CONCRETE BLOCK PAVING FOR AIRCRAFT HARDSTANDINGS AND TURNING AREAS

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SUMMARY

Trials have been carried out using concrete block paving on an aircraft parking stand and on one of the runway end turning areas at Luton Airport in the U.K. The results indicate that concrete blocks may have certain advantages over the pavement quality concrete and Marshall asphalt traditionally used for surfacing aircraft pavements. Concrete block paving has, so far, been found to; (i) be able to withstand the static loads of medium haul aircraft, (ii) be resistant to aviation fuel, hydraulic oils, anti-icing and de-icing fluids, (iii) withstand the effect of jet engine blast from aircraft at 'take-off' and (iv) be capable of rapid installation and repair. Further tests are to be carried out to determine what contribution the concrete block surfacing makes to the overall strength of the aircraft pavement.

1. INTRODUCTION

Engineers responsible for the design and maintenance of aircraft pavements have, for many years, been searching for a surface with the following properties:-

1. Durability
2. Surface stability with tyre pressures up to 1.4 MN/m^2
3. Good frictional characteristics
4. Good standard of rideability
5. Rapid removal of surface water
6. Capability of rapid repair and maintenance
7. Resistance to thermal movements
8. Resistance to high jet engine exhaust velocites and to thermal shock
9. Resistance to de-icing and anti- icing agents, aviation fuels and hydraulic oils.

Recent trials carried out at Luton Airport, using concrete block paving, suggest that it has certain advantages over the pavement quality concrete, and Marshall asphalt surfaces traditionally used. Work by Knapton (1) concludes that the friction generated by the sand vibrated into joints between blocks permits them to interlock and distribute vertical loads over a wider area than that to which the load is applied. Further, interlock is improved as the applied load increases, indicating that concrete blocks may provide a suitable alternative surfacing for aircraft pavements. These, on the evidence so far gathered, appear to have most of the properties listed above.

2. DESIGN AND CONSTRUCTION OF AIRCRAFT PAVEMENTS

Most Aircraft pavements in the United Kingdom have been designed and are assessed in accordance with the Load Classification Number (LCN)* system. The method was formulated by the Air Ministry Directorate-General of Works and adopted in 1956 by the International Civil Aviation Organisation (ICAO) as one of two methods advocated for the evaluation of the bearing capacity of aircraft pavements. In 1971, the Directorate of Civil Engineering Development, of the Department of the Environment (D.O.E.) produced a document (2) which modified the LCN system in the light of experience gained during a long period of designing and evaluating aircraft pavements. This document gives recommended thicknesses of rigid, composite and flexible pavements which have been based upon loading and stress considerations, with allowances made for the effect of varying number of applications. Because of many variables e.g. load on undercarriage gear, configuration of wheels and tyre pressures, aircraft have been classified on a numerical scale representing the severity of load, and a similarly related scale to represent the strength of the pavement. Thus, each aircraft is given a range of LCNs (3) depending on its

* A new method of pavement classification has now been adopted by the ICAO i.e. the ACN-PCN system, but this is not considered relevant to the content of this paper.

loading, and the pavement is designed or assessed to be compatible with aircraft typically using it. (Figure 1).

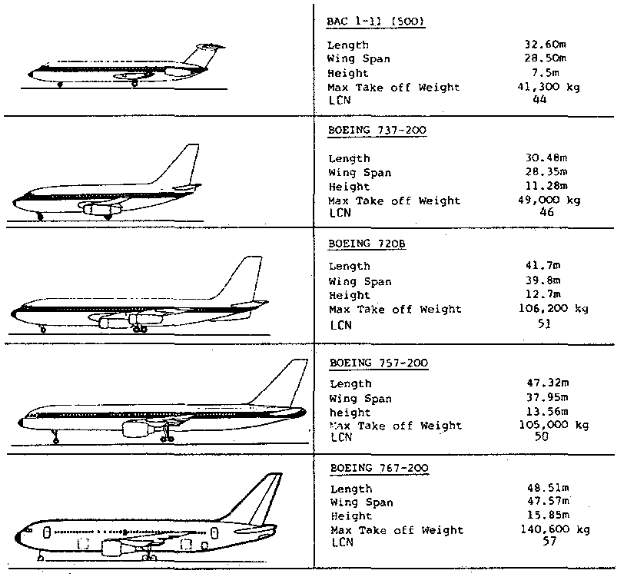

Figure 1: Probable mix of aircraft using Luton Airport in 1984.

