on wet roads}}{\text{Total number of accidents.}}$$

This is related to the percentage of time during which roads are wet, under general conditions of rainfall and humidity. It is necessary to consider the distribution of rainfall and the reactions of drivers faced with them; it is thus that in certain countries where rainfall occurs in the form of very violent storms, the risk of skidding accidents becomes almost nil, for the simple reason that traffic stops during rainfall.

As far as riding quality is concerned, it should be noted that:

- deformations occuring in a road surface, either in the longitudinal or transverse profile, produce harmful and unpleasant vibrations in the vehicle.

- "harm" arises essentially from the relationship between vibrational frequencies emitted by the road (resulting from the combination of geometric wavelength of the deformations and speed of the vehicle) and the resonant frequencies of different parts of the vehicle.

We can recognise two frequency ranges:

. the frequency range 1-2 Hz, corresponding to the intrinsic frequency of sprung weight and affecting the comfort of passengers.

. the frequency range 10-20 Hz corresponding to the intrinsic frequency of unsprung weight and affecting safety (road holding, rebound reaction).

But, in fact, the other frequency ranges have an equally harmful effect, since they play a part in the mechanical wear of the vehicle.

B. The wearing course must resist traffic stresses so that the preceeding properties are not destroyed.

It must resist vertical stresses:

. deformation effects which depend directly on tyre pressure and tread pattern. These effects, which are increased by low speeds and high temperatures in the case of bituminous materials, play an important part in "rutting" phenomena (accumulation of permanent deformations)

. general resistance of the road to pavement deflection, under the action of an axle load transmitted to the road by the tyres.

These vertical stresses can, naturally be increased by dynamic overloads from several sources but of which the most important are those resulting from defective road regularity. In fact, the dynamic overloads (which can reach 40% of the static axle load), play a small part in the general behaviour of the structure because of the inertia of the masses which come into play and their deformability but they play an important role in the behaviour of the wearing course ..... crushing of aggregates, attrition.

It must resist tangential stresses:

At each passage of a vehicle, even if the vehicle is neither accelerating nor decelerating, (and especially if this is so) the road is stressed by horizontal forces.

These horizontal stresses diminish very quickly with depth, and consequently only affect the wearing course by causing:

. stripping and "plucking" of chippings (surface wear).

. polishing of chippings

. creep of coated materials

These horizontal forces exert a harmful effect on the permanence of bonding between the wearing course and its support (base layer), they are particularly responsible for slippage, detachment and tearing from which thin carpets suffer.

Wear edges, the resultant of horizontal stresses is no longer balanced by the total interia of the layer and creates a pushing action responsible for slippage and lateral creep, this force is unfortunately even further increased in that:

. because of the geometric road layout, the right-hand wheels (in countries which have adopted 'Right-hand' driving, naturally!) of vehicles, and in particular lorries, pass very near the edge.

- very frequently the standard of laying and compaction of the materials, particularly compaction, is not as good at the edges of the road as at the centreline.

Naturally these mechanical forces and especially the deflection to which the wearing course is subjected depends upon:

- traffic characteristics (numbers, load, speed)

- subgrade soil characteristics

- the overall structure of the road.

We must distinguish very clearly:

- pavements subject to deformation, consisting essentially of layers of untreated material, which have only a low stiffness and no resistance to tractive forces (therefore, a very weak "slab effect")

- pavements with low deformation characteristics, consisting essentially of layers of treated material (with bitumen, cement, crushed slag etc).

In the former, (deformable roads) one is made to realise more and more that the solution which consists of constructing a relatively weak wearing course of bituminous premix (eg less than 5 or 6 cm) is not to be recommended; indeed such a layer is subjected to large fatigue forces and fails by cracking ("alligator cracking") in a very short time. It seems to be more rational in this case to decide upon a surface dressing (or of coated sand if chippings of adequate quality are not available and good quality sand can be obtained).

If traffic is too heavy for this solution to be adopted, it is preferable from the technical and economic viewpoint to use treated materials for constructing sub-base and base rather than to increase the thickness of bitumen premix wearing course.

C. The wearing course must, equally, resist stresses arising from external influences other than traffic:

- Sun, and oxygen in the air which causes oxidation of the bitumen, which up to a certain stage, can be considered as beneficial (hardening accompanied by a lowering thermal susceptibility), but beyond that stage becomes harmful (excessive brittleness of the bitumen).

- Water which can act mechanically (erosion) or by physico-chemical action (stripping). On this subject, we must consider that the equilibrium of aggregate - water - bitumen is only favourable to bitumen in the cases of calcareous aggregates (and not even all of those!).

  For other aggregates, theoretical equilibrium is obtained by the displacement of bitumen (stripping). Fortunately, this displacement has to take place by opposing viscous forces and is thus more difficult (and hence takes longer) when bitumen is harder.

Let us note that we require not only that the wearing course should itself be resistant to the action of water, but also to protect the other pavement layers and the subgrade soil against the ingress of water.

We thus introduce an impermeability requirement for the wearing course (which is, incidentally, a favourable factor for increased resistance to stripping).

Temperature affects considerably the properties of bituminous materials. To illustrate this temperature effect, for frequencies of 1Hz, 10Hz and 30Hz the moduli obtained for premixed bituminous base (40/50 pen) at temperatures of -10°C, 10°C and 30°C are given below:

(Moduli in bars)

Frequency	- 10°C	10°C	30°C
1Hz	170,000	70,000	10,000
10Hz	222,000	110,000	35,000
30Hz	250,000	140,000	50,000

One is aware of the harmful effects caused by excessive softening, arising from high temperatures (remembering that in a black bituminous road, temperatures can exceed the ambient air temperature and can reach 60-70°C, perhaps more in certain African countries (fatting-up, plastic deformation ....).

It is thus necessary to select the grade of bitumen to be used for wearing course in a (given) country appropriate to the surface temperatures in the hottest periods of the year.

To illustrate this ability to select, we give below, four different bitumen grades and in France, the temperatures at which we obtain, for 2 frequencies 1Hz and 30Hz moduli of 3000 and 90,000 bars respectively.

(Temperatures in °C)

Temperature at which:	20/30	40/50	60/70	80/100	180/220
. a modulus of 3000 bars is obtained for a frequency of 1Hz	40	32	29	24	17
. a modulus of 90,000 bars is obtained for a frequency of 30Hz	7	5	4	-1	-10

Another problem arises; that of temperature variations. If variations occur slowly, as for example the variation between summer and winter, the problem is not very serious since bituminous materials are capable of sustaining large variations.

