THE F.O.D. RESISTANCE OF SURFACE LAYERS ON AIRFIELDS IN THE NETHERLANDS; IN SITU AND LABORATORY TESTING

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SUMMARY

A CROW working group has been set up in the Netherlands to establish whether there are any existing surface layers or coatings that meet the provisions of the national environmental legislation that came into effect in 2001 and that are qualitatively comparable to ANTISKID®, which is used at most of the country's airports. ANTISKID® is a tar-bearing bituminous surface coating that protects the underlying (asphalt) pavement construction and has excellent surface friction and texture properties. Unfortunately, the material no longer meets the Dutch environmental standards for Polycyclic Aromatic Hydrocarbons (PAH). The use of coatings containing PAHs on runways has been exempted from the new environmental provisions until 2005, however.

The study looked at surface coatings with a low-tar or tarless binder, asphalt surface layers like Stone Mastic Asphalt (SMA) and Supergrip® and grooved asphalt as these have been used on runways in Europe. The working group focused primarily on the properties of these materials and on whether they meet the statutory requirements regarding skid resistance and texture depth, and on the life cycle costs and the ravelling resistance (Foreign Object Damage resistance) of the materials. The skid resistance and texture depth were measured in situ according to the current ICAO standards.

There are no standards available for determining the Foreign Object Damage (F.O.D.) resistance of the materials so a test procedure was developed. The procedure consists of taking measurements and samples in situ and laboratory tests. It also included a test of the ravelling resistance of the surface layers or coatings resulting from exposure to chemicals. The study involved the ravelling tester developed by Netherlands Pavement Consultants (NPC) for in situ measurements of the ravelling resistance and the steel brush test developed by the Polytechnic School of 's-Hertogenbosch (in cooperation with the Association of Asphalt Road Constructing Companies) for establishing chemical resistance. There are no standards for these tests either. The results were used to compare the various coatings in a ranking system, and ANTISKID® was included in the study as a reference. This paper provides insight into the procedures used and an overview of the results.

Abbreviations:

PAH	= Polycyclic Aromatic Hydrocarbon (chemical substance causing cancer)
ANTISKID®	= a tar-bearing bituminous surface coating
Supergrip®	= thin surface layer with an open structure
CROW	= CROW Technology Centre

Disclaimer:
CROW does not endorse products or manufacturers. Trade or manufacturers' names appear in this paper only because they are essential to its objectives.

INTRODUCTION

Many asphalt runways in the Netherlands have been covered with a surface coating to improve the skid resistance and texture. The reasons for this coating are the large aircraft wheel loads, crosswind limits and climatic effects on most of the Dutch airport runways. The coating presently used is called ANTISKID® and is produced and applied by the Possehl company. The texture of the surface coating is designed to improve water drainage between tyre and pavement, to keep the skid resistance well above maintenance level for a long period of time and to preserve the underlying layers from wear, heat, fuel and chemical substances. It is therefore important to ensure good bonding to the underlying asphalt layer. ANTISKID® tar-bearing bituminous coatings score well on this requirement, which is why they are used successfully and have become more or less the standard solution on both civil and military runways in the Netherlands.

The Building Materials Decree (Dutch Environmental Protection Act) came into effect as of 1 July 1999, and contains the stipulations for tar-bearing materials. As of 1 January 2001, the standards for materials containing PAH became mandatory and ANTISKID® does not meet these standards. The Dutch Ministry of Housing, Spatial Planning and the Environment has granted an exemption for PAH coatings intended for use on runways and taxiways on airfields and airports until 1 January 2005. A condition for this exemption is that a study is to be conducted prior to that date to establish whether there are alternative low-tar or tarless surface layers or coatings that are comparable to ANTISKID® in terms of material properties and cost effectiveness, and whether they meet all current statutory requirements. These alternatives are tested (in situ and in laboratory) on their most important properties (surface friction, texture depth, F.O.D. resistance and chemical resistance). The study was limited to existing surface layers since the CROW working group was not responsible for developing new products or techniques.

