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CONCRETE PAVING TEXTURE

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Wet pavement skid resistance - especially at high speeds - is the road surface characteristic most relevant to the safety of road users. It is related to following factors :

- a harsh microtexture, which rules out the presence of polishable materials (stones and sand) at the surface of the pavement;

- a rough macrotexture which can be obtained by means of an adequate surface treatment.

For about twenty years, the Belgian Road Research Centre has been making considerable effort in order to improve the skid resistance properties of both concrete and bituminous pavements. This research has resulted in developing various surface treatments which are the subject of tender specifications for motorways and national roads.

Belgium has a long experience in the field of concrete pavements. Since 1970, the Ministry of Public Works has resolutely opted for the technique of continuously reinforced concrete for the construction of motorways with a concrete surfacing. These pavements are characterized by the absence of transverse joints. This allows to carry out lasting pavements requiring virtually no maintenance, at a construction cost which is competitive compared to other types of pavements, thanks to an advanced laying technology. Since 1981, new motorways are all carried out with continuously reinforced concrete; bituminous surfacings being reserved for pavements in built-up areas (problems related to underground pipes) and for improving existing roads by thin overlays.

Together with the development of this large road and mortorway network, various surface treatments have been developed in order to improve the safety and comfort of users, particularly with respect to wet pavement skid resistance, evenness and noise.

As for concrete pavements, permitted surface treatments are transverse brushing, deep transverse grooving, chip-sprinkling and aggregate exposure.

The most widely used surface treatment on concrete pavements is transverse brushing or deep transverse grooving. It consists of creating transverse grooves in relation to the axis of the road, aimed at draining surface water in rainy weather conditions and at reducing, especially at high speed, the thickness of the water film between the tyre and the surface of the pavement.

In Belgium, the Road Administration opted in a first stage, and this since 1970, for imposing deep transverse grooving in tender specifications for motorways and main roads.
The depth of the grooves is about 5 mm and their spacing, first fixed and than variable, between 15 and 30 mm. On top of its easy application and its low cost, the main advantage of this technique is that it accelerates the surface drainage of the pavement and hence improves its skid resistance properties, mainly at high speed.

On the other hand, rolling noise is relatively high and the durability is closely linked to the intrinsic quality of the surface mortar. As regards the constituents of the concrete, the presence of sand or aggregates which are liable to polishing must be prohibited.

Longitudinal grooving is also used in certain countries; this technique has the advantage of producing less rolling noise, but on the other hand reduces the quality of surface drainage.

The objective of the development of the new surface treatments described hereafter, i.e. chip-sprinkling and aggregate exposure, was to palliate the above-mentioned disadvantages : reduce the rolling noise, increase durability and, in the case of chip-sprinkling, the possibility to use local aggregates, even with a low resistance to polishing, in the bulk of the mix.

The sprinkling treatment consists of spreading highly polish-resistant chippings of a given size on the surface of a pavement under construction, and then partly impacting them so as to create a rough surface macrotexture.

Chip-sprinkling of concrete pavements has been developed in Belgium in the mid seventies, by analogy with chipped bituminous pavements. However, this treatment never went further than the experimental stage, namely because of the difficulty in uniformly impacting the chippings in the fresh concrete. But after development and improvement, the technique has been applied on several motorway sections in France from the beginning of the eighties, namely on the A26 motorway between Reims and Calais. Since 1984, the technique is used there in combination with chemically exposed aggregate finish, which allows to carry out a more homogeneous texture and hence to improve surface performance.

Concrete aggregate exposure consists of removing the surface mortar of the concrete so as to lay bare its mineral structure. Like transverse grooving this technique requires hard and polish-resistant aggregates (P.S.V. ≥ 0.50). As a result, the technique can only be applied in regions where sufficient quantities of such materials are available; it is the case in Belgium where there are numerous deposits of porphyry, gravel and sandstone.

This technique has developed in two stages :

a) <u>Mechanical aggregate exposure</u>

In the first stage, the treatment was carried out mechanically by simultaneously watering and brushing the surface of the fresh concrete by means of a rotary brush (figure 1). The water and the laitance are then removed from the surface of the concrete. Mechanical aggregate exposure has been applied on 700,000 m² of pavement in Belgium between 1975 and 1981. Since then, the technique has been superseded by chemical aggregate exposure which allows to carry out the brushing later after concreting and is consequently less sensitive to possible fluctuations in the consistency of the fresh concrete.

b) <u>Chemical aggregate exposure</u>

This technique consists of spraying an appropriate setting retarder on the fresh concrete immediately after concreting. After hardening of the concrete and at the earliest 24 hours after concreting, the surface is mechanically brushed so as to remove the mortar that has not set and to expose the surface aggregate of the concrete.

