CONCRETE BLOCK PAVING AT UK MILITARY AIRFIELDS

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SUMMARY

Concrete block paving has been used in UK military airports since 1984. Since then, over 250,000 m^2 have been placed in aprons and parking stands for a wide range of aircraft types and weights. This paper provides design conditions for military aircraft and history on the development of a UK military specification for block paving airfields, as well as design requirements. A list of airfields using block paving is provided with the application, construction year and a brief description of performance. The paper concludes with experience gained and lessons learned from over 20 years of using concrete block paving in airfields.

1. INTRODUCTION

Paved surfaces on airfields were first needed to combat the problem of traffic generated mud immediately outside the entrance to the sheds or other covered space used to protect aircraft. Constructed, as were many roads at that time, of some form of hard ballast surface with town gas tar macadam the area came to be known as "the tarmac" and often still is even when constructed in concrete. Taxiing routes round the edges of airfields were the next areas to be firmed up – known as perimeter taxiways or more commonly peritracks. It was not until the 1939-45 war that paved all weather runways came into general use and replaced grassed strips which were unable to sustain the increase in weight and number of aircraft movements.

In these early years of airfield pavement works the design parameters were very similar to that of a road. What subsequently changed in the 1940s onwards was the development of aircraft technology. Aircraft became much larger, faster and altogether more sophisticated. This substantially changed the design parameters for airfield pavement works and brought in special considerations with particular regard to safety of aircraft operations. The following are key requirements of airfield pavements:

a. High strengths and stabilities to withstand the shear stresses induced by heavy wheel loads and high tyre pressures. See Table 1.
b. Good friction between tyres and pavement, especially in wet conditions.
c. Surface evenness to provide good rideability.
d. High surface integrity. Jet engine aircraft are very susceptible to damage from loose material being drawn into engine intakes. Also loose material or sharp pavement edges can damage tyres, hydraulic systems/undercarriages and aircraft skins; the term often used to describe this potential source of damage is FOD - Foreign Object Damage.
e. Durability and economic maintenance. The difficulties in getting access to carry out maintenance works make durability a key issue.
f. Resistance to fuel spillage and jet blast, de-icing chemicals and action of sweepers including snow and ice removal.

The relative importance and stringency of the above requirements depends on the nature type and frequency of aircraft operations, function of the pavement (e.g. runway or hardstanding) and other economic and local factors. For runways, good rideability and friction characteristics are very important. In addition runway ends, dependent on types and frequency of operations may also need to have resistance to jet blast and fuel spillage/venting. Aircraft parking areas and runway holding positions will generally need to have resistance to fuel and oil spillage. In addition some of these areas, especially heavily used parking areas may also need to be resistant to indentation by high tyre pressure aircraft and impact and wear from ground equipment and trolleys. Harrier Vertical Take-Off and Landing (VTOL) pads and Engine Running Platforms (ERPs) for high performance jet aircraft provide the most severe conditions for pavements on MOD airfields.

Airfield pavement engineers in the UK first considered the potential for concrete block paving to provide best Value For Money (VFM) in particular circumstances in the early 1980s. This followed extensive use in Europe and subsequently in the UK for such applications as ports, garages and urban streets. The first use of concrete block paving on a UK airfield of note was at Luton International Airport in 1981

The first trial area of concrete block paving on an MOD airfield was laid in 1984 at RAF Abingdon. Since that time it has been used on a number of airfield pavement projects at MOD airfields and has proved to be an effective surfacing solution for specific applications. The following gives a history of the introduction of concrete block paving on MOD airfields, the development of a Standard, the performance of the pavements and a summary of 20 years experience.

2. RANGE OF REQUIREMENTS ON MOD AIRFIELDS

The range of aircraft types using MOD airfields is such that design parameters can vary considerably between airfields. Some airfields are mainly used by fast jets (including V/STOL aircraft), some by medium and heavy transport/reconnaissance aircraft whilst others are dedicated to use by light trainer aircraft or helicopters. Table 1 illustrates this variance.