STATUTORY REQUIREMENTS

The statutory requirements for surface layers on runways that currently apply in the Netherlands take the following aspects into account:

1. skid resistance
2. texture depth
3. the environment

Skid resistance

Legislation in the Netherlands governing skid resistance is identical to that contained in the ICAO Manual [1] and the FAA Advisory Circular [2] with regard to the Design Objective Level or D.O.L. Depending on the type of equipment, the type of measuring tyre and the test speed, the required skid resistance values on a newly laid surface are (Table 2.1):

Table 1.
Required skid resistance values on newly laid surfaces in the Netherlands

	Dutch legislation (newly laid)		FAA and ICAO Design Objective Level		Experiences with ANTISKID®
Type of equipment	SFT and BV11		SFT and BV11		SFT
Type of measuring tyre	Smooth	Aero profile	Smooth	Aero profile	Smooth
Test speed:					
65 k.p.h., 1 mm water	0.82	0.70	0.82	0.70	
95 k.p.h., 1 mm water	0.74	0.60	0.74	0.60	0.81-0.96
120 k.p.h., 1 mm water					0.74-0.87

Unlike the ICAO Manual, the D.O.L. is normally applied in the Netherlands as a hard and fast requirement immediately after a surface is laid. The ICAO only applies the D.O.L. as a target value.

Texture depth

The requirements set in the Netherlands for texture depth are also the same as those in the ICAO Manual and the FAA Advisory Circular. To restrict the danger of aquaplaning, etc., the average texture depth for newly laid surfaces (determined using the sand patch test) must be at least 1 mm.

The environment

Since 1 January 2001, materials used for road pavements must meet the requirements laid down in the Building Materials Decree. This contains composition values (mg/kg dry material) and emission levels (mg/m^2 per 100 years) for various types of impurities. For the content of 10 substances containing PAHs, the maximum composition value is 75 mg/kg dry material.

PRESELECTION

On the basis of past experience and skid resistance and texture depth measurements, the working group finally made a preselection of promising alternatives for ANTISKID®, a surface coating based on a tar-bearing bituminous binder. A precondition for the selection of the alternatives is that they must be existing products and proven techniques for surface layer systems that have already been used on runways. The selection consisted of the following 5 alternative systems for surface layers or coatings:

A. Surface coatings with a tarless bituminous binder.

B. Surface coatings based on a 2-component synthetic binder.

C. Stone Mastic Asphalt (graded as 0/11, 0/14 or 0/16 mm).

D. Supergrip®.

E. Mechanically treated surface layers (grooved asphalt).

A. Surface coatings with a tarless bituminous binder

In recent years the Possehl company developed a surface coating which can be compared to ANTISKID® but with a tarless bituminous binder. This coating meets the statutory requirements (skid resistance, texture depth and environmental standards). Many of the material's properties are comparable to those of the tar-bearing ANTISKID®. The binder's adhesive properties are not as effective as the tar-bearing binder, however, so F.O.D. can be expected to occur at an earlier stage. The resistance to extreme temperatures (jet blast) and to oils and chemicals is also lower than ANTISKID®.

B. Surface coating based on a 2-component synthetic binder

Apart from coatings with bituminous binders, also products with synthetic binders were brought on the market. In the past few years some test sections with this kind of coating have been realised and they performed well. That was enough reason to consider this alternative in the study. The skid resistance of coatings depends on the type of binder and the grading of the aggregates. In general synthetic coatings show a skid resistance level of about 0.80, measured by Saab Friction Tester at 95 k.p.h. Mechanical properties are very good and the chemical resistance is reasonable. A drawback is that application of such coatings needs a lot of attention and experience, also weather conditions can play a dominant role. In case of neglecting these aspects unexpected damage can sometimes occur.

C. Stone Mastic Asphalt (SMA)

Because SMA is being used as a surface layer on roads, it is believed that there are chances for SMA as a surface layer on airport pavements. Experience in road construction has shown that the skid resistance of SMA develops as soon as a road is opened to traffic. Initial skid resistance levels do not meet the standards in the case of newly laid surfaces due to the presence of a bitumen film on the aggregate. After a few months, the film disappears and the skid resistance is sufficient. However, the initial skid resistance can be improved if the surface is treated by bush hammering immediately after being laid. Stone Mastic Asphalt is a durable surface layer, according to road pavement experiences.