It is necessary, however, to ensure that if a bitumen grade has been chosen appropriate to the highest temperatures, that it is not within its brittle range at periods of lowest temperature. In continental-type climates, which exhibit at times high maximum temperatures and low minimal temperatures, the above limitation requires that the best possible compromise solution for the 2 extreme conditions be found. The solution to the problem can only be found in a modification of the rheological properties of bitumen, aimed at producing lower thermal susceptibility. To take an example, a 40/50 bitumen described as "of low thermal susceptibility" exhibits the moduli given earlier at temperatures for 33°C and -12°C. Thus for slow stresses and high temperatures it behaves as a normal 40/50 bitumen but for rapid stresses and low temperatures, more similar to a 180/220 grade.

This solution, equally may be applied when one is faced with the problem of rapid temperature variations (particularly relevant in countries where the difference between day and night temperatures can be very high).

This modification of the rheological properties of bitumen can be obtained by treatment during the course of refining and by the addition of synthetic products (polymers, elastomers .....).

As to the effects of sun, water and temperature it is advisable to look at some of the features of the African climate.

a) A favourable factor is obviously the absence of low temperature, which eliminates all the problems of frost and winter durability (consequently these will not be discussed).

b) One must distinguish - with the exception of the Mediterranean type of climate found in the Maghreb and in the coastal zones of Libya and Egypt:

Equatorial climates (or humid tropics) characterised by:

a fairly constant temperature of 24-30°C

a high rainfall (1-5 metres per year or more)

a high and constant humidity (85°)

low evaporation

which implies either

the employment of materials resistant to water (gravels)

or to give them a degree of resistance (by treatment with hydraulic or hydrocarbon binders or other agents).

or to protect them against all imbibition (use of very dense materials, impermeable surfacings, careful provision for runoff and drainage).

On the other hand, the high humidity and relatively constant temperatures are factors favourable to the performance of cement-stabilised materials, because of the limited thermal stressing.

Bituminous binders generally give good results. However, in surfacings, the adhesion of the binder to certain types of aggregate (siliceous) can pose serious problems: the use of additives (dopes) is sometimes necessary.

The curing of fluid bitumens (cut-backs) may be difficult if low-volatility solvents are used. The use of rapid-curing cut-backs is recommended.

Tropical climates characterised by well-defined dry and wet seasons (the duration of the dry seasons being considerably longer). The average temperatures depend, of course, on the altitude. Highway engineering in these conditions must take account of both very wet and very dry periods.

Desert climates characterised by the rarity and irregularity of rainfall. The average temperature lies between 20-30°C but the diurnal range is very wide. In extreme case the temperature can range from 0°C at night to 45°C during the day. There is, of course, very low humidity and high evaporation. Further the intensity of sun shine is very great - in particular ultra-violet rays are practically not at all filtered out.

For roads, the dryness has certain favourable consequences: the soils and road materials have a very low equilibrium moisture content. Furthermore, run-off and drainage are easy to ensure with low risk of saturation. It follows that:

water-sensitive materials (silty, clayey or gypseous) can be used almost without special precautions.

the properties of soils at low (or zero) moisture content can be considered, this allows everything being equal, considerable reductions in the design thickness of roads.

On the other hand the shortage of water makes normal adjustment of moisture content for compaction very difficult. There is a great call for the development of the techniques of dry compaction, by vibration (for granular materials).

It is to be noted that cohesive materials at low moisture contents most often behave rigidly; their low deformation can be at the same time an advantage and a disadvantage.

In a general way, the low humidity and the alternating thermal stresses due to diurnal variations of temperature are factors very unfavourable to the satisfactory behaviour of material despite their having little rigidity. In particular, materials treated with hydraulic binders are subject to considerable cracking so much so that they should <u>not</u> be specified for use in this climate.

In addition, an extremely rapid ageing of bituminous binders is observed. For mixed materials one is led to formulate mixtures with a very high binder content at the risk of having initially lower stability which however increase later as the binder hardens. In any case, because of the very high temperatures (up to 70^{o} at the surface) that can be attained in the surfacing, the right compromise is difficult to find. For surface dressing two cases can be considered

if because of sand storms, there is no fear of 'fatting-up' one can exceed normal rates of spread of binder

if not, one must expect more frequent application of maintenance treatment (single surface dressing or sanding)

This analysis shows clearly that the problem is very complex. In practice certain requirements appear contradictory.

All solutions must therefore be compromises that take account of:

climatic conditions
actual traffic conditions (maximum axle-weights, overloading, speed, tyre pressure, traffic intensity)

economic conditions (relative costs of available materials)

general technical conditions (definition of the total structure of the pavement, importance given to different objectives)

the possibilities arising from the construction equipment of contractors or maintenance services, the materials and personnel.

This accounts for the great diversity of solutions practiced and also for the fact that it is not possible to crudely adopt solutions imported from elsewhere. It is necessary always to make as complete and objective analysis as possible of the technical and economic conditions prevailing in order to determine the best solution.

This is the aim of this first chapter. In the following two chapters, dealing respectively with surface dressing and with premix material I will not attempt to describe in detail techniques used in France which with regard to what has been said in the first chapter, will only be a slight interest to you. In any case those who want to, can find out about them from.

"DIRECTIVE POUR LA REALIZATION DES ENDUITS SUPERFICIELS"
(Directions for carrying out surface dressing)
SETRA-LCPC Feb 1972

"DIRECTIVE POUR LA REALIZATION DES COUCHES DE SURFACE DE CHAUSSEE EN BETON BITUMINEUX"
(Directions for manufacture of road surfacings of bituminous premix material)
SETRA-LCPC Sept 1969

Instead, I will attempt to put forward the advantages and disadvantages of each technique and the most favourable technical conditions for their application with the best chance of success.

II Surface Dressings

Surface dressing is achieved by successive application under carefully controlled conditions of

a layer of hydrocarbon binder (bitumen or tar.....)
a layer of chippings as perfectly graded as possible

The dressing is known as "single" (monocouche) if a single layer of binder is spread

"double" (bicouche) if two layers of binder are spread

"triple" (tricouche) if three layers of binder are spread

It is a very long established technique but which after the second world war declined in importance at the expense of "bituminous premix". On the other hand, at the present time, there is a lively renewal of interest in the technique. The balance sheet of advantages and disadvantages is:-

Advantages

(a) Surface dressing, properly executed ensures a water-proof surface that prevents ingress of surface water to the base of the road.