Table 1. Sample Aircraft Data

Aircraft Type	**Typical Max Wt. (Kg)**	**Tyre Pressure (MPa)**	**Jet wake velocity – 5m rear of aircraft** (typical)	**Jet wake temperature – 5m rear of aircraft** (typical)
Fighters	25,000	2.3	> 3200 kph	> 1000º C
Heavy transports (jet)	250,000	1.4	Circa 480 kph	Circa 100º C
Trainers	1000-6000	0.4 – 1.1	-	-
Helicopter	1000 – 23,000	0.4 – 1.5 + Skids	-	-

The aircraft characteristics and the functional requirements as described in paragraphs 2 and 3 present a wide range of design requirements. An additional design factor is whether the pavement works are to comprise a new one or a refurbishment of an existing pavement. With such a range of requirements it

is readily apparent why the MOD uses a number of different construction types to meet its overall aim of providing best Value for Money (VFM) consistent with safety and durability.

3. DEVELOPMENT OF A TECHNICAL STANDARD

The MOD Standard for use of block paving on airfields was published in 1996. It had been under continuous development for over 10 years prior to this and was the culmination of knowledge gained and lessons learned from R&D trials and several major projects involving concrete block paving on MOD airfields in the eighties and early nineties. The need for a bespoke Standard for airfields was determined at a very early stage principally to take account of the specific functional and critical safety requirements as outlined above compared with typical urban and seaport applications for concrete block paving. The following sets out some of the main elements of the MOD standard together with the rationale behind them.

3.1 Concrete Blocks

At the time of the early MOD trials much of the published data related to rectangular blocks, also cost and availability in the UK much favoured rectangular blocks and they where more comprehensively specified in the British Standard (BS 6717 1986). Various shaped blocks appeared to have some advantages particularly in respect of machine laying. However limited experience with machine laying in "clusters" indicated potential complications in ensuring even spacing of joints/"clusters" and in achieving robust details around obstructions/service pits and at edges/joints of pavements. The 80mm thickness of rectangular block was selected as giving the best balance between strength and cost. The standard of finish to blocks was not covered by the BS and was found to be variable from different suppliers and within the same production from a block manufacturer. Also the requirements for material qualities were much less onerous than applied to other construction types used on airfields. These factors may not have been particularly critical for sea-ports, garages and urban applications. However for blocks to be used in the more demanding environment of airfield pavements and particularly with regard to the need for high surface integrity and durability it was considered necessary to introduce additional quality requirements in the MOD Standard compared to those set out in the national one. These are as follows:

a. Initial approval of a representative sample of blocks to include for the range of manufacturing tolerance in respect of surface texture and general standard of finish. These are to be used as the standard for approval of all consignments of blocks for the project.
a. Site testing of all consignments of blocks with none being laid until the first consignment has been tested and approved.
c. Quality test requirements on aggregates and a maximum size limit of 6.3mm for gravel aggregates; all subject to approval prior to production.
d. Either weathering test (now included in BSEN 1338/2002) on blocks or soundness test on aggregates.
e. In general a higher frequency of testing is required and also tighter tolerances (except for block dimensions) compared with non-airfield applications.

3.2 Laying patterns

The preferred standard laying pattern is the herringbone one at 45 degrees to the predominant direction of traffic to maximise interlock and lateral stability. The joint details at edge/intermediate restraints and at obstructions/service pits are key factors in the performance of the pavements and the following design guidance is given in the Standard:

a. Blocks cut to fill very small closing spaces are prone to subsequent displacement, spalling and cracking, leading to a FOD risk to aircraft.
b. It has been common practice to lay a herringbone pattern with end blocks cut to fit at an angle against a double row of "stretcher" blocks laid adjacent to an end restraint or obstruction. These have a tendency to spall even at a relatively low level of loading leading to a FOD risk to aircraft.
c. Cut blocks are a major source of weakness. They cannot be provided with chamfers or nibs and this combined with a less than high standard of cutting is likely to result in block to block contact, excessive joint widths, spalling and instability leading to a FOD risk to aircraft.
d. The ideal block paving layout would have no cut joints. Following trials carried out on MOD airfields it was concluded that whilst this was feasible under highly controlled conditions in practice it isn't a realistic goal mainly due to the 2:1 aspect ratio of the blocks, the manufacturing tolerances for blocks and the construction tolerances for joint widths.
e. The Standard concentrates on laying pattern details for minimising the need for cut blocks including alignment of pavement and obstructions, maximum use of mitre blocks at edges/obstructions and restricting closing sides as much as possible to non/low trafficked areas. Regular checks on alignment throughout block laying including regular co-ordinated setting out points are also a requirement.

