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THE USE OF INTERLOCKING CONCRETE BLOCKS ON AN AIRCRAFT PAVEMENT IN AUSTRALIA

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SUMMARY

The paper discusses the recent introductory use of interlocking concrete blocks in aircraft pavements at Cairns International Airport on both the domestic and international parking aprons. The former usage was a trial to repair severe loss of shape in the wide body aircraft stands. A full-scale application was then constructed on the new international apron, where 15,000 m^2 were installed on three aircraft stands in late 1990. Design methods, special specification requirements and construction methods to ensure that the high standards demanded on aircraft pavements were met are reported. The design of the pavement is evaluated using mechanistic procedures and it is demonstrated how these procedures can be used to design these types of pavement. A brief comparison of costs compared with conventional pavement structures is also included. Difficulties encountered in the initial trial, including water ingress through the joints, surface texture deficiencies and erosion of the jointing sand, and steps taken to rectify these problems prior to the full-scale installation, are discussed. A significant advance was made in the construction process; integral spacing nibs were moulded onto the vertical faces of the blocks to prevent block-to-block contact and the subsequent spalling so hazardous to aircraft operations. The work reported in the paper is seen as important in resolving some of the perceived disadvantages of block pavements in heavy wheel load applications.

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INTRODUCTION

The use of interlocking concrete blocks on aircraft apron pavements provides a compromise between the inherent problems associated with conventional rigid and flexible pavements. Many of the disadvantages of both conventional pavement types can be eliminated in a block pavement provided some problems associated with their use (e.g. loss of jointing sand, block spalling and rotation, and water penetration through the joints) can be minimised or eliminated.

Some of the advantages of block pavements are as follows:

- no high cost formalised contraction/expansion joints;
- non-temperature susceptible, abrasion resistant and fuel resistant surface;
- compatible with flexible pavements;
- easily repaired when localised damage sustained; and
- cost generally between those for flexible and rigid pavements.

Concrete block pavers were first used in aircraft load applications in the UK to resurface a number of jet aircraft aprons and turning nodes at Luton International Airport(1),(2). These trials were used to evaluate surface characteristics of the blocks and the structural performance of the block pavement and, since then, blocks have been installed in several similar applications in the UK. In November 1990, about 25,000 m^2 of blocks were laid on three crossover taxiways at Dallas/Fort Worth International Airport(3).

The first such application in Australia occurred in 1989, when concrete blocks were trialled as part of the rectification of a distressed section of the domestic apron at Cairns International Airport. Following this trial, about 15,000 m^2 of new concrete block pavement was installed on three parking bays of the international apron in August-September 1990.

This paper describes the introductory use of concrete block pavement for heavy commercial jet aircraft applications in Australia. Details are provided regarding the initial trial, during which some problems were identified, the design of the new pavement, and the steps taken to rectify the problems encountered in the first trial during the subsequent construction. The design of the pavement is evaluated using mechanistic procedures and it is demonstrated how these procedures can be used to design these types of pavement.

A number of issues have been identified during the course of the project to date and it is suggested that significant progress has been made towards the further development of concrete block pavements in this type of application.

BLOCK PAVEMENT DESIGN CONSIDERATIONS

A variety of design methods for interlocking concrete block pavements have been developed over the years for both road vehicle and heavy duty applications. Many of these methods are mechanistically based and rely on charts produced from analysis by computer programs of modelled pavements using elastic layer theory. Other methods are empirically based. Some methods include consideration of the block surface gaining a degree of "lock-up" over time, either in terms of an increase in block stiffness after a certain number of vehicle passes or in terms of some type of materials equivalency.

Knapton and Emery(4) adapted the (empirical) U.S. Federal Aviation Administration design charts for flexible aircraft pavements to incorporate interlocking concrete blocks. Basically this involved substituting the 100-125 mm of asphalt surfacing with bedding sand and 80 mm thick concrete blocks, i.e. no "lock-up" over time is assumed.

Design curves for concrete block pavements were published by the Cement and Concrete Association of Australia (CACA) in 1986(5) and a computer program, LOCKPAVE, has been developed which can be used to design block pavements for a range of conditions and loadings(6). A method for the design of road pavements was also produced by the National Association of Australian State Road Authorities (NAASRA) (now AUSTROADS) in 1987 and this procedure can be adapted for block pavements, as demonstrated later.