D. Supergrip®

In 1998, a thin surface layer with an open structure called Supergrip® was used on runway 04R-22L at Copenhagen Airport, Denmark [3]. This surface layer contains a foamed bitumen. The skid resistance of newly laid Supergrip® is about 0.1 lower than new ANTISKID®. The texture depth is >2 mm, so the discharge capacity and drainage during heavy rainfall are sufficient. The resistance to the effects of weather and chemicals will probably be lower than ANTISKID®.

It takes considerably longer to lay Supergrip® than ANTISKID®. Approximately 500 m^2/hour can be laid compared to 2,500 m^2/hour for ANTISKID®. There is as yet insufficient experience with the product to make an accurate estimate of its life cycle. Experiences up to now are good, although material loss is a significant drawback. That's why exits and high-speed turnoffs are constructed in SMA in stead of Supergrip®. The life cycle in the touchdown zone is estimated at 8 years. If this surface layer is sealed with a spray-on bitumen, the zone can be upgraded once (after 4 years). The life cycle of the rest of the runway is estimated at 10 years. Repairs are not easy.

E. Mechanically treated surface layers (grooved asphalt)

The initial skid resistance of grooved asphalt does not always meet the requirements of newly laid surfaces immediately after grooving. However, the operational skid resistance is excellent in such weather conditions as rain. The water storage capacity is much better than ANTISKID®. Grooving a surface layer material is laborious and takes a long time, however, as do repairs.

TEST PROCEDURE FOR F.O.D. RESISTANCE

The skid resistance and texture depth data on the 5 selected systems is already available. The working group estimated the system's F.O.D. resistance to be one of the main properties and focused on that aspect, but didn't disregard other properties.

The following test sites (5 in the Netherlands and 1 in Denmark) were selected for the various investigations:

- Runway 04-22 at Amsterdam Schiphol Airport; a test section with an epoxy-based surface coating (applied manually)
- Runway 18C-36C at Amsterdam Schiphol Airport; a recently constructed runway pavement with a tar-bearing ANTISKID®. This site also serves as a reference
- The main runway at Twente Airport; a surface coating with a tarless modified bitumen
- The secondary runway at Twente Airport; SMA 0/11 type 2
- Lelystad Airport; grooved dense asphalt concrete (DAC 0/16)
- Copenhagen Airport in Denmark; Supergrip®

Investigations performed:

- In situ measurements of the bonding level of a surface coating to the underlying asphalt layer
- In situ measurements of the ravelling (and F.O.D.) resistance using the ravelling tester developed by NPC

- Laboratory tests on submerged cores using the steel brush test to determine chemical resistance

A F.O.D. study is yet to be performed on Supergrip®.

Bonding test

This test has only been conducted on surface coatings. Holes are drilled in the pavement to a depth of 20 mm so that the drill bit passes through the surface coating. The surface is heated dry and steel plates with pull-hooks are stuck to the surface with a quick-hardening adhesive. Once the adhesive is dry, the antiskid layer is removed and the tensile force measured. The photograph below shows the set-up that was used.

Photo 1. Set-up for bonding tests on surface coatings.

The results of the failure load measured during the bonding strength test on the pavement depend on aspects that include the ambient temperature. The temperature in Amsterdam was different to that in Twente. The temperature was assumed to have no effect on the tensile strength tests on the epoxy, while a temperature correction was made for the ANTISKID®.

There is a clear difference in the location of the failure interface in the 3 surface coatings. The tar-bearing ANTISKID® surface coating and the tarless bitumen coating were pulled entirely free from the underlying pavement. In the case of the epoxy coating, the aggregate was pulled away from the surface coating that stuck to the underlying layer. The results of the coating on epoxy basis are comparable to tar-bearing ANTISKID®. The results for the tarless coating on bitumen basis were clearly poorer. Average failure stresses are presented is presented in table 2.

