New Type of Ultrathin Friction Course

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A new kind of ultrathin surfacing, intermediate between chip seal and very thin asphalt hot mix, has appeared recently. It basically consists of a layer of hot precoated aggregate, spread over a binder spray application. A specifically designed machine spreads both binder and coated aggregate in a single pass and smooths the course. The machine includes a receiving hopper, conveyors, binder storage tanks, a variable-width spray bar, and a light heating screed unit with extensions. It operates at high speed, currently about 20 m/min. The binder is a modified emulsified asphalt. Its application rate varies between 0.6 and 1.2 kg/m². The friction course itself consists of an aggregate, mostly 6 to 10 mm in size, coated with a mortar made of sand, filler, and asphalt cement. The latest content ranges from 5 to 5.5 percent. The course thickness is between 1 and 2 cm. Its application rate of total mix is between 23 and 28 kg/m². The resulting surfacing is homogeneous. It offers a rough macrotexture and high levels of skid resistance. It has shown some capacity of leveling existing small irregularities of the support. Its rolling noise is significantly lower than that of chip seals made with aggregate of the same size. To date, the behavior of this friction course appears to be promising, as no deterioration of any kind has been observed after 2 years, even under heavy traffic.

Chips seals provide widely recognized advantages, such as waterproofing and skid resistance, but they also present serious drawbacks such as no reshaping capacity and high rolling noise. Moreover, their success always depends on the climatic conditions, not only at the time of application, but also during the first months of trafficking. Adverse weather or inadequate application procedures inevitably result in whip-off or bleeding.

In the field of surface treatment, there has consequently been a need for a new technique that would eliminate the defects in chip seals while keeping the main qualities of skid resistance and impermeability.

The new type of surfacing described here is the outcome of a continuous evolution in French asphalt wearing courses. In the 1970s, classical hot-mix wearing courses were ranging between 6 and 10 cm in thickness; they were used chiefly for structural reasons. In the second half of the 1970s, "thin" hot mixes (3 to 5 cm) appeared, mainly designed to meet maintenance requirements; a tack coat was then systematically applied to ensure complete bonding of the thin course to its support. In the early 1980s, because maintenance requirements were mostly concerning surface service quality, "very thin" hot mixes (2 to 3 cm) were developed and are now extensively utilized—50 000 000 m² in the 1984 to 1989 period.

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Such very thin asphalt is always placed on a generous tack coat, the amount of which can reach 0.7 to 0.8 L/m² of emulsion in some cases.

The ultimate step in this evolution has been a new decrease in the thickness of hot mix and a simultaneous increase in the tack coat application rate. A new type of friction course has resulted, as described in the following sections, intermediate between very thin hot-mix asphalt and chip seal. It is being developed under a cooperative agreement between the Laboratoire Central des Ponts et Chaussées (LCPC) and SCREG Routes.

THE CONCEPT

The technique involves three indissociable elements:

- Materials,
- Design, and
- Equipment and application method.

The friction course consists of a layer of hot precoated chippings, spread over a binder spray application. A machine, specially designed for this process, spreads both binder and aggregate in one pass and smoothes the course, at high speed.

Aggregates, prepared in a hot-mixing plant, are coated with mortar consisting of a bituminous film considerably thickened by fine mineral materials. They are hot-applied and spread on the binder layer sprayed a few seconds before.

Such a coating ensures a strong bonding between the chippings, which can be superposed in depressions and therefore level distorted surfaces to a certain extent. As a result of their immediate application to the binder, chippings are perfectly held in place, whip-off is totally eliminated, and the working site remains clean all over.

The machine finishes the application by ironing the chippings layer. This operation provides a good riding quality. Moreover, because the aggregates are laid flat (Figure 1), the rolling noise is reduced.

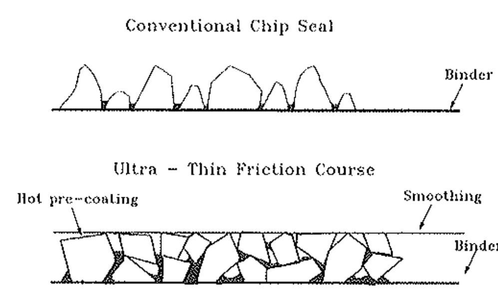


FIGURE 1 Comparison of conventional chip seal with ultrathin friction course.