Neither the CACA nor the AUSTROADS design curves are suitable for aircraft pavement design applications because they are based on "Standard Axle" and "Equivalent Standard Axle" considerations and specific distributions of axle loads on highway pavements are assumed. This does not, however, preclude the use of the theory behind such curves to be adapted for aircraft loading, e.g. the use of the elastic layer program CIRCLY, or similar programs (ELSYM5, BISAR, etc.), where the response to aircraft load of a candidate pavement can be determined and the "life" estimated based on empirically-based life/strain relationships. Similarly, techniques such as the method of equivalent layer thicknesses can be used.

Emphasis in Australian research is now being placed on characterising the pavement materials in the laboratory in order that more realistic moduli values can be input into these computer programs and also in relating predicted life determined in the laboratory with observed life under field conditions. Linked with this is the development of back-calculation models to determine the stiffness of the layers in an existing pavement based on surface deflection measurements.

At present, Airplan base their pavement thickness design on the assumption that the concrete blocks act only as a surfacing layer to a conventionally-designed flexible pavement. The pavement structural design is carried out in accordance with the U.S. Army Corps of Engineers CBR design method(7) and the concrete blocks and bedding sand are substituted for the usual asphalt surfacing. This approach allows no materials equivalency for the blocks and assumes that their performance is similar to unbound crushed rock (similar to the assumption adopted for thin asphalt surfacings). Consequently, any "lock-up" which may occur in the block layer due to the wedging action of the joint filling sand is not recognised in the design, but provides a factor of safety should weathering and creep of the block pattern under traffic occur (the lock-up effect is dependent on maintaining the block joints completely filled with sand).

It is apparent from the experience gained over the years with heavy duty block pavements that the stiffness of the pavement structure on which the blocks are placed is critical to the satisfactory performance of the block pavement in service. Although not all the stiffness criteria have been quantified, it is clear that the magnitude of deflections at the surface should be limited to avoid excessive block rotation and subgrade strain, particularly when the pavement is subjected to heavy (aircraft) wheel loads.

Airplan have a mandatory requirement that the basecourse of a block pavement be cement modified in order to increase the stiffness of the pavement but whilst continuing to permit flexible behaviour. Moisture susceptibility of the layer is also reduced.

PAVEMENT TRIALS AT CAIRNS INTERNATIONAL AIRPORT

Initial Trial

Interlocking concrete blocks were trialled in a pavement repair exercise on the domestic apron at Cairns International Airport, where the original pavement (shown in *Fig. 1a*) which had been constructed in 1983, had seriously distressed. This distress was manifest as excessive loss of surface shape. An investigation conducted by Airplan indicated that the base and sub-base material was only marginal in quality.

The trial consisted of the replacement of the top 250 mm of the existing asphalt-surfaced flexible pavement with 150 mm of cement-stabilised (4%) FCR, a nominal 20 mm of compacted bedding sand and 80 mm Type A blocks (see *Fig 1b*).

The repairs were restricted to the two domestic wide body parking positions and the aircraft tug track at the (then) international bay, and only covered the main gear standing positions, tug and nose wheel track and container/pallet loader positions.

A number of problems were encountered, both during construction of the block pavements and subsequently in service, including:

- block surface defects,
- deficient joint spacings,
- ingress of water into pavement sub-base/subgrade,
- block rotation, spalling and cracking, and ultimately
- pavement distress, manifest as significant loss of shape following prolonged wet weather.

While the block pavement performed satisfactorily during dry weather, the torrential tropical rain during the wet season soon penetrated to the moisture susceptible sub-base/subgrade layers and severe loss of shape resulted. This experience supports the findings of Sharp and Armstrong(8) regarding the permeability of a block pavement surface and the need to design block pavements, and select base and sub-base materials, with full aware ness of this aspect.

The other issues (block defects, joint spacings, etc.) are discussed in subsequent sections of the paper where specification and construction practices are addressed.

New International Apron

The new international apron is a new flexible pavement of total area approximately 35,000 m^2 constructed on fill which had been surcharged and proof rolled.

