DESIGN & PERFORMANCE OF CONCRETE BLOCK PAVEMENTS FOR HANGAR APRONS SERVING HEAVY-DUTY AIRCRAFTS

by

ILAN ISHAI

Associate Professor of Civil Engineering,
Transportation Research Institute,
Technion, Haifa, Israel

UZI MAURER

Plant Engineer,
Israel Aircraft Industries Ltd., Israel

RAPHAEL HASSON

Partner,
Hasson-Jerushalmi, Consulting Engineers,
Tel Aviv, Israel

ABSTRACT

During 1989, the Israel Aircraft Industries (IAI) designed the construction of a new hangar for the maintenance of B-747 aircraft. This hangar included an exterior apron of about 6,300 m^2. The standard conventional pavement solution called for a concrete rigid pavement with jointed concrete slabs of 35 cm. thickness. With the developing technology of Concrete Block Pavements (CBP), and with the encouragement of the block industry and academic consultants, the CBP option was considered for the hangar apron. Consequently, an extensive engineering-economical evaluation and comparison was made for the two alternatives. As a result, a decision was arrived at, and CBP was constructed in 1990. Furthermore, an additional adjacent hangar was erected in 1992 with a 7,000 m^2 of concrete block pavement apron. Today, after three years of service, the concrete block pavements have performed excellently under heavy aircraft operations, with an average saving of about $30.- per sq.m. as compared with the conventional rigid concrete pavement. The paper presents in detail the engineering-economical aspects and data comprising the decision process, pavement design and construction of the CBP for the two B-747 hangar aprons.

BACKGROUND

As a part of its expansion program, the Israel Aircraft Industries (IAI) planned the addition of two new hangars for the maintenance of Boeing 747 aircraft. The construction phase of these projects was scheduled to commence in 1990. Early in 1989, the design phase of the first project -- Hangar No. 10 -- was initiated. It included a 6,500 m^2 steel structure with an interior jointed concrete floor. Adjacent to the hangar, an open apron of 6,300 m^2 was also designed. The construction of Hangar 10 and its apron was terminated at the end of 1990.

The design of Hangar 11 was accomplished during 1991. In addition to its similar steel and interior floor structures, it also included an adjacent open apron with the area of 7,000 m^2. The construction of that hangar and apron was implemented during 1992. However, before the construction, an area of about 2,300 m^2 of the exterior apron of the newly-erected Hangar 10 had to be dismantled for relocation, due to a design modification in Hangar 11.

Today, at the end of 1993, both hangars and aprons are under full operation, serving heavy-duty aircraft, mostly Boeing 747s.

PAVEMENT SELECTION

The conventional design and construction of aircraft apron pavements used by the Israel Airport Authority and the Israel Aircraft Industry, utilizes rigid portland cement concrete pavements. The typical apron pavement comprises 20-35 cm. thick reinforced, or non-reinforced, concrete slabs founded on a granular base course (usually stabilized) and sub-base course composite structure. The thickness of the total pavement and its components are a function of the soil type and condition, and of the aircraft loading.

Similarly, the original pavement design of Hangar 10's apron called for a 35 cm. thick reinforced concrete slab to be founded on 45 cm. of granular base and subbase courses. However, with the developing Concrete Block Pavement (CBP) technology in industrial applications in Israel, and with the encouragement and support of the largest block manufacturer in the country [1], the CBP option was also considered by the IAI officials as a possible engineering alternative.

Consequently, an extensive engineering-economic evaluation and comparison was made for the two alternatives. As will be discussed later, a decision was arrived at to choose a concrete block pavement structure for the hangar apron. Among other factors, this decision was also based on the recent success of CBP applications at several civilian airports in England and the United States [2,3,4,5], and on recommendations and backup given by academic and professional consultants [6,7].

PAVEMENT DESIGN

The engineering and economic analysis and comparison between the two pavement options required an accurate pavement design process for the suggested CBP alternative. The adopted design method was based on the local CBP technology which was mainly applicable for heavy industrial loading [8,9,10,11,12], and on the modified FAA pavement design curves for CBP in airports [3,7].

