KEY ELEMENTS IN THE CONSTRUCTION OF AIRCRAFT PAVEMENTS - A MANUFACTURER'S & CONTRACTOR'S VIEW POINT

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Summary
Since the first reported use of concrete block pavers in an aircraft pavement, at Luton Airport, UK, in 1983, there has been steady increase in this type of pavement construction.
In 1994 Knapton & Emery [1] recorded that approximately 800,000m^2 of concrete block aircraft pavements have been constructed to date. Within the next 2 years there will be a further 0.5 million m^2 of blocks laid in aircraft pavements in the Asia Pacific region.

This paper examines key elements, from a Manufacturer's and Contractor's perspective, that are considered paramount to ensure a quality product.

Lower Pavement Layers
The pavement layers below the blocks and sand should be designed and constructed in accordance with good engineering practice. While it is not the intention of this paper to discuss the design of these layers, it is important that the Contractor has a quality commitment to ensure that the pavement layers satisfy the structural requirements. Another important aspect is that the finished top course surface smoothness, finish levels and surface texture are such that the bedding sand thickness will not deviate by more than ±5mm.

A top course with an open textured surface may cause an uneven surface of the block layer, because the bedding sand may be absorbed into the surface voids. If a geotextile layer is specified to be laid over stabilised base course (to stop the bedding sand infiltrating surface cracks), it is important to ensure that the geotextile is in continuous contact and not spanning across voids in the surface.

Bedding Sand
Investigations of block paving failures often conclude that the main causes have been variations in bedding sand thickness, excessive thickness, breakdown under load, sand loss or a build up of pore pressure. There has now been much research on the desirable quantities of bedding sand.

The general consensus of block paving practitioners is that the bedding sand layer should be as thin as 20mm, incorporating no more than 3% passing the 0.075mm sieve, well graded and of a quality that resists degradation under load. The current British standard [2] grading envelope specifies 0-3% passing the 0.075mm sieve whereas the current Australian industry notes [3] allow 0-10% passing the 0.075mm sieve. The Micro Deval Test [4] can be used to measure the sand's resistance to breakdown.

It is not always possible to obtain a well graded sand with 0-3% passing a 0.075mm sieve and resistant to breakdown. Therefore it may be necessary to modify available sand accordingly.
This may be achieved by screening, washing, drying and blowing off the fines, or a combination of one or more of these practices.

The use of conventional screeding (manually or mechanically pulling a screed along screed rails) has some disadvantages. It is slow, difficult to control surface smoothness and finished levels, and requires a full time survey crew to set up the rails and continuously check accuracy. This significantly slows the process of laying large areas of blocks.

The Author sought a quicker but accurate method. Trials using an asphalt paving machine as an alternative were carried out in Manchester, England, in September 1995. A section of completed asphalt surfaced dual carriageway was overlaid with bedding sand by an asphalt paver to assess the speed and accuracy of this method of placement. The tolerance on the surface smoothness of this section of asphalt road was similar to aircraft pavement specifications with a surface texture similar to cement stabilised base course. Bedding sand with the correct grading envelope was locally acquired and used without adjusting its moisture content. The asphalt paving machine was fitted with two independent levelling systems, one laser controlled and one sonic controlled.

The laser system works on a principle of keeping the placing screed at a constant height in relation to the laser beam. This ensures conformity of the finished pavement within the specified level tolerances.

The disadvantages of this method were noted as being:-

- if the base has been laid out of tolerance, the thickness of bedding sand may vary excessively.

  it can only be used in areas of constant grade.

The sonic system works by measuring the distance to a reference surface (base course) by using high frequency sound waves. If the distance changes the control system sends a correction signal to the paver's height control mechanism. This system lays a constant sand thickness but can also compensate for "within tolerance" irregularities in the base.

The compaction of the sand by the vibrating screed on the asphalt paver was also investigated. Various machine settings and techniques were tried and it was concluded that

fully compacting the sand gave the smoothest surface finish, and inaccuracies of the finished level of the sand were negligible. Also, after placing blocks, the finished block pavement met all level and surface smoothness requirements.

The blocks were hand laid directly on the compacted sand. It was found that after plate vibrating the blocks in spite of the bedding sand being pre-compacted, sand worked its way up the joints and the blocks were bedded satisfactorily. Tighter tolerances than stated in BS6717 for block thickness are necessary to ensure lipping is acceptable.