Aircraft pavements are generally limited to three types, each having a 100mm sub-base layer of lean concrete, and are described in the D.O.E. document as follows:-

(i) Rigid pavements of unreinforced pavement quality Portland cement concrete which are usually selected for runway ends, runway and taxiway junctions, aprons, hardstandings and runway turning-circles, i.e. where aircraft will stand and where jet heat, blast and aviation fuel and hydraulic oil attack is likely. For design purposes, a minimum flexural strength of 3.5 MN/m^2 and compressive strength of 35 MN/m^2 is assumed for pavement quality concrete, at the time the pavement is brought into use. Normally the sub-grade is considered in two conditions only, i.e. 'good' and 'bad' on the basis of traditional Westergaard 'k' values, which are determined using 762 mm diameter plate bearing tests. The range of 'k' values considered to apply for most UK soils being between 15 and 200 MN/m^2/m.

(ii) Composite pavments of continuously reinforced concrete with bituminous surfacing offer the best 'bump free' riding, and water free surfacing, which are preferred for those lengths of runways and taxiways along which aircraft travel at speed.

(iii) Flexible pavements, composed of bound granular materials with bituminous surfacing are not considered to be economical for heavy duty pavements. For light aircraft they provide an alternative to composite pavements and offer similar advantages.

3. THE AIRCRAFT PAVEMENTS AT LUTON AIRPORT

Luton Airport lies at 160.00 AOD, some 3km east of the town centre of Luton. The geology of the airport area comprises a deposit of glacial clay between 7.5 m and 12 m thick over most of the runway site, reducing to 2.5 m at the eastern extremity, all overlying chalk. The modulus of sub-grade reaction 'k' has been given as 15 MN/m^2/m at formation level, i.e. equivalent to a CBR of approximately 2 per cent.

The airfield at Luton was first licensed as a Municipal Airport in 1938, with grass runways and concrete aprons. In 1959 the Council commenced the construction of the east-west or 08-26 runway (Figure 2) and after extensions added in 1964 and 1965, is now 2,160m in length and 46m wide.

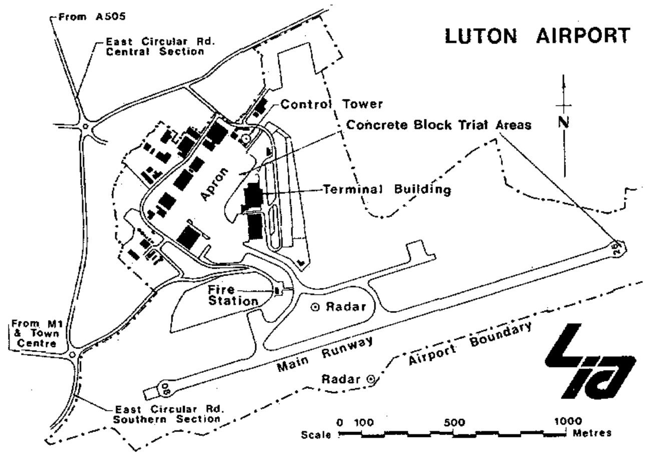

Figure 2: Luton Airport Layout

The first 305m from the 26 end of the runway is of flexible construction, consisting of a 40mm rolled asphalt wearing course, on 75mm rolled asphalt base course, on 225mm layers of broken brick, blinded with hoggin, giving a total depth of construction of 665mm over-filling, forming an embankment at this end of the runway. The remaining length of runway, taxiways and apron areas are generally of rigid construction with 250mm unreinforced pavement quality concrete, having no form of load transfer, laid in 4.6m bays and having expansion joints at 25m centres, over 100mm dry lean concrete. During the winters of 1973/1974 and 1974/1975 most of the apron areas, the taxiways, and the runway were provided with a Marshall asphalt overlay, consisting of 60mm base course overlain by 40mm wearing course. Additionally, the runway received a 20mm friction course, and the runway turning circles a 40mm layer of a surfacing made up of an open-graded bitumen macadam with a cement, p.f.a., epoxy grout vibrated into its voids.

