TRANSPORT RESEARCH LABORATORY

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ASSESSMENT OF AXOFLEX, THE REDLAND THIN ASPHALT SURFACE COURSE

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EXECUTIVE SUMMARY

This report was commissioned by Redland Aggregates Limited in order to obtain an independent assessment of their thin surfacing material, AXOFLEX, for use in the United Kingdom. In particular, Redland required the available information to be compiled in a form appropriate for the Highways Agency to evaluate its suitability for type approval as a thin wearing course systems and for other Highway Authorities to have access to information on this product.

AXOFLEX is a thin asphalt surface course material that was developed in France by Redland Route and assessed by the Laboratoire Central des Ponts et Chausées for compliance with the Norme Française for very thin asphalt concretes. The results of the testing carried on AXOFLEX with UK aggregates for this assessment, together with knowledge of the extensive and successful use of AXOFLEX with French aggregates on French motorways and other roads, allows the properties of "British" AXOFLEX to be understood.

The available data indicate that AXOFLEX can be manufactured satisfactorily in thin layers and, when using the 0/14 mm grading, it can achieve a 1.5 mm texture depth which should be effectively maintained with wear. The material is resistant both to permanent deformation and to degradation due to moisture. It also has acceptable structural properties, although these are of limited applicability because the material is laid in a thin layer. Hence, it has the properties required of a thin asphalt surfacing material. This is confirmed by its use on major roads in France.

To complete Stage 4 of the Highways Agency's 5-stage assessment procedure, a road trial on a moderately heavily trafficked trunk road needs to be monitored for about 2 years to ensure that the various properties are maintained in practice; the Stage 5 specification trial is not necessary because a specification already exists. This procedure will be superseded by the Highway Authorities Product Approval Scheme for thin surfacing systems (to be run by the British Board of Agrément). The scheme is expected to retain a road trial as part of the procedure for product approval.

Subject to completing a road trial, 0/14 mm AXOFLEX has the necessary properties for use as a thin asphalt surfacing on UK high-speed trunk road and 0/10 mm AXOFLEX on other roads.

ASSESSMENT OF AXOFLEX, THE REDLAND THIN ASPHALT SURFACE COURSE

ABSTRACT

AXOFLEX is a thin asphalt surface course material that is being marketed by Redland Aggregates Limited. It was originally developed in France by their French associate company, Redland Route, and tested by the Laboratoire Central des Ponts et Chausées for compliance with the Norme Française for very thin asphalt concretes. The data from that assessment, together with other information, is assessed to evaluate the suitability of AXOFLEX for use on UK roads, and in particular on high-speed trunk roads with the requirement for a texture depth of 1.5 mm as measured by the sand-patch method. The data show that AXOFLEX has the potential to be a satisfactory thin asphalt surface course material for use in the United Kingdom.

1. INTRODUCTION

The harmonisation of European standards being undertaken through the Comité Européen de Normalisation (CEN, or European Committee for Normalisation) has identified the variety of asphalt mixtures that are used in the different parts of Europe. Although some of this variation results from different climatic conditions or the local availability of different component materials, many of the differences have arisen because of the difference in historical developments of asphalts. These CEN activities have created opportunities for transferring technology from other parts of Europe, either in totality or as developments of existing technology. One of the transfers into the UK has been the concept of thin surfacings developed in France using their Avis Technique system.

Several UK asphalt suppliers have either obtained licenses for thin surfacing systems developed in France or developed their own systems along similar lines. Redland Aggregates Limited have developed a material, known as AXOFLEX, with the assistance of their French associate company, Redland Route. AXOFLEX is a proprietary thin asphalt surfacing for which a UK Registered Trade Mark is being sought under application No. 2056945. It was developed in France with 6 mm or 10 mm aggregate to be laid 20 to 30 mm thick. In the UK with a greater demand on texture, the 14 mm variation has been used; this increases the maximum layer thickness to 35 mm. The binder for AXOFLEX is an elastomer polymer-modified bitumen for use on heavily trafficked roads and unmodified bitumen on lightly trafficked roads, mixing taking place at a temperature of approximately 165°C. An emulsion tack coat is always required, in most cases modified with an elastomeric polymer.

To ensure that the material will provide the properties required for use on roads in the United Kingdom and to provide an independent assessment to those properties, Redland Aggregates Limited have commissioned the Transport Research Laboratory to review the available information on AXOFLEX.

2. FRENCH ASSESSMENT OF THIN SURFACINGS

2.1 AVIS TECHNIQUE SYSTEM

In France, there is a system for providing technical advice on products not covered by national specifications known as the Avis Technique, or Technical Opinion. The Laboratoire Central des Ponts et Chausées (LCPC), the national highway research laboratory, carries out tests on a material and offers an opinion on the suitability of the product. This is reviewed by a Committee involving the Specifying Authorities, the Assessing Organisation and the Manufacturer and, if approved, a document is drawn up setting out its range of applications (including traffic categories, see Appendix A) and sites where it has been used. This Avis Technique is then used by Highway Authorities in the procurement of the material with the document being valid for 3 years. The introduction of the Avis Technique procedure has promoted innovation in road materials in France.

2.2 CLASSIFICATION OF MATERIALS

The requirements for asphalt materials in France have been mechanical properties (rut resistance, profile) and durability (water-sensitivity), but now skid-resistance has been included. However, French materials tend to be laboratory-designed and they have no design method for skid-resistance and so this property has to be selected by past experience (Delorme, 1993). The materials that are used in France have been classified in terms of their relative skid-resistance (Table 1), but this can only be a guide because some material types can be sub-divided into groups with different properties. Nevertheless, the Table gives a useful indication of the material types available in France.