It is concluded that this method of screeding and compacting is accurate and fast, compared with conventional methods, and can be implemented just in front of the laying operation.
This is important when working during inclement weather or in tropical or sub tropical regions, as it is cost effective in minimising rectification work of sand adversely affected by rain.

Excessive water in bedding sand may also contribute to failure. It can cause a build up of pore pressure, and can transport fines. Knapton [5] has shown that fine particles in bedding sands are transported by water and recommends that materials passing the 0.075mm sieve should be minimised. Also, to reduce the possibility of pumping, positive drainage of the bedding sand layer is desirable. It is considered good practice [6] to dissipate excess water by draining the bedding sand into the drainage system via geotextile covered weep holes, or similar drainage systems. Details are shown in Fig. 1. The use of surface sealants may minimise water penetration.

Block Shape

Numerous papers by various supporters of rectangular blocks have argued that shaped blocks are no better than rectangular blocks. However, the Author agrees with proponents of shaped blocks that they offer a degree of resistance to joint spread [7] and their interlock may provide some load transfer.

Lilley [8] reports that with shaped blocks, there is a potential risk of excessive joint widths developing during laying unless there is strict control of all the plan dimensions of the block.
This has also been observed by Mackisack and Pywell [9] in their research on block paver gaps.

Block Manufacture

All aircraft pavements constructed in Australia to date have been in shaped 80mm thick blocks, whereas elsewhere in the world, both shaped and rectangular blocks are used.

The dimensional accuracy of blocks directly affects the ability to consistently achieve conforming joint spaces and to avoid lipping. The Author [10] identifies mould accuracy, mould wear and slumping as significant factors affecting dimensional variability. The joint spacing in the block paving layer is considered a critical aspect to the structural integrity of the pavement. If blocks are manufactured to the dimensional tolerances stated in BS6717 and MA20, (the British and Australian standards,) which allow plan dimensions of ± 2mm and

thickness of ± 3mm, it is unlikely than conforming joint spaces of 3.00mm can be consistently achieved. Furthermore, random selection and installation of blocks from the production run will increase the likelihood of non conforming joint spacing.

It is recommended that shaped interlocking blocks have at least 10 spacer nibs that finish below the chamfer. This is to ensure no face to face contact occurs, thus eliminating the likelihood of spalling. The size and location of spacer nibs can influence the effectiveness of maintaining consistent joint spaces. By allowing the nibs to be within 5mm of the chamfer, mechanical laying machine clamping is possible, while still maintaining no block to block contact at the surface.
A special requirement for aircraft pavements is that the surface of the blocks must be tightly bonded to prevent the dislodgment of aggregate or particles that may cause Foreign Object Damage (FOD) to aircraft engines. This requires greater control in block manufacture than what is normally necessary to produce blocks for general use.

To minimise the need for testing of significant quantities of blocks to assess the surface texture, samples of datum blocks are used at the manufacturing plant and on site, showing acceptable, borderline and those to be rejected. As blocks are stacked or laid, they are rejected by the workmen prior to incorporation into the pavement, thus reducing the need for rejection and removal of finished works.

If it is intended to mechanically lay blocks, they must be supplied to the job site in a format ready for use. Ideally the blocks should be made in the same format as the required cluster pattern. This is only possible if a large format block machine is used. When manufacturing blocks using smaller machines it will be necessary to restack the blocks after curing, in the correct format. This may seem economically inefficient but in countries with emerging economies, it may be desirable because it creates employment.

Block Laying
Hand laying by skilled paviours can achieve high quality work, but with relatively low productivity. There is likely to be an increased occurrence of repetitive strain injuries, and other work related health risks. It has been reported in the Netherlands [11] that illness absenteeism is 5 % higher than for the rest of the construction industry. Mechanical laying is able to consistently satisfy high productivity but it can be difficult to conform to stringent pavement specifications.

Mechanical laying machines were developed initially for the German market but are now predominately used in Europe and the USA. In these countries, blocks are generally rectangular, dog bone (“H” blocks) or ‘L’ shape interlocking blocks, laid in clusters, in patterns where the clusters do not link together to form a completely homogenous surface. Often there is evidence of “cluster effect” (large joint spaces between clusters.) The mechanical laying of shaped interlocking blocks in true herringbone pattern is difficult and is not normally undertaken. However, it is desirable for aircraft pavements to have an homogenous surface with no cluster effect or wide joint spaces.