The design parameters were as follows:

Subgrade: An expansive heavy-clay classified as A-7-6 or CH, with a design CBR of 4.0%;

Loading: B-747 aircraft with gross weight of 600,000 lbs;

Coverages: "Annual Departures" of 1,200 applications or less.

The initial local design called for a 110 cm. pavement thickness with 10 cm. thick "shaped" blocks. The modified FAA curves required a 122 cm. (48 inches) pavement, a 28 cm. thick stabilized base course, and 8 cm. thick rectangular blocks (see Figs. 1 and 2).

The final design, which compensates the changes in shape and thickness of the blocks and in the thickness of the stabilized base-course, is as follows (see also Fig. 3):

Rectangular concrete blocks	--	8 cm.
Natural sand	--	4 cm.
Stabilized base course	--	23 cm.
Sub-base course	--	95 cm.
Total pavement thickness:		130 cm.

Two membranes were introduced into the pavement structure mainly for functional engineering purposes. In order to protect the subgrade moisture equilibrium and to promote sub-surface drainage, an industrial elastomeric asphaltic membrane was placed on top of the compacted subgrade. This membrane, which is reinforced by a polyester fabric, also provides a separation and reinforcing role in the interface between the pavement structure and the clay subgrade.

On top of the base course and beneath the sand layer, a geotextile fabric was also introduced. Its main role was the prevention of the loss of sand particules by filtration and penetration down to the pervious base-course. This should prevent any differential settlement of the paving blocks.

COST ANALYSIS

A comparative cost analysis was made between the conventional rigid pavement solution and the proposed CBP alternative under

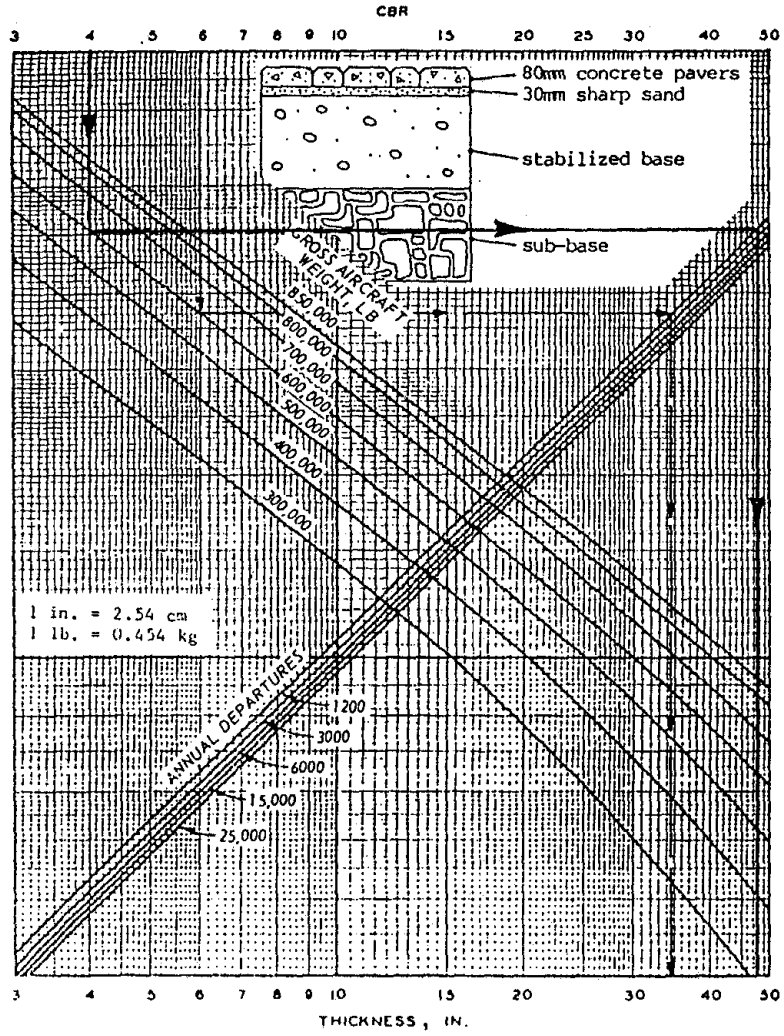

Fig. 1: Modified FAA CBP design curves for critical areas for B-747-100, SR, 200B, C, F [3].