DESIGN

Components

Aggregates are in compliance with the French Directive for Surface Dressing. To date, 6 to 10 mm has been the most commonly used size, but in some cases 4 to 6 or 10 to 14 mm grading sizes are preferred. Typical aggregate gradations are the following:

	Aggregate Size Range (mm)		
	10–14	*6–10*	*4–6*
Sieve Size (mm)	*Percentage Passing (by Weight)*		
20	100	–	–
14	83	–	–
12.5	53	100	–
10	7	89	–
8	1	44	100
6.3	–	8	95
5	–	1	51
4	–	–	5
2	–	–	1

Aggregates are coated with a mastic that usually contains pure bitumen. However, for roads with heavy traffic, the use of a modified binder can be justified.

This mortar is usually made with sand of 0 to 2 mm, a typical gradation of which follows:

Sieve size (mm)	4	2	1	0.5	0.315	0.2	0.08
Percentage passing	100	93	62	44	35	28	19

The coating mortar represents 20 to 25 percent (by weight) of the total mix. The bitumen content in the total (aggregate plus mortar) ranges from 5 to 5.5 percent.

The binder applied on the support is either a latex- or elastomer-modified emulsion. The use of classical cationic CRS emulsion of plain asphalt cement should be possible for low traffic, but certainly not for medium or high traffic, because of bleeding hazards.

Application Rates

The application rate of the binder layer depends on traffic and support condition. For the jobs carried out so far, emulsion rates have ranged from 0.6 to 1.2 kg/m^2 (most of them bewteen 0.7 and 1 kg/m^2), that is, from 0.4 to 0.7 kg/m^2 of residual binder.

For aggregates, average site values vary between 23 and 27 kg/m^2 of coated 6- to 10-mm aggregate.

Overall application rates are close to those of conventional chip seal:

System	*Total Asphalt Cement (kg/m²)*	*Aggregate (kg/m²)*
Single-seal with 6–10 mm	1.3	14
Single-seal with double-chipping application 10–14/4–6 mm	1.6	20
Double seal 10–14 + 4–6 mm	2.0	25
Ultrathin friction course	2.0	26

EQUIPMENT AND APPLICATION

In order to execute all operations required for application of the product, new equipment had to be designed capable of providing the various functions and integrating the specific constraints stemming from the new material used, including the use of hot, self-bonding chippings, in place of cold, free-running chippings.

Another constraint was introduced by the comparatively low spray rate of the binder, approximately half that for a conventional chip seal. The binder film must be protected from any form of vehicular traffic, to guarantee the continuous impermeability of the road structure and to ensure impeccably clean job sites.

Moreover, application has to be completed by ironing of a more or less monogranular layer of aggregate, performed at high speed, three to four times that of a conventional finisher. For this reason, particular attention was paid to the smoothing device to be used.

A machine shown in Figure 2 has been designed to complete the three operations of spreading the binder, applying the hot precoated chippings, and smoothing the course in a single pass in a short time. Figure 3 shows a schematic of this machine. At present, five machines of this type have been constructed and are in operation.

Schematically, this equipment comprises the following components:

- A receiving hopper for precoated chippings, with a self-locking hook for the supplying truck;
- A scraper-type conveyor;
- A chippings storage chamber with appropriate thermal insulation and a total capacity of 5 m^3;
- Several binder tanks, thermally insulated, with a capacity of 12 m^3 (more than a half-day of work);
- A conveyor transferring chippings to the screed unit;
- A variable-width spray bar;
- Two spreading screws; and
- A variable-width heating screed unit.

Special attention was paid to the design of the spray bar. It includes wide-angle nozzles, whose delivery is slaved to the road speed of the machine. This ramp has a variable width, and the constant application rate for variable widths is ensured by an original system.