3.3 Edge and intermediate restraints

The standard practice is to provide edge restraints to maintain the integrity of the pavement and ensure structural stability. However notwithstanding the provision of typical edge restraints, an early experience with a large area of block paving on an MOD airfield showed that considerable expansion could occur sufficient to cause a blow-up where the block paving abutted another pavement area. The photograph at Figure 1 illustrates this failure which resulted in heaving and rotation of the block paving and the edge/intermediate restraint and also of the adjacent asphalt; some of the blocks were also cracked. The width of block paving was in excess of 150 metres and blow-ups occurred at both sides where the block paving abutted another pavement. In the longitudinal direction no blow-ups occurred. Following this experience the standard detail adopted for junctions between block paving and other pavements on MOD airfields is shown in Figure 2. It is also recommended that this detail be adopted as an intermediate restraint within very large or irregular shaped areas of block paving for the purposes of establishing a suitable block laying pattern, providing a means of controlling the pattern over large areas during construction and for controlling expansion.



Figure 1. Expansion and Blow-Up of Pavement

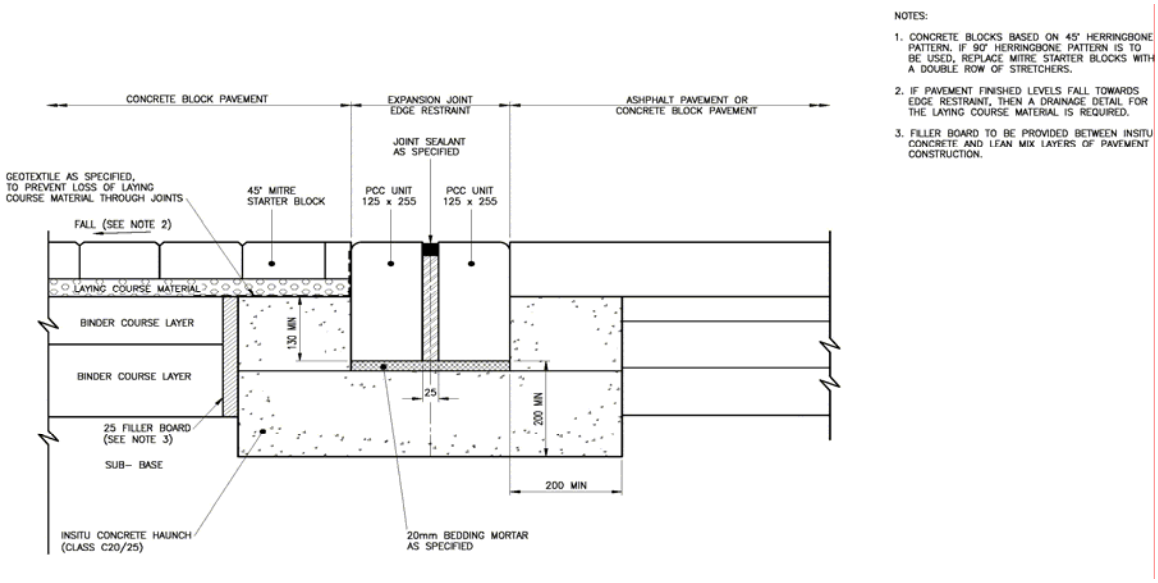

Figure 2. Edge Restraint Incorporating an Expansion Joint

3.4 Sand laying course

The standard practice is to use clean sharp naturally occurring silica sand to minimise the likelihood of degradation of the bedding layer and consequent settlement and to facilitate some degree of upsurge into joints in order to aid interlock of the block paving. However in addition the early experiences on MOD airfields and at UK civil airports were that the rate of incidence and severity of localised settlement caused by deficiencies in the sand laying course was too high. Investigations showed that this was either due to excessive thickness of sand, or variability of thickness, or poor compaction, or washout of sand caused by poor drainage of this layer. Primarily the latter defect occurred at low points adjacent to drains. As a result of these investigations the MOD Standard set the thickness of sand laying course to 40mm plus laying tolerances and a base level tolerance of plus or minus 10mm. In some respects a thinner laying course would have been desirable since this would have lessened the potential for differential settlement in the blocks. However, tolerance in level of the underlying surface and the dimensional tolerances on the blocks themselves had to be accommodated without the finished surface straying outside its own tolerances. 40mm appeared to be the best compromise between conflicting requirements. In addition pre-compaction of either the total or lower two thirds thickness of the bedding sand was set as a requirement. It was also made a requirement to provide a drainage connection between the bedding sand and the drains at low points. However it was decided that systematic drainage of the laying course sand whilst desirable would probably be unrealistic in most cases. Attempts to achieve this (e.g. by using underlying porous/no fines concrete drains) tended to create more problems with long term performance than they solved. Instead the emphasis was put on the provision of a stable layer of sand with minimum silt content, to reduce moisture sensitivity and also to apply a joint sealer to the finished block paving to minimise ingress of water. It should be noted that joint sealing was also considered necessary to prevent premature erosion of sand joints in the block paving due to regular sweeping of airfield pavements, low jet blast and propeller wash/rotor down-wash.

