Road Surface Texture and the Slipperiness of Wet Roads

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The texture required of a road surface, so that it shall be as resistant to skidding as possible, is harsh for low speeds and harsh and large-scale for high speeds. The function of the texture is to assist drainage of the water to achieve dry contact as quickly as possible and maximum deformation of the tire tread surface by the asperities of the road surface. This is achieved by easy (large) flow channels and by sharp (harsh) asperities generating high pressure. These conclusions are illustrated in an examination of how the skidding resistance of actual surfaces varies with speed, and how rubber hysteresis increases friction. Aquaplaning is also considered. How suitable textures are being obtained in the United Kingdom and the researches relevant to this subject being planned or in progress at the Road Research Laboratory are discussed.

•FOR this paper, surface texture does not mean the composition of the surface—so much binder, sand, etc.—but the geometrical form of the road surface, that is, the shapes of the asperities large and small that make contact with the tire tread, or deform it, and the channels in between them. The purpose of the paper is to present the views of the British Road Research Laboratory on the importance of the texture thus defined and to outline its plans for research in this field.

TYPE OF TEXTURE REQUIRED

The view of the Road Research Laboratory is that all roads require a harsh texture when wet and that high-speed roads require a coarse texture as well. When speeds are low, for example, town roads restricted to 30 mph, a coarse texture is not required. A road surface is said to be harsh when the fine-scale asperities are angular with sharp points or edges, so that it feels somewhat like sandpaper to the touch. The type of surface that is undesirable feels smooth or polished to the touch even though it may contain large-scale, rounded asperities.

The reason for requiring these types of texture is, first, to facilitate the removal of water from the tops of the asperities so that as far as possible contact can be made between them and the tire tread and, second, to ensure that, in making such contact or even when approaching it, the asperities shall deform the tread by generating high pressures. The high pressures not only assist in the process of water removal, they also ensure that the deformation of the tread is such as to give rise to the frictional force due to the hysteresis of the tread material, the so-called hysteresis friction as distinct from the adhesional friction. Frictional forces are produced effectively only if there is dry contact or deformation of the tire tread. Dry contact produces adhesion and hysteresis friction, deformation produces hysteresis friction only.

Figure 1, an ink contact print, shows the areas of actual contact between tire and road in a static condition, and shows clearly (the white areas) how much larger the drainage system is on a coarse surface. From the print alone it would be expected that the tread pattern can add little to the drainage effectiveness of a sufficiently coarse

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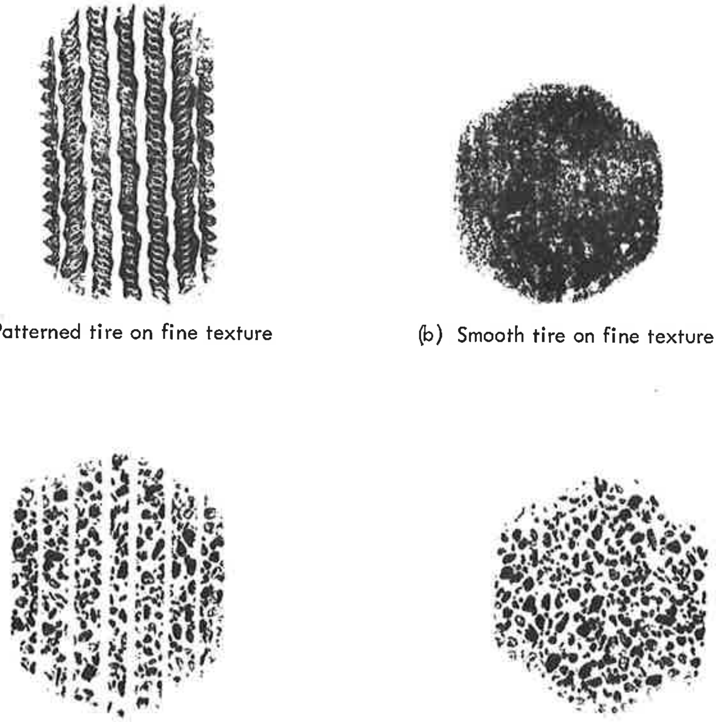

(a) Patterned tire on fine texture

(b) Smooth tire on fine texture

(c) Patterned tire on coarse texture

(d) Smooth tire on coarse texture

Figure 1. Points of contact between tire and road.

surface, and this is found to be the case. Patterned and smooth tires perform very similarly on such surfaces, and a smooth tire is as good as a patterned one or even better.