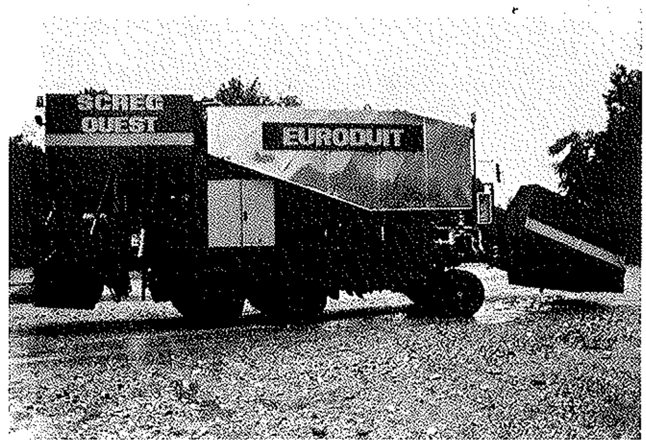
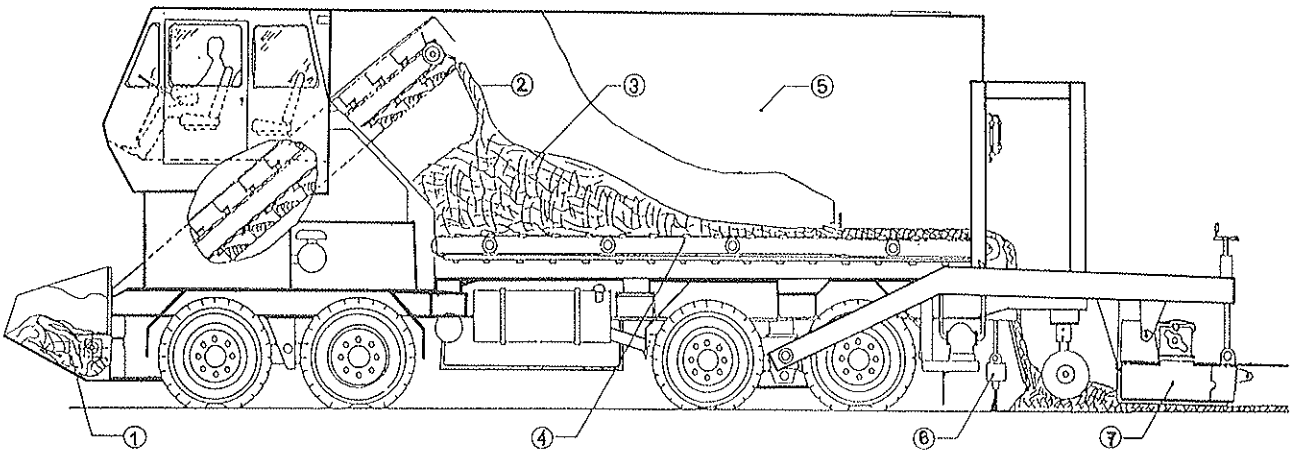


FIGURE 2 Photograph of single-pass machine for rolling Novachip friction course.



1	RECEIVING HOPPER	5	BINDER (EMULSION) TANK
2	SCRAPER-TYPE CONVEYOR	6	SPRAY BAR
3	HOT PRECOATED AGGREGATE	7	SCREED UNIT
4	FEED CONVEYOR		

FIGURE 3 Schematic of single-pass machine for rolling Novachip friction course.

The adjustable width of the spreading and smoothing system varies from 2.50 to 4.20 m.

The friction course is applied at high speed, always >10 m/min, and able to reach 20 to 25 m/min.

The three operations of spraying the binder, applying the precoated chippings, and smoothing the course are all completed in a few seconds. This quick application results in

- Good bonding of coated chippings to the binder and between themselves, even when the weather is cool or unsettled;
- Clean site (no plant or truck traffic on the binder layer); and
- Short construction time, thus reduced inconvenience to road users.

Finally, the friction course is rolled (Figure 4) and can be open to traffic as soon as it is cooled.

FIGURE 4 Photograph of rolling operation of ultrathin course.