Of these material types, very-thin and ultra-thin asphalt concrete materials are considered to be among the most promising techniques in terms of a compromise between comfort, safety and inconvenience to users (Bellanger et al, 1992). These types of materials are now also being used on an increasing scale in the United Kingdom.

TABLE 1

Skid-Resistance Criteria for Selecting Asphalt Materials

(Delorme, 1993)

Material Type	French Abbreviation	French Standard	Layer Thickness (mm)	Skid-Resistance	
				Initial	After 5 years
Cold-Mixed Coated Material	ECF	-	10 - 15	2	3 - 4
Ultra Thin Asphalt Concrete (Ultra Thin Hot Mix Asphalt Layer)	BBUM (UTHMAL)	-	15 - 20	2	2
Coated Sand with Chippings	SEC	-	20	1	2
Very Thin Asphalt Concrete (Very Thin Surface Layer)	BBTM (VTSL)	NF P 98-137	20 - 30	2	3 - 4
Mastic Asphalt	AC	NF P 98-145	15 - 30	2 - 3	3 - 4
Asphalt Concrete with Chippings	BBC	NF P 98-133	30	1	2
Thin Asphalt Concrete	BBM	NF P 98-132	20 - 50	2	3
Porous Asphalt	BBDr	NF P 98-134	30 - 50	1	2
Asphalt Concrete with Chippings	BBC	NF P 98-133	50 - 70	1	2
Semi-Granular Asphalt Concrete	BBSG	NF P 98-130	50 - 90	3	3
High-Modulus Asphalt Concrete	BBME	NF P 98-141	60 - 90	3	2 - 3
Skid-Resistance Categories	1	2	3	4	
Description	Good	Moderate	Fair	Mediocre	

The most common grading of thin surfacings is 0/10 mm with a gap between 2 mm and 6 mm, although there are some 0/6.3 mm and, to a lesser extent in France, 0/14 mm gap-graded materials (Bellanger et al, 1992). The filler content (passing a 80 μm sieve) is generally between 6 and 9 per cent and the 6/10 mm fraction in a 0/10 mm mixture is 65 to 70 per cent in a very thin mixture and 75 to 80 per cent in an ultra-thin mixture. The binder is usually 60/70 bitumen (occasionally 80/100) at 5.8 to 6.0 per cent by weight in a 0/10 mm very-thin mixture and 5.2 to 5.6 per cent by weight in a 0/10 mm ultra-thin mixture. Polymer-modifiers and fibres are often added to enhance certain properties.

2.3 STANDARD SPECIFICATION FOR VERY THIN SURFACE LAYER

The Norme Française (French standard) for thin surface layer asphalt concrete is NF P 98-137 (AFNOR, 1992a) and now replaces the need to have Avis Technique documents for such materials.

In NF P 98-137, thin asphalt surfacings are classified by:

- the nominal aggregate size (0/6.3 mm, 0/10 mm or 0/14 mm);
- the binder (unmodified or modified bitumen); and
- the compaction properties (type 1 or 2) as deter mined by the compaction test using the gyratory compactor (AFNOR, 1991a).

The required properties of the component aggregates are specified to the relevant French Standard (AFNOR, 1990a) in terms of mechanical strength, polished stone value, angularity and grading for various categories. Up to 10 per cent rounded sand is permitted.

The requirements for fillers are more explicit, these being:

- Rigden coefficient of voids (AFNOR, 1990b) of not less than 40 per cent;
- absorption property (AFNOR, 1991b) such that at least 40 g of filler is required to absorb 15 g of 60/70 grade bitumen;
- stiffening property (AFNOR, 1979) to increase the softening point of a 60/70 grade bitumen by between 10°C and 20°C when added to form a mastic with 60 per cent filler, 40 per cent bitumen; and
- methylene blue value (AFNOR, 1990c) of not less than 1 g of methylene blue absorbed by 100 g of filler.

The required properties of laboratory mixtures are:

- ratio of Duriez test at 18°C (AFNOR, 1991c) after immersion compared to the value when dry to be not less than 0.8;
- voids after 25 gyrations on gyratory compactor (AFNOR, 1991a) to be:
  - between 6 and 17 per cent for type 1
  - between 18 and 25 per cent for type 2; and
- ratio of texture depth (AFNOR, 1992b) after 3,000 cycles of simulated traffic at 60°C to that prior to trafficking is not less than 0.5.

Norme Française NF P 98-137 requires thin asphalt surfacings to have a tack coat, to be laid using a mechanical sprayer and, when using unmodified bitumen, to be laid at 135°C. The minimum required texture (AFNOR, 1992b) on the road is 0.6 mm for the 0/6.3 mm size and 0.8 mm for the 0/10 mm and 0/14 mm sizes.

3. BRITISH ASSESSMENT OF THIN SURFACINGS

3.1 HIGHWAYS AGENCY FIVE STAGE ASSESSMENT PROCESS

Thin surfacings have only recently been introduced into the United Kingdom and, therefore, there is as yet no British Standard for this class of materials. However, the Highways Agency (HA) has had a five-stage system for assessing new and innovative materials, as given in Appendix B. This process was followed for the introduction of the first two thin surfacings introduced onto the British market, with the evaluation carried out for the HA by TRL (Nicholls et al, 1995).

A draft specification (Appendix C) has been prepared by the HA for use with thin surfaces; it relies primarily on type approval of the system. At present, only two systems have that approval and, with the increasing number of similar systems being offered on the market, the HA expect promoters to compile the necessary evidence to satisfy the requirements at their expense.