A typical herringbone cluster pattern contains 39 blocks, with an additional 2 stack bonded blocks in diagonally opposite corners. This is necessary to assist in accurate location and laying of the cluster and also helps to keep the cluster together during transportation. Some machines have a clamp device that pushes the cluster down the instant that the cluster clamp is released. This helps avoid blocks jamming on those previously laid. After laying the cluster, it is necessary to remove one comer block and stitch the clusters together. Refer to Fig. 2.

The laid blocks should be checked, and if necessary, adjusted for alignment against datums parallel to a 5m x 5m surveying grid, and the joints checked and adjusted to ensure conforming joint spaces.

After the blocks are laid, they are bedded with a vibrating plate compactor. Plate compaction equipment must be tailored to suit the construction circumstances, be capable of achieving bedding of the blocks, minimise lipping between adjacent blocks, and not damage or break blocks. Weissig [11] recommends high frequency vibrating plates with a minimum frequency of 65Hz, weight of 170 - 200kg and a centrifugal force of at least 20kN, with the plate equipped with a protective polyurethane mat for 80mm thick blocks. However, experience and equipment trials have demonstrated that when bedding blocks on 20mm thick pre-compacted sand, plate compactors with 40kN centrifuged force and a weight of 350kg perform more efficiently.

It is recommended that the joint sand grading be such that all the sand particles will be able to pass into the minimum allowable joint widths. Dry sand is preferable because it flows very easily into the joints. 886177: Part 3 specifies a grading envelope that allows *5%* passing a 2.36mm sieve. This may cause inadequate joint filling and hence compromise the structural integrity of the pavement, where the joints are less than maximum particle size. It is also recommended to stabilised the joint sand to resist washing out, or jet blasting. This can be achieved by using specially manufactured sand with additives that, when wetted forms a pliable gel that adheres the joint sand particles together and to the blocks. Alternatively, the joints (and the pavement surface) can be sealed by the application of a proprietary sealant.

Suitable dry sand may not be economically available, therefore consideration must be given to processing sand, in a similar fashion to bedding sand as discussed above.

Edge Details

Edge restraints are necessary to hold the block surface in place and to prevent creep. Full depth restraints are preferable because they will also contain the whole pavement.

Specially made closure and half blocks shown in enhance the structural integrity when used adjacent to edge restraints or penetrations. Preference should be given to the use of these blocks against drainage systems (to minimise cut blocks at these locations). Cut and chamfered blocks, may be used at other interfaces in the pavement, such as around pits and structures. Fig. 3 illustrates typical edge details.

Alternatively, for square and rectangular pavements whose overall dimensions are nominal, the pavement size can be adjusted to coincide with an exact number of full blocks.

The pavement levels should be designed so that the blocks finish nominally above all drainage points. To achieve a neat cut and minimise the risk of FOD, blocks must be cut and chamfered by diamond blade water cooled/lubricated saws. No cut blocks should be less than 25% of the plan area of full block. Where cut blocks are laid against edge restraints, a small quantity of joint sand is poured into the space between the block and edge to ensure a nominal 3mm joint space is maintained during the initial compaction process.

Conclusion

The success of the project may not be guaranteed purely by a rigid specification. It is preferable to select a manufacturer and contractor who are committed to work closely together, and to develop Project Specific Quality Procedures to ensure the pavement meets the client's expectations.