(b) it provides a very satisfactory solution to the skidding problems because the macro-texture is exceptionally large compared with other surfacings. Naturally, in order to profit from this advantage, it is necessary to use chippings of hard and non-polishing rock. The small quantities required allows one to 'pay the price' for this without considerably increasing the total price per square metre of pavement.

(c) it integrates well into a policy of stage construction because no large initial investment of capital is required for a pavement where the traffic does not justify it. For example:

1st stage of improvement of unsurfaced road, after shaping with a grader, surface dressing which:

provides an impermeability which improves performance in wet weather

improves the skid-resistance

acts as an anti-dust treatment

2nd stage of improvement, when the traffic requires it of a reinforcement which again can be a surface dressing.

3rd stage of improvement can be the placing of a wearing course of bituminous premix.

Spraying will then serve the purpose of maintenance (preserving the characteristic of impermeability).

(d) It is cheap per m^2.

(e) Only relatively small investment is needed.

Disadvantages

(a) It does not provide, of itself, any improvement of riding quality. It can only be applied, therefore to readily shaped surfaces.

(b) Surface dressings require chippings in sufficient quantity and of suitable quality.
This quality (strength, resistance to various demands....) cannot be specified except with regard to the characteristics of the traffic, of climate etc).

(c) It only provides weak protection to the substrate against horizontal (shearing) forces. When traffic becomes heavy, the materials of the base having an insufficient cohesion, the application of a running surface of premixed bituminous material becomes indispensable.

(d) It provides no structural strength to the pavement except indirectly insofar as it waterproofs the surface against surface water.

(e) It is very sensitive to the good construction technique, to the quality of the binder and chippings and conditions during construction.

The following are particularly important:

cleanliness and stripping characteristics of the aggregate
uniformity of materials
the professionals skills of the operatives - to a large extent surface dressing is an "art".

(f) surface dressings are insufficiently durable under heavy traffic - and fail rapidly under such conditions.

These last two disadvantages have caused engineers in our country to be disinclined towards the use of surface dressings, despite recognition of their advantages, on heavily trafficked roads (3000 vehicles per day). At the present time it has proved necessary, in order to overcome disadvantages (e) and (f), to carry out studies in depth.

Adhesion-Cohesion

It is particularly necessary that the binder and aggregate show in relation to one another good 'wetting' characteristics (active adhesion). It is necessary that the binder is capable of 'wetting' the aggregate even if it is damp, in order to provide a bond. With the exception of calcareous aggregates, this is not generally possible and it is necessary to modify the interfacial conditions by addition of surface-active agents. Once a bond is established, it resists the action of water (passive adhesion) and of traffic. The cohesive characteristics of the binder are brought into play - there is no cohesive failure in the body of the binder.

Under this heading, the particular problems posed by the use of fluid or fluxed bitumens, whose cohesion varies as the flux evaporates.

Cleanliness

The presence of a film of dust on the surface of the chippings is very harmful:

when the fines are "active" (plastic)
when the fines are inert (rock fines)

The binder adheres to the film of dust and not to the surface of the aggregate. There is 'false adhesion' which will be easily destroyed by traffic.

Unfortunately this is the normal (I would say the inevitable) situation.

It is therefore necessary to introduce a complementary operation in the preparation of the chippings which could be:

Pre-treatment

Complete wetting, followed or not by drying, by a solution (or a dispersion) of an adhesion agent (surface active) in water or an oil.

Material so pre-treated should be used immediately, or if this is impossible may be stockpiled for a short time (2-3 days) protected from the weather.

Pre-coating

Covering of the chippings by a continuous film of binder, either with or without dope.

This precoating may be made with penetration grade bitumen, cut-back bitumens or emulsions. Precoated chippings may be stock-piled for several months. In general it is not recommended to use them straight away - storage is required, varying with the nature of the binder from 1 to 3 weeks.

These treatments (pre-treatment, pre-coating) improve the situation both with respect to dustiness and adhesivity: their use is strongly recommended.

Where cationic emulsion is used as binder no pre-treatment or pre-coating of the aggregate should be carried out: in fact

on one hand it is not necessary for adhesion since this happens naturally, since the emulsifier used in preparation of the emulsion is a surface active agent (adhesion agent).

and on the other hand, it is harmful

In contact with a mineral surface pre-treated or pre-coated, the 'break'

of a cationic emulsion can only be considerably delayed; the surface dressing will therefore only very (too) slowly achieve cohesion and in its early life will be destroyed by traffic action.

There are thus two solutions:

pre-treated or pre-coated chippings - fluid or cut-back bitumen untreated chippings - cationic emulsions

In both cases the base bitumen used in the manufacture of the cut-back or emulsion should be chosen with due regard to climatic conditions.

For African climates, we believe one should tend towards the use of 60/70 or 40/50 grade bitumens. In the same way, to prevent too great a flow of bitumen after spraying down the cross-fall of the road, and at the same time in order that the bitumen will attain as quickly as possible its cohesion characteristics, the use is advised of:

very viscous cut-back bitumens

rapid breaking emulsions with high (65-70%) content of bitumen.

III Premixed bituminous materials

Prepared by mixing, in a pug-mill, aggregates of specified grading and bituminous binder in specified quantity, these 'premix materials' are spread on the road by appropriate machines and compacted.

Three conditions must obtain if the coating (formation of a thin continuous film of binder on each particle of aggregate) is to be possible

1. the binder should be sufficiently fluid

2. This fluidity should not be too much changed by contact with the aggregate

3. the binder must be capable of wetting the aggregate which implies

   (a) that the aggregate is dry
   (b) that the aggregate has been modified by the addition of surface active agents.

There are two possible solutions:

Hot-coating

the (penetration grade) bitumen is heated to 130-180° (condition 1) according to its consistency

the aggregate is dried and heated (conditions 2 and 3a)

Cold-coating

the binder is a cut-back bitumen or an emulsion (conditions 1 and 2)
the aggregate is neither dried nor heated
the cut-back is doped) condition 3b
a cationic emulsion is used) condition 3b

Cold-mixed material is basically used for maintenance work: wearing courses are

basically made with hot dense premix (compaction greater than 91%). In most countries hot premix have been extensively developed; the balance sheet of their advantages and disadvantages is:

Advantages

(a) Dense premix materials when correctly made, assure an impermeability, which although not as efficaceous as the waterproofing provided by a surface dressing, prevents to a large measure the penetration of water to the interior of the pavement.

