ENVIRONMENTALLY FRIENDLY FUEL RESISTANT SURFACINGS

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ABSTRACT

Some trafficked areas are subjected to attack from hydrocarbons, particularly aircraft and road vehicle fuel. For a long time the solution was to manufacture fuel resistant pavements using a binder based on pitch produced by processing coal, to which PVC type polymers were frequently added to increase resistance to mechanical stresses. However, about ten years ago the competent authorities classed pitch as highly toxic and it has been shown to be extremely damaging to health so its use was, of course, prohibited by a number of road construction companies. The search for alternative products was launched with the aim of protecting the environment and the health of workers. It led to the development of a range of non-toxic, often bitumen-based, surfacings, that are able to withstand attack from oil derivatives. Thus, different types of surfacings were designed, some hot laid (using a coating binder to produce fuel resistance in the mass) and others cold laid (using a bituminous binder or synthetic resins in aqueous emulsion to provide surface protection). The resulting products take the form bituminous mixes, percolated mixes, unchipped prefabricated membranes, surface dressings manufactured with bitumen and/or resins and microsurfacings but also related products such as two component cold-applied mastics used for joint seals. None of these products contains products that are known or assumed to be toxic. As we lack a standard method for characterizing fuel resistant surfacings or products, a method for classifying their fuel resistance and mechanical performance is also described. Each type of product can be tested in the laboratory using a specified methodology. At the same time, requirements with regard to resistance to hydrocarbon solvents (K), resistance to puncturing (P), resistance to rolling loads (R) have been laid down for the different types of structure (airports, service stations, car parks, depots, etc.). It is thus straightforward to find a product that meets the K, P and R criteria specified by the client.

KEYWORDS:

FUEL RESISTANT SURFACINGS / ENVIRONMENT / BITUMINOUS MIXES / THIN FILMS / MICROSURFACING / MECHANICAL PERFORMANCE / METHOD

1. INTRODUCTION

Pavement surfacings can be subjected to varying degrees of attack from oil products such as fuel. Binders that consist of pure bitumen, which is an oil vacuum distillation residue, are compatible with this type of flux which tends to soften them and therefore weaken the structure. Initially, this weakening may affect only to the surface, but when the chemical attack is combined with mechanical aggression (puncturing, horizontal shear, traffic, vehicle manoeuvres, etc.) the damage may be deeper. This process particularly affects areas where vehicles remain stationary or are refuelled and can involve light vehicles, HGVs or aeroplanes. For a long time the solution that was adopted was to use surfacings manufactured from pitch, obtained by the pyrolysis of coal. As their chemical structure is different from oil products, products derived from the chemical modification of coal are not compatible with normal oil solvents and are therefore not attacked by them. These materials could be laid hot (using a coating binder to provide fuel resistance in the mass) or cold (with a binder in aqueous emulsion to provide surface protection). However, about ten years ago, the competent authorities classed pitch as being highly toxic (carcinogenic) and it has been shown to be extremely harmful to health (risk phrase R45). The use of pitch-based binders has therefore been prohibited by a number of road construction companies and alternative techniques have been proposed. Research has resulted in the development of a range of fuel resistant products (denoted by the letters “AK”) which do not contain coal derivatives that are harmful to human health.

This paper begins by presenting a methodology for characterizing the fuel resistance and mechanical performance of these surfacings, the results from which can then be compared with the requirements for structures that are to be built. To this end each surfacing has been assigned levels of AK resistance and mechanical performance on the basis of measurements using appropriate test procedures. These levels have been denoted by Kx, Py, Rz, where K stands for “fuel resistance”, “P” for “resistance to puncturing” and R for “resistance to rolling loads”. At the same time, requirement levels for fuel resistance and mechanical performance have been specified for different structures. These are denoted in the same way by Kx, Py and Rz.

2. CLASSIFICATION OF SURFACINGS WITH REGARD TO CHEMICAL AND MECHANICAL STRESSES

2.1. Requirement classes for resistance to hydrocarbon solvent attack: determination of the criterion Kx

The Kx values are assessed according to the type of fuel resistant surfacing (the same tests are not used for all types of surfacing), where x varies between 0 and 3.

- K0: the surfacings are not subjected to hydrocarbon attack.
- K1: the level of hydrocarbon attack is deemed to be low. This arises when slightly aggressive hydrocarbons of the heating fuel oil and heavy oil types remain briefly in contact with the surface after an accidental spillage,
- K2: the level of attack is deemed to be moderate. This occurs in the following situations:
- either when aggressive hydrocarbons are briefly in contact with the surface from time to time,
- - or when aggressive hydrocarbons (such as premium grade petrol and light oils) are frequently but briefly in contact with the surface.
- K3: the level of hydrocarbon aggression is deemed to be high. This arises when aggressive hydrocarbons are frequently present on the surface.