Fig. 1

Bedding Sand Drainage

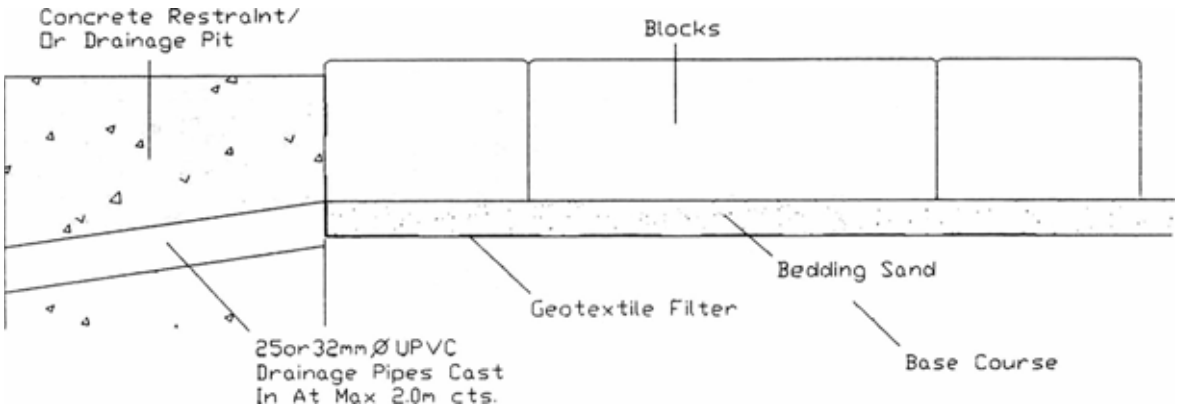
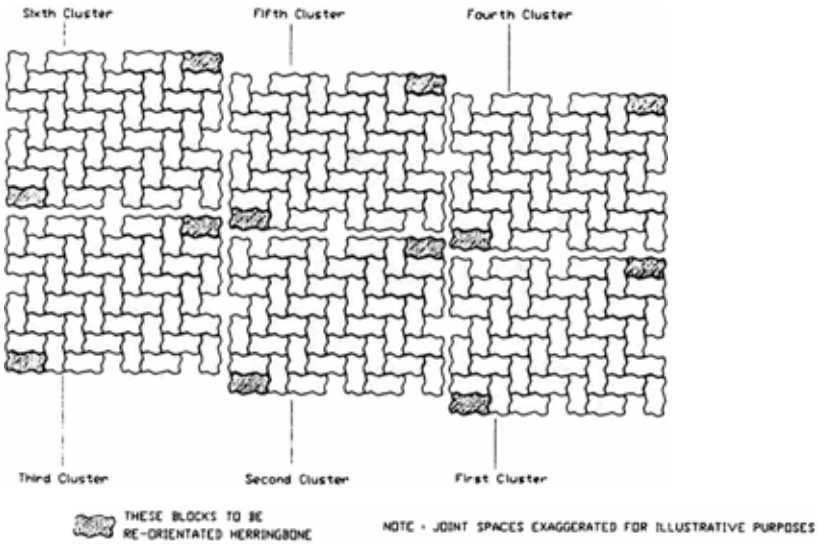


Fig. 2

Mechanical Laying Sequence

CLUSTER LAYING SEQUENCE



CLUSTER STITCHING

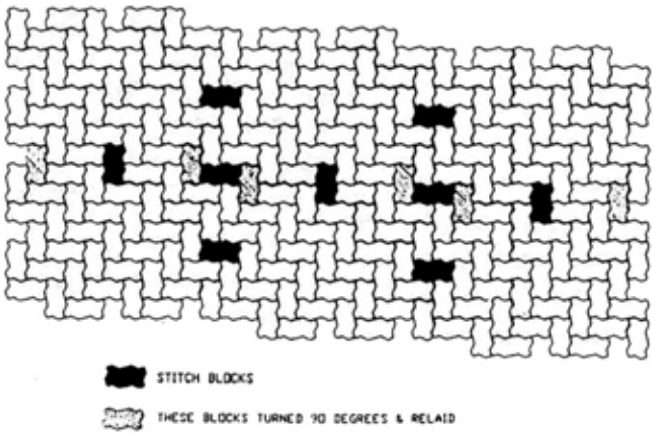
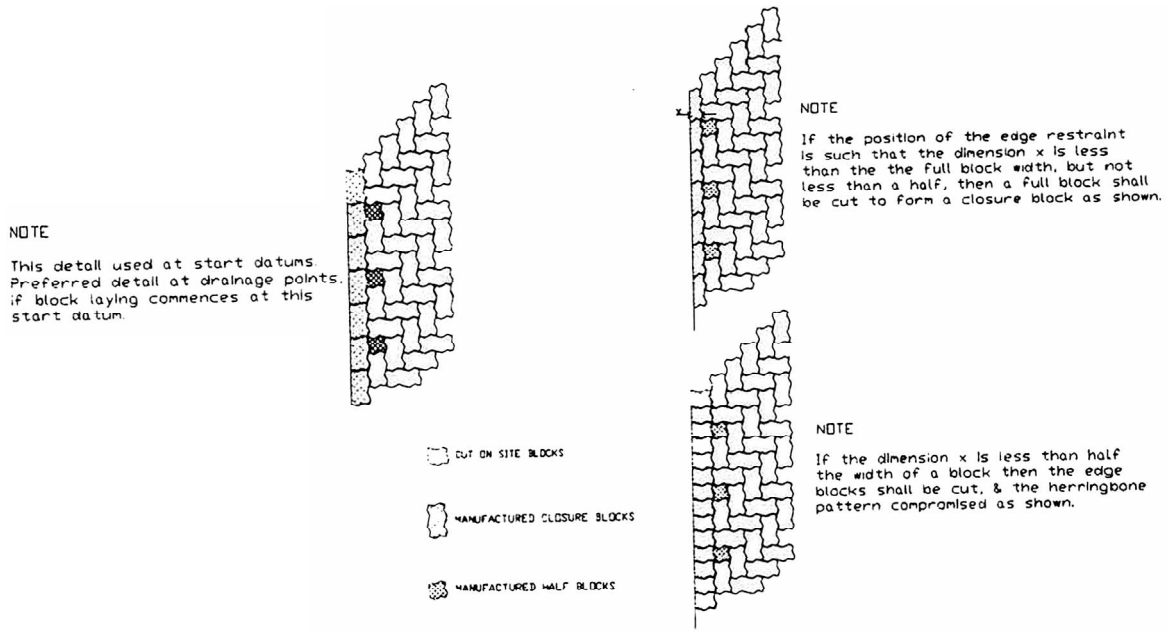