Three aircraft parking bays for Boeing 747-400 (B747) aircraft and the tug pavements (area approximately 15,000 m^2) were surfaced with interlocking concrete segmental blocks to:

- provide a durable, temperature insensitive surface resistant to oil and fuel spills and surface damage due to apron servicing equipment;
- permit easy repair of localised depressions which may occur due to post construction settlement in the pavement layers, or other localised damage; and
- enable surface repairs to be conducted in such a way that the pavement could be restored without presenting a patched appearance which may permit water penetration.

The apron was designed for an aircraft load spectrum of various international aircraft, predominantly heavy wide-body jets, including B747-200/400, DC10-30, A300B4 and B767-200. Of these, the B747 is the most demanding on the pavement and, for design purposes, all the other aircraft were considered in terms of equivalent B747 loadings. The design life adopted was 15 years and the pavement design was based on aircraft movement forecasts for this period.

A gross design mass of 370 t was adopted for the B747, this being the maximum load that could be accommodated on the length to which the runway was being developed (3557 m).

The apron was designed as a flexible pavement for reasons of economy. Details of the pavement profiles are shown in *Figs* 2a and *b*. *Fig. 2a* shows the pavement incorporated in the 20,000 m^2 not surfaced with blocks. As already discussed, the pavement was designed in accordance with the empirical US Army Corps of Engineers CBR procedure, and the design chart for the B747 is shown in *Fig. 3*.

The concrete block pavement consists of 80 mm thick Type A blocks layed in herringbone bond on 20 mm nominal (compacted) thickness of bedding sand on 250 mm of fine crushed rock basecourse cement modified with 2% Portland cement (CMFCR) for the reasons outlined earlier. A 5 mm size primer seal was applied to the top surface of the CMFCR to ensure water did not enter the pavement layers or subgrade (*Fig. 2b*). Type X (machine-laid) blocks were not used because of the perceived problems associated with joining the clusters, joint width being seen as a critical aspect in the performance of the pavement (see later).

The FCR was a high quality 20 mm nominal maximum size material (maximum PI of 5) and in line with normal Australian aircraft pavement specifications. The 25 mm nominal maximum size crushed rock sub-base had a maximum PI of 6, whilst the select fill was a non-plastic rubble material with a nominated design CBR of 20. The primer seal coat was considered necessary because of the prevailing heavy tropical rainfall at Cairns (annual rainfall about 1200 mm), especially after the experience with the trial pavement. It is considered good practice to incorporate a primer seal in block pavements generally where the subgrade is moisture susceptible.

Construction of the pavement was completed in September 1990 and a general view of the finished pavement is shown in *Fig. 4*. Performance to date has been excellent, with no visible surface rutting or surface defects (spalling, abrasion, etc.) evident. A major fuel spill of 7500 L occurred on one section of the pavement about six weeks after it was opened to traffic and several significant spillages have occurred since, with no visible effect on the block pavement section of the apron. However, significant damage, necessitating closure of the parking bay, occurred due to damage to the asphalt-surfaced portion of the pavement.

Evaluation of Design using Mechanistic Procedure

In order to confirm the adequacy or otherwise of the empirical design procedure used, a check design was conducted using the mechanistic procedure documented in the NAASRA Guide to the Structural Design of Road Pavements(9). This procedure involves two steps: (1) the response model, and (2) the performance model. In the former, the elastic layer program CIRCLY is used to predict the key responses to load under multiple wheel loads, in this case the horizontal tensile strain at the base of the cement-modified layer (fatigue cracking) and the vertical compressive strain at the surface of the subgrade (surface rutting).

Pavement Model

The pavement shown in *Fig. 2b* was modelled for a range of block layer moduli as detailed in *Table 1*. The cement-modified fine crushed rock (CMFCR) base was modelled as an isotropic material, whilst the sub-base and subgrade layers were modelled as anisotropic materials in line with NAASRA recommendations. The stress dependency of the sub-base layer was catered for by sub-layering, again in line with NAASRA recommendations. The concrete blocks were also assumed to be an anisotropic material in order that some allowance could be made for the fact that this layer is not homogeneous or linear elastic. The procedure requires that cracking of cemented layers be catered for by calculating Stage 1 life (prior to cracking) and Stage 2 life (after cracking), assuming that the layer, although cracked and less stiff, is still contributing to the structural performance of the pavement. Tensile strain of the cemented material is no longer an issue in Stage 2 life and performance is based solely on the vertical compressive strain generated on the surface of the subgrade. Miner's hypothesis is then used to calculate total life.