Before the Marshall asphalt overlay was added, the LCN of the pavement was calculated as 45. However, during 1969, the then Ministry of Public Building and Works carried out load bearing tests which resulted in the pavements being upgraded to a published LCN of 60.

4. PROBLEMS WITH EXISTING SURFACES

The high shear stress and rhythmic vibration imposed by modern aircraft equipped with high pressure tyres had taken their toll, especially on the rigid pavements. The pavement quality concrete bays sustained considerable cracking and spalling failures, which, in some areas, led to mud-pumping problems. Repairs to these surfaces had to be made during night closures of the runway, usually during mid-winter. Most of the remedial work consisted of making good spalled areas with mastic asphalt, grouting under areas subject to mud-pumping, and in extreme cases, complete bay replacement using high alumina cement concrete. Repairs using epoxide mortars usually ended in failure, probably due to the extreme cold and damp conditions when they were being placed. It was also necessary to re-seal joints in some areas where failure of the joint sealing compound had occurred. With the passage of time, reflective cracking has developed in the Marshall asphalt overlay and these cracks have been sealed by normal 'banding' methods. A far more serious problem exists on the apron area, and the runway turning areas. Spillage of aviation fuels and hydraulic oils have attacked the bituminous surfaces leading to their progressive deterioration. Various proprietary 'fuel resistant' coatings have been applied to some of these surfaces, without success.

5. CONCRETE BLOCK PAVING TRIALS

During 1981, it was decided to carry out trials using concrete block paving, to determine whether they would be suitable as an overlay on the apron stands, replacing the existing damaged asphaltic surfacing. Following the apparent success of the blocks in this situation, a further trial was carried out on the eastern runway end turning-circle to prove their ability to withstand the turning action, and jet engine blast of aircraft at take-off.

6. DETAILS OF TRIALS

(i) Apron Stand No. 7.

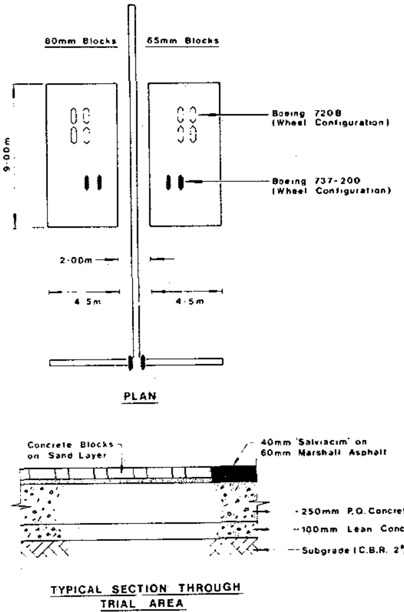

Figure 3: Stand 7 Trial Areas.

Figure 3 gives details of the two areas which formed this trial. They were selected to ensure that the main undercarriages of aircraft using this stand occupied the trial areas. During October 1981 the 100mm thick asphaltic overlay was broken out. 65mm and 80mm rectangular blocks were bedded on a screeded layer of zone 2/3 sand (4) laid to a depth which ensured that the blocks, when compacted, were level with the surrounding asphaltic surfacing. A 10:1 mix of dry fine sand and lime was vibrated into the surface of the blocks to 'seal' the joints and minimise the ingress of water, aviation fuel and oils into the sand bed.

To date, the trial areas have been subjected to more than 4,000 aircraft movements, with no apparent damage.

Some indication of what is expected of the surfacing of apron stands can be gained from figure 4, in which an aircraft, a Boeing 720B, is shown jacked-up on the 65mm blocks to facilitate a wheel change. On this particular occasion a spreader plate is seen in use, but it is not uncommon for it to be discarded. It is estimated that without the plate a stress of approximately 6.5MN/m^2 is transmitted to the surface of the blocks; yet even after this abuse the blocks do not appear to have been damaged, or displaced.