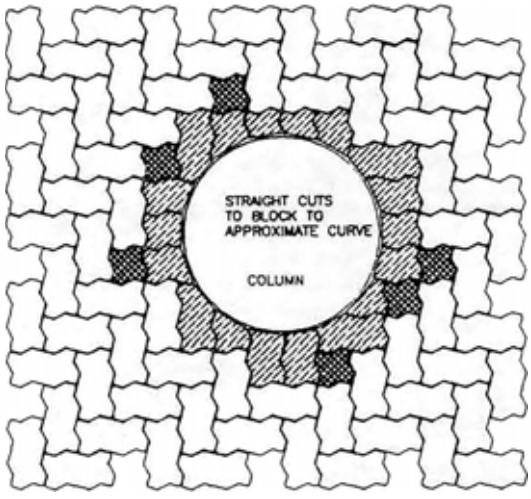
Fig.3

Edge Details

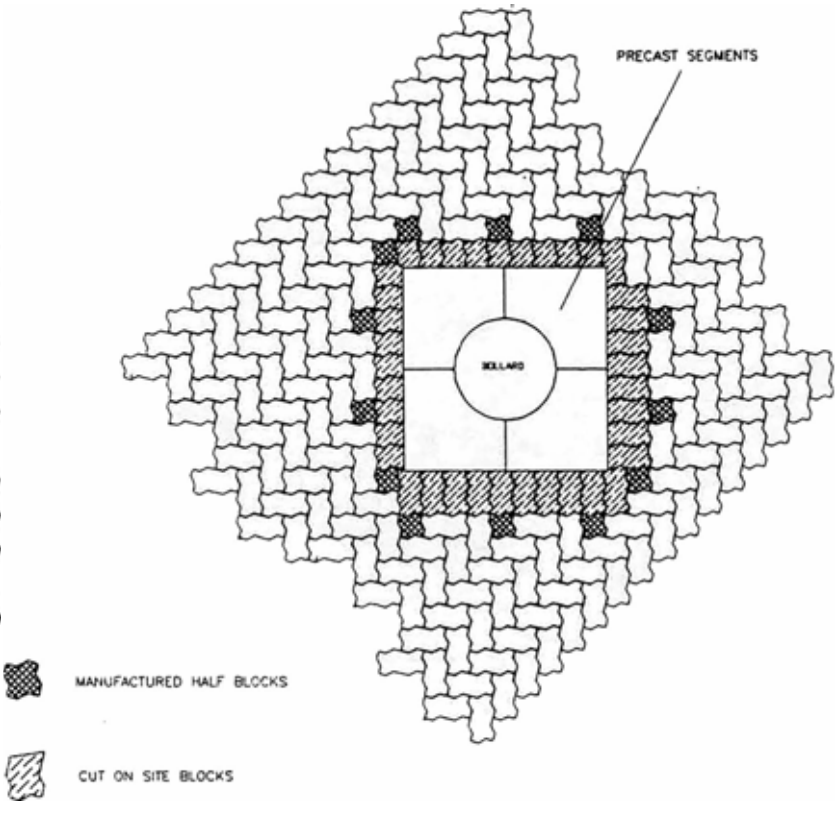


Penetration Details

TYPICAL DETAIL AT COLUMN



TYPICAL DETAIL AT BOLLARD



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