3.2 HIGHWAY AUTHORITIES PRODUCTS APPROVAL SCHEME

In order to deal with innovative products not covered by current specifications, and in anticipation of the introduction of European Technical Approvals (ETAs) for products, the HA, together with the other Overseeing Organisations and the County Surveyors' Society, have asked the British Board of Agrément (BBA) to set up a Highway Authorities Product Approval Scheme (HAPAS) for thin surfacings. This will define explicitly the properties required of thin surfacings and how they shall be measured in order to be certified as suitable for use on UK roads. The group responsible for advising BBA had their first meeting in September 1996, so the existing approval scheme for HA may well be extant for some time. However, it is anticipated that the procedures developed for HAPAS will take note of the 5-stage assessment procedures already completed or in hand, as well as the French procedure.

4. DESIGN OF AXOFLEX

The Laboratoire Régional des Ponts et Chaussées d'Autun has studied AXOFLEX with aggregates from French quarries for Redland Route. Also, Redland Aggregates Limited commissioned the Laboratoire Régional des Ponts et Chaussées d'Autun to assess AXOFLEX mixtures using aggregates from the United Kingdom. The particular aggregates studied were gritstone from the Dry Rigg quarry and granite from the Mountsorrel quarry for both 0/10 mm (Perron & Genet, 1994) and 0/14 mm (Perron & Genet, 1995) AXOFLEX; the fine aggregate (0/4 mm) was granite and the course aggregate (6/10 mm or 6/14 mm, depending on which size AXOFLEX) was gritstone. The gradings are given in Table 2 and the aggregate properties in Table 3.

The filler used for the laboratory trials had a specific gravity of 2.828 Mg/m^3 and the binder was a Shell polymer-modified bitumen with a penetration of 47 mm/10 and a Ring and Ball softening point of 60.2°C.

Several combinations of aggregates were tested, with the selected mixtures being given in Table 4.

The resulting aggregate gradings are shown in Figure 1 using UK sieve seizes.

5. PROPERTIES

5.1 COMPACTION

The ease with which a mixture can be compacted is measured in France using the gyratory compactor (AFNOR, 1991a). The degree of compaction (in terms of the proportion of the maximum theoretical density) is measured at a series of gyrations and the relationship between gyrations and compaction derived in the form of Equation (1).

$$C_i = A + K \log_n (i)$$

where

C_i is the degree of compaction (per cent);

i is the number of gyrations;

A is the derived constant for the intercept; and

K is the derived constant for the slope.

TABLE 2

Grading of Component Aggregates

Sieve Size	Granite	Gritstone	
	0/4 mm	6/10 mm	6/14 mm
14 mm	-	-	96 per cent
12.5 mm	-	100 per cent	71 per cent
10 mm	-	95 per cent	6 per cent
8 mm	-	52 per cent	1.5 per cent
6.3 mm	-	13 per cent	13 per cent
4 mm	96 per cent	3 per cent	3 per cent
2 mm	73 per cent	2.3 per cent	2.3 per cent
1 mm	53 per cent		
0.4 mm	34 per cent		
0.2 mm	23 per cent		
0.08 mm	14 per cent		

TABLE 3

Properties of Component Aggregates

Aggregate	Los Angeles	Micro-Deval (wet)	Polished Stone Value	Aggregate abrasion value	10 % fines value
Gritstone	13	c.20	62	7.0	320 kN
Granite	23	7	52	2.1	220 kN

TABLE 4

Component Materials for AXOFLEX

Component Material	AXOFLEX	
	0/10 mm	0/14 mm
0/4 mm granite	30 per cent	32 per cent
6/10 mm gritstone	66 per cent	-
6/14 mm gritstone	-	64 per cent
Filler	4 per cent	4 per cent
Modified binder	6.0 per cent	6.0 per cent

