INFILTRATION OF FUELS THROUGH PAVER JOINTS

John Emery - Technical Director .
Advanced Construction Materials Ltd., Newcastle upon Tyne, England

Summary

Hundreds of thousands of square metres of pavers have for many years been successfully used on service station and aircraft pavements.However, with the proposed introduction of increasingly stringent health & safety and environmental legislation a reassessment of this form of surfacing pavements is necessary to ensure that compliance with the new requirements can be achieved.
Because a paver surface comprises small element units having sand-filled joints typically 2-4mm wide the surface is pervious.There is a generally held view that these joints seal with time so that infiltration of water and other liquids is avoided. Whilst this may occur in heavily trafficked areas there are many areas of pavers where the joints remain pervious. One of the primary reasons for providing a surface to a pavement is to protect the underlying pavement structure, including the subgrade, from the ingress of water.
The potential infiltration of water and other liquids through a paver surface is a particularly relevant issue at service stations and airports where this may lead to fire and environmental hazards.
This paper discusses these potential hazards and describes investigations into quantifying the amount of fluid which can be expected to filter through a paver surface. It also describes a method of sealing joints with a liquid pre-polymer and a test procedure for measuring the infiltration of water and fuels through a paver surface.

Introduction

Over the last decade there has been a steady increase in the use of pavers for surfacing at service stations and on aircraft pavements.Recently,however,doubts have been raised by petroleum officers and environmental agencies concerning the ability of this form of surfacing to prevent the ingress of fuels into the underlying pavement structure.The infiltration of fuels they consider to be a potential fire hazard and potential cause of contamination of water supplies.
Because a paver surface comprises small element units laid into a sand bed and having joints typically 2-4 mm wide filled with sand, the surface is pervious. There is a

widely held view that paver joints seal with use and time so that eventually the surface becomes sealed. Whilst this may occur in areas that are heavily trafficked,there are many other areas where the joints remain pervious. As discussed later, **Smith**[1] has reported that pavements which have sealed can be subsequently unsealed by certain types of traffic. One of the principal reasons for surfacing a pavement is to protect the underlying pavement structure - including the subgrade - from ingress of moisture. Therefore, the potential ingress of fluid through a paver surface is a relevant issue in all categories of paving and is particularly important at service stations and airports where a leaking pavement can create safety and environmental hazards.
Investigations have been carried out to determine the amount of fluid which can be expected to infiltrate through a paver surface are reported in this paper. A test is also proposed which can be used in the field to assess by how much an existing pavement is leaking. Many service station forecourts and aircraft pavements surfaced with pavers are now treated with a fuel resistant elastomeric pre-polymer formulated specifically to reduce infiltration and for this reason, the pre-polymer has been included in the test program reported in this paper.

Background

During 1981 an investigation was undertaken by a group of paver manufacturers to determine the extent of fuel penetration through paving. The combustibility of the atmosphere just beneath the pavers was measured using an 'explosimeter'. This equipment expresses the vapour content as a percentage of the Lower Explosive Level (LEL). Readings made under both block paving and reinforced concrete pavements were compared. The findings were that both surfaces exhibited similar LEL's, indicating that the anticipated fire hazard under block paving was similar to that under conventional surfacing materials. Three causes of concern were identified during these investigations. They were :

(1).Immediate explosion and fire hazard resulting from major spillage:
(2).Explosion and fire hazard resulting from an accumulation of minor spillages:
(3).Migration of fuel into neighbouring properties.

The conclusion from the 1981 investigation was : " There is no guaranteed solution to eliminate any of these with any type of surfacing material.Concrete block paving gives no more cause for concern than any other paving material ".
Since 1981 a good deal of debate has surrounded the growing use of pavers at service stations and on aircraft pavements. Whilst some authorities have been ready to accept the material, often subject to rigorous conditions, e.g. joint sealing, others have preferred to await further research data. This paper provides that data for a range of liquids, paver materials and jointing materials.

Paving

Paver surfaces for service station forecourts normally consist of either 80mm thick concrete pavers or 65mm thick clay pavers. Aircraft pavements are normally surfaced using 80mm thick concrete pavers. Where the shape of the pavers permits, the surface is laid to a herringbone pattern on a carefully selected sand laying course approximately 30mm thick after compaction with a plate vibrator. During compaction

some of the laying course sand is forced up into the joints of the pavers. The joints are appproximately 3mm wide and are filled with a fine jointing sand which is also compacted. Most pavers are chamfered around their upper perimeter and the sand should be kept away from those chamfers. The sand-filled joints are an important feature of this form of surfacing ; they ensure that the pavement behaves in a similar way under load to a conventional flexible pavement and that interlock is developed between individual blocks. Thus, when a wheel load is applied to a paver, the load is spread to adjacent blocks. Interlock can be defined as the inability of an individual paver to move in isolation from its neighbours. Because of this a paver pavement can be designed by standard methods for flexible pavements, the pavers and their sand being substituted for an equivalent thickness of bituminous material. The general arrangement of paver pavements is shown in Figure 1.