Table 2.
Average failure stress

Material code	Average failure stress [MPa]
Surface coating with epoxy binder	1.34
Surface coating with tarless modified bitumen	0.65
Tar-bearing surface coating ANTISKID®	1.41

Photo 2. Surface coating on epoxy basis.

Photo 5. Surface coating based on tarless bituminous binder.

Ravelling tester, in situ measurement of the ravelling resistance

General description

To establish the ravelling resistance of a surface layer, the ravelling tester is used to expose the pavement surface to repeated shear stresses. To do so, a ring-shaped rubber load plate (outside diameter 200 mm, inside diameter 100 mm) is placed on the asphalt and rotated repeatedly. The frequency of this rotation can be varied between 0 and 25 Hz. This frequency range corresponds to a driving speed of approximately 50-80 k.p.h. The weight of the apparatus was set at approximately 500 kg (based on a friction coefficient of 0.5-0.7). The test involves the application of a dynamic load. This choice is based on the efficiency of the measurement. The required torsion is generated by rotating eccentrics, which are positioned out of the rotation centre of the apparatus. The eccentrics rotate in a plane that is parallel to the pavement. The driving system for the apparatus is shown in the figure below:

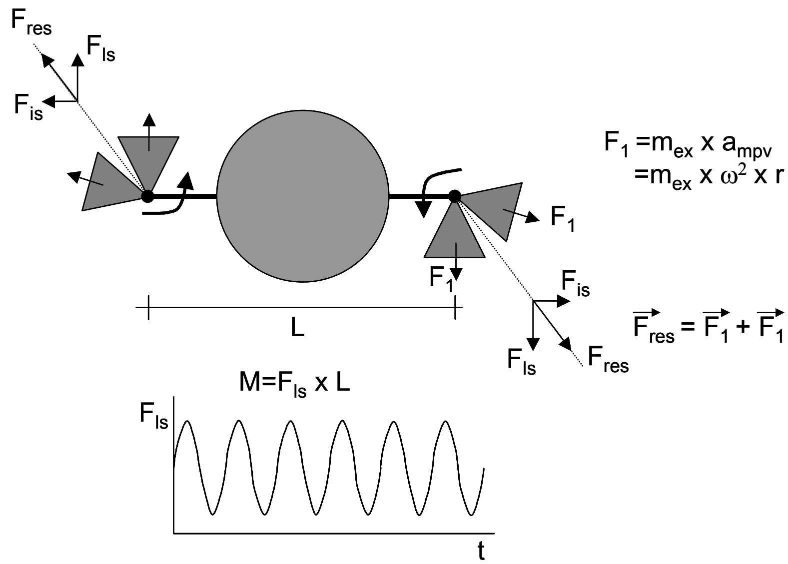

Figure 1. Driving system for the ravelling tester.

Legend to the figure:

m_{ex} : The weight of the eccentrics

M : Moment

a_{mpv} : The centrifugal acceleration

F : Force

ω : The angular velocity of the eccentrics

L : Distance between the centres of rotation of the eccentrics

r : Distance between the mass centre of gravity and the centre of rotation of the eccentrics

The apparatus has two adjustment parameters, only one of which, the frequency parameter, was operational when the test was performed.

1. The size of the angle between the eccentrics. By changing the angle between the eccentrics, the driving moment can be altered for each frequency. The smaller the angle, the larger the driving moment;

2. The frequency of the driving moment. This can be adjusted using the revolution speed of the motor that drives the eccentrics.