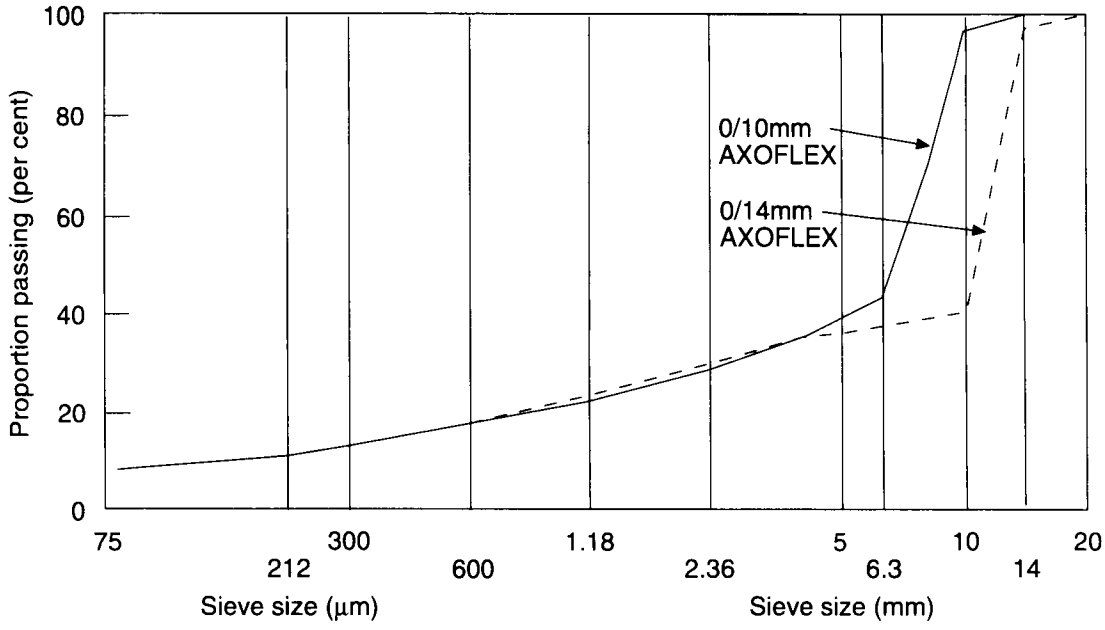

Fig. 1 Grading curves for AXOFLEX

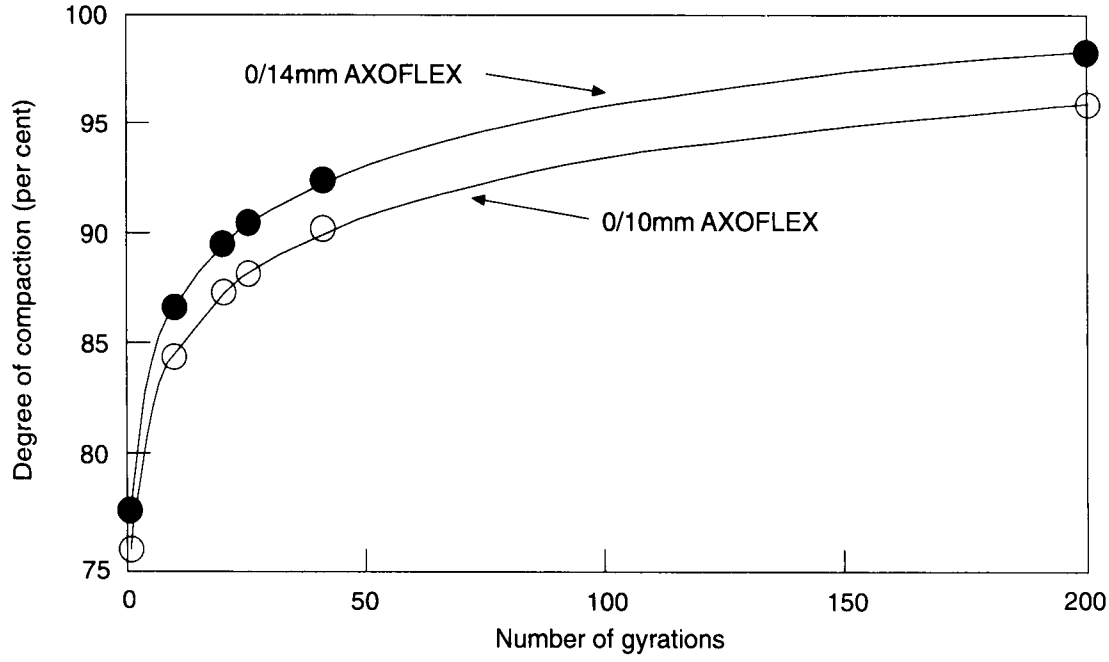

FIG. 2 Degree of compaction with number of Gyrations

For the 0/10 mm AXOFLEX, K was found to be 3.93 (Perron & Genet, 1994) whilst, for 0/14 mm AXOFLEX, K was 4.08 (Perron & Genet, 1995); the results are shown in Figure 2. Norme Française NF P 98-137 (AFNOR, 1992) for Type 1 materials (Section 2.3) requires a voids content of between 6 and 17 per cent (83 to 94 per cent compaction) after 25 gyrations to ensure that the mixture is compacted at that point without having become unstable; the 0/10 mm AXOFLEX has a compaction of 88.2 per cent and the 0/14 mm AXOFLEX 90.5 per cent.

5.2 TEXTURE DEPTH AND RESISTANCE TO WEAR

Norme Française NF P 98-137 (AFNOR, 1992a) requires that the ratio of texture depth (AFNOR, 1992b) after 3,000 cycles of simulated trafficking at 60°C relative to that prior to trafficking is not less than 0.5 (Section 2.3). The results for AXOFLEX (Perron & Genet, 1994 & 1995) are given in Table 5.

The texture depth was to the French standard rather than to Clause 4 of BS 598: Part 105 (BSI, 1990a), although the

TABLE 5

Texture Depth Retention with Simulated Trafficking

	AXOFLEX	
	0/10 mm	0/14 mm
Initial Texture Depth	1.05 mm	1.82 mm
Texture Depth after Trafficking	0.88 mm	1.48 mm
Ratio	0.84	0.81

difference in the two procedures is not considered to be significant. However, the texture depth of 0/10 mm AXOFLEX ranged from 1.1 mm to 1.5 mm with a typical value of 1.4 mm when it was measured on two contracts in the United Kingdom. This is consistent with that reported on French roads (Section 6.1). Nevertheless, on UK high-speed trunk roads where 1.5 mm is required, the 0/14 mm grading will have to be used to ensure compliance. The texture of "British" AXOFLEX is shown in Figure 3.

5.3 SKID-RESISTANCE

Sections of four different materials, including AXOFLEX with French aggregates, laid on the A330-RD974 link road were measured for skid-resistance by the Laboratoire Régional des Ponts et Chaussées de Nancy (Jouaville & Boutonnet, 1993). The results for the AXOFLEX sections are given in Table 6. No equivalent results using the Sideway-force Coefficient Routine Investigation Machine (SCRIM) and the aggregate to be used in the United Kingdom are, as yet, available.