The procedure was used for the first time on a mortorway test section in Denmark in 1976, but it mainly developed in Belgium since 1980, namely after research carried out by the Association of the producers of hard and polish-resistant stones, in co-operation with the Belgian Road Research Centre.

The technique has the following peculiarities :

- the setting retarder consists of a solution of sugar, but also includes other components in order to increase viscosity, as well as a pigment;

- immediately after spraying, the surface is protected against drying, by rolling out a plastic sheet on the fresh concrete. This sheet is removed just before brushing;
- brushing is carried out under water by means of two steel wire rotary brushes, installed on a self-propelled vehicle moving on the hardened concrete. This activity takes place at the earliest 24 hours after concreting, but according to above-mentioned research, it can be postponed up to 72 hours after concreting. If the brushing is carried out before 48 hours, the surface should be protected by spraying a curing compound after brushing.

For the time being, more than 8 million m² of pavement have been treated with this technique in Belgium, among which most of the recent motorway surfacings carried out with continuously reinforced concrete. The technique is also used in France since 1985, as well as in other countries such as the Netherlands, Italy and Austria.

Systematic measurements of surface characteristics on test roads, as well as research conducted at the Belgian Road Research Centre in this field, allow to draw the following conclusions on the performance related to safety and comfort :

a) <u>Skid resistance</u>

The various surface treatments described above allow to carry out pavements with high and lasting skid resistance, and to meet the criteria fixed in tender specifications with respect to skid resistance (the sideway force coefficient measured at 80 km/h and brought to 20 °C must be higher than 0.45 for each 100 metre section).

b) <u>Evenness</u>

Measurements carried out with the Longitudinal Profile Analyser (APL) do not allow to establish a systematic impact of surface treatment on the evenness. One notes however that for reasons inherent in the different types of materials and construction methods, longitudinal evenness at short spans (shorter than 3 m) and thus rolling comfort are generally not as good on concrete pavements as on bituminous pavements.

c) <u>Noise</u>

Beside rolling comfort and skid resistance, other concerns have gained increasing importance in the last years, namely the acoustic environment of the pavement and rolling resistance.

Research conducted at the Belgian Road Research Centre made it possible to highlight texture-related parameters which have an influence on rolling noise. One should note that the noise reduces not only the comfort but also the safety by contributing to the fatigue of the driver and likely to reduced performance.

Figure 2 shows how a tyre deforms when rolling on different ranges of road profile irregularities.

Three ranges of irregularities are distinguished according to wavelength as compared to the footprint length of the tyre.

Short wavelength irregularities cause only small dynamic deformations : the tyre only envelopes the protrusions of the surface. This range of wavelengths corresponds to the macrotexture. It results in providing small drainage channels for surface water at the tyre/pavement interface, thus ensuring wet pavement skid resistance. In addition, it attenuates rolling noise by draining off the air entrained in the grooves of the tyre tread. These two functions can also be performed by vertical drainage, i.e. by an inverted macrotexture : such is the case with porous asphalt.

At the other end of the scale, long wavelength irregularities, i.e. those referred to as roughness, also do not cause great tyre deformations. They act mainly on the suspension system.

Between those two extremes, there is a critical wavelength which maximizes dynamic deformations or, in other words, the vibrations of the tyre. This wavelength is of the order of half the tyre footprint size. Such irregularities are responsible not only for tyre/road noise but also for extra rolling resistance, which may lead to an up to 10 % excess of fuel consumption; these effects are usually, but wrongly, ascribed to macrotexture.

In the Technical Committee Report on Surface Characteristics to the PIARC World Road Congress in Brussels in 1987, the role of this type of irregularities was demonstrated and they were given the name of 'megatexture'. They range between macrotexture and roughness, which means that, by convention, they cover the range of wavelengths from 50 to 500 mm although the shortest among them, i.e. those from 50 to 150 mm, give the most trouble.

Figure 3 shows an overview of the effects of the different ranges of surface irregularities on the various aspects of vehicle/road interaction. It can be seen that, with one exception that can be considered as of minor importance (tyre wear), micro- and macrotexture only have beneficial effects, whereas all adverse effects can be attributed to megatexture and roughness.