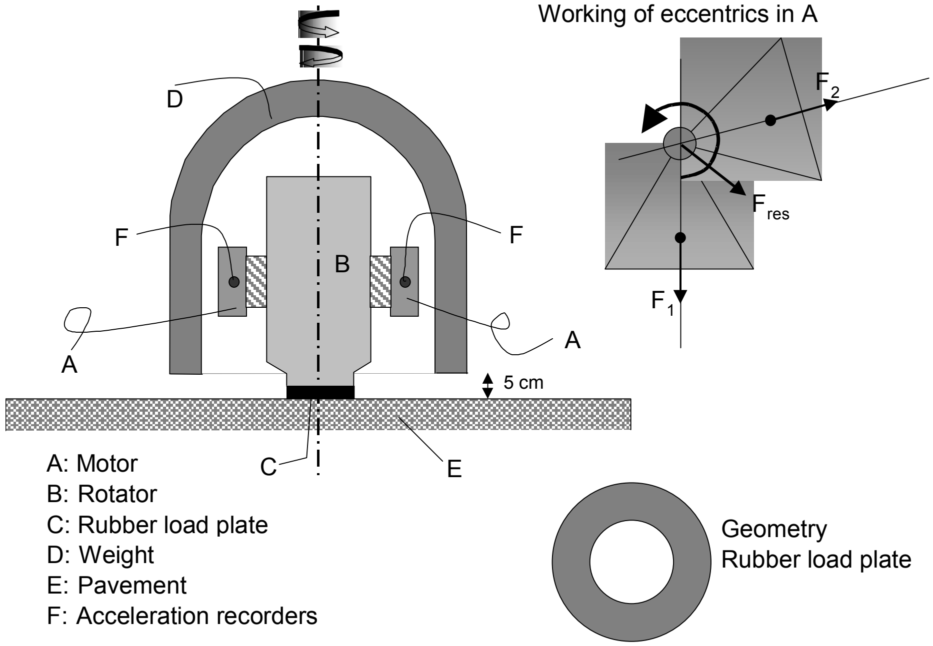

Figure 2. Asphalt ravelling tester set-up.

During the measurement, the rotation of the load plate is measured using acceleration recorders (with separate power supply and built-in amplifier) mounted on the apparatus. The measuring device built by NPC is shown in the figure below.

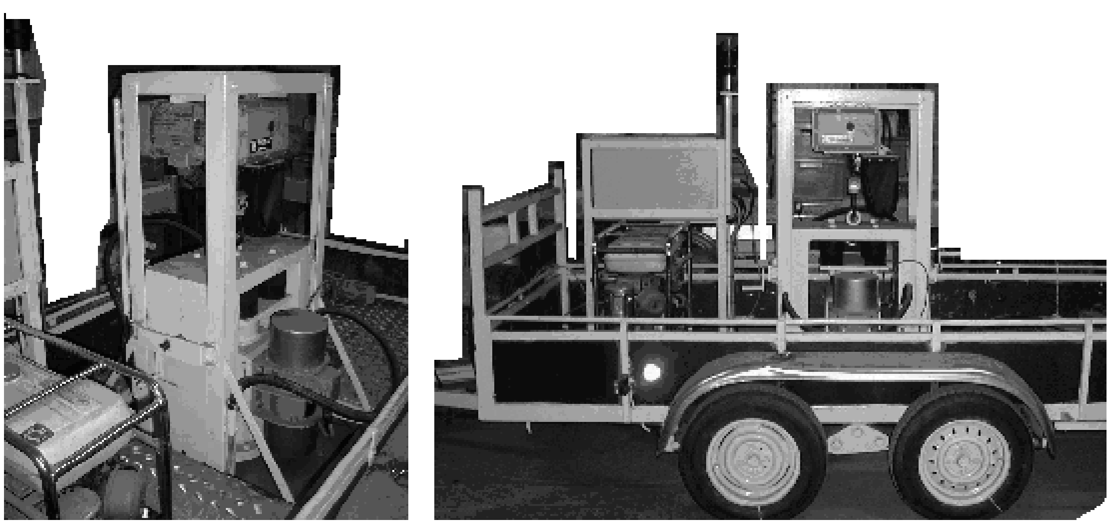

Photo 3. Asphalt ravelling tester mounted on a trailer.

A rotating, ring-shaped rubber plate transfers the applied load to the pavement surface. The frequency can be adjusted in advance. The normal vertical stress is constant (weight of the apparatus is constant). Geophones measure the acceleration (and the displacement) of the ring-shaped load plate.

Like the load placed on the surface, this will have the form of a sine.

$$a = A_{acceleration} \sin(\omega t + b)$$

The displacement is generated by a double integration. The amplitude A of the displacement will equal:

$$A_{displacement\#} \approx \frac{1}{\omega^2} A_{acceleration}$$

The amplitude of the displacement is directly proportional to the amplitude of the acceleration. Ultimately, then, there is a relationship as shown in the following figure.