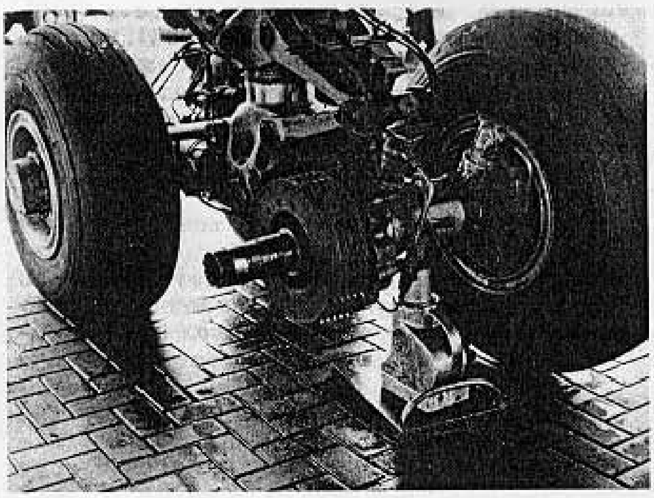

Figure 4: Wheel change on Stand 7.

(ii) Runway Turning Circle - East End.

During May, 1982, a trial area measuring 10m x 2m, was constructed on the eastern (26) runway turning-circle using 80mm thick "S" shaped concrete blocks.

The area was chosen because:

(a) this end of the runway is used for approximately 70% of aircraft movements;

(b) it is an area affected by aviation fuel spillages and in winter, treated with de-icing and anti-icing fluids;

(c) it is traversed by most aircraft using this turning-circle; and

(d) it receives the maximum effect of jet blast from aircraft at take-off.

To date, there have been an estimated 36,000 Air transport movements from this end of the runway since the blocks were laid.

Construction of the trial area consisted of breaking out the asphaltic surfacing to a depth of 120mm and replacing it with the block paving bedded on a 40mm layer of screeded sand. A 10:1 mix of dry fine sand and lime was vibrated into the pavement as for the Stand 7 trial area.

7. DISCUSSION

The desirable properties for aircraft pavement surfaces as identified in 1 to 9, in the introduction to this paper, are considered below with respect to the concrete block paving trials carried out at Luton Airport.

1. Durability:-

Of all the properties listed, this is considered to be the most important, and has an influence on some of the other properties. Aircraft pavements must have long lasting and hard wearing surfaces because of the abnormally heavy loads they are required to carry and because of the difficulty in gaining access to these surfaces for maintenance purposes. The high compressive strength of concrete blocks, (generally in excess of $50MN/m^2$ compared to the $35MN/m^2$ specified for pavement quality concrete) bedded on zone 2/3 sand, which is confined at its edges and compacted to refusal, is thought to provide a surface greater in strength and durability than either Marshall asphalt or pavement quality concrete. Experimental work by A.J. Clark (5) has shown that the water/cement ratio used in the manufacture of concrete blocks is low, but generally difficult to check. However, he considers that if the cement content does not fall below 380 kg/m^3 a good level of durability will result.

2. Surface Stability:-

Modern jet aircraft are susceptible to damage from loose material drawn into engine intakes. It is essential, therefore, that any surfacing remains coherent and does not produce potentially damaging loose debris. Pavement quality concrete slabs are prone to spalling, particularly along joint edges, and have led to engine ingestion problems. It is thought that concrete blocks having chamfered edges will reduce this threat.

3. Good frictional characteristics:-

The frictional characteristics of a runway are measured by means of a 'mu-meter', a machine fitted with a self-wetting attachment capable of depositing approximately 0.5mm depth of water beneath the measuring wheels. The device is towed at a steady speed of 130 km/hr. The operational frictional requirement is 0.77 ± 0.3 based on 'mu-meter' readings. Obviously this criterion would not apply to apron stands, but it would appear to be desirable, though not mandatory, for runway ends. In this connection it is hoped that the Department of Flight, of Cranfield Institute of Technology, will soon be able to carry out friction measurements on concrete block paving to enable a comparison to be made between the runway friction course material and concrete block paving.

4. Good Standard of rideability:-

This property is not considered essential for apron areas and runway turning areas, which are generally subjected to slow moving traffic only. It is unlikely that concrete blocks would be considered for use on runways, where aircraft speed on 240 km/hr are common.

5. Rapid removal of surface water:-

Experience with concrete block paving at Luton Airport has shown that the rectangular blocks which have chamfered edges are capable of rapid removal of surface water. The shaped blocks on the runway turning circle are considered to be as good as, if not better, than the existing bituminous surfacing in the removal of surface water.