The conditions in the contact area are illustrated diagrammatically in Figure 2, where a tire is shown advancing in a thick film of water. The bulk of the water

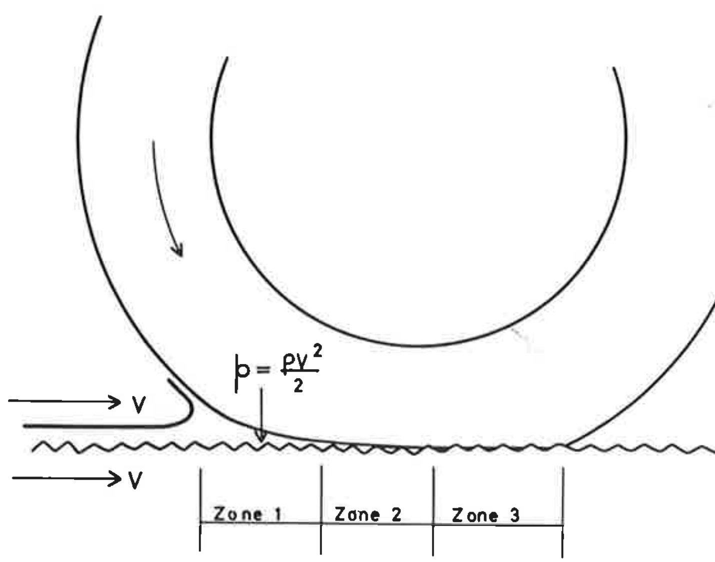

Figure 2. Displacement of water by tire in successive zones.

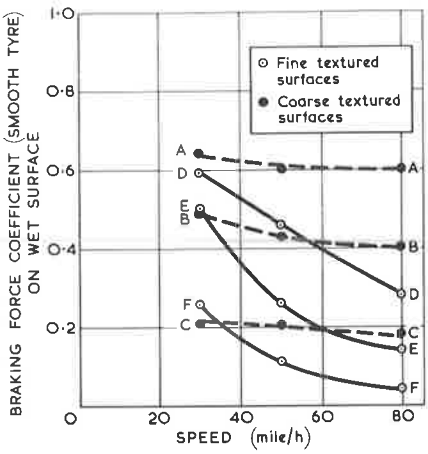

Figure 3. Change in skidding resistance with speed on six surfaces on the Road Research Laboratory test track.

is displaced in zone 1 by the dynamic pressure generated in the water. To the first order this pressure depends on the speed but not on the water depth, so that as far as pressure goes thick films are as easily displaced as thin ones. The total thrust of the water on the tire increases with the thickness of the water, although the pressures remain of the same order. However, the viscosity of water prevents it from being swept away entirely, and the tire is left descending on a much thinner layer in zone 2. If there is time for it to squeeze out all the water it can, zone 3 is formed, where maximum contact and friction are achieved and the water carries none of the load. Clearly, coarseness and harshness of texture would be effective almost entirely in zones 2 and 3. As speeds increase and the time for expelling the water diminishes, the boundaries of the zones move backwards. There is less and less contact and less and less friction. Finally if the dynamic pressure appropriate to the vehicle speed exceeds the pressure which normally exists under the tire and supports it (very approximately equal to the internal pressure, the inflation pressure), only zone 1 remains and the tire is supported on a relatively thick water film. The tire is then said to be in a state of dynamic aquaplaning. The thinner the water layer the larger the part played by viscosity and probably by turbulent energy dissipation in the water and the more the behavior may be expected to depart from the simple conditions just described.

EFFECT OF TEXTURE ON FRICTIONAL COEFFICIENTS

The effects of coarseness and harshness on the coefficient of skidding resistance are shown in Figure 3. The relatively flat curves showing a slow falloff with speed are for coarse surfaces, that is, for good drainage. The swiftly descending curves are for fine-textured surfaces, that is, for poor drainage. However, some surfaces of each class have considerably higher coefficients than others in the same class. These are surfaces which are harsh rather than polished. It is to be noted that the coefficients at 30 mph can put surfaces in a very different order of merit from coefficients at, say, 80 mph if the textures of the surfaces are not similar. At 30 mph it is the harshness which largely determines the coefficient, while at 80 mph the scale of the texture is becoming much more important. A measurement of friction at 30 mph together with a knowledge of the texture would give a fair idea of what could be expected at higher speeds.

HIGH SPEEDS, DEEP WATER AND AQUAPLANING

High speeds or thick layers of water tend to make more difficult the problem of water removal, i.e., causing the load to be supported directly by the surface and not through the water. Figure 4 shows the much lower coefficient obtained in 1 in. of water than in 0.007 in. The rapid descent (between 30 and 40 mph) may be due to the approach of dynamic aquaplaning.

An example of the effect of drainage alone, although it is drainage in the tire tread rather than in the road surface, is shown in Figure 5. This

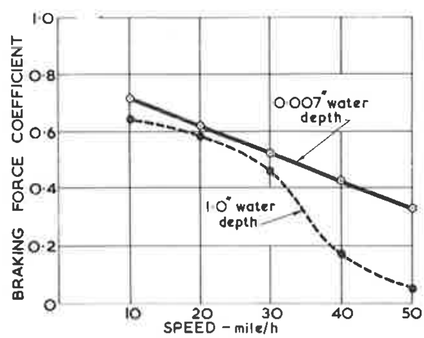

Figure 4. Effect of water depth on the results of locked-wheel braking tests on a smooth surface with a patterned tire.

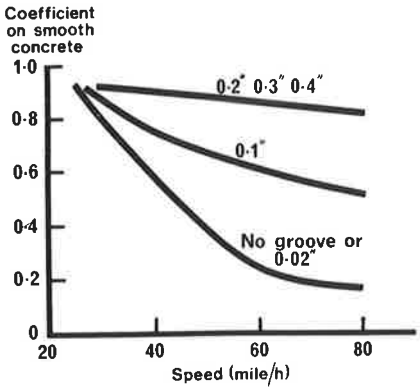

Figure 5. Effect of tire drainage grooves of different widths.

shows the peak braking force coefficient for longitudinally ribbed tires, which differed only in the separation between the ribs of the tread. If the grooves were mere knife cuts, the coefficient was almost the same as for an uncut tire. Grooves 0.1 in. wide gave a much better performance than no grooves, and grooves 0.2 in. wide gave very good results. No further improvement was evident if the grooves were made still wider. It is also clearly shown that increases in drainage which produced little effect at 20 or 30 mph were of great importance at 70 or 80 mph. All this is in agreement with the fact that the percentage falloff in coefficient between 30 and 80 mph correlates to a considerable extent with the texture depth, the simple measure of coarseness of texture.

Dynamic aquaplaning requires a certain depth of water depending on the surface texture and the tire tread. In England we do not regard aquaplaning of this type as a very serious danger on our roads in the water depths commonly encountered. On airfields it may be quite a different matter. On roads, the water depth rarely exceeds about 0.1 in., except of course in puddles where the water is standing. The impression has been given that complete aquaplaning takes place on ordinary wet roads at a definite speed depending on the inflation pressure of the tire. This may be so in deeper water, but we have found it impossible to produce complete aquaplaning on our test track at Crowthorne at depths approaching 0.1 in. except with smooth tires on our smoothest surfaces. With good modern tread patterns quite high coefficients are still obtainable at 2.5 times the aquaplaning speed. Figure 6 shows such a result. The peak coefficient is very adequate and there is no sign of aquaplaning at about 130 mph.

Our view, at the Road Research Laboratory, is that the dynamic type of aquaplaning should be rare. It is a real danger but should occur only in special conditions and can ordinarily be eliminated by a good surface texture, a good tread, and prevention of puddles. Viscous support of the tire has been recognized for many years as a cause of low friction. We should think that lowered friction due to this cause on fine-textured and polished surfaces was more likely to be a significant cause of accidents at the present time. Skidding accidents were found to become frequent enough for the sites to be regarded as accident black spots at places where the sideway force coefficient at 30 mph fell below about 0.4. Fortunately a good surface texture is able to limit this danger under most conditions in England. Very heavy rainfall may, of course, present greater problems in other places.

It is of interest in connection with Figure 6 that the coefficient does not appear to increase at very high speeds. Rising coefficients have been obtained at the Road Research Laboratory but only on coarse surfaces and with a different technique from that used to obtain the results shown in Figure 6. These coarse surfaces can apparently be harsh or polished and the tires that were used showed severe signs of heating and wear. It has been suggested that hysteresis friction could increase in this manner owing to the greater speed of sliding; it is therefore of interest that Figure 6 does not show it even at the high speed attained.

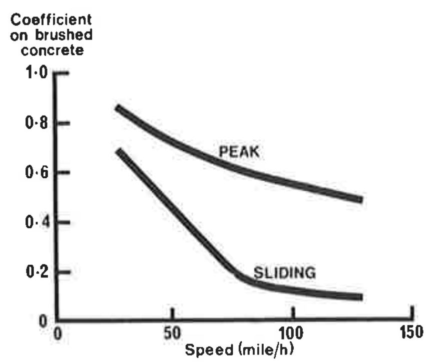

Figure 6. Braking force coefficients up to a high-speed, patterned tire.

There is a very large difference between the peak and the sliding coefficients in Figure 6. In

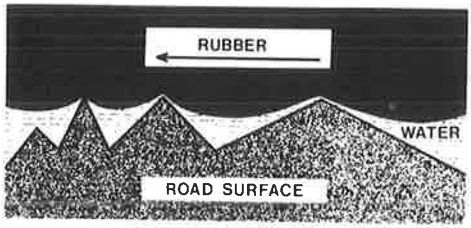

Figure 7. Contact, and deformation of tread, at tops of asperities.

normal driving, friction would be available up to the peak value, and the driver might therefore not realize that if he locked his wheels in an emergency he would experience a very large drop in friction. This emphasizes the need for some device on the vehicle to make wheel locking impossible.

HYSTERESIS FRICTION

In order to get a useful contribution from the hysteresis component of friction one cannot use a smooth surface but must have a texture that will deform the tread rubber at the asperities. This deformation can occur with dry or lubricated contact as shown in Figure 7. The frictional force comes from the pressure difference between the two sides of the asperities when the rubber rebounds less vigorously than it is displaced. It can clearly exert these pressures through a water film if necessary, but the smaller the asperities in relation to the film thickness the smaller their effect will be. Small asperities can be swamped in a way that larger ones will not.

Angularity, steep slopes, sharp edges and points (all that go to make a surface harsh) increase the hysteresis friction. The scale of the asperities is relatively unimportant in itself, but small ones will be swamped in a thin film of water which large ones might penetrate. On the tops of large asperities, where the pressures are likely to be high and water films, if present, very thin, small asperities should still be effective. The coarse, supposedly non-skid, surfaces that turned out to be quite slippery failed because the tops of the large asperities became polished and lost their harshness. Such surfaces, although slippery enough to be unsuitable for roads, do not give the extremely low coefficients which fine-textured surfaces can give. The only way to prevent or reduce polishing is to use a stone which is resistant to it.

PRODUCTION OF DESIRABLE TEXTURES

Large-scale textures are obtained in bituminous surfaces by the use of large aggregate directly in the mix or as a closely packed layer of precoated chippings rolled into the top of a fine-textured asphalt. Some idea of the textures that are attainable can be gained from a number of surfaces that have been in use for over three years on a fast road that carries about 12,000 tons a day. A macadam had a texture depth of 0.06 in., an asphalt with precoated chippings and a surface dressing had texture depths of about 0.07 in. A high-stone-content asphalt, which had failed to maintain an adequate surface because the stones became too embedded, had a texture depth of 0.012 in.

Concrete roads may be given a coarse texture by brushing when new or by cutting grooves when old. In England, concrete is being brushed much more severely than formerly, and an average texture depth of 0.030 in. and a minimum of 0.025 in. are being required.

When concrete is grooved, the direction of grooving is unimportant at, say, 30 mph but can be very important at high speeds. Locked-wheel braking force coefficients at 80 mph on a concrete airfield were about 0.2 on the untreated surface, almost the same in the direction of the grooves, and about 0.6 perpendicular to the grooves. The water depth was about 0.010 to 0.020 in. in these tests, the water tending to drain into the grooves.

Having chosen a method of construction which will give a texture of the right kind, one aims to keep it harsh by the use of stones that resist polishing. In England, stones from each quarry are periodically tested for what is known as their polished-stone value. Roads and sections of roads have been classified into groups according to the severity of polishing expected and the likelihood of skidding, and stone of a sufficiently high polished-stone value is required to be used according to the group concerned. The levels of polished-stone value thus laid down are not obligatory standards, but they are largely effective in that the Ministry of Transport will not approve a scheme unless the levels are adhered to.

Where a road surface consists largely of stone, there is quite a good correlation between the polished-stone value of the stone concerned and the skidding resistance as measured by the sideway force machine or the British pendulum tester.

RESEARCH TRENDS AND POSSIBILITIES

The Road Research Laboratory is following a number of different lines of research in relation to surface texture. Attempts will be made to produce freely draining surfaces which will become no more than damp when it rains. Such surfaces are easy to make, but they tend to close up if heavily trafficked, to disintegrate in frost, or to become filled with silt. It is expected that organic growth may occur in the interstices and contribute to clogging up the drainage. One length of this type of concrete road has been laid, and it is planned to lay a series of experimental lengths in bituminous materials. Not only would such surfaces eliminate the possibility of aquaplaning, they would also to a large extent eliminate the splashing nuisance.

Because there is not likely to be available enough stone of the highest polished-stone value, work is being started on artificially treated aggregates. A calcined flint, heat treated to turn it white, has been found to be among the very best materials for resisting polishing. In view of this, the heat treatment of other aggregates is to be investigated.

Methods of brushing and raking concrete are being studied. As already mentioned, texture depths of 0.030 in. are now being required for motorway construction. The new coarser surfaces have given good resistance to skidding when new, but not a great deal is yet known about the rate at which they will polish. Polishing and wear are certainly taking place fairly rapidly in some cases. Investigation of grooving techniques and the rate of wear is also taking place.

An investigation is being continued in which the best texture for high-speed roads is being sought by directly correlating the skidding accident record of lengths of road with their texture and skidding resistance. Studies are also being made of the relation between texture and hysteresis and of the geometrical characteristics of the texture that are associated with the most effective surfaces.

One of the main purposes of this symposium is to indicate areas where research might usefully be encouraged and I should like to suggest, besides those aspects just mentioned, further theoretical and experimental investigations of the dynamics and physics of the tire-road interaction. The theoretical investigations of the past have mostly been based on very simplified models of the processes involved. It may be that a fuller understanding of what is going on may suggest new lines of practical progress. Those contributing to this symposium from the theoretical side probably have a number of suggestions to offer already.

ACKNOWLEDGMENT

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