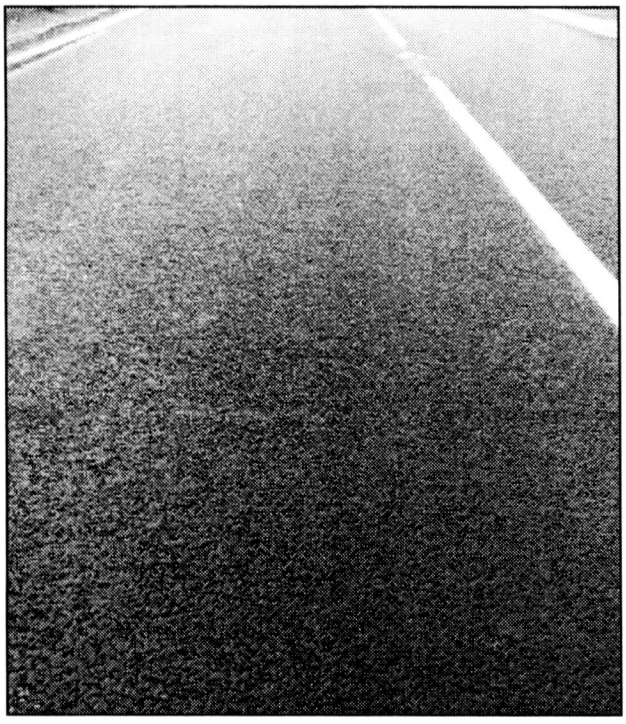

Fig.3 Texture of AXOFLEX

These results show that AXOFLEX with French aggregates is considered satisfactory in France, which does not have such high skid-resistance requirements as the United Kingdom. However, the skid-resistance is predominantly dependant on the polished stone value (PSV) of the aggregate and, using gritstone coarse aggregate with a PSV of 62, the material would be expected to be satisfactory for most uses in the United Kingdom. Nevertheless, appropriate PSV levels are selected on site-specific requirements.

5.4 RESISTANCE TO PERMANENT DEFORMATION

The results of the French wheel-tracking test to Norme Française NF P 98-253-1 (AFNOR, 1991d) are given in (Perron & Genet, 1994 & 1995). In this test, samples are trafficked for 3,000 cycles by a wheel fitted with a 80 mm wide treadless pneumatic tyre and applying a load of 5 kN at a temperature of 60°C. The result is reported as the rut depth as a proportion of the layer thickness in per cent.

Redland Aggregates Limited performed four individual determinations of the wheel-tracking test to BS 598: Part 110 (BSI, 1996a) except that the test temperature was 60°C and the nominal specimen thickness of the 0/10 mm AXOFLEX was 25 mm. The results are also given in Table 7 and confirm the findings of the French tests that AXOFLEX is likely to be resistant to permanent deformation. However, it must be borne in mind that the results reflect both the deformation resistance of the material and the limited thickness to deform. Generally, tests on samples with thicknesses 40 mm and above are considered not to be affected by sample thickness whilst those below may be.

5.5 ELASTIC MODULUS AND DYNAMIC LOAD STIFFNESS MODULUS

Repeated load indirect tensile tests at 20°C to DD 213 (BSI, 1993) were carried out by Redland Aggregates Limited on specimens of 10 mm AXOFLEX manufactured as for the design of rolled asphalt to BS 598: Part 107 (BSI, 1990b). Repeated load axial tests to DD 226 (BSI, 1996b) but at the non-standard test temperature of 40°C but standard axial stress of (100 ± 2) kPa were then carried out for 3,600 load

TABLE 6

Coefficient of Longitudinal Friction

Speed	Minimum Permitted in France	*AXOFLEX Section* 1	2	3	4	Mean
40 km/h	0.52	0.58	0.66	0.66	0.67	0.64
		0.56-0.59	0.64-0.67	0.62-0.67	0.65-0.69	0.56-0.69
60 km/h	0.39	0.48	0.50	0.51	0.52	0.50
		0.44-0.50	0.48-0.52	0.48-0.53	0.50-0.54	0.44-0.54
90 km/h	0.28	0.36	0.38	0.36	0.37	0.37
		0.32-0.39	0.34-0.41	0.29-0.40	0.33-0.41	0.29-0.41

TABLE 7

Wheel-Tracking Results

		AXOFLEX 0/10 mm	AXOFLEX 0/14 mm
LCPC	Rate of Compaction	94.8 per cent	92.8 per cent
(France)	Rut	2.3 per cent	3.8 per cent
Redland Agg. Ltd	Wheel-tracking rate	0.7 mm/h	-
(UK)	Rut depth	1.6 mm	-

cycles on the same specimens. The mean results for two sets of six specimens, one set compacted with 50 blows and one with 75 blows, are given in Table 8.

These values show that AXOFLEX has properties comparable to conventional UK materials but, because the material is designed to be laid relatively thin, any structural contribution will be limited.

5.6 RESISTANCE TO MOISTURE

Norme Française NF P 98-137 (AFNOR, 1992) requires that the result of the Duriez test (AFNOR, 1991c) should be not less than 0.8 (Section 2.3). The Duriez test result is a ratio of the compressive strength of a laboratory prepared sample after storage for 7 days at 18°C in air to a similar sample after storage in water; hence it is a measure of susceptibility to damage by water. The results for AXOFLEX (Perron & Genet, 1994 & 1995) are given in Table 9.

Hence, the material should not be susceptible to damage by water.

TABLE 8

Results of Moduli Tests

	0/10 mm AXOFLEX 50 blows	0/10 mm AXOFLEX 75 blows
Elastic Modulus	3.2 GPa	3.6 GPa
Microstrain after 3,600 cycles	5,770	4,636
Dynamic Load Stiffness Modulus	17.3 MPa	21.6 MPa

6. IN-SERVICE EXPERIENCE

6.1 EXPERIENCE IN FRANCE

Since 1988, AXOFLEX has been used in France by the Ministry of Transport and by various motorway companies; by 1994, two million square metres had been satisfactorily laid (Laviron, 1994) and, by 1996, this had increased to three million square metres. Details of some of the work carried out in France is given in Table 10.