(b) Although the formulations have not been specially studied, they provide a solution to the problem of slipperiness sufficient for average present day conditions - although not at the same level as that provided by surface dressings.

(c) When laid by appropriate machines (finishers) they provide a very good riding quality.

(d) If laid sufficiently thick they very adequately protect the road base from destructive horizontal (shearing) forces.

(e) If laid sufficiently thick they contribute to the mechanical strength of the pavement.

(f) It is a technique less 'sensitive' than surface dressing - more a science than an art.

There application is much less subject to hazards, particular those hazards of climate and traffic.

(g) Correctly manufactured and at correct thickness they are notably more durable than surface dressings.

Disadvantages

(a) They are costlier per m^2 and require larger quantities of materials of high quality.

(b) Considerably higher investment in material is required.

(c) Transport costs of these materials is relatively high. Their use can only be justified for large tonnages.

In urban areas this does not present any problem — a large quantity of the network. The unit cost per tonne of the manufactured product depends to a large extent on the capacity of mixing plants and the total tonnage required from them.

When the problems of formulation of hot premix for running surfaces are considered one finds that these can be classified in two groups which tend to be contradictory.

First group

The resistance to permanent deformation (rutting, wheel-tracking)
The skid-resistance characteristics

Second group

Impermeability

Fatique resistance

In France we have been obliged to give priority to the first group, while attempting to maintain adequate impermeability; the quality of resistance to fatique of the wearing course appears less essential since they only come into consideration at final design stage when all the problems of the structural strength properties of treated bases have been resolved.

There are a number of means of providing resistance to deformation (rutting)

(a) Use of hard bitumens

The use of bitumen of low penetration (60/70-40/50) results in an increase in the modulus of the premix - which is always sensitive to high temperatures and long loading times.

The improvement in resistance to deformation by the use of harder bitumen is demonstrated by the simulative test using a 'wheel-tracking' machine - an apparatus which allows a loaded wheel (weight 500kg, tyre pressure 5 bars) to track back and forth over a slab of premix. Figure 1 shows that for an asphaltic concrete, the depth of wheel-track obtained after 300 000 passages of the wheel at 45°C is 3 to 4 times less when 40/50 pen is used than when 180/220 pen bitumen is used.

(b) Use of crushed material

The presence of very angular aggregates (specially the sand) increase the shear strength because of higher internal friction of the skeleton.

Fig 2 shows that addition of 15% of rounded sand to an asphaltic concrete made entirely with crushed stone leads to a wheel-track depth obtained after 200 000 passages at 40°C, 4 to 5 times greater.

(c) Use of 'granular' or 'semi-granular' specifications

That is containing a high proportion of stone and a small proportion of sand.

Figure 3 shows results obtained with 3 asphaltic concretes with specifications called respectively "nougat", "semi-granular" and "granular". These three formulations have the specifications given below.

	"nougat"	"semi-granular"	"granular"
Percentage of material retained 6mm	22	28	37
Percentage of material passing 2mm	50	34	25

As for skid-resistance properties it is apparent that to obtain high macro rugosity it is convenient to use a specification with a high proportion of stone and a low proportion of sand.

The use of hard bitumen and crushed stone aggregate ensures the retention of this macro-rugosity under traffic.

The statistical distribution of roughness (sand depth) obtained by the specifications of 'nougat', 'semi-granular' and 'granular' type is given below.

Texture	Specification "nougat"	Specification "semi-granular"	Specification "granular"
very fine HS < 0.2	0%	0%	0%
fine 0.2 < HS < 0.4	20%	17%	7%
medium 0.4 < HS < 0.6 0.6 < HS < 0.8	65%) 15%) 80%	30%) 43%) 73%	33%) 46%) 79%
coarse 0.8 < HS < 1 1 < HS < 1.2	0%) 0%) 0%	10%) 0%) 10%	7%) 7%) 14%
very coarse HS > 1.2	0%	0%	0%

These results show

a rapid diminution of the percentage of fine texture
the progressive appearance of the percentage of coarse texture
in the class 'medium texture' a movement towards the category 0.6-0.8 at the expense of category 0.4-0.6.

Besides, the use of crushed aggregate manufactured from hard, non-polishing rock, whose faces do not polish and whose asperities do not become blunted, favours initial high skid resistance and its retention.

Fig 4 shows the coefficient of lateral friction obtained by the 2 types of specification "semi-granular" and "granular" compared with the results as a whole obtained on the roads of France.

It is to be noted however that the specifications to which the research on this first group of properties had led results in bituminous premixes of poor workability, with a very open stone skeleton and therefore difficult to lay and compact.

On the other hand the second groups of properties are more easily attained with materials that are easy to compact.

The impermeability and resistance to water action is greater when air-voids are small.

The compromise necessary between the two groups of qualities of bituminous premix is obtained by using specifications that give materials that are not easily worked (laid) and the qualities in the first group are obtained by the most effective compaction possible.

Thus two points are essential:

<u>To use vigorous methods of compaction</u>

Bituminous mixtures with poor workability can only be compacted by the use of pneumatic-tyred rollers operating immediately behind the laying machine. Their

kneading action gives a better compacting action, even better when it is exerted on surfacing that have not had time to cool down. An adequate weight per wheel (2-2.5 tonnes) must be used and they should be so disposed that each point on the surfacing in as short a time as possible received the same number of passes.

To compact in sufficiently thick layers

It has been observed that for bituminous premix material of poor workability compacted with pneumatic tyres, the thicker the layer compacted the lower the air-voids. This result is explained by -

in a thick layer, the coated material stays for a long time at a sufficient high temperature to make compaction efficacious.

in a thick layer, there is a greater volume unaffected by either the restraint of the base or the pneumatic tyres in which slow movement under the influence of the roller is possible.

In general, an increase of thickness of 1cm leads to dimination in air-voids of 0.5-1.0 percentage on average.

Fig 5 shows the correlation obtained on site between thickness of the layer of coated material and content of air-voids: in spite of all other parameters which come into play (temperature, composition, number of passes of the roller, reaction of the substrate'....) layer thickness exerts a strong influence. Fig 7 shows results obtained on a number of sites.