2.1.1. Hot mixes and percolated mixes

For hot mixes and percolated mixes, the Kx value is obtained from the Duriez type r/R strength ratio after immersion in kerosene. The tests are conducted according to a test procedure derived from the French standard NF P 98-251-1. The dry Duriez compressive strength “R” is determined for specimens that are conserved for 24 hours at ambient temperature after manufacture and then for 7 days at 18° and 50% relative humidity. The compressive strength after immersion “r” is measured after the specimens have been conserved for 24 hours at ambient temperature and then immersed in kerosene for seven days at18°C.

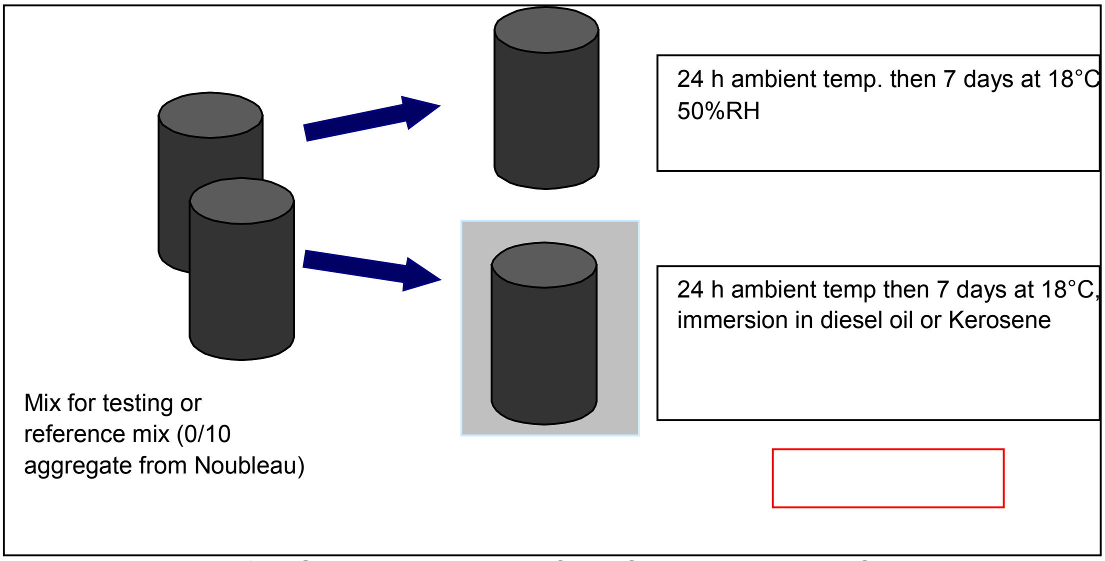

Figure 1 – Characterization of the fuel resistance of mixes

The performance levels must be obtained with the type of constituents and the formula that can be expected at the worksite. A reference mix is used for studies that aim to investigate or evaluate binders.
Table 1 sets out the levels of resistance that have been fixed.

Table 1 – Determination of Kx levels for mixes

Duriez r/R type compressive strength results	Kx value
r/R < 0.35	K0
0.35 ≤ r/R < 0.50	K1
0.50 ≤ r/R < 0.65	K2
0.65 ≤ r/R	K3

2.1.2. Thin surfacings

Duriez compression tests cannot be performed on thin surfacings (membranes, surface dressings or micosurfacings). The Kx level is evaluated after the specimen has been attacked by the hydrocarbon solvent and a comparison with the level of resistance exhibited by the reference surfacings [as specified in the standards Emulsified Coal-Tar Pitch (Mineral Colloid Type) ASTM D 3320 and the Standard test method for films deposited from Bituminous Emulsions ASTM D466-42]. The principle of the test is as follows: open-ended cylinders are bonded to the surface that is to be tested, which has itself been laid on a reference mix. A precise mass of kerosene is placed in each cylinder and left in contact with the surface for 24 hours. After this period, the appearance of the residual solvent and the surfacing is observed and compared with the result for a film which is considered to have poor resistance (a film of pure bitumen) and one which is considered to have good resistance (a film of pure resin).
Table 2 shows the levels of resistance that have been fixed for surfacings in relation to performance under attack.

Table 2 – Determination of the Kx levels for thin films

Results of evaluation after attack	Kx value
level 0: pure bitumen level 1 level 2 level 3: pure resin	K0 K1 K2 K3

2.2. Requirement classes with regard to resistance to puncturing: determination of the criterion Py

The puncturing tests are performed on hot mix surfacings, applying the method that is described in the Annales de l'Institut Technique du Bâtiment et des Travaux Publics – Recommandations F.N.T.P.: "Revêtements de sols industriels – Recommandations pour un essai de poinçonnement statique", n° 465 - juin 1988". The test consist of measuring the depth of the indentation made by a punch of specified surface area over time, at given temperatures and under given loads. The depth of indentation is expressed in mm and depends on the duration of the test, the applied load, the temperature at which the test is conducted and the surface area of the punch. The values of these parameters, selected on the basis of the use to which the tested products will be put and the environment in which they will be used, are set out in Table 3.