The sand-patch texture depth (AFNOR, 199b) of 0/10 mm AXOFLEX has been measured after 3 years trafficking on three of the sites with the results as reported in Table 11.

Theses results show that, although starting with texture depths below the UK limit for new high-speed trunk roads, the AXOFLEX maintained a reasonable texture that would be considered satisfactory for in-service roads in the United Kingdom.

TABLE 9

Results of Duriez Tests

	AXOFLEX	
	0/10 mm	0/14 mm
Specific Gravity	2.36	2.44
Voids Content	4.7 per cent	1.6 per cent
Compressive Strength after Storage in Air(R)	12.1 MPa	11.3 MPa
Compressive Strength after Immersion(R')	10.6 MPa	10.9 MPa
R'/R ratio	0.88	0.96

TABLE 10

Sites on which AXOFLEX has been Laid in France

Road	Year Laid	Area Laid	Road	Year Laid	Area Laid
A31	1988	13,500 m^2	A42	1992/3	100,000 m^2
A9	1990	6,900 m^2	RN6	1993	16,300 m^2
A36	1990	326,000 m^2	D4	1993	287,000 m^2
A49	1991	436,000 m^2	RD973	1993	11,000 m^2
A40	1991/2	92,000 m^2	RD54	1993	16,800 m^2
A64	1992	310,000 m^2	A43	1993	1,050 m^2
RN97	1992	37,000 m^2	A4	1993	240,000 m^2
RN98	1992	58,000 m^2	A16	1994	100,000 m^2

TABLE 11

Sand-Patch Texture Depth after Three Years Trafficking

Site	Traffic Category*	Date		Surface Texture (mm)		Change in Texture (%)
		Surfaced	Tested	Initial	After Traffic	
A42	t_{5-}	1993	1996	1.25 - 1.40	1.15 - 1.30	- 7.5
A43	t_{0+}	1993	1996	1.20 - 1.50	1.40 - 1.60	+ 11
RD974	$t_{1+} - t_{0-}$	1992	1995	1.25 - 1.40	1.10 - 1.20	- 21

* See Appendix A for definition of French traffic categories.

TABLE 12

Sites with AXOFLEX in the United Kingdom

Location	Grading	Date laid	Quantity Laid
High Street, Scole, Norfolk	0/10 mm	June 1995	295 tonnes
Eastern & Western Esplanade, Southend-on-Sea, Essex	0/10 mm	April/May 1996	586 tonnes
Traffic Safety Scheme, Arlesey Stotford, Bedfordshire	0/14 mm	March 1996	635 tonnes
Hoverton to Horning road, Norfolk	0/10 mm	April 1996	1,177 tonnes

6.2 EXPERIENCE IN THE UNITED KINGDOM

Redland Aggregates Limited have laid AXOFLEX on various UK roads, including the sites listed in Table 12. To date, Redland report that the Client response to the material laid has been positive. However, some areas of the surface at the Southend site appear to be binder-rich due to overheating the mixture at the plant.

7. DISCUSSION

AXOFLEX has been assessed by the LCPC and found to be satisfactory in terms of Norme Française NF P 98-137 (AFNOR, 1992). In assessing it for use in the United Kingdom, the possible additional issues that need to be addressed are:

- any difference in the climate between France and the United Kingdom;
- any difference resulting from the use of UK, rather than French, binders;
- any difference resulting from the use of UK, rather than French, aggregates; and
- any differences between the requirements for wear ing course materials in France and in the United Kingdom.

There is obviously a significant difference between the climate of the Mediterranean coast of France and the north of Scotland whilst there is little difference between that of northern France and southern England. The requirements for southern France need to be much more stringent for resistance to permanent deformation whilst those for northern Scotland need to include more consideration of brittle failure. However, the Alpine region of France also has severe winter weather and these will have been considered in the French assessment. Therefore, it is not considered necessary to extend the assessment for climatic conditions.

The binder suppliers tend to be multi-national companies who supply to both France and the United Kingdom. Although the precise grades offered will reflect the different national standards for binders, the quality will not vary significantly and, again, it is not considered necessary to extend the assessment for the quality of the binder.

The difference in aggregates and in the requirements for wearing courses are interlinked. The United Kingdom has more stringent requirements for texture depth and skid-resistance and also has a wider variety of aggregates to supply these needs. The coarse aggregate of AXOFLEX when offered in the United Kingdom is suitable to provide adequate skid-resistance for most situations. Therefore, the main consideration is to ensure that AXOFLEX can be laid with sufficient texture depth to satisfy the requirement of a minimum of 1.5 mm sand-patch for high-speed trunk roads. This aspect is demonstrated in the wear resistance measurements on the 0/14 mm AXOFLEX by LCPC (Section 5.2) as well as the good retention of texture by 0/10 mm AXOFLEX on French roads (Section 6.1).

In general, the available data indicate that AXOFLEX can be manufactured satisfactorily and laid in thin layers which, with the 0/14 mm grading, can achieve a texture depth above 1.5 mm where this is required. The material is resistant both to permanent deformation and to degradation due to moisture. It also has substantial structural properties, although these are of limited use in structural design because the material is laid in a thin layer. Hence, it has the properties required of a thin asphalt surfacing material. This is confirmed by its use on major roads in France. However, to complete Stage 4 of the Highways Agency assessment procedure, a road trial on a moderately heavily trafficked trunk road needs to be monitored for about 2 years to ensure that the various properties are provided and maintained in practice; the Stage 5 specification trial is not necessary because a specification already exists. Thin surfacing materials of similar specification and properties have been laid on heavily trafficked roads

with no apparent adverse effect and AXOFLEX, with its modified binder, would be expected to provide comparable performance to these materials.