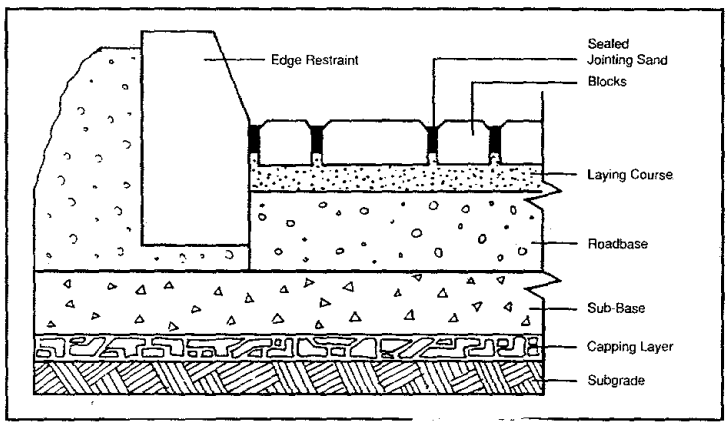

Figure 1 : Typical section through paver pavement

Penetration through paver surfacing

Research in the US by **Smith** [1] has shown that paver surfaces should always be assumed to permit the infiltration of water. Smith states, " Concrete block paving placed on a sand and gravel base, trafficked by automobiles, does not always have the joints fill over time with detritus (generating a high run-off coefficient). The sealing action of sediment and detritus in the joints may be negated or even reversed by sucking and pumping action of automobile tires on the concrete block paving ".
Further investigation work by **Knapton** [2] concluded that :

(1) The ingress of moisture through block paving can have a marked effect upon the structural performance of the pavement.
(2) Under an adverse combination of water, material and traffic, a concrete block pavement can develop significant levels of rutting after a few thousand 8000 kg standard axles, even though the requirements of **BS 7533** [3] are satisfied.
(3) The application of a polymer sealer to a fully granular concrete block pavement can result in a significant improvement in pavement performance.

Laboratory Testing

a. Infiltration

Four areas of rectangular pavers were prepared, two using 80mm thick concrete blocks and two using 65mm thick clay pavers. One area of each type of paving was sealed using a proprietary liquid pre-polymer. 140mm diameter glass cylinders, 100mm high having a wall thickness of 5mm were affixed to each panel using an epoxy mortar to form a water-tight seal at the paver/glass interface. (see Figure 2).

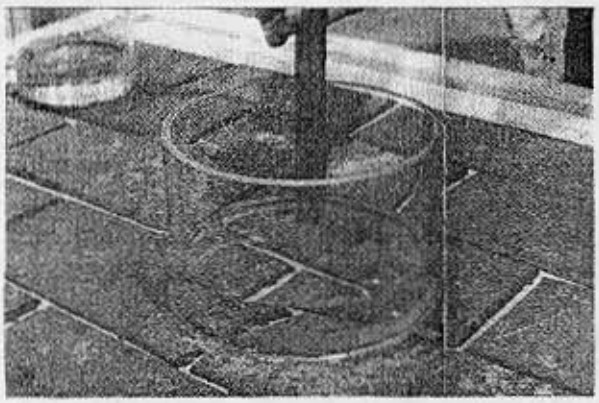

Figure 2 : Infiltration trials showing glass permeameter fixed to pavers

Water, Avgas (aviation fuel), petrol and diesel were carefully poured into each cylinder and the infiltration rates in ml/second were measured for each. A half litre sample of liquid was used for each test, which is equivalent to an initial head of 34mm. This height was considered to be appropriate and is probably more severe than is likely to occur (even during spillage of fuel on a service station forecourt).

The results of the infiltration tests before and after sealing are shown in Figures 3 & 4.

