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NOISE-REDUCING CONCRETE PAVEMENTS

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1. INTRODUCTION

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 the 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 efforts in order to improve the skid resistance properties of both concrete and bituminous pavements. This research has resulted in developing various surface treatments which have been included in the specifications for motorways and national roads (1).

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 pavements in constructing motorways with a concrete surfacing. These pavements are characterized by the absence of transverse joints. This makes it possible to construct durable pavements requiring virtually no maintenance, at a cost which is competitive compared to other types of pavements, using advanced laying technology. Since 1981, new motorways have all been constructed with continuously reinforced concrete; bituminous surfacings being reserved for pavements in built-up areas (due to problems related to underground pipes) and for improving existing roads by thin overlays.

Together with the development of Belgium's 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.

Permitted surface treatments for concrete pavements are transverse brushing, deep transverse grooving, chip-sprinkling, and aggregate exposure (figure 1).

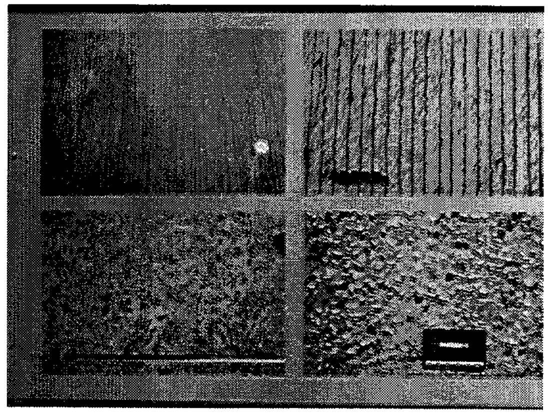


Figure 1 :

Surface treatements for fresh concrete.

Top left : transverse brushing;
top right : deep transverse grooving.
Bottom left : aggregate exposure;
bottom right : chip-sprinkling.

Besides rolling comfort and skid resistance, other concerns have become increasingly important in recent years, namely the acoustic environment of the pavement and rolling resistance.

Research conducted at the Belgian Road Research Centre has made it possible to highlight texture-related parameters wich have an influence on rolling noise. It should be noted that noise reduces not only comfort but also safety by contributing to the fatigue of the driver, and is likely to reduce his performance.

2. SURFACE TREATMENTS OF CONCRETE PAVEMENTS

2.1 Brushing or deep transverse grooving of fresh concrete

The most widely used surface treatment on concrete pavements is transverse brushing or deep transverse grooving. This consists of creating grooves transversely to the centre line of the road, which are aimed at draining surface water in rainy weather conditions and at reducing the thickness of the water film between the tire and the surface of the pavement, especially at high speed.

The macrotexture obtained by brushing is finer than by grooving. This results in lower values for skid resistance at high speed, surface drainage and durability than in the case of grooving, but also in lower rolling noise.

In Belgium, the Road Administration first opted in 1970 for imposing deep transverse grooving in the specifications for motorways and main roads (2).

The depth of the grooves was about 5 mm and their spacing was first regular and then randomly varied between 15 and 30 mm. On top of its easy application and 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 susceptible 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 and can lead to difficulties in handling motorcycles.

The objectives of the development of the new surface treatments described hereafter, i.e. chip-sprinkling and aggregate exposure, were to overcome the above-mentioned disadvantages, i.e. reduce the rolling noise and increase durability, and in the case of chip-sprinkling, permit use of local aggregates, even those with low resistance to polishing, in the bulk of the mix (3).

2.2 Chip-sprinkling of concrete pavements

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 embedding them so as to create a rough surface macrotexture (4).

The chippings used are usually in the size range of 10 to 14 or 14 to 20 mm, and they are spread at a rate of 6 to 7 kg/m^2. These chippings must meet strong criteria with respect to their shape, cleanness, mechanical resistance and Polished Stone Value (PSV).

Chip-sprinkling of concrete pavements was developed in Belgium in the mid-seventies, by analogy with chipped bituminous concrete. However, this treatment never went further than the experimental stage, because of the difficulty of uniformly embedding the chippings in the fresh concrete. But after development and improvement, the technique has been applied on several motorway sections in France since the beginning of the eighties, namely on the A26 motorway between Reims and Calais (figure 2). Since 1984, the technique has been used there in combination with a chemically exposed aggregate finish, which achieves a more homogeneous texture and hence improves surface performance (5).

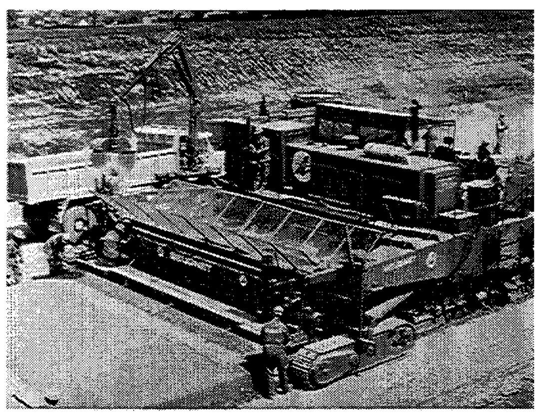


Figure 2 :

Construction work site of the A26 motorway in the North of France : thick slab with chipped surface.