Most thin surfacings have lower noise emissions than conventional rolled asphalt due to their "negative" texture. However, as yet there is no data available to confirm that this is also true of AXOFLEX.

8. CONCLUSIONS

The conclusions drawn from studying the data presented are as follows:

1) AXOFLEX has been assessed and found to be a suitable material for use on French roads by the Laboratoire Central des Ponts et Chausées.

2) A road trial of 0/14 mm AXOFLEX on a trunk road needs to be monitored for two years to complete the Highways Agency five-stage assessment procedure; the properties monitored should include skid-resistance, texture depth and visual condition.

3) Subject to the results from the road trial, 0/14 mm AXOFLEX has the necessary properties for use as a thin asphalt surfacing on UK high-speed trunk road and 0/10 mm AXOFLEX on other roads.

9. ACKNOWLEDGEMENTS

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APPENDIX A: FRENCH TRAFFIC CLASSIFICATIONS

A.1 BASIS

The French traffic categories are based on the number of heavy lorries with a laden weight in excess of 50 kN, which have been converted to design traffic in million standard axles (Caroff et al, 1994). Design for flexible pavements in France is based on a life of 15 years and a standard axle is 130 kN, the permitted maximum.

A.2 EQUIVALENCE TO UK COMMERCIAL TRAFFIC

The French design traffic has been converted to UK design traffic, with a 20 year design life, assuming an annual cumulative growth rate of 5 per cent, and a standard axle of 80 kN and the values given in Table A.1. These values have been further converted to the traffic flow in commercial vehicles per day using Figure 2.1 in HD 24/94 (DMRB 7.2.1) for single carriageways of flexible and flexible composite construction separately for 0 to 25 per cent, 50 per cent, 75 per cent and 100 per cent of the traffic having 4 or more axles (OGV2 classification).

A.3 REFERENCES

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CAROFF, G, E LAYERLE, H LE CAIGNEC and A SPERNOL (1994). Manuel de Conception des Chaussées d'Autoroutes. Scetauroute Direction Technique.

TABLE A.1

Conversion of French Traffic Classifications to Commercial Vehicle Flow

Classification	Heavy lorries ≥ 50 kN	Design Traffic (million standard axles)			Commercial vehicles per day ≥ 15 kN			
		15 years		20 years	0-25 %	50 %	75 %	100 %
		130 kN	80 kN	80 kN	OGV2	OGV2	OGV2	OGV2
	150	0.88	6.14	9.41	510	450	310	240
t_{2-}	200	1.17	8.16	12.5	650	590	410	320
t_{2+}	300	1.75	12.2	18.7	900	900	620	480
t_{1-}	500	2.92	20.43	1.3	1230	1230	1040	800
t_{1+}	750	4.38	30.5	46.8	1700	1700	1560	1200
t_{0-}	1200	7.01	48.9	75.0	2400	2400	2400	1900
t_{0+}	2000	11.7	81.6	125	3700	3700	3700	3200
t_{s-}	3000	17.5	122	187	5200	5200	5200	4800
t_{s+}	5000	29.2	204	312	8000	8000	8000	8000
t_{ex}	8000	46.7	326	499	12800	12800	12800	12800

APPENDIX B: HIGHWAYS AGENCY PROCEDURE FOR EVALUATING NEW MATERIALS

The procedure for evaluating new materials is carried out in 5 stages.

Stage 1 Desk Study

Assess and evaluate existing information on the material.

Stage 2 Laboratory Study

Test the mechanical properties of materials to allow theoretical predictions to be made of their performance.

Stage 3. Pilot-Scale Trials

Evaluation of construction and performance of materials in small scale trials.

Stage 4 Full-Scale Trials

Full-scale trial on a trunk road to establish whether the previous assessments obtained from Stages 2 and 3 are realised.

Stage 5 Highways Agency Specification Trials

This stage is necessary to carry out further evaluation of the material and to test the specification under contract conditions.

NOTES

(1) Stages 1 to 4 are financed by the manufacturer of the material. For Stage 5 the additional cost, if any, of the material is borne by the manufacturer.

(2) Stages 1 to 4 can be carried out by the TRL or other independent organisation. In the latter case, the reports are appraised by the TRL.

(3) In all cases, the new materials are compared with conventional materials to obtain comparative performance.

APPENDIX C: DRAFT SPECIFICATION FOR THIN SURFACE COURSE SYSTEMS

1. Thin wearing course systems shall comply with Sub-Clauses 2 to 26 of this Clause and the requirements of Appendix 7/1.

2 Thin wearing course systems shall have a British Board of Agrément Roads and Bridges Certificate. In the event that no such Certificates have been issued, thin wearing course systems shall have Departmental type approval.

Aggregates and Filler

3 Coarse aggregate shall be crushed rock complying with Clause 901 and BS 63: Part 2: Table 2, unless agreed otherwise by the Engineer before commencement of work.

4. When tested in accordance with the procedure of BS 812, the coarse aggregate shall additionally have the following properties:

Polished Stone Value (PSV) - as specified in Appendix 7/1.

Ten Per Cent Fines Value (TPV) - not less than 180 kN, or as specified in Appendix 7/1.

Maximum Aggregate Abrasion Value (AAV) - not more than 12, or as specified in Appendix 7/1.

Flakiness Index (I_F) - not more than 25 per cent.

5. Fine aggregate shall comply with Clause 901 and shall be either crushed rock fines or natural sand or a blend of both. Fine aggregate shall be added as required to suit the particular system.

6. Filler shall be crushed limestone complying with the requirements of BS 594: Part 1. Filler shall be added as required to suit the particular system.