Hence, it is possible to set a simple criterion for optimising surface characteristics of a road surfacing : there is a range of irregularities which must be present (micro- and macrotexture) and another range of irregularities which are undesirable (megatexture and roughness).

Now let us look at the matter from a concrete point of view. First of all what does megatexture actually consist of? As far as concrete roads are concerned, it may have three origins :

1) It may result from surface deterioration, for example scaling or loss of aggregate.

2) It may be caused by the surface treatment of the fresh concrete, for example deep transverse grooving or chip-sprinkling with an uneven distribution of the chips will lead to irregularities with wavelengths typically in the range of megatexture.

3) There is also a type of megatexture which is specific to concrete, consisting of small undulations with a wavelength of the order of 100 mm which can be observed in the fresh concrete behind the laying machines. It is thus very important to smooth out these small irregularities before the surface treatment, which can be achieved by the use of a longitudinal finishing beam (supersmoother) behind the paver.

The reason why concrete pavements are generally more noisy than bituminous pavements is that, when comparing their respective mega- to macrotexture amplitude ratio, they systematically exhibit, at equal macrotexture, a higher level of megatexture (figure 4).

When comparing the noise level measured outside a private car at a speed of 80 km/h on various types of surfacing, it can be noted again that concrete pavements are generally more noisy than bituminous pavements, in particular grooved or chipped pavements with 14/20 aggregates (figure 5).

On the other hand, it should be noted that the noise level of some concrete roads may be comparable to some porous asphalts. In this respect, the exposed aggregate finish technique is most advantageous, provided the concrete has optimum grading. In Belgium, we normally use continuously graded concrete 0/32 mm. For optimum noise reduction, the maximum aggregate size in the wearing course should be reduced to 7 or 8 mm, as it has been reported in the Technical Committee Report on Concrete Roads at the latest PIARC World Road Congress in Marrakech, based on recent work sites in the Netherlands and in Austria.

By way of conclusion, it is thus possible to construct concrete pavements which are both safe, comfortable and economical to the road user and friendly to the acoustic environment.

With a view to reducing noise levels on existing concrete pavements, a new technique has been applied by grinding with a diamond blade groover.

This technique has been used successfully for many years in the USA as a part of the concrete pavement restoration programme, mainly in order to restore the evenness of the concrete surface. By using high-powered machines - production may be up to 2.000 m² of treated surface per day - it is thus possible to restore the properties of old, irregular and uncomfortable concrete roads into new, safe and comfortable road surfacings.

Two experiments have been recently carried out in Belgium :

- the first experiment consisted of restoring the evenness of a section of the A12 Brussels-Antwerp motorway. This road exhibited longitudinal irregularities by step faulting at joints, as a result of local slab repairs. Measurements carried out before and after grinding yielded very positive and promising results, for evenness as well as for skid resistance and noise levels;

- the second experiment was undertaken on a section of the A2 motorway between Leuven and Diest, which consists of a continuously reinforced concrete pavement with a deep transversely grooved surface. The main objective of this experiment was the reduction of the rolling noise level. Traffic noise measurements have been carried out before and after the treatment by the B.R.R.C. The results show a significant reduction of the rolling noise level, both for private cars and for heavy vehicles, ranging respectively from 5,3 to 5,8 dB(A) and from 3,2 to 4,5 dB(A) (Table I and II). The final noise level is about the same in both directions.

As a conclusion, it can thus be said that based on the experiments carried out in Belgium as well as in some other European countries, grinding has proven to be an efficient technique for restoring the surface properties of old concrete roads, and should thus be considered in some cases as an economical alternative to asphalt overlays in renovating concrete roads.