Three types of requirements can occur:
- P1: Low static loads
- P2: Moderate static loads
- P3: High static loads

To meet these requirements, after the puncturing test the surfacings must exhibit an indentation of less than the values given in Table 3 at both temperatures.

Table 3 – Determination of the Py levels

Static puncturing in mm under a load of 5MPa after 24 h using a punch with a surface area of 8cm^2	
at 25 °C	at 60°C
P1: P ≤ 10 mm P2: P ≤ 7 mm P3: P°≤ 1 mm	P1: P ≤ 17 mm P2: P ≤ 13 mm P3: P ≤ 8 mm

2.3. Requirement classes for resistance to rolling loads: determination of the criterion: Rz

Currently, no tests exist for evaluating resistance to rolling loads or shear for road surfacings. The levels of resistance (Rz) that are given in Table 4 are estimates based on experience.

Table 4 – Determination of Rz levels

Requirements	Pressure applied by each wheel	Vehicle type and number of passages
R1	LV, HGV<6t, light passenger planes (pressure <0.5MPa)	< 100/d
R2	LV, HGV, light passenger planes (pressure <1MPa)	HGV 10-100/d LV 100-1 000/d
R3	LV, HGV, all types of planes (including military transport planes) except very large jumbo aircraft (pressure <1.5MPa)	HGV 100-300/d LV 1 000-3 000/d
R4	LV, HGV, all types of planes including jumbo aircraft, eg: B777, A340-600, A380, fighter planes) (pressure >1.5 MPa)	HGV > 300/d LV > 3 000/d

3. CHARACTERIZATION OF THE PRINCIPAL DOMAINS OF APPLICATION OF FUEL-RESISTANT SURFACINGS

3.1 The principle domains of application

These consist essentially of the following structures:
- airports and airfields: runways, runway thresholds, taxiways, hangars, aprons, refuelling areas,
- service stations,
- parking areas, for HGVs, light vehicles or military vehicles,
- fuel depots, containment tanks in pumping stations.

3.2 Levels required for the criteria Kx, Py and Rz, depending on the type of structure

Table 5 presents some standard requirements for resistance to hydrocarbons (Kx), resistance to puncturing (Py) and resistance to rolling loads (Rz).

Table 5 - Kx, Py and Rz level required depending on the type of structure

Type of structure	Requirement class
Civil airports and military bases	
Runway threshold	
Taxiways	K1-P2-R3 or R4
Hangars	K2-P2-R3 or R4
Aprons	K2-P3-R3 or R4
Refuelling areas	K2-P3-R3 or R4
	K3-P2-R2
Civil airfields	
Hangars	K2-P2-R1
Aprons	K2-P2-R1
Refuelling areas	K3-P2-R1
Stations services	
LV Refuelling areas	K3-P1-R2
HGV Refuelling areas	K2-P2-R3
Other	K2-P1-R2
Parking areas	
PL	K2-P2-R3 or R4
VL	K2-P1-R2
Military vehicles	K2 or K3-P2 or P3-R2
Fuel depots	
Retention tank	K2 or K3-P1-R1
Pumping station	K3-P2-R2

4. THE RANGE OF FUEL-RESISTANT PRODUCTS

A full range of fuel-resistant products has been developed:

- bituminous mixes,
- percolated bituminous mixes,
- unchipped membranes manufactured with bitumen and/or resins,
- chipped surface dressings manufactured with bitumen and/or resins,
- microsurfacings or slurry seals manufactured with bitumen and/or resins,
- there is also two component cold-applied mastic used for sealing the joints between concrete, metals, paving blocks, bituminous mixes, or epoxy-urethane modified asphalt.

4.1 Bituminous mixes

These are manufactured using modified bituminous binders. They provide a wearing course whose effectiveness with regard to attack from oil products is fairly long lasting as a result of the fact that it is modified in the mass. They can be used to rectify the profile or evenness of the existing surface. They have good resistance to rutting, tangential stresses and shear. Depending on their formulation, mixes of the COLNAK, COMPOMODULE AK, COMPO AK type can attain class K3 classification on the basis of the method described above. The table below gives some examples of the K values obtained from the tests described in the method.