Recent developments in back-calculation models and subgrade characterisation in Australia have resulted in the recommendation that the non-linear characteristics of the subgrade be catered for by dividing it into four layers of fixed thickness and variable moduli (using a program called NONCIRL). It was not necessary to adopt this procedure here, however, because the CBR was sufficiently high (20%) that linear behaviour could be assumed. The relationship recommendeo by NAASRA [modulus (MPa) = 10 x CBR] was therefore used.

Load

The load modelled was based on the following calculations:

all-up mass of B747: 370 t
5% of the load carried on the nose wheel (as per standard design practice)
main gear load consists of 4 main legs, each with 4 wheels
therefore wheel load = (370 x 0.95)/16 = 21.97 t (215.5 kN)

One main leg (4 wheels) was modelled, the distance between the wheels being 1120 mm (transverse) and 1470 mm (longitudinal) respectively.

Response to load was calculated at the base of the CMFCR layer and at the surface of the subgrade both under a wheel and between the wheels.

Performance Model

Pavement life (N) is estimated using empirical equations of the general form $N = (k/\mu\varepsilon)^n$, where $\mu\varepsilon$ is the maximum strain and n is the damage exponent. The performance model for the subgrade recommended by NAASRA(9) is inappropriate for heavy aircraft pavements because it is based on the empirical (CBR/traffic/thickness of cover) design chart for unbound granular pavements where traffic is expressed in terms of ESAs only. The subgrade strain criterion recommended by Shell(10) for a 95% confidence limit was therefore used. The performance models adopted were:

CMFCR	$N = (280/\mu\varepsilon)^{18}$
subgrade	$\log N = (\log 0.018 - \log \varepsilon)/0.25$

The damage exponent of 18 for cemented materials is based on limited laboratory testing conducted in Australia in the mid-1980s. One of the major aims of the Accelerated Loading Facility (ALF) trial recently completed in Melbourne is an evaluation of the fatigue properties of cemented material.

Results

The results of the analysis are shown in *Table 2*. Miner's hypothesis was not required to calculate the life of the CMFCR because cracking occurred after the first pass in all cases; performance was therefore assessed on the basis of subgrade strain using the Shell relationship given above.

The minimum number of load repetitions determined, based on a block modulus of 1000 MPa, was 79,290 which, for a design life of 15 years, corresponds to an average of 14.5 movements/day, i.e. 2.4 occupancies per day per parking bay, which approximates the average forecast traffic of 2.8 wide-body planes/parking bay/day (about one-third of which were B747, the rest being the other wide body aircraft).

This value of block modulus considers no lock-up effect in the block layer. As the value attributed to block modulus increases, the permissible load repetitions also increases, and for a 500% increase in block modulus the permissible repetitions of load is almost doubled (see *Table* 2). On the other hand, if the subgrade stiffness is decreased by only 25% (CBR 20 to CBR 15), then the permissible life is halved (see *Table* 2), i.e. similar decreases/increases in life were achieved for a 500% change in block modulus and a 25% change in subgrade modulus. As pointed out in Sharp and Armstrong(8) and confirmed again here, predicted pavement response, and hence life, is far more sensitive to changes in subgrade modulus than to changes in block modulus. It would seem appropriate at this stage to take a conservative approach for heavy aircraft pavement applications and adopt moduli values for blocks of the order of 1000-2000 MPa.

CONCRETE PAVING BLOCK SPECIFICATION CONSIDERATIONS

The Concrete Masonry Association of Australia (CMAA) issued a guide specification (MA20)(11) as a basis for compilation of specification Clauses for block pavements. Whilst this document is quite basic, it is considered suitable for block paving applications up to road vehicle loads. For higher loadings and applications such as airports, special attention to some critical aspects are required, and for aircraft pavements it has been found necessary to specify particular requirements in the following areas.

- the dimensional accuracy and structural integrity of the blocks,
- the quality and uniformity of the bedding sand layer,
- joint width and the adequacy of joint filling, and
- the adequacy of the bedding sand layer.

Surface Integrity of Blocks

To prevent the occurrence of potential Foreign Object Damage (FOD) to aircraft engines and components, it is essential that the surface of the pavement be tightly bonded. The surface of the blocks should not contain weakly-bound aggregate particles or voids in order that concentrated loads do not break or chip the surface.