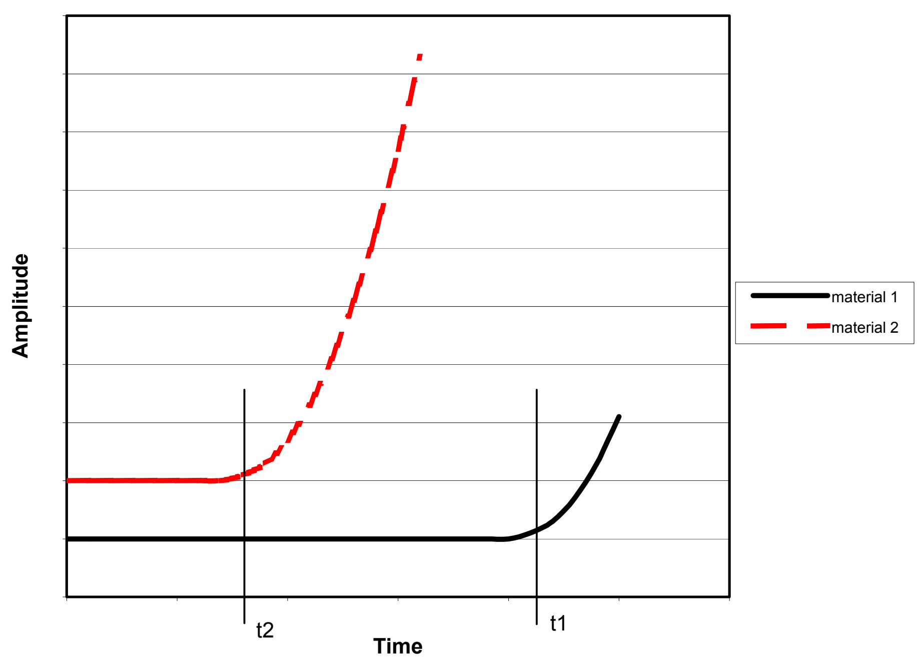

Figure 3. Asphalt ravelling tester: measured results.

In figure 3 t1 and t2 are the times when material 1 and material 2 fail. Using the frequency, it is possible to convert the times into a series of load repetitions until failure. This ‘ranks’ the various products according to ravelling resistance.

Measurements conducted with the ravelling tester have shown that there is still too much interference in the output signals. The apparatus is still not finished. The adjustment and the mass still have to be refined. The amplitude increased when the epoxy-based and tarless modified bitumen surface coatings were measured. The other surface layers showed no increase and even a slight decrease in amplitude.

Steel brush test, laboratory test of the chemical resistance

Each selected surface layer with or without coating has 9 cores available for chemical resistance tests (steel brush tests) [4]. The test procedure is as follows:

1. All extracted cores are sawed to the same height (60 mm).
2. All test samples are weighed.
3. For each paving material, 3 cores are submerged in kerosene (1 hour), 3 cores are submerged in Clearway One (72 hours) and 3 cores are submerged in Killfrost (72 hours). The submersion times are based on practical experience. When kerosene spills on the runway, it is quickly removed from the surface. Clearway One, however, is designed to keep the runway skid resistant and free of ice for as long as possible. Killfrost that ‘spills’ from aircraft wings is never removed and has to wash away naturally.
4. After drying, the test samples are brushed with a steel brush at a pressure of 6 bar for 90 seconds. Each test sample is weighed every 30 seconds and the loss of mass is determined.

Photo 4: Steel Brush Test set-up.