2.3 Exposed aggregate finish

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

This activity takes place no sooner than 24 hours after paving, but according to the above-mentioned research, it can be postponed up to 72 hours after paving. If the brushing is carried out before 48 hours, the surface should be protected by spraying a curing compound after brushing.

To date, more than 10 million m² of pavement have been treated with this technique in Belgium, including most of the recently constructed motorway surfacings in continuously reinforced concrete. The technique has also been used in France since 1985, as well as in other countries such as the Netherlands and Austria. In order to minimize the noise level, the maximum aggregate size in the wearing course has been reduced to 7 or 8 mm in these other countries. This has been achieved by using two-layer constructions with only small-size aggregate in the upper layer (8).

2.4. Achieved performance

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

a) Skid resistance

The various surface treatments described permit construction of pavements with high and lasting skid resistance, and meeting the criteria set in specifications with respect to skid resistance (the sideway force coefficient measured at 80 km/h and converted to a standard temperature of 20 °C must be higher than 0.45 for each 100-metre section).

b) Roughness

Measurements carried out with the Longitudinal Profile Analyser (APL) do not permit establishment of a systematic impact of surface treatment on roughness. It has been noted, however, that for reasons inherent in the different types of materials and construction methods, longitudinal roughness at short spans (shorter than 3 m) and thus rolling comfort are generally not as good on cement concrete pavements as on bituminous pavements.

c) Noise

Figure 6 shows how a tire deforms when rolling on roads in different ranges of profile irregularities.

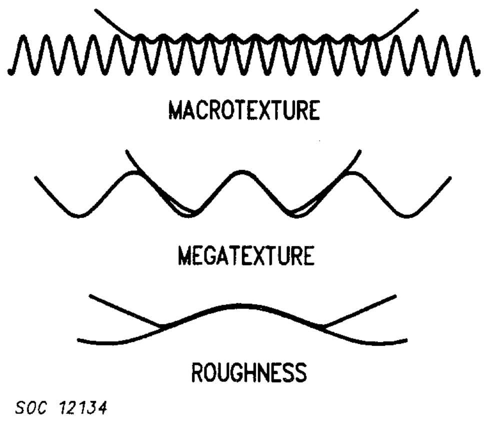


Figure 6 :
Sketch showing how a tire deforms when rolling on different ranges of road profile irregularities.

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

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

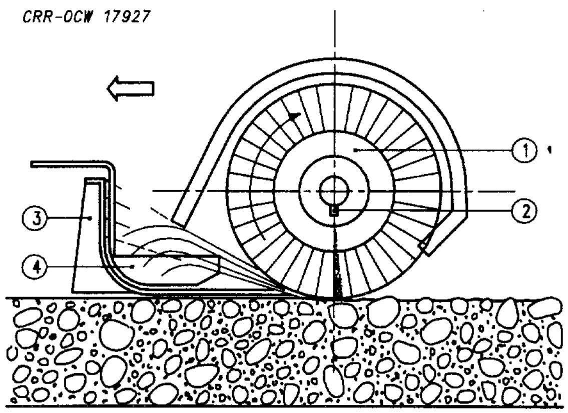
At the other end of the scale, long-wavelength irregularities, i.e., those referred to as roughness, also do not cause great tire deformations. They act mainly on the suspension system.

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

This technique has developed in two stages :

a) Mechanical aggregate exposure

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 3). The water and the laitance were then removed from the surface of the concrete. Mechanical aggregate exposure was 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 permits brushing later after paving and is consequently less sensitive to possible fluctuations in the consistency of the fresh concrete.



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

Figure 3 :
Schematic diagram of mechanical aggregate exposure.

b) Chemical aggregate exposure

This technique consists of spraying an appropriate set retarder on the fresh concrete immediately after concreting. After hardening of the concrete and at the earliest 24 hours after paving, the surface is mechanically brushed 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 motorway test section in Denmark in 1976 (6), but it began to develop mainly in Belgium since 1980, after research had been carried out by the Association of the producers of hard and polish-resistant stones in co-operation with the Belgian Road Research Centre and a contracting firm specialized in concrete road treatment (7).

For the reasons that will be explained hereafter, this technique gives the best compromise between skid resistance, riding comfort and rolling noise, and has therefore been applied on most of the motorway surfacings constructed in Belgium since 1982.

The technique has the following peculiarities :

- The set 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 (figure 4). This sheet is removed just before brushing.

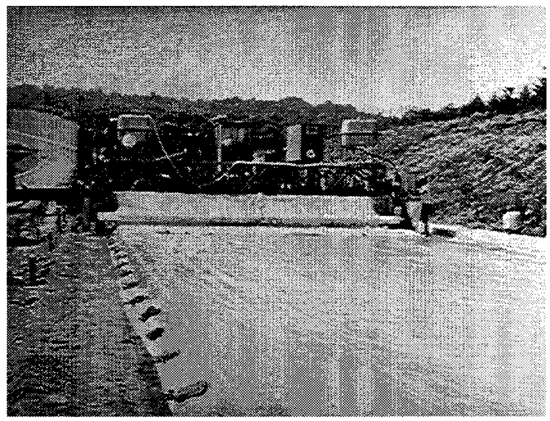


Figure 4 :
A retarder is sprayed into the surface, which is then protected with a plastic sheet.

