THE USE OF PERMEABLE PAVERS IN THE RECONSTRUCTION OF THE FIRE TRAINING GROUND AT JERSEY AIRPORT

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ABSTRACT

Concern had been expressed at the pollution being generated at Jersey Airport's Fire Training Ground. The airport authority decided to install a new Fire Training Ground in which none of the precipitation and fire fighting materials would drain into the ground or into the downstream sewerage. This involved the construction of an Evaporative Cell in which all of the water would be evaporated into the air. The cell allows water to drain through the pavers into a voided pavement structure from where it is sprayed back over the surface of the Fire Training Ground to encourage evaporation. It is explained that during the winter months, there will be a build up of water and during the summer months, the water will evaporate.

The paper deals with the concept of an Evaporative Cell and shows how permeable pavers were used as the surfacing material. Full scale testing of pavement components and also of a trial section of the finally selected pavement are described. The paper also describes the anticipated maintenance regime.

Keywords: Paving systems, Permeable paving, Pollution, Fire Training, Pavement maintenance, Airport paving, Full scale testing.

1. INTRODUCTION

All commercial airports are required to maintain a fire fighting capability otherwise the airport loses its licence. Training exercises are undertaken typically on a weekly basis involving dealing with a fire in either a disused aircraft or a fabricated steel tube as shown in Figure 2. The training exercise generates pollutants from the oil used to initiate the fire and from the materials applied to the fire. Jersey, the largest of the UK Channel Islands has a medium size commercial airport which was constructed principally to serve the island's tourist business.

Because the island relies upon ground water for its water supply, with many residents using their own boreholes, and because several residents near to the airport's Fire Training Ground (FTG) were complaining that foam appeared when they ran a bath, it was decided to reconstruct the FTG in such a way that there would be no outflow of clean or polluted water. The island's sewerage system was already running above its capacity so it was decided to construct the entire 8,000m^2 FTG as an Evaporative Cell (except for a 2000m^2 central area where fires were started). The Evaporative Cell was designed such that all of the precipitation and fire fighting water would drain through permeable pavers into voided material below from where it would be pumped to nozzles which would spray it back over the FTG where it would evaporate.

A study of the likely levels of evaporation and precipitation led to the conclusion that during the months September to March, there would be an accumulation of water within the cell but during the months April to August, the water would evaporate, emptying the cell. These calculations led to the need to create a water detention space beneath the pavement. In order to reduce the likelihood of flooding to acceptable levels, it was calculated that a space of thickness 300mm comprising 100% void would be required. It was calculated that this space would be overfilled at the end of March on a 1 in 80 years return period.

Tests were undertaken to assess the water retaining capability of various materials. For example, a locally available 20mm to 5mm graded stone could accept 32% by volume of water. A 125mm single sized stone could accommodate 46% water, but would not be suitable as a roadbase. If only those materials were used, the pavement thickness required for water retention would have been excessive. Therefore, various manufactured products were investigated. Figure 1 shows a load test being undertaken on the selected product which has 90% retention. In Figure 1, a single 150mm thickness unit is being loaded directly by a 6,000kgf wheel on one of the airport's fire tenders.



Figure 1. Testing of selected water retention unit using Jersey airport's fire tender.



Figure 2. Use of existing Fire Training Ground.

2. AIRPORT OBLIGATIONS

The States of Jersey comprise an independent country which is loyal to the Queen but not to the UK and which is not part of the European Community. Jersey Airport is licensed in accordance with the International Civil Aviation Convention and with Jersey's Harbours and Airport Committee except for aviation security and safety. Under these obligations the Airport has a duty to meet expected standards for airfield safety and to have due regard for the health, safety and welfare of its employees and users of, or visitors to, the Airport.

In line with the Committee's self-regulatory policy this requires compliance with various United Kingdom (UK) Civil Aviation Publications (CAP). The CAP's are reinforced by various 'Fire Service Memoranda' and other requirements. Jersey Airport, however, was not fully meeting its obligations for the Airport Rescue and Fire Fighting Service (ARFFS) under the CAP and Fire Service Memoranda requirements. Hence the need for the Evaporative Cell.