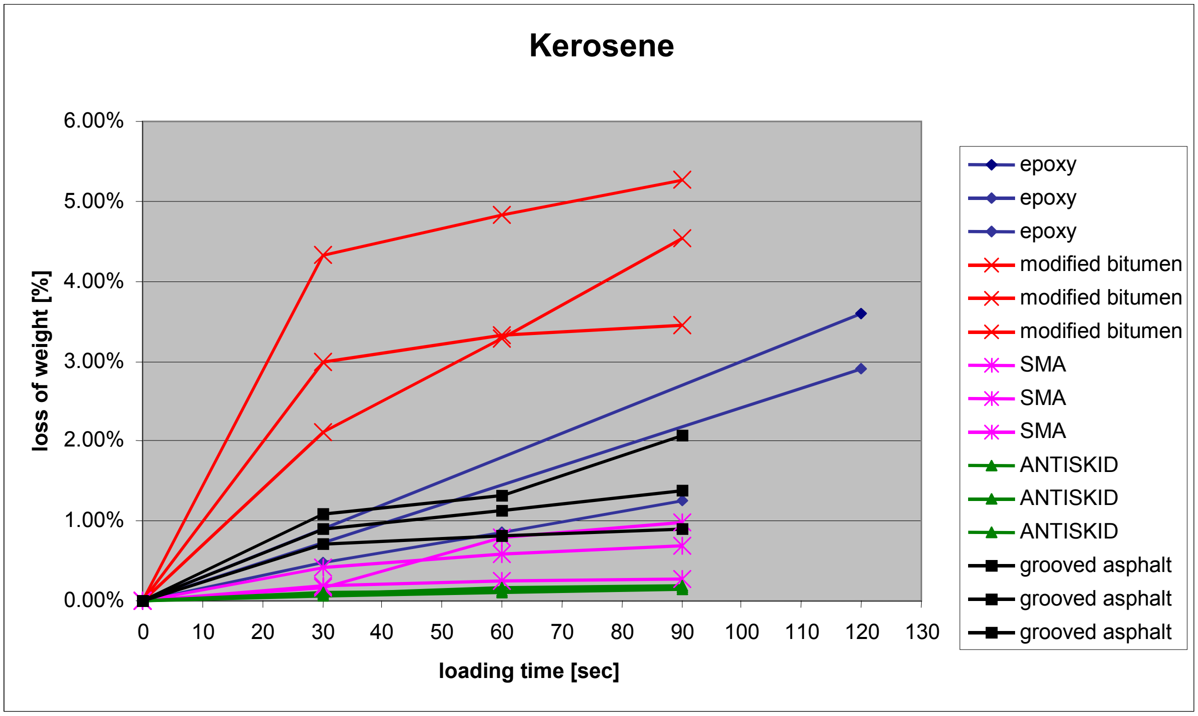

Figure 4. Results of steel brush tests.

This graph shows the results of the kerosene resistance test.

The chemical resistance of ANTISKID® shows the best results but SMA scores well too. Both tarless surface coatings (with epoxy and modified bitumen) show significantly poorer results.

CONCLUSION

In order to be able to rank various surface layers and coatings regarding F.O.D.-resistance, three different test methods have been performed. The most discriminating test is the steel brush test, while the bonding test and ravelling test give a good impression about the characteristics to be expected in practice. The ravelling tester is rather new and needs to be further developed.

The results of the bonding test, ravelling test and steel brush test in this study have shown that none of the selected promising alternative surface layers that have been tested (Supergrip® has not been tested yet) achieves the same results on all properties as the tar-bearing ANTISKID®. The alternative coatings are comparable on skid resistance and texture depth, but their F.O.D. and chemical resistance are substantially lower. The use of Grooved Asphalt or Stone Mastic Asphalt as a surface layer results in runways with lower skid resistance than the Design Objective Level.

Market parties (suppliers, contractors) will have to develop new products to find a material that meets the statutory requirements and has the same F.O.D. and chemical resistance as the tar-bearing reference material ANTISKID®.

The general conclusion is that although in some cases no alternatives for tar-bearing ANTISKID® are available, in other cases compromises can be made. This means that airport managers could consider one of the operational aspects less important for their specific airfield situation, except of course the statutory requirements. This results in that one of the selected alternatives can perform reasonable well on other aspects and can be chosen for that situation.

The results achieved by this CROW working group are that they will help supporting decisions to be made by Dutch airport managers in their choice for a specific type of surface layer.

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