7. When sampled and tested in accordance with the procedures of BS 598: Parts 100, 101 and 102, the aggregate grading shall fall within the envelope formed by the limits given in Table 1, unless agreed otherwise by the Engineer before the commencement of work.

8. The design and selection of aggregates, filler and bitumen proportions shall be the responsibility of the Contractor, who shall supply the necessary details to the Engineer for information only.

Binder

9. The binder shall be petroleum bitumen complying with BS 3690: Part 1. The penetration of the bitumen shall be grade 70, 100 or 200 penetration, as selected by the Contractor, unless stated otherwise in Appendix 7/1. A polymer may be added, as selected by the Contractor.

10. The choice of bitumen grade and the penetration and softening point of the modified or unmodified binder shall be notified to the engineer before the commencement of work.

11. When sampled and tested in accordance with the procedures of BS 598: Parts 100, 101 and 102, the binder content of the surfacing material shall be in the range 3.5 to 7.5 per cent, by mass of total mixture.

12. Where appropriate to the system, the target binder content shall be determined by the binder drainage test in Clause 939, except that the range to be tested shall be amended to suit the grading of the aggregates proposed for use. The target binder content determined in the laboratory may be adjusted to suit the mixing plant and the aggregate type which is used, subject to plant trial and delivery distance. The adjusted binder content shall be notified to the Engineer prior to delivery and shall not be lower than that specified above. The tolerance on sampling and testing for binder content shall be ± 0.3 per cent.

TABLE 1

Aggregate Grading

BS Sieve size	Per Cent by Mass of Total Aggregate Passing	
	Nominal Size	
	14 mm	10 mm
20 mm	100	
14 mm	80 - 100	100
10 mm	50 - 80	55 - 100
6.3 mm	15 - 50	20 - 55
5.0 mm	10 - 45	15 - 55
2.36 mm	8 - 45	15 - 45
1.18 mm	7 - 30	10 - 35
600 μm	5 - 25	7 - 30
300 μm	5 - 20	5 - 25
75 μm	0 - 15	0 - 15

Tack Coat

13. Tack coat shall be a hot-applied cationic bitumen emulsion complying with BS 434: Part 1, with a minimum bitumen content of 38 per cent. To suit the particular system, it may be modified with a polymer. The choice of tack coat shall be notified to the Engineer before commencement of work.

Surface Preparation

14. Existing surfaces shall be cleaned using steel brooms and suction sweeping or other appropriate means. The surface may be moist but not wet; standing water shall not be present. All mud, dust, dirt and other debris and organic material shall be removed.

15. Where necessary or required by the Engineer, existing surfaces shall be regulated in accordance with the requirements of Clause 907, in advance of laying surfacing material to this Clause.

16. Unless raised prior to surfacing, iron-work and reflecting road studs shall be located for lifting and relaying after completion of surfacing works. Gullies shall be covered prior to surfacing.

17. Where possible, existing road markings shall be removed.

Mixing

18. The material shall be mixed in accordance with the requirements of BS 4987: Part 1, such that an homogeneous mixture of aggregate, filler and bitumen is produced at a temperature of 150 - 180 degrees C.

Transportation

19. Mixed materials shall be protected from contamination and undue heat loss by being transported to site in sheeted lorries. To facilitate discharge of the materials, the floor of the lorry may be coated with the minimum of light vegetable oil or liquid soap or other non-solvent solution. When such coating is used, the lorry body shall be tipped to its fullest extent with the tailboard open to ensure drainage of any excess, prior to loading. The floor and sides of the lorry shall be free from adherent bituminous materials or other contaminants before loading the surfacing material.

Laying

20. Tack coat shall be spray-applied, in accordance with the requirements of the SHW Series 900, at a rate selected by the Contractor and notified to the Engineer before the commencement of work, to completely cover the surface where the material is to be placed. The particular spray rate shall be dependent on the proprietary system and the porosity of the surface being covered.

21. Bituminous materials shall be applied at a suitable temperature and compacted by at least two passes of a tandem roller, capable of vibration, and with the minimum deadweight of 6 tonnes, before the material cools below 80 degrees C, measured at mid-layer depth.

Surface Texture

22. Where stated in Appendix 7/1, the texture depth of the surfacing shall be in accordance with the requirements of Clause 921 after compaction.

Details to be Supplied

23. The Contractor shall supply all the details required in this Clause to the Engineer before commencement of work under this Clause and when requested during the work.

24. Checks shall be made at the end of each working day and records kept, to determine the quantities used of both tack coat and bituminous material.

25. The Contractor shall supply the Engineer with test certificates stating the properties of the materials used. Samples of emulsion tack coat, modified or unmodified bitumen or mixed bituminous materials from either the spray bar or storage tank or the pavement surface or other suitable sampling point shall also be supplied to the Engineer by the Contractor when so instructed by the Engineer.

Guarantee

26. The Contractor shall guarantee the surfacing materials and workmanship for a period of two years from the date of opening the surfacing to traffic. This guarantee shall exclude defects arising from damage caused by settlement, subsidence or failure of the carriageway on which the material has been laid, but shall include for fretting, stripping, loss of chippings and loss of texture to below 1 mm measured by the sand patch method described in BS 598: Part 105.

MORE INFORMATION

The Transport Research Laboratory has published the following other reports on this area of research:

1. PR79 Road trials of thin wearing course materials. J C Nicholls, J F Potter, J Carswell and P Langdale. Price code H

2. TRL264 Review of UK porous asphalt trials. J C Nicholls. Price code H

3. PR61 Assessment of Multiphalte, the Shell Multigrade bitumen. J C Nicholls 1994. Price code E

4. PR65 Evaluation of stone mastic asphalt (SMA): a high stability wearing course material. M E Nunn and T Smith 1994. Price code E

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