3. PROJECT OVERVIEW

The overall project objectives included:

- To develop a scheme which would remediate the existing site leading to the minimisation of the risk of further pollution through isolation and the restoration of the full fire training ability of the site. This involved the removal of contaminated material prior to the installation of the Evaporative Cell.
- By using the best techniques and best environmental practices that were available, so far as is reasonably practical to meet the requirements of the Water Resources Regulator acting under the Water Pollution (Jersey) Law 2000. The requirements of the regulator are as follows:-
  - Remediate to make safe, any earth and other material from the Airport Fire Training Ground that has been contaminated with constituents of fire fighting foam and hydrocarbon fuels and their residues.
  - Carry out appropriate works to contain any existing pollution at the Airport Fire Training Ground and its environs.
  - Restore the groundwater as far as reasonably practical under the Airport Fire Training Ground and its environs to an agreed concentration based on current limits of detection.

The following were the design objectives:

- The facility must allow trafficking by fully loaded fire service appliances. The resultant surface design must be capable of bearing all the airport fire fighting vehicles parked on the training surface at any one time.
- No precipitation must infiltrate the surface of the fire training ground under operational or passive conditions other than as part of a controlled drainage system.
- Untreated effluent must not be discharged to the environment from the facility.
- Operational use of the facility must accommodate the temperatures associated with the combustion of atomised 28-second fuel oil (the technical description of aviation fuel) and LPG from a dual rig.
- The design life of the civil works is to be warranted for a minimum of 20 years.
- The replacement for the current fire-training rig with a dual fuel (28-second fuel oil & LPG) is to be incorporated into the design.
- The Airport's Chief Fire Officer is to be formally consulted on the proposals before finalisation of the frozen design for planning application purposes.
- The design must be submitted for a specification audit by the environmental consultants and engineering departments prior to issuing a final design for planning or construction tendering purposes.

4. DESIGN CRITERIA AND DISCUSSION

The main area is to be trafficked by fire tenders on a weekly basis. The tenders presently in service have three driven axles, one at the front with a maximum static load of 10.5tonnes and two at the rear, each with a static load of 11.25tonnes as shown in Figure 2. Once per week, one or two vehicles will enter the site as if attending an emergency. They will attain a speed of 15mph as they enter the area and will execute a sharp turn and braking manoeuvre. There is a 2000m^2 area in the centre of the site where fires are started. This will be used by pedestrians only.

The subgrade comprises diorite rock which is weathered at its upper surface. In the weathered zone, there is a mixture of weathered rock, sandy clay and sandy silty clay. The pavement will be required to retain all of the precipitation and fire hose water & foam. The only escape for these fluids will be by evaporation. The area is required to perform for 20 years with a minimum of maintenance. Where aggregates are used within the pavement structure, they had to be readily available on the island of Jersey

Prior to the construction of the Evaporative Cell the fire tenders travelled over a loose stone surface which developed ruts especially where the fire tenders executed turning & braking manoeuvres as shown in Figure 2. Loose stone had developed on the surface through use as the finer binding material which was formerly at the surface had vibrated to a lower level. Excavating through the stone revealed that at a depth of 100mm to 200mm, the stone included fine material. If this material were to be saturated for some or all of the time, it is likely that its stability would diminish to a level whereby the fire tenders would struggle to make progress and may have become trapped within the material.

It was necessary for both stability and hydraulic reasons to eliminate the fine material from the stone. Crushed rock materials derive their stability through the macadam effect in which fine material is added to the coarse in order to bind the coarse materials and so provide stability. If this fine material is absent, stability is compromised. The presence of water within the stone further reduces stability.