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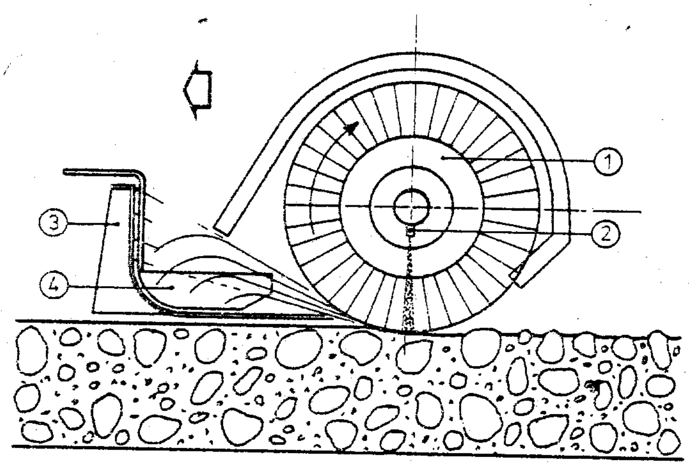
TABLE I : REDUCTION OF THE ROLLING NOISE LEVEL AFTER GRINDING ON THE A2 MOTORWAY - LIGHT VEHICLES

DIRECTION	DIEST		LEUVEN	
Date of measurements	260391	230591	260391	230591
Number of vehicles	205	207	215	212
Mean speed (km/h)	108	111	116	108
Mean noise level (dBA)	90,0	84,7	91,3	84,5
Differences (dBA)	- 5,3		- 5,8	

TABLE II : REDUCTION OF THE ROLLING NOISE LEVEL AFTER GRINDING ON THE A2 MOTORWAY - HEAVY VEHICLES

DIRECTION	DIEST		LEUVEN	
Date of measurements	260391	230591	260391	230591
Number of vehicles	104	140	126	136
Mean speed (km/h)	88	89	92	90
Mean noise level (dBA)	92,9	89,7	93,8	89,3
Differences (dBA)	- 3,2		- 4,5	



1. Rotary brush
2. Spray bar
3. Receiving trough
4. Scraper for removing the laitance

Figure 1

Schematic diagram of a mechanical stripping machine

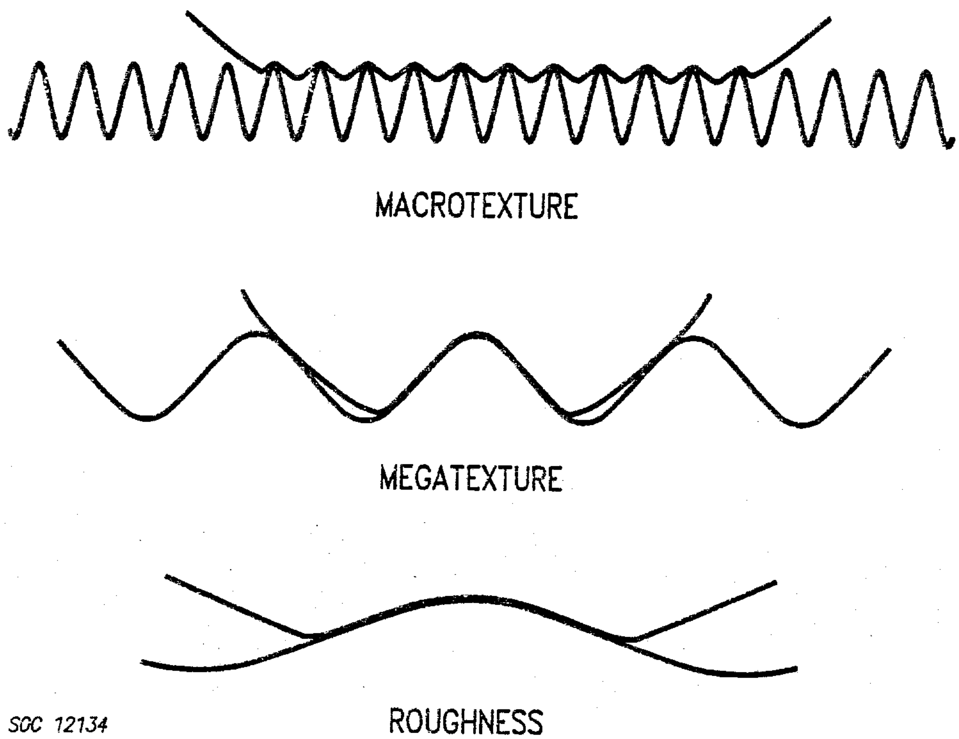


Figure 2

Sketch showing how a tyre deforms
when rolling on different ranges of road profile irregularities

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	Texture			Roughness
	Micro	Macro	Mega	
Skid resistance	+	+		
Road-holding qualities				–
Splash and spray		+		
Reflectance		+		
Dynamic loads				–
Vehicle wear				–
Tyre wear	–			
Rolling resistance		(–)	–	(–)
Vibrations (inside vehicles)			(–)	–
Noise (inside vehicles)			–	
Noise (outside vehicles)		+	–	

Figure 3

Overview of the surface characteristics influences on the various aspects of vehicle/road interaction.
+ and - denote favourable and adverse effects, respectively.
(-) denote less significant or controversial influences.