In the initial trial, a significant number of blocks with honeycombed surfaces were supplied and built into the works despite the blocks apparently meeting all the requirements specified in MA20. These honeycombed blocks resulted in the breaking out of aggregate particles under traffic - see *Fig. 5*.

To overcome this situation in the new international apron works, a maximum average surface texture value for the blocks was required. A modified version of the standard sand patch test was used to assess the adequacy of samples. A range of block surface textures were visually assessed as to their acceptability and the average surface texture depth was measured. A value of 0.11 mm was set as the maximum average surface texture depth permissible. It was found that the test method was not sufficiently repeatable to be confident that satisfactory control of quality inthis respect was achievable. Consequently, visual comparisons with accepted samples were used as acceptance criteria.

Jointing Sand

The need for a jointing sand which would not erode from the joints between blocks under adverse weather conditions or due to aircraft jet engine blast became evident during the initial trials. While the erosive effect of jet blast was not readily apparent, the high rainfall at Cairns tended to wash the sand out of the joints and onto the block surface.

Various spray on sealing materials similar to those trialled and used overseas(12) were considered, but it was concluded that the economy and effectiveness of these materials was somewhat questionable. Eventually, a proprietary product consisting of a single-sized fine sand containing a hydrated polymer glue was selected following successful local field trials. When wetted, following placement of the sand in the joints, the glue is activated and weakly binds the sand particles in a flexible state.

Spacing Nibs

Interlocking concrete blocks are required to comply with CMAA(11). The commercial standards detailed in this publication for Type A blocks have generally been found to be acceptable for use in aircraft pavement works. However, initial experience with Type A blocks at Cairns Airport resulted in additional requirements including:

- blocks to be manufactured with nibs on the vertical faces, sufficient to ensure that the blocks cannot be placed touching one another (except at the nibs); and
- the surface macrotexture of the blocks to be limited to ensure that the potential for surface spalling is eliminated.

BLOCK PAVEMENT CONSTRUCTION CONSIDERATIONS

Block Laying

Most block pavements are laid by hand because of the versatility this permits. Machine laying requires specialised equipment and only specially designed block shapes can be placed. These types (designated Type X) are not discussed in this paper because they were not evaluated in this application.

Type A blocks have been identified within the industry as the only suitable hand-placed type for use on heavy duty pavements because of their resistance to horizontal displacement under traffic. The herringbone laying pattern is preferred for similar reasons.

This finding is based on research work by Shackel and reported in a number of his papers over the past ten years (e.g. (13)). However, these studies have been confined to road vehicle and heavy industrial traffic applications.

The recommended procedures for hand laying the blocks are well documented in CMAA publications and these are generally accepted.

Edge Restraints

The concept that the block pavement is behaviourally similar to a flexible pavement is important when considering the junction between blocks and other pavement types. Heavy aircraft pavements deflect measurably under large wheel loads and in flexible pavements these deflections can lead to permanent deformation in the subgrade or other layers with time. Rigid elements within a flexible (or block) pavement (e.g. pits, drains, edge restraints, etc.) are potential discontinuities. In lightly-loaded pavements (e.g. road pavements) the deflections are generally small enough to avoid any discontinuity problems developing at the interface between the two different structures. When the wheel loads are of the order of those of heavy commercial aircraft, permanent surface deformations develop adjacent to rigid elements in trafficked areas.

Airplan addressed this problem by designing an asphalt edge restraint, which functions somewhat as a transition pavement element. It was evaluated in the initial trials and found to perform satisfactorily. Consequently, the design was incorporated into the New International Apron pavement, and the performance has been very encouraging, despite the hot climate.

Bedding Sand Layer

Heavy aircraft pavements are subject to loss of shape under load if any layer in the pavement structure and subgrade to a depth of approximately 2 m is deficient in density. The bedding sand layer is at a critical location in the pavement because it is sandwiched between incompressible blocks and weakly-cemented, highly-compacted fine crushed rock. Any deficiencies in density in the sand will thus be picked up by aircraft wheel loads and post-construction compaction will occur, resulting in loss of shape in the pavement surface. Consequently, it follows that the thinner the bedding sand layer, then the less is the chance of the occurrence of low density areas or loss of shape.