- 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 (figure 5).

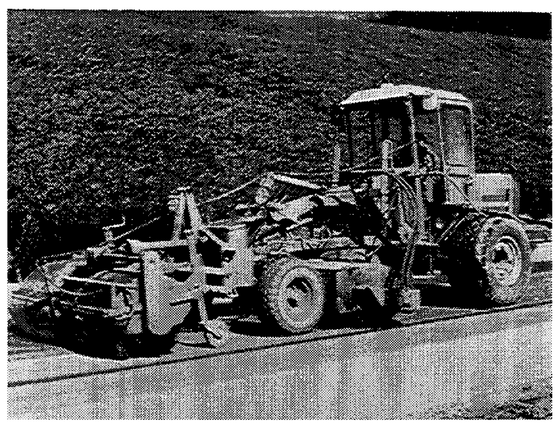


Figure 5 :
Thorough brushing to remove the unhardened mortar the day after concreting.

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

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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 7 :

Overview of the surface characteristics influences on the various aspects of vehicle/road interaction.

+ and - denote favorable and adverse effects, respectively.
(-) denote less significant or controversial influences.

Hence, it is possible to set a simple criterion for optimizing the 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).

As far as concrete roads are concerned, megatexture 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. This can be achieved by the use of a longitudinal finishing beam (supersmoother) behind the paver.

By way of indication, figure 8 shows the noise level ranges measured outside a vehicle driven on various types of pavements at 80 km/h. One notes that concrete pavements are generally more noisy than bituminous pavements, in particular grooved or chipped pavements with 14 to 20 mm aggregates.

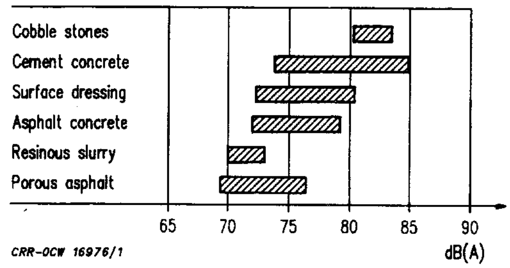

Figure 8 :

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

Furthermore, in the case of transverse grooving, the acoustic spectrum presents a characteristic peak at a frequency which depends on the spacing between the grooves and on speed; this can sometimes lead to an annoying whistling. On the other hand, the denser and finer texture obtained by aggregate exposure does generally lead to a rolling noise which is lower than on grooved and chipped pavements and of the same order as on asphalt concrete or even porous asphalt. Belgium normally uses continuously graded aggregate for concrete (0/32 or 0/20 mm). For optimum noise reduction, the maximum aggregate size in the wearing course should be reduced to 7 or 8 mm. This was reported in the Technical Committee Report on Concrete Roads at the PIARC World Road Congress in Marrakech in 1991 and is based on observations on recent work sites in the Netherlands and in Austria.

By way of conclusion, the exposed aggregate surface treatment permits construction of concrete pavements with high skid resistance and low noise levels, and thus makes it possible to construct concrete pavements which are both safe, comfortable and economical to the road user and friendly to the acoustic environment.

REFERENCES

1 Ministère des Travaux Publics - Administration des Routes,
Cahier des Charges-type 150 (Edition 1988).

2 J.-P. Leyder,
Dix ans d'expérience de striage transversal profond du béton à l'état frais.
2e Symposium Européen des Routes en Béton, C-8, 311-323, Bern 1973.

3 F. Fuchs,
Traitement de surface du béton frais par cloutage ou par dénudage.
Symposium International sur les Routes en Béton, Londres, 1982.

4 F. Fuchs,
Texturing of cement concrete pavements by chip-sprinkling of the fresh concrete.
Transportation Research Record 821, Transportation Research Board, Washington D.C. 1981.

5 Y. Charonnat,
Dénudage et cloutage-dénudage. Utilisation et performances.
Compte rendu des travaux du Congrès, pp. 313-314.
XVIIIe Congrès Mondial de la Route, A.I.P.C.R., Bruxelles 1987.

6 G. Christiansen,
Five years of experience with the concrete test road on M 20 Olby-Ringsted.
XVII World Road Congress, Question II, P.I.A.R.C., Sidney 1983.

7 J. Chavet, G. Lefèbvre, J. Manouvrier, M. Roegies,
Traitement de surface des revêtements en béton de ciment. Dénudage par voie chimique.
La Technique Routière, 1/1983, 16-30, Bruxelles 1983.

8 H. Sommer,
Herabsetzung des Rollgeraüsches bei Betonfahrbahndecken.
Zement Beton 3/90, Wien 1990.