For each specification there is a minimum thickness below which it is impossible to compact to sufficiently low void-content: in order to determine the average desirable thickness it is necessary to take into account that the minimum thickness is less than the average thickness by at least 2cm.

In order to determine how far these principles can be applied to the technique of bituminous coated materials in Africa, one must consider the relative importance that it is appropriate in local conditions to give to each of the contradictory qualities.

It appears to us that in tropical and equatorial climates it is absolutely necessary to have high resistance to wheel tracking (rutting). This consideration may however be modified in the light of actual traffic conditions:

legal maximum axle load (varying from 8 to 13t)
the percentage of total traffic accounted for by heavy lorries
the extent (percentage and maximum load) of overloading
the inflation pressures of tyres.

The demands requiring impermeability would seem to be of the same order as in France.

As far as fatigue resistance is concerned, it appears necessary to distinguish 2 cases:

for heavily trafficked roads, the demands for structural strength necessitate the use of treated bases; one would find oneself in a situation similar to that in France. Specifications of the 'semi-granular' type should satisfy all demands.

for lightly trafficked roads, whose untreated bases are more deformable. Here it would be necessary when using coated materials for wearing courses,

to obtain a high fatique resistance. The addition of a small quantity of rounded sand or sharp sand (at the rate of 10-15% of the aggregate content) and the use of specifications less rich in stone.

But in our opinion the best solution for this condition is the use of surface dressing.

It could happen that the use for the entire wearing course of aggregates from rock which is variable and not resistant to polishing causes a costly economic problem. It is however possible to reduce the requirements of the aggregate for the premix by using surface dressing as a final treatment. For this purpose it is absolutely essential to provide chippings of hard, non-polishing rock but the quantities required are reduced.

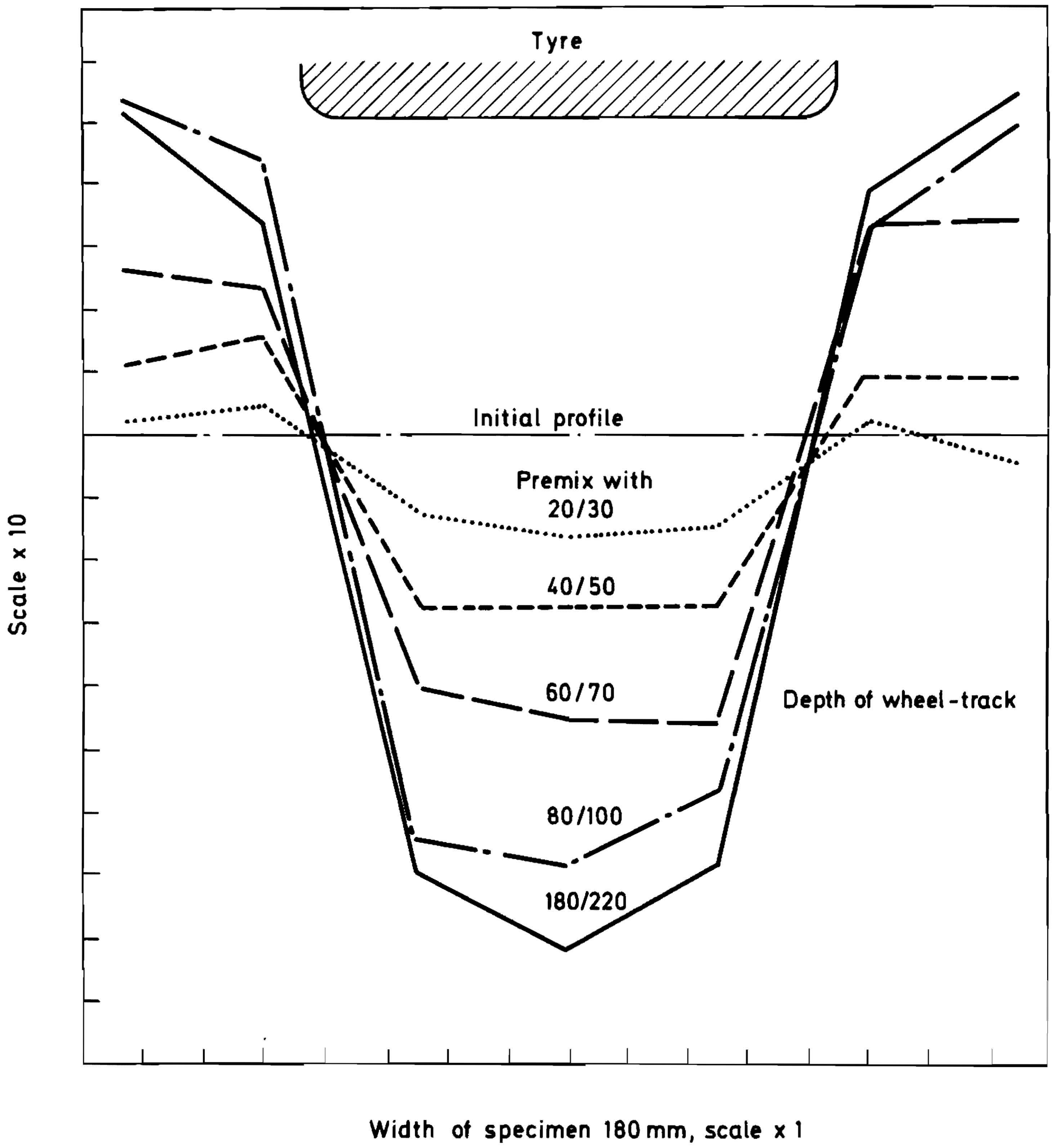
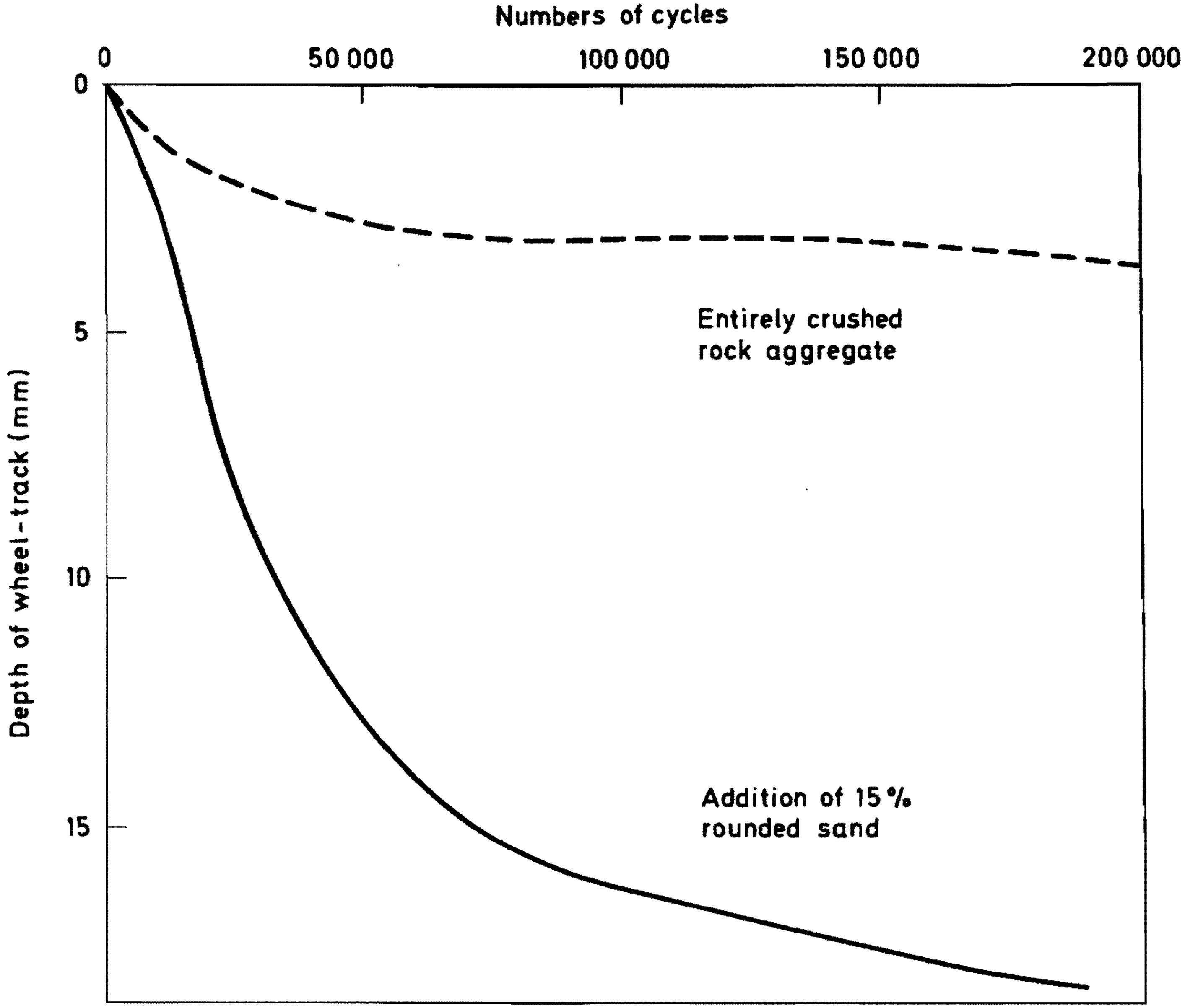