IN-PLACE CHARACTERISTICS—BEHAVIOR UNDER TRAFFIC

Projects Completed

The first trial sections took place in the fall of 1988. In 1989, more than 800 000 m^2 were applied from May to October, in varied regions and under different traffic ranging from medium-low (T3) to very high (T0). French traffic classes are defined as follows:

Traffic classes	T5	T4	T3	T2	T1	T0	TE
Average daily number of heavy vehicles per lane	0–25	25–50	50–150	150–300	300–750	750–2,000	>2,000

Reference is made to the average daily number of heavy vehicles traveling in one direction on the most heavily trafficked lane. Heavy vehicles are defined as those vehicles having a payload of at least 5 metric tons. According to the French legislation, the maximum axle load is 13 metric tons.

In 1990, the surface area treated will exceed 3 000 000 m^2. All French regions have been involved, with a variety of climates, types of support, and traffic intensities. Several jobs were also carried out in Sweden and Belgium.

In-Situ Properties of the Surfacing

A multiyear assessment program has been set up and funded jointly by SCREG Routes and LCPC to evaluate the effects of mix parameters and to monitor the in situ behavior of the friction course. These parameters are presented in Table 1.

Effect on Riding Quality

Three sets of measurements have been analyzed, as presented in Table 2.

TABLE 1 LCPC–SCREG MONITORING PROGRAM

Parameter studied	Measurement					
	Profile Analyzer Coefficient (PAC)		Surface texture depth (sand patch and laser texture meter)	Longitudinal Friction Coefficient	In place Permeability	Noise
	Before	After				
Binder spray rate Aggregate size	X	X	5 sections	5 sections	5 sections	3 sections
Asphalt coating content	X	X	2 sections	2 sections	2 sections	
Mortar content			3 sections	3 sections	3 sections	
Aggregate type			2 sections	2 sections	1 section	

TABLE 2 EFFECT OF FRICTION COURSE ON RIDING QUALITY

Friction course = 23 kg/m2

PAC*	< 6 (%)	< 13 (%)	< 16 (%)	Job
Before	13	62	76	CD 312 (Maine et Loire)
After	19	85	96	

Δ = ≈ + 6

Friction course = 28 kg/m2

PAC	< 6 (%)	< 13 (%)	< 16 (%)	Job
Before	23	90	94	RN 23 (Maine et Loire)
After	39	97	97	

Δ = ≈ + 16

Friction course = 25 kg/m2

PAC	< 6 (%)	< 13 (%)	< 16 (%)	Job
Before	36 à 53	96 à 98	98 à 99	RN 18
After	59 à 72	98 à 99	99 à 100	Meuse

Δ = ≈ + 20

*PAC : Profile Analyzer Coefficient

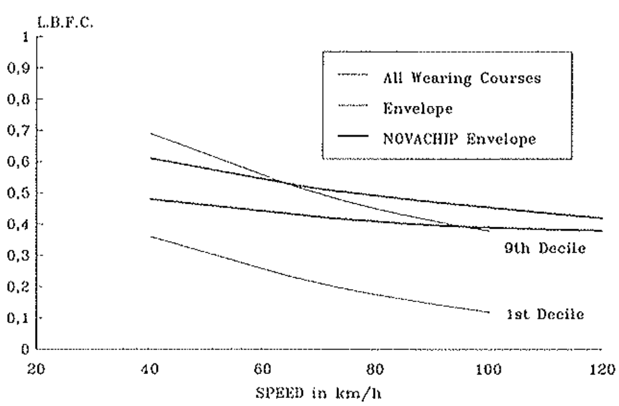


FIGURE 5 LBFC versus traffic speed—comparison of envelopes for all wearing courses and Novachip.

Figure 5 shows the results obtained on one of the sites. (NOVACHIP is the trade name of the ultrathin friction course developed by SCREG Routes, in cooperation with LCPC).

These results prove that such an ultrathin friction course has, somehow unexpectedly, a limited but real leveling capacity. Indeed, it appears that precoated aggregates can be superposed and stand up to traffic effects in this position. It is estimated that, in case of light traffic (up to T3), the total thickness in depressed areas can reach up to 4 cm.