3.5 Fuel spillage/venting

Experience on early projects showed that fuel spillage on concrete block paving could lead to some softening of bituminous bases/regulating layers with subsequent bleeding of bitumen to the surface. As a consequence it was made a requirement that a layer of bituminous bound base material immediately beneath a sand laying course should either have resistance to fuel or be provided with a fuel seal coat. This was in addition to the provision of a joint sealer on the block paving.

3.6 Structural design

The structural value assigned to concrete block surfacing for the early projects carried out on MOD airfields was that 80mm thick blocks on sand bed equated approximately to 100mm of bituminous surfacing. This was based on research carried out by others in the 1970s and 1980s. However it was apparent that this early work concentrated on the use of flexible pavements with bases of relatively low stiffness compared to the semi-rigid bases used for new construction or existing rigid pavements which would typically form the foundations for concrete block surfacing on MOD airfields. Consequently as part of the development of the MOD Technical Standard for concrete block surfacing, three structural investigations were carried out to assess the contribution of blocks on semi-rigid bases. Two were carried out using a Falling Weight Deflectometer (FWD) on existing pavements (i.e. measurements taken before and after construction of concrete block surfacing) and the other was an accelerated load test in TRL's Pavement Test Facility with blocks on a cement bound base, again with measurements taken using an FWD. The tests yielded a significant variation of results but nevertheless showed that the original structural value of 100mm of bituminous surfacing was over optimistic. The conclusion made was that a concrete block surfacing should be allocated a structural equivalency of 50mm of bituminous surfacing when laid on either concrete slabs or a bound base.

4. USE OF CONCRETE BLOCK PAVING AT MOD AIRFIELDS

Concrete block paving has been used on about 20 projects for the construction of new and refurbishment of existing airfield pavements on MOD airfields. Table 2 gives data on the main projects undertaken together with comments on performance. Figure 3 is a general view of a concrete block hardstand used by large aircraft at an RAF airfield.

Table 2. Summary of the Main Block Paving Projects on MOD Airfields

Location	Application	Area (m^2)	Construc-tion Year	Performance
RAF Northolt	Hangar apron – HS125s	2000	1986	Satisfactory condition. Some broken blocks replaced. Weathered surface-coarse aggregate protruding about 2 mm. Ongoing routine maintenance *
	Hangar apron - HS 125s	3100	1990	Satisfactory condition. Weathered surface. Ongoing routine maintenance.*