Fig. 1. PROFILES OF WHEEL-TRACK OBTAINED IN THE WHEEL-TRACKING TEST WITH BITUMEN OF DIFFERENT PENETRATIONS ("SEMI-GRANULAR" PREMIX WITH 6·5 % BITUMEN TEMPERATURE 45° - 300 000 PASSES) VERTICAL. SCALE 10 TIMES HORIZONTAL SCALE

G5845



G 5846

Fig. 2. INFLUENCE OF THE ADDITION OF ROUNDED SAND ON THE RESISTANCE TO WHEEL-TRACKING OF A PREMIX MATERIAL

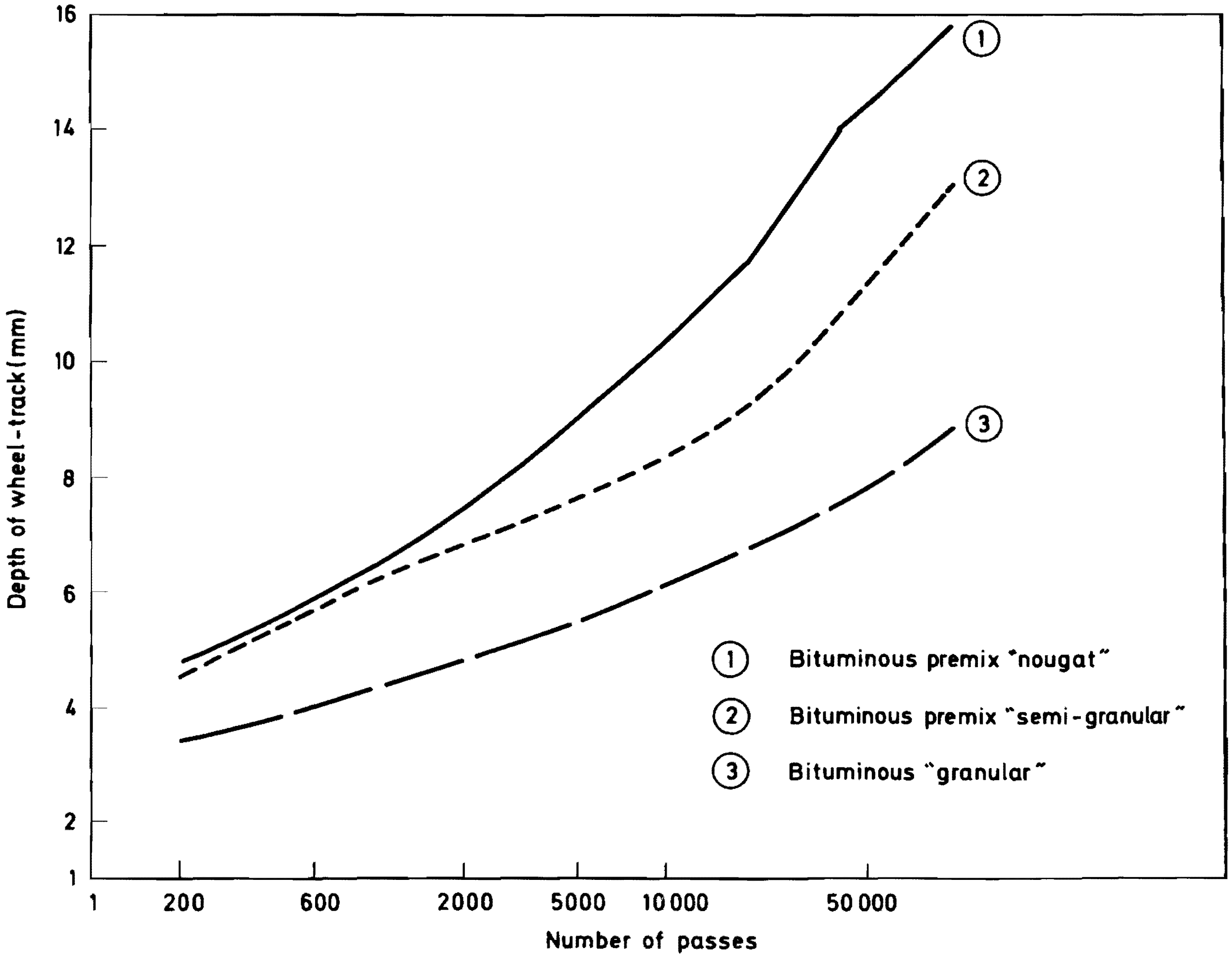


Fig. 3. COMPARISON OF THE WHEEL-TRACKING BEHAVIOUR OF THREE BITUMINOUS PREMIXES WITH DIFFERENT SPECIFICATIONS

G 5847

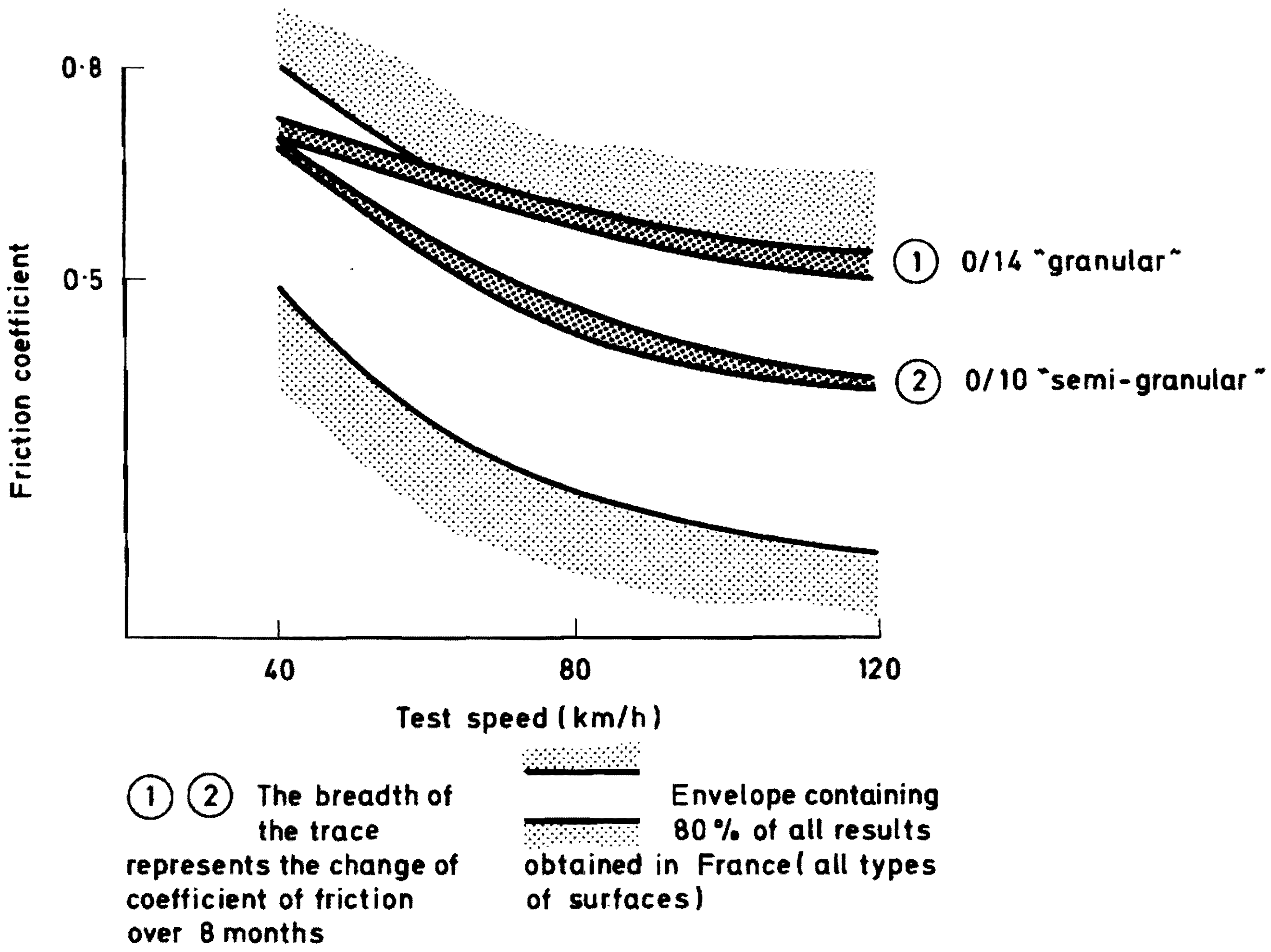


Fig. 4. COMPARISON OF LONGITUDINAL FRICTION COEFFICIENTS (SMOOTH TYRE, LOCKED WHEEL) ON TWO BITUMINOUS PREMIXES OF DIFFERENT GRADING