Airplan specify a nominal compacted thickness of bedding sand of 20 mm, which is at the lower end of the range normally recommended. However, it was observed during the construction of the block pavement on the new international terminal apron that a thinner layer of sand may be satisfactorily used. With the high surface smoothness tolerances required of the pavement basecourse, bedding sand thicknesses of, say, 10-15 mm (15-20 mm loose thickness) would appear to suffice.

Jointing

Because of the critical requirements of evenness of laying pattern and joint spacing, significant skill and care is required during the hand placing of the blocks. It is accepted within the industry that the blocks are placed in a pattern and in such a manner that an adequate joint width is achieved (i.e. the blocks are visually spaced). Blocks are lightly held against the face of the adjacent previously-placed blocks and allowed to slide into position. This procedure generally achieves the normally specified 3 mm (range 2-4 mm) joint spacing required, but allows some block to block contact. This contact must be avoided in high wheel load applications, because the resultant pavement deflection causes rotation of the blocks and spalling may occur (the provision of a chamfer on the top edges of blocks only partially assists in avoiding spalling).

During the trials at Cairns it was observed that the conventional placing technique did not achieve the nominated joint spacing consistently, and a considerable number of blocks were placed touching one another. The importance of joint spacing was demonstrated when blocks rotated under load and spalling occurred.

For the International Apron, Airplan specified that the blocks be manufactured with nibs on the vertical faces in order to ensure a minimum joint width, thus removing the reliance on the skill of the block layers to space the blocks.

Instead of block to block contact, the nibs were generally placed in contact with the block faces. The joint widths obtained when the blocks were laid in this manner were very uniform and generally at the lower limit of the recommended range.

Proof Rolling of the Block Surface

Compaction of the concrete block surface layer was conducted using vibrating plates only. Some light wheel loads were applied during construction by delivery vehicles and pallet trolleys, but they are insignificant compared to the in-service wheel loads of heavy aircraft. Consequently, in order to ensure adequate bedding of the blocks and stability against rotation, the specification required that the completed works be compacted with a pneumatic-tyred roller of high wheel load and tyre pressure. During such proof rolling, the stability of the blocks can be observed and any deficiencies in jointing sand corrected: open joints can be refilled and, if necessary, loose or broken blocks replaced.

This requirement is specifically designed to ensure that all areas of the block/sand layer a stable and that the jointing sand adequately fills the joints prior to opening to aircraft traffic.

It was noted during the proof rolling of the block pavement at Cairns that the occurrence c instability was minimal. This is attributed to narrow joint spacings and the use of the fine, singl sized joint filling sand.

Joint Sealing

The erosion of jointing sand from the joints in block pavements contributes to a number o defects, which may lead to degradation and ultimate failure, such as the loss of interlock, bloc rotation, spalling, and the ingress of water.

It has been widely claimed that the joints in block pavements are water impermeable because over time, detritus such as oil and grease, rubber deposits and air-borne dust tends to seal th joints in road vehicle pavements. This is not the case for aircraft pavements where the standar of pavement cleanliness is much higher and far fewer vehicles operate. This is supported b Sharp and Armstrong(8).

It is essential, therefore, that the jointing sand be both erosion resistant and relatively wate proof. The use of surface sealers has been proposed but it is believed that the cost/benefit aspects of these are not high.

The proprietary sand joint filler previously discussed, and used on the International Apron at Cairns, appears to satisfy all the special requirements for airport pavements.

COST COMPARISONS

In the following comparison of the cost of interlocking concrete block pavements with flexible and rigid pavements, only the pavement structure above the subgrade or select fill level has been considered. While subgrade type is a significant factor in the selection of the pavement type to be used, this is not considered here, and the comparisons are based on a particular common subgrade type.

Pavement thicknesses are those required for B747-200/400 type aircraft and can be taken as 400 mm for rigid pavements and 550-650 mm for flexible and block pavements. The range of costs for each pavement type considered are as follows.