Surface Texture Depth

A considerable number of measurements have been obtained with the sand patch test (SPT) method or with the laser Mini

TABLE 3 TEXTURE DEPTH MEASUREMENTS BY SAND PATCH TEST

Aggregate size (mm)	Sand Patch Depth (mm)	
Size range 6-10	Minimum 1,1 Mean 1.9 Maximum 3,2	(50 measures)
Size range 4-6	Minimum 1 Mean 1.3 Maximum 1.4	(8 measures)
Size range 10-14	Minimum 2.1 Mean 3.8 Maximum 3.2	(12 measures)

TABLE 4 TEXTURE DEPTH MEASUREMENTS BY MINI TEXTURE METER

Aggregate size (mm)	Sensor Measured Texture Depth (mm)	
Size range 6-10	Minimum 0.65 Mean 0.85 Maximum 1.01	(145 measures)
Size range 4-6	Minimum 0.43 Mean 0.52 Maximum 0.64	(100 measures)
Size range 10-14	Minimum 1.24 Mean 1.75 Maximum 2.04	(130 measures)

TABLE 5 VARIATION OF LBFC FRICTION WITH TRAFFIC SPEED

- At 60 km/h

	T2 Traffic		T1-T0 Traffic	
	CD 1	CD 12	RN 23	RN 24
After 5 months	0.53	0.52		
After 8 months			0.46	0.48
After 16 months	0.53			

- At 90 km/h

	T2 Traffic		T1-T0 Traffic	
	CD 1	CD 12	RN 23	RN 24
After 5 months	0.47	0.45		
After 8 months			0.40	0.43
After 16 months	0.40			

- At 120 km/h

	T2 Traffic		T1-T0 Traffic	
	CD 1	CD 12	RN 23	RN 24
After 5 months	0.40	0.39		
After 8 months		0.38		

Texture Meter (MTM), on job sites between 1 and 10 months old. The results are as follows:

- Manual SPT. Seventy-six tests were executed on nine different job sites. The statistical profile is presented in Table 3.
- Mini Texture Meter. The number of measurements gathered here amounts to almost 400, and yields the sensor-measured texture depth (SMTD) results presented in Table 4.

Skid Resistance

Consistent results were obtained after 4 to 5 months on three jobs, with 6- to 10-mm aggregate. Values of the longitudinal braking force coefficient (LBFC) were as follows:

Speed km/hr	*LBFC*
40	0.61
60	0.53
90	0.45
120	0.39

Measurements carried out on some of the 1988 sections contained little variation between 5, 8, and 16 months, as presented in Table 5.

The levels of skid resistance obtained generally classify this type of friction course as among the most effective surface treatments available (Figure 6). This effectiveness is clearly because of the rough and open macro texture and, to a lesser extent, the hardness and polishing resistance of the aggregate selected.

Rolling Noise

Rolling noise measurements were performed in accordance with the French-German method, i.e., using three different vehicles (with engine running) with different types of tires at various speeds. This methods establishes a correlation between acoustical pressure Lp_{max} and vehicle speed. Figures 7 and 8 show an example of rolling noise recoding.

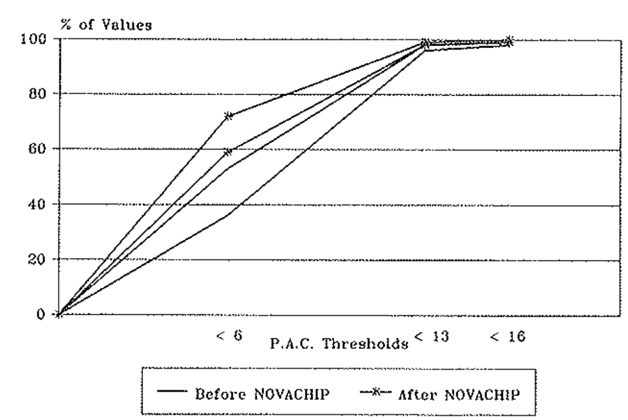


FIGURE 6 Profile analyzer coefficient values for Novachip RN 18 (Meuse, France).