Table 6 – Example of results from the characterization of AK binders and mixes

Base bitumen		B1	B1	B1 + A1	B4
$T_{R\&B}$	°C	65	56		57
Penetration at 25°C	1/10mm	38	44		41
Storage stability(3 j -170°C) $T_{R\&B}$ (high) $T_{R\&B}$ (low)	 °C °C	 61.8 61.0	 56.0 56.2		 55.6 55.8
Viscosity 125°C 150°C 175°C	mPa.s	 4000 1100 360	 2,300 640 235		 2,300 640 220
K	-	0.67	0.68	0.67	0.70
R, 7 d at 18°C, 50% RH	MPa	17.4	13.3	18.1	13.5

The resistance of surfacings to puncturing and tangential stresses can be improved so as to reach a level of P2 or P3 and R4 by using special formulations (MULTICOL, COMPOMODUL THP, SACERFALT EXP).

4.2. Percolated mixes

These are composite materials which combine the flexibility of a bituminous concrete matrix with the strength of a hydraulic concrete - polymer composite. In particular, they exhibit high resistance to puncturing. They also have very satisfactory resistance to tangential stresses and rutting. Their surface roughness can be varied according to the application. Their high stiffness means they can only be laid on substrates with low levels of deformability.
Using the above technique, mixes of the RODAL, COMPOCEM or SACERSOL type are classified as P3 and can reach a level of K3, on condition their surface is protected.

4.3 Thin surfacings

4.3.1 General considerations

These are unchipped membranes, chipped surface dressings manufactured with bitumen and/or resin, and microsurfacing manufactured with bitumen and/or resin. The fact they take the form of emulsions means they can be laid cold using simple equipment, reduces problems in relation to the environment, hygiene and safety, and allows them to be laid using techniques that require little energy. Their surface texture provides them with good frictional qualities. Repairs can be performed easily and rapidly, even when limited to a small area. As an approximate guide, using the method described and depending on the techniques involved, the following levels can be attained by these products:

- unchipped membranes manufactured with bitumen and resin (COLNAK, EMULAK AH, INDAS AK): K2 or K3.
- Chipped surface dressings manufactured with bitumen and resins (COLNAK sealed surface dressing)
SPRAYGRIP-COLGRIP): K2
- microsurfacing or slurry surfacing manufactured with bitumen and/or resin (COLNAK microsurfacing/slurry surfacing RUGOSEAL AK): K2

4.3.2 Membranes manufactured with resin

Fuel-resistant surfacings that are manufactured with resins in aqueous dispersion of the EMULAK AH or INDAS AK type can by used for all road or aeronautical traffic classes, on condition that the are laid on a suitably designed structure. However, they are not appropriate where the traffic applies powerful aggregate stripping stresses (for example, areas where solid-tyred vehicles operate or where lorries make U-turns).

On the basis of the method for choosing fuel-resistant surfacings that we have described above, this type of product falls into class K3, that is to say it has very good ability to withstand hydrocarbon solvent attack, and R2, that is to say it has moderate resistance to puncturing. The latter can, nevertheless, be improved (R3) if an additional layer of the product is laid.

The tests conducted to establish the resistance to hydrocarbon attack have shown the superiority of this type of slurry surfacing over techniques that involve the use of pure bitumen and even over pitch-based emulsions. The fact that it is waterproof means that it provides very effective protection.

A surfacing manufactured with a pure bitumen emulsion which is unable to withstand any kerosene attack is assigned the level 0. When provided with a protective layer of resin emulsion, the same substrate mix is not attacked by the solvent and undergoes no damage.

Table 7 - K values for unchipped membranes

Surfacing	Appearance after 24 h	Appearance of kerosene after 24h	Rating
EMULAK AH / INDAS AK	Unchanged	Light-coloured clear solution, similar to the reference kerosene	Level K3
Pure bitumen emulsion	Attack: film destroyed	Opaque black solution	Level K0
Pitch emulsion	Slight attack	Brown clear solution	Level K2

The conditions that are specified in their respective technical notes must be complied with when these surfacings are laid (with regard to ambient air temperature and humidity, substrate consisting of close graded asphalt, proportioning, time elapsing between the laying of successive layers).

These surfacings combine the advantages of products that are in an aqueous phase (they do not give off harmful volatile organic compounds) with ease of use and economy. They belong to the family of thin films and provide surface protection which is effective, but dependent on the applied stresses.
They present no major hazard for laying teams, or for users as long as the rules for laying are followed. They are not environmentally harmful either and do not require a transport classification.

Photo 1 – Laying an unchipped membrane

5. CONCLUSIONS

This method makes it possible to select solutions from among those available which are appropriate with regard to oil solvent resistance and mechanical strength requirements for the specific domains of application.
It is nevertheless essential to check that the selected techniques meet the other requirements specified in the contracts, particularly with regard to skidding resistance. The classifications and data that are presented here are based on current information and are liable to change with the state of knowledge and experience.
The various fuel-resistant products described in this paper have been the subject of many successful applications in the field. They are effective both with regard to resistance to hydrocarbon solvent attack and mechanical strength.

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