A related problem, that of water penetrating through the joints and into the sand laying-course, has been investigated by the Cement and Concrete Association. Their report (6) concludes that saturation of the sand layer is not detrimental to the concrete block paving. This remains true even when the water in the saturated sand laying-course freezes. The water content of the laying-course is unlikely to exceed 25% and if this water expands by 9% upon freezing, the movement of the blocks bedded on 50mm sand, would be no more than 1mm. Experience has shown that the joints in concrete block paving eventually become 'sealed' with detritus, oil etc. In order to hasten this process lime was added to sand filling in the joints. It was decided to use lime rather than cement, as it was considered that the lime would not cause the blocks to become bonded together.

6. Capability of rapid repair:-

The use of concrete block paving has one major advantage over the traditional surfacings of aircraft pavements; that is, it can be laid and repaired in sub-zero temperatures. Once laid and compacted it can be put into immediate use. This was well exemplified by the runway turning-circle trial area, which was constructed within one day, between aircraft movements, and traversed by aircraft immediately on completion.

7. Resistance to thermal movements:-

Differential thermal movements in the underlying pavement quality concrete appear not to have produced any visible movement in the concrete block paving. This is considered to be due to the fact that the blocks act as a flexible surfacing and the individual blocks articulate without significant opening of the joints.

8. Resistance to high jet engine exhaust velocities and thermal shock:-

Concrete is generally preferred where jet efflux gases are likely to damage the pavement surfaces. On take-off, exhaust velocities can be in the order of 640 km/hour and exhaust temperatures of up to 93°C can occur approximately 10m beyond the rear of the aircraft where they impinge on the pavement surface.

After two severe winters, no damage has been noted on the blocks used on the runway end turning circle and it seems safe to assume that damage is unlikely to occur as the result of jet blast at take-off.

9. Resistance to de-icing and anti-icing agents; aviation fuels and hydraulic oils:-

Aircraft pavements, perhaps more than any others must be capable of surviving an exceptionally harsh environment. Runways in particular are generally located in exposed areas and subject to extreme low temperatures, down to say -30°C. Because of its corrosive effect on aluminium surfaces, salt is not used for the removal of ice. At Luton Airport urea is used as an anti-icing agent, and glycol mixtures for de-icing purposes. Glycol is known to have a damaging effect upon concrete owing to the very rapid cooling effect within the surface of the pavement which can freeze any moisture present. An immediate volume increase of approximately 9% in the interstices holding moisture can lead to an almost immediate disintegration of the surface. It is thought that urea does not present a serious problem to concrete surfaces. Tests are in progress to verify this Statement. Portland cement concrete has generally been found to be resistant to aviation fuels and hydraulic oils, but these fluids have been found to have a deleterious effect on joint sealing compounds, even on those which are claimed to be resistant to these materials. This danger is averted by using concrete blocks, which do not require the use of sealants.

Fears of concentration of aviation fuel accumulating in the sand layer under the blocks appear unfounded. Tests carried out, under the supervision of the County Petroleum Officer, indicated that no explosive vapours were present, when sample blocks were removed from the apron trial area.

Figure 5: Stand 8 in use.(80mm blocks).

8. CONCLUSION

It is thought that concrete blocks, once laid and vibrated into the sand laying-course, and the joints filled as previously described, form a durable, flexible surfacing that appears to satisfy most of the properties referred to in the introduction. They are considered to be suitable for all aircraft pavements which are subject to slow-moving aircraft.

It is hoped that if the concrete blocks continue to perform satisfactorily, it may be possible to carry out plate bearing tests to determine whether the concrete block surfacing makes any contribution to the overall LCN of the total aircraft pavement.

During February 1983, it was decided to proceed with resurfacing Apron stands 1 to 9 at Luton Airport using rectangular concrete blocks - a total area of 2700 sq.m. - and these are seen to be performing satisfactorily (Figure 5). It is also hoped to commence in the near future the surfacing of the two runway end turning circles using concrete block paving - total area 10,000 sq.m.
There has been a considerable international interest in the use of concrete blocks for the surfacing of aircraft pavements. Enquiries, so far, have been received from Australia, Belgium and Brazil. In the United Kingdom, interest has been shown by British Airports Authority, Ministry of Defence and Property Services Agency.

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