Pavement Type	*Range of Unit Cost ($/m^2)*
Rigid	120-150
Block	70-95
Flexible	50-70

CONCLUSIONS

This paper has illustrated the suitability of interlocking concrete blocks in a heavy commercial jet aircraft pavement application and, in particular, has confirmed their superior fuel resistance. non-temperature susceptibility, abrasion resistant surface properties and economical construction cost. As a result of this first Australian aircraft pavement usage of interlocking concrete blocks, a number of significant developments have been made which will enhance the performance of block pavements in harsh service conditions. These include the introduction of spacing nibs on blocks, water-proofing layers, special jointing treatments and heavy proof rolling. The potential use of mechanistic procedures to design heavy duty aircraft pavements has been demonstrated, including a good correlation to conventional empirical design procedures.

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Table 1

Pavement Model Used in Mechanistic Analysis

Layer	Thickness (mm)	Poisson's Ratio	Degree of Anisotropy	Modulus (MPa)
blocks	100	0.20	anisotropic	1000-5000
CMFCR (Stage 1)	250	0.20	isotropic	2000
(Stage 2)	250	0.35	isotropic	600
FCR(1)	125	0.35	anisotropic	500
FCR(2)	125	0.35	anisotropic	316
subgrade	semi-inf.	0.45	anisotropic	200

(1), (2): layers 1 and 2 of fine crushed rock layer.
Stage 1, Stage 2: Stage 1 and Stage 2 life.

Table 2

Results of Mechanistic Analysis of Pavement Structure

(see Table 1 for Pavement Structure)

Block Modulus (MPa)	Stage 1			Stage 2		Stage 2 Movements per Day
	CMFCR $\mu\varepsilon_{HT}$	N	Subgrade $\mu\varepsilon_{VC}$	Subgrade $\mu\varepsilon_{VC}$	N	
Subgrade CBR: 20						
1000	349	<1	858	1072	79,490	14.5
2000	312	<1	793	1001	104,557	19.1
3000	312	<1	758	961	123,083	22.5
4000	303	<1	730	934	137,944	25.2
5000	273	<1	710	914	150,420	27.5
Subgrade CBR: 15						
1000				1310	35,646	6.5
5000				1115	67,919	12.4

CMFCR: cement-modified crushed rock.
$\mu\varepsilon_{HT,VC}$: maximum horizontal tensile strain at base of CMFCR and maximum vertical compressive strain on surface of subgrade.

50	Asphalt	100	Blocks and Sand
200	Fine Crushed Rock (FCR)	150	Cement-Stabilised (4%) FCR
150	Soil Aggregate	150	Soil Aggregate
100	Cement-Stabilised Soil Aggregate	100	Cement-Stabilised Soil Aggregate
150	Cement-Stabilised Fill	150	Cement-Stabilised Fill
	Select Fill (silty)		Select Fill (silty)

(a) Original Pavement **(b) Initial Trial Pavement**

Fig. 1 - Profiles of original pavement and pavement monitored in initial trial

50	Asphalt	100	Blocks and Sand
250	Fine Crushed Rock (FCR)	250	Cement-Modified (2%) (FCR)
250	Crushed Rock	250	Crushed Rock
	Select Fill (rubble)		Select Fill (rubble)