	Main apron - Small/medium transport aircraft.	60,000	1993/94	Satisfactory condition. Lightly weathered surface; very few damaged blocks. Partial reconstruction and upgrading of edge restraints due to expansion/blow-up. Replacement of 'strips' of sunken blocks coincident with underlying joints in old concrete slabs. Ongoing routine maintenance. *
RAF Woodvale	Apron - Light trainers	5000	1987	Satisfactory condition. Weathered surface. Ongoing routine maintenance.*
RAF Lyneham	Hangar apron Medium-heavy transport	7000	1988	Satisfactory condition. Some localised settlement. Ongoing routine maintenance.*
RAF Valley	Apron – Medium helicopters	20,000	1989/90	Satisfactory condition. Weathered surface. Slightly undulating profile-no reported ponding. Some reconstruction of spalled edge restraints. Ongoing routine maintenance.*
RAF Dishforth	Apron – Medium helicopters	36,000	1990	Satisfactory condition. Small number of blocks subject to cracking/spalling on main heli-spots. Localised settlement around service pits/obstructions. Latter to be rectified, cracked blocks monitored and ongoing routine maintenance.*
RAF Benson	Apron – Medium helicopters	10,000	1992	Satisfactory condition. Ongoing routine maintenance. *
RAF Brize Norton	Main apron between parking stands.	20,000	1993	Satisfactory condition. A few localised depressions. A few localised areas of sunken blocks/level irregularities adjacent to service pits have been reconstructed. Poor edge detail adjacent to concrete stands has resulted in small/ triangular cut blocks which will require replacement in medium term. Baggage trolleys caused small areas of damage to blocks that had to be replaced. Ongoing routine maintenance.*
	Apron – Heavy transports	25,000	1995	Good condition. Some localised differences in level between mitre blocks and intermediate kerb restraints (up to 10mm) - possibly due to expansion and rotation of units. Short lengths of reconstruction of intermediate restraints/adjacent blocks anticipated in medium term as well as ongoing routine maintenance. *

	Hangar apron – Heavy transports	35,000	1998	Very good condition. The improved standard for intermediate restraints incorporating expansion joint is performing well. Ongoing routine maintenance. *
RAF Kinloss	Hangar aprons – Heavy recce/ transports	20,000	2002	Very good condition. One localised depression giving rise to shallow ponding in need of reconstruction. Ongoing routine maintenance.*

* Ongoing routine maintenance comprises localised application of weed killer and topping up and resealing of sanded joints



Figure 3. Concrete Block Hardstand at RAF Airfield

5. CONCLUSIONS

Experience gained and lessons learned:

a. Movement of concrete block paving considered to be due to thermal expansion has resulted in small but significant distresses at the edges/intermediate restraints at two sites having the largest areas. Initial conclusions are that the detail at Figure 2 is suitable for areas of paving up to 100 metres in length in the UK climate.
b. Localised depressions due to failure in bedding sand can be significant where associated with either cracks/joints in the underlying pavement construction or at low points adjacent to restraints/drains. Both cases require attention to detail at the design stage to minimise the possibility of wash-out of sand; the former requires a membrane over joints/cracks the latter reinforces the need for drainage of bedding sand at low points/restraints.
c. The incidence of localised shallow depressions following implementation of the Technical Standard has been much reduced and is not significant in the context of aircraft aprons subject to low frequency use. However it probably would be significant for taxiway

applications unless further improvement could be made to the Standard. In addition achieving the necessary high standard of surface regularity required for taxiways during construction of concrete block surfacing can also be problematic.

d. For principal aprons/flight lines subject to high frequency use by medium/heavy aircraft or by aircraft with high tyre pressures the indications having regard to paragraph 16c together with a few observations made of localised cracking, are that settlement/depressions/block cracking would be problematic unless the Technical Standard could be improved. In this respect the introduction of innovative block designs using mechanical keys may be a way forward in the future.
e. Compared with insitu concrete paving, concrete block paving can be laid faster without the need for curing thus reducing disruption to aircraft operations.
f. Concrete block paving can provide an economic means of refurbishing old aprons and re-providing a fuel resistant surface for low frequency trafficking. It can also provide good VFM for new aprons subject to low frequency trafficking when used in conjunction with cement bound bases (i.e. a standard construction practice at MOD airfields).
g. There is a lack of predictability of performance of concrete block paving when subject to high levels of jet efflux and an associated high risk of an ‘un-sympathetic’ and sudden mode of failure.
h. Careful consideration needs to be given to the nature and frequency of use of ground equipment and jacks and the suitability of the concrete blocks and the laying course sand to withstand the anticipated loads.
i. Good design layout including block laying patterns, positioning of restraints and service pits and drainage details are key to pavement performance.
j. A high degree of quality control during construction is essential if the functional requirements for airfield pavements are to be met including that of safety and durability.
k. The use of concrete block paving on MOD airfields is restricted to apron areas.