The provision of a paver surface re-established the stability of the stone through its self-weight and in the case of interlocking paving systems, through the interlock. Interlock is defined as the inability of a paver to move independently of its neighbours. Although some manufacturers claim to have a proprietary shape with enhanced interlocking properties, the authors' experience suggests that paver shape is a secondary factor in the development of interlock. Accuracy of paver manufacture and installation are the key factors. Because rectangular pavers are straightforward to install, they have been found to be at least as successful as proprietary shapes in developing interlock. Experience suggests that a herringbone pattern of installation enhances the interlock with rectangular pavers. It was concluded that an interlocking paving system should be used as the surfacing material and that rectangular pavers should be installed in a herringbone pattern. The orientation of the pattern with respect to the direction of trafficking was not considered to be a matter of concern. In view of the severe dynamic loading applied by the fire tenders, edge restraint was considered to be a crucial issue. A conventional kerb bedded and haunched to highway standards was considered to be required around the perimeter of the surfaced area.

Because all of the precipitation plus the water & foam generated during fire training must enter the pavement, a permeable surface was required. In the UK, a permeable pavement is required to infiltrate 180 litres/hectare/second and this was deemed to be appropriate in Jersey.

There are several permeable paving systems available in the UK which achieve this figure.

The most successful systems allow water to infiltrate through a joint of approximately 6mm around the perimeter of each paver. Nibs of width 5mm are introduced on the paver sides during the manufacturing process to ensure that the gap is developed during installation. Formerly, no-fines concrete was used to allow water to percolate through concrete pavers but such systems soon became clogged to such an extent that for all practical purposes, they became impermeable. The authors' research (Knapton, Cook & Morrell) has confirmed that even with the wider joints, correctly designed pavers retain their interlock.

Most of the permeable paver systems available are manufactured from concrete. Because concrete can spall in fire and because of the effect of oil and other deleterious materials on concrete, clay pavers were selected as the surfacing material.

5. DESIGN SOLUTIONS

5.1 Alternative (a): Crushed rock pavement design and specification

If the whole pavement structure had been constructed from crushed rock materials, care would have needed to be taken in the specification of the different courses to achieve:

- Adequate bedding material to ensure flat stable paver surface
- Sufficient stability to ensure that surface deformation is minimised
- Sufficient voids to ensure the efficient storage of water.

The authors' research (Knapton, Cook & Morrell) has proven the suitability of materials for these purposes. The most successful bedding material has been found to comprise a 6mm single sized grit. This material can be used as the bedding material and as the jointing material in a flexible paver system. The thickness required is 50mm. This takes into account level tolerances and provides sufficient thickness to achieve a dense course.

The material required beneath the bedding material must have sufficient stability to operate as the roadbase i.e. the structural course even when subject to standing or running water. Traditionally, granular roadbases relied upon the macadam effect to achieve this i.e. the pressing of fine material into the voids between the larger stones to bind the whole together. This will not work in this situation since the fine material would be washed away and the roadbase would lose its stability. The authors' research (Knapton, Cook & Morrell) has demonstrated the suitability of 20mm to 5mm coarse graded aggregate to BS882 (i.e. 20mm concrete aggregate). Such material remains stable when saturated and includes approximately 32% voids for the storage of water

The remainder of the pavement was to comprise a 125mm coarser aggregate of sufficient thickness to provide the storage volume required. This material had a void ratio of 46% and would form an efficient water detention material.

Based upon the above, the following design section was proposed:

- 65mm thickness Permeable Clay Pavers
- 50mm thickness of 6mm single sized grit
- 300mm thickness of Coarse Graded Aggregate to BS882
- 1000mm thickness of 125mm single size aggregate
- Impermeable membrane

5.2 Alternative (b): High Capacity Void Pavement Design & Specification

It was considered that Alternative (a) was excessively thick so a thinner design section was developed in which the high void ratio of a proprietary product was used to reduce pavement thickness.

The section which was actually installed comprised:

- 65mm thickness Permeable Clay Pavers
- 50mm thickness of 6mm single sized grit
- Layer of woven geotextile
- Two layers of high void proprietary unit
- Layer of woven geotextile
- Impermeable membrane
- DTp Type 1 crushed rock regulating layer

In order to prove this design, tests were undertaken in which the section was trafficked by both the airport's heaviest fire tender and also by a heavier off-road dumper truck operated by a local quarry where the trial took place. Prior to testing, the trial pavement was filled with water as shown in Figure 5. The fire tender had little effect on the surface, generating ruts of 4mm after 25 passes although the heavier quarry dump truck generated ruts of depth 25mm after 40 passes. This can be seen in Figure 4.