(a) Asphalt Pavement **(b) Parking Bay**

Fig. 2 - Pavement profiles selected for new international apron

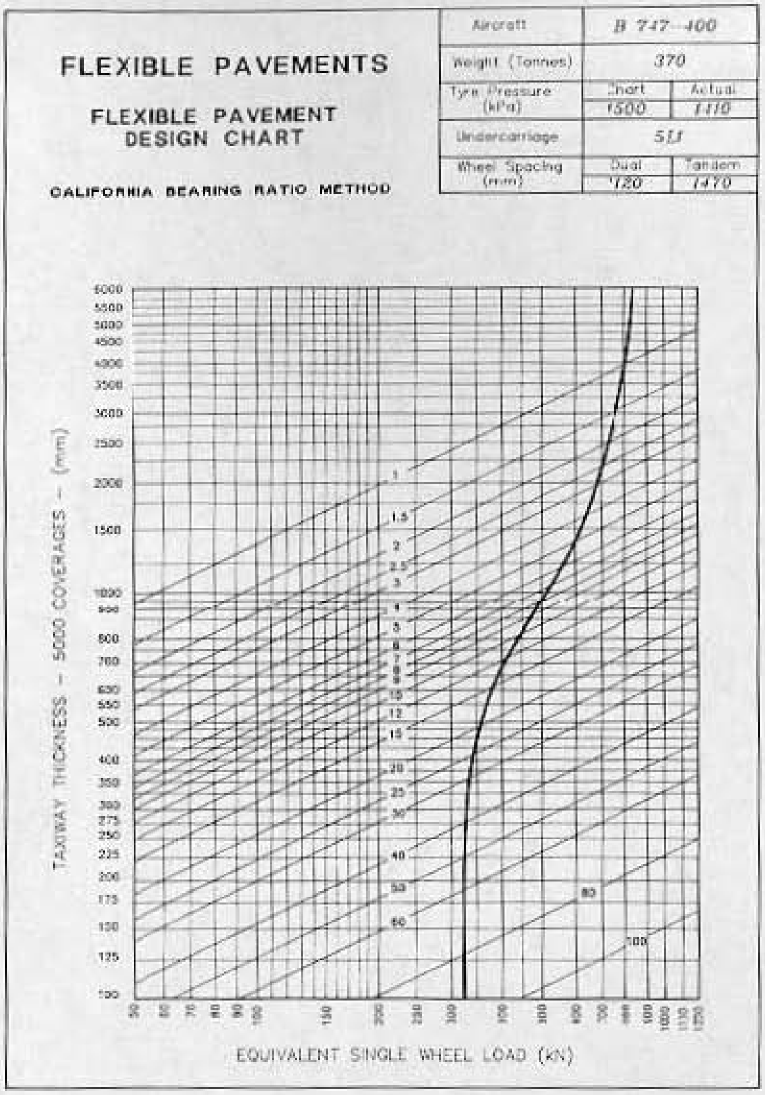

Fig. 3 - Design chart for B747 aircraft

Fig. 5 - Breaking-out of aggregate particles under traffic

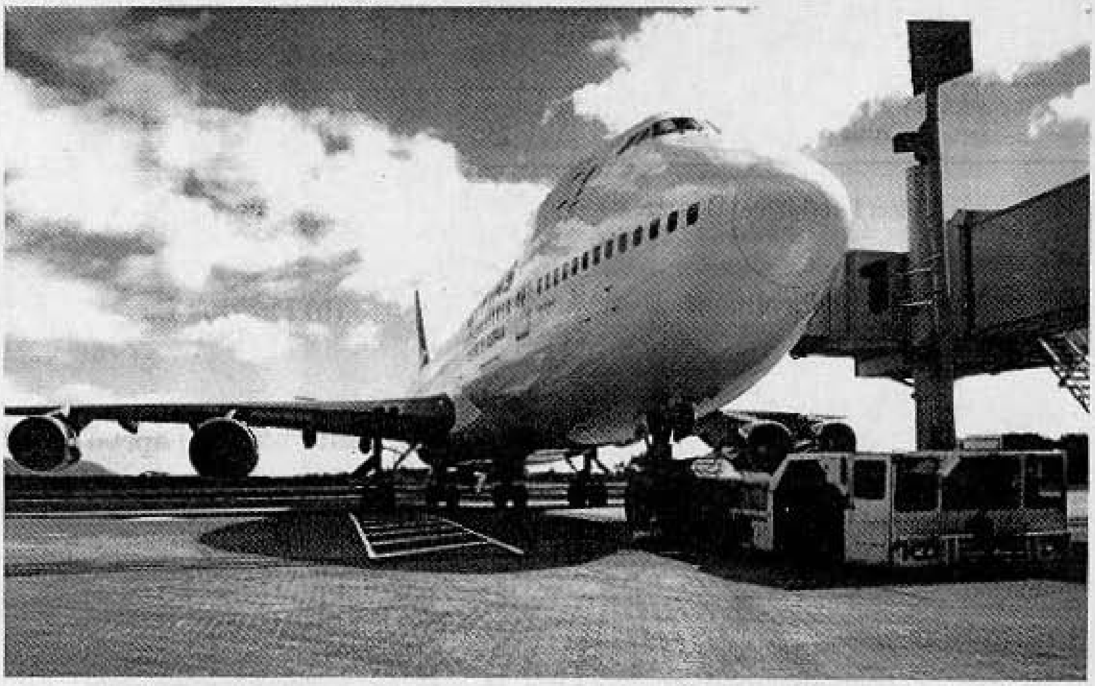

Fig. 4 - General view of completed parking bay