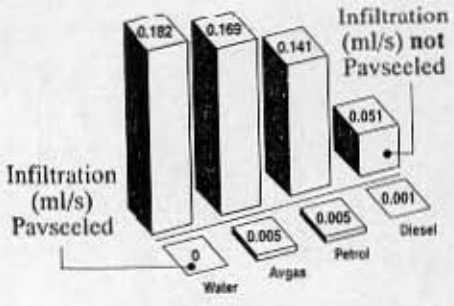

Figure 3 : Infiltration test results Concrete pavers

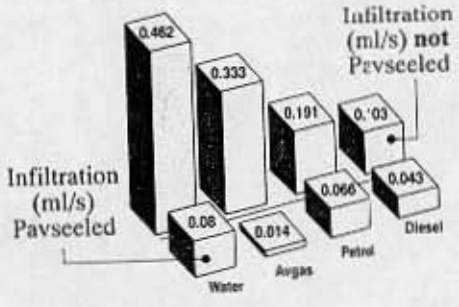

Figure 4 : Infiltration test results Clay pavers

The concrete pavers provided greater resistance to infiltration before and after
than was the case with the clay pavers. Sealing the concrete pavers rendere
virtually impermeable to water. Infiltration rates for petrol and Avgas were simi
provided excellent resistance to infiltration after sealing. The results are prese
terms of ml/sec, i.e. the rate of loss of volume of liquid from the permeameter. I
to appreciate these results, consider the value of 0.005 ml/sec for petrol infiltr
sealed concrete paver surface. The area of the permeameter is 15,400 mm ^{2}
the above figure represents the infiltration of approximately I litre of petrol pe
through a pavement area of 1m^2 in the case when petrol is standing 34mm
over the pavement. This figure ignores the effect of evaporation losses, wh
taken into account, would reduce the measured infiltration rate of pet
approximately 8%.
The equipment used for determining the infiltration rates in the laboratory w
readily available and could successfully be used for site testing. Because of thi
proposed that the test be adopted as the field compliance test for petrol s
pavements. The procedure evolved out of attempts to use several dif
glass/paver adhesives and represents a simple site test for determining whet
not a petrol station forecourt is sufficiently impermeable.

b. Skid Resistance

To determine the effect of the application of the polymer sealer on the skid resis
of concrete and clay pavers, tests were undertaken using a portable pend
friction tester. The results of these tests are shown in Figure 5.

Surface Tested	Pendulum Test Result
Concrete pavers (Unsealed)	75
Concrete pavers (Sealed)	56
Clay pavers (Unsealed)	72
Clay pavers (Sealed)	84

Figure 5 : Results of skid resistance tests

These results indicate an initial reduction in the skid resistance value (SRV
concrete pavers after the application of the sealer. Experience has shown that the
is temporary as subsequent trafficking restores the micro texture of the con
surface as the sealer is abraded. With the clay pavers, SRV values increased
sealing.
The SRV values obtained for the concrete and clay pavers, whether seale
unsealed, are satisfactory for vehicular traffic and for pedestrian slip resistance.

Sealing of Pavers

Investigations into the erosion of jointing sand by Emery [4] revealed that if a l
pre-polymer was applied to the pavers and allowed to penetrate the joints
polymerisation, the jointing sand was not only stabilised but ingress of water thr

joints and into the underlying pavement structure was reduced to a negligible level. Furthermore, the specifically formulated polymer retained its elastomeric properties with time thus making it ideal for sealing a flexible concrete and clay paver surfacing.
The concept of stabilisation of jointing sand in block paving was developed initially to prevent erosion resulting from jet blast from aircraft operating at full take-off thrust. Tests carried out on block paving panels by **British Aerospace**[5] at their Hot Gas Laboratory indicated that polymer sealed blocks withstood Harrier VSTOL (Vertical Take-Off and Landing) take-off conditions operating at ambient temperature.
Subsequent use of the polymer sealer has demonstrated its effectiveness in preventing the erosion of jointing sand by suction sweepers and by turbulent water flow.

Conclusions

The following conclusions may be drawn from the research programme undertaken at the University of Newcastle upon Tyne.

(1) Providing the joints are sealed, forecourts surfaced with pavers are no less safe than those surfaced with traditional concrete slabs: the amount of fuel which can penetrate a sealed paver surface is negligible.
(2) Those paved forecourts which have not been sealed may give rise to unacceptably high LEL. In such cases the areas should be sealed retrospectively.
(3) The sealing of concrete pavers with a liquid pre-polymer reduces the infiltration of spillages of the three fuels tested, i.e. Avgas, petrol and diesel to an insignificant level.
(4) Sealing of clay pavers also inhibits the infiltration of the same fuels but not to the same order as for concrete pavers. This is due to the fact that clay pavers are more porous than concrete. The performance of clay pavers in this respect can be enhanced by a secondary application of the sealer. Therefore, it is recommended that clay pavers be subjected to two applications of polymer material within 5m of any fuel pump.
(5) Sealing of concrete pavers renders the surface virtually impermeable to water.
(6) The skid resistance value and slip resistance of concrete pavers is satisfactory after sealing.
(7) The skid resistance value and slip resistance of clay pavers is improved after sealing with the pre-polymer tested.
(8) The equipment used to determine infiltration rates in the laboratory is suitable for in-situ infiltration measurements at existing forecourts. The equipment comprises readily available materials.
(9) It is recommended that petrol station forecourts should be tested for infiltration using all of the fuel products which are to be sold there and also using water.
(10) The recommended maximum permitted infiltration rates are:

Water	0.05 ml/sec;
Petrol	0.02 ml/sec;
Avgas	0.02 ml/sec;
Diesel	0.02 ml/sec.

References

(1) Smith, D.R. and Hade, J.D. (1988). " Permeability of concrete block pavements".
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(2) Knapton, J. (1992). " An investigation into the effects of water penetrating the surface of concrete block paving ". Journal of the Institution of Highways & Transportation, Aug. 1992, No. 8, vol. 39, pp 8-13.

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(4) Emery, J. (1992). " Erosion of jointing sand from concrete block paving ". Proc. 4th International Conference on Concrete Block Paving, vol. 2, pp 295-299 . Auckland, New Zealand.

(5) British Aerospace Plc (1991). " Report No. BAE-WWT-EN-GEN 0013 ", unpublished data.