Figure 3. Testing of design section using airport's heaviest fire tender with 11.5t axle loads.



Figure 4. Testing of design section using off-road dump truck with 14t axle loads.



Figure 5. Trial pavement filled with water prior to testing.

6. MAINTENANCE

It is anticipated that maintenance will be confined to ensuring that the surface remains sufficiently permeable to permit the infiltration of water and the evaporation of that water. This will involve the cleaning of the paver joints from time to time. Because the nature of the loading is unusual, it is difficult to be precise in specifying the cleaning interval. For a conventional permeable pavement, an interval of 7 years is commonly adopted. In this case, it was recommended that an interval of 5 years would be more appropriate. The cleaning will involve the use of high pressure washing equipment. It may be possible to use the fire fighting equipment for this.

Also, it was recommended that a water quantity and quality monitoring regime should be included within the project. A reinforced concrete inspection chamber was installed at the edge of the area to include a graduated vertical transparent pipe to allow the level of the water beneath the pavement to be monitored. Readings should be taken weekly. A simple self-recording weather station was installed and records maintained to supplement the Airport's weather monitoring system. The inspection chamber included a facility to permit samples of water to be collected from time to time for the laboratory determination of heavy metals content and the presence of isocyanates and other toxic materials from the foam.

7. CONCLUSIONS

It is concluded that permeable paving systems can be used in conjunction with crushed rock roadbases as a permeable paving system which has sufficient stability to withstand the occasional use by heavy commercial vehicles. When loads exceed those which are normally applied on a highway, ruts will develop in the surface of such pavements. The tests described in this paper were undertaken whilst the pavement trial section was filled with water which represents the most onerous condition. Crushed rock with no fine material is essential to avoid the loss of stability which would ensue from the removal of fine material by water cascading through a permeable pavement as shown in Figure 5. Coarse Graded Aggregate has been found to constitute a stable material and can be used as a roadbase. However, it is recommended that a full scale trial be undertaken as described in this paper prior to constructing a permeable pavement subject to heavy vehicles.

Where a large water retention capability is required, pavements designed using crushed rock may be excessively thick. The pavement thickness can be reduced by including proprietary products designed to achieve 90% void, as opposed to typical values of 30% to 50% for stone. The paper demonstrates that products are available which can support heavy vehicles.

This case study shows that pavers can be used to surface pavements in which all of the precipitation can be dealt with by evaporation. It is considered that there will be many situations where the Evaporative Cell concept will provide a cost effective solution, both in the short term and in the long term when there is no opportunity for downstream drainage.

8. REFERENCE

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CURRICULUM VITAE
John Knapton

John Knapton left his post as Professor of Structural Engineering at Newcastle University last year to concentrate on his consulting work, his writings, his broadcasting and his work as Ghanaian Chief Nana Odapagyan Ekumfi I. He continues as Chairman of the Small Element Pavement Technologists Group and has accepted appointments as visiting professor at The National University, Colombia and the Kwame Nkrumah University of Science & Technology, Ghana. His recent paver related work includes writing the UK Interpave permeable paving design guide, designing paver projects in Bogota, Jersey, Ireland and the UK. During the last three years he has written three books on ground bearing concrete for highways, industrial hardstandings and floors. His previous work includes the UK Civil Aviation Athority guide on pavers for aircraft pavements, the British Ports Authority design manual for heavy duty pavements and the British Standard for the design of roads surfaced with pavers. He was appointed by legal team representing Lloyds, insurers of the Twin Towers to advise on whether the design and construction of the Towers might have contributed to their collapse. He advises the UK government on the possible result of terrorism on major public buildings in London as structural engineer to The London Resiliance Team. He is a Fellow of the Institution of Civil Engineers, The Institution of Structural Engineers and The Institution of Highways and Transportation. He feels that his major achievement has been his contribution through research to the worldwide adoption of rectangular pavers of Dutch origin.