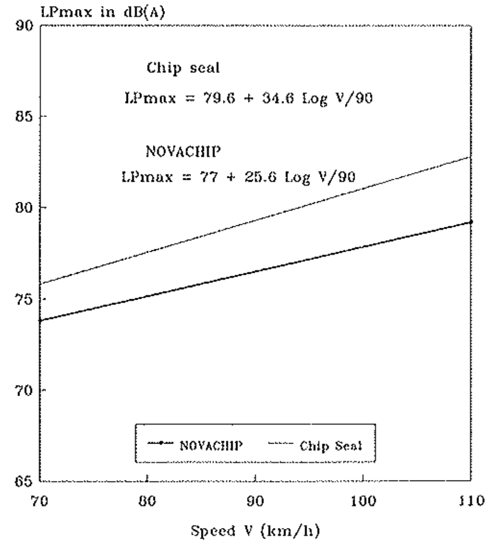


FIGURE 7 Regression analysis for rolling noise versus traffic speed.

The noise values recorded indicated that ultrathin friction courses cause lower rolling noise than conventional chip seal using the same aggregate size.

The reduction amounted to 2 to 3 decibels within the usual vehicle speed range. This benefit was significant for neighboring residents and user comfort, because acoustical energy was decreased by 30 to 40 percent.

Overall Behavior

To date, all visual observations and in-place assessments indicate that this ultrathin friction course performs satisfactorily.

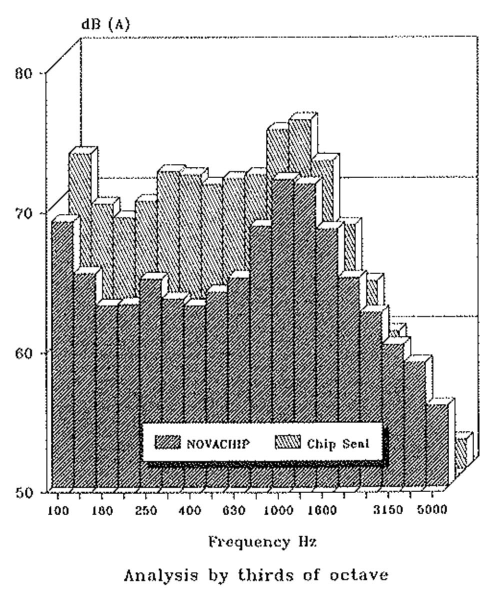


FIGURE 8 Spectrum analysis of rolling noise at 90 km/hr.

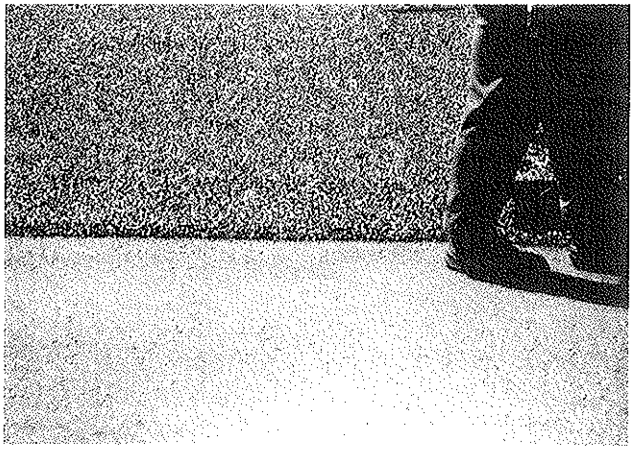


FIGURE 9 Photograph of surface aspect of ultrathin friction course.

FIGURE 10 Photograph showing open surface texture of ultrathin friction course.

- Its surface aspect is homogeneous (see photograph in Figure 9),
- No aggregate dislodgment has been noticed,
- No bleeding nor fatting up has occurred,
- The surface texture is open (see photograph in Figure 10) and appears to be stable even under heavy traffic (up to T0).

Consequently, no traffic volume limitation can so far be determined or suggested for application.

CONCLUSION

The first results, as well as the favorable answer of road authorities and users, are encouraging.

It has been established that ultrathin friction courses can readily be applied at spread rates well below 30 kg/m^2 and at high speed (>20 m/min).

The resulting coarse-graded courses have a thickness ranging from 10 to 20 mm and provide high skid resistance and satisfactory waterproofing. As compared with conventional chip seals, major improvements have been achieved, including virtual elimination of aggregate dislodging, better riding quality, and lower rolling noise.

At present, there is no evidence for any traffic volume limitation.

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