G 5840

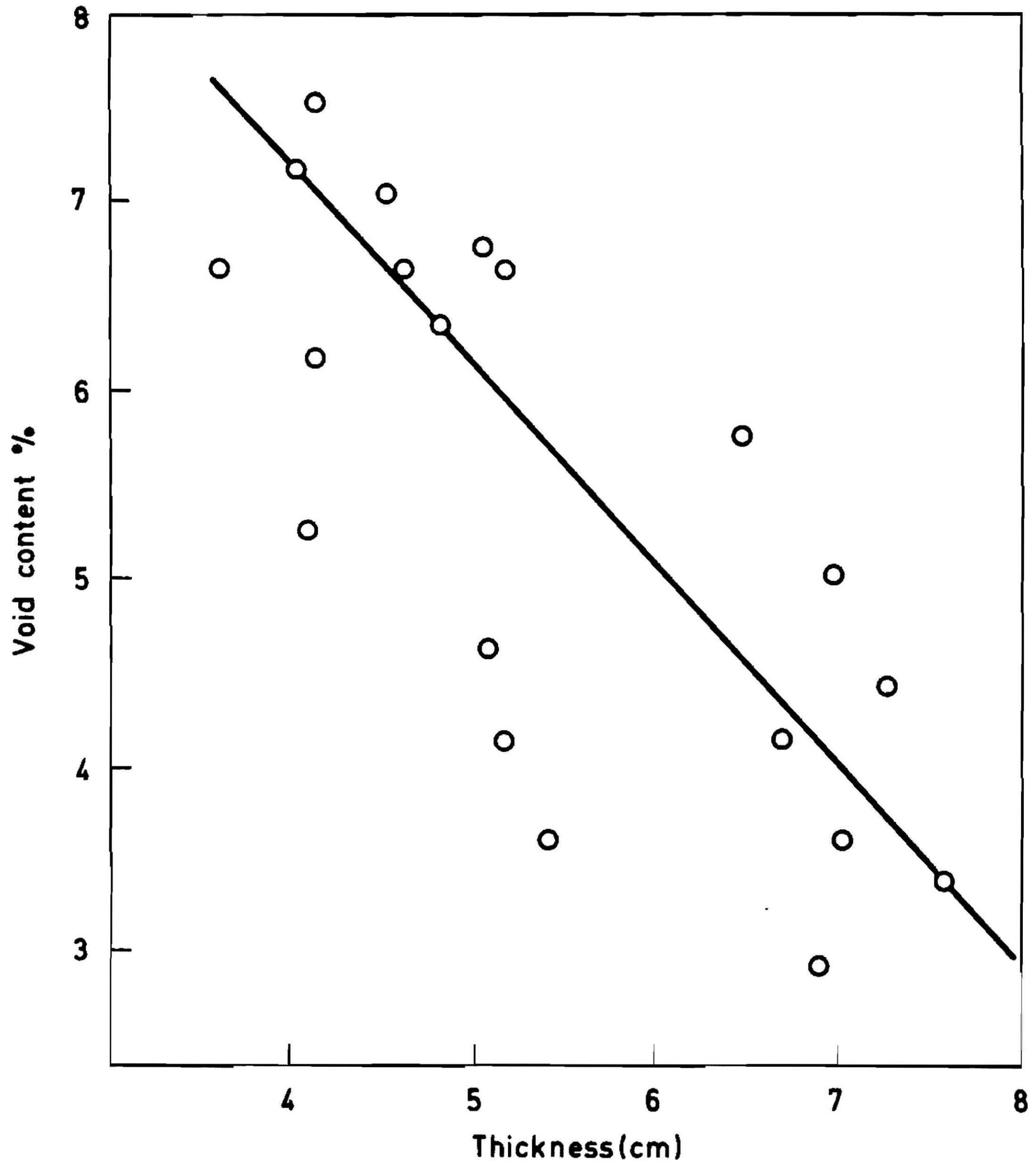


Fig. 5. RELATION BETWEEN THICKNESS OF SURFACING AND 'IN SITU' VOID CONTENT - PREMIX 0/10, SEMI GRANULAR WITH 37 % PASSING 2 mm. EACH POINT REPRESENTS A CORE

G5849

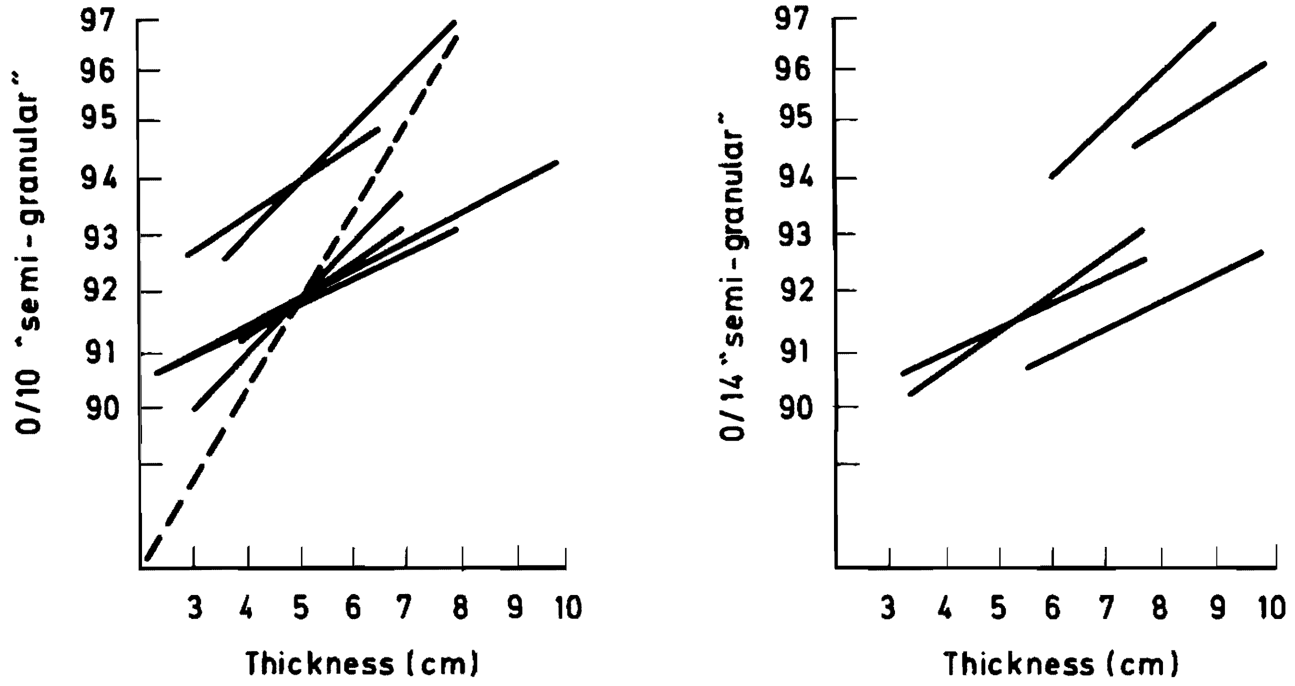


Fig. 6. CORRELATIONS BETWEEN COMPACTION AND THICKNESS FOR BITUMINOUS SURFACINGS ON DIFFERENT PAVEMENTS

G 5850

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