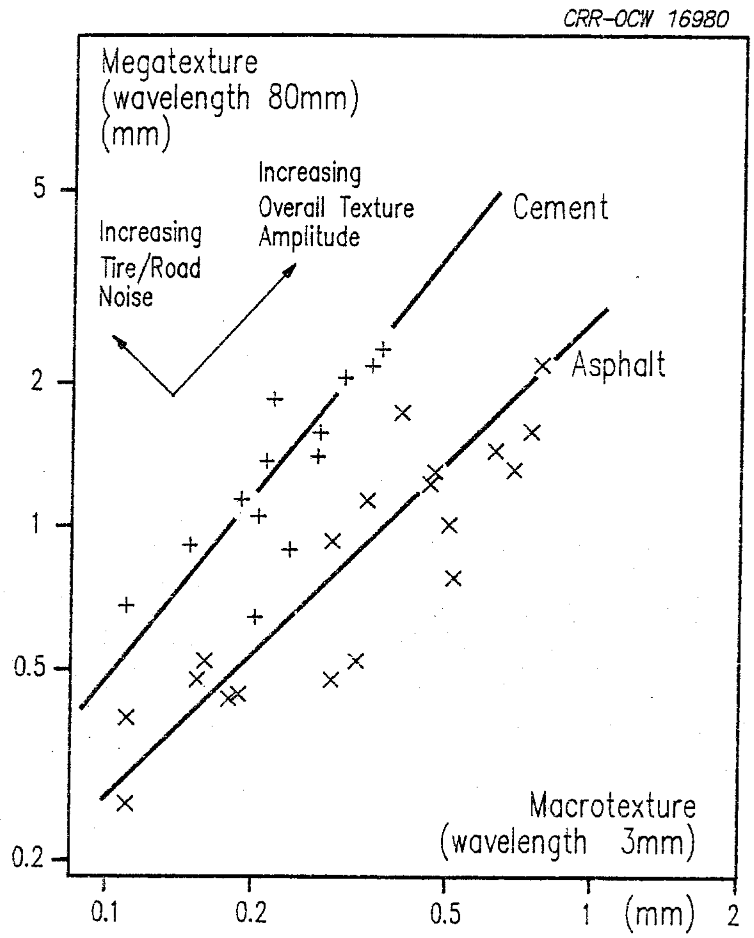

Figure 4

Comparison of cement and asphalt-bound surfacings
(asphalt concretes and surface dressings)
regarding their respective mega- to macrotexture amplitude ratio.

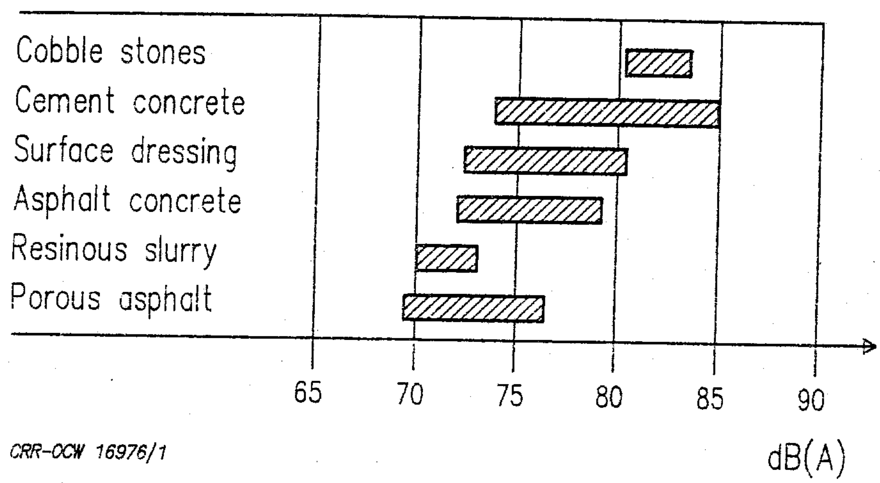

Figure 5

Comparison of various types of surfacings regarding their noisiness in terms of coasting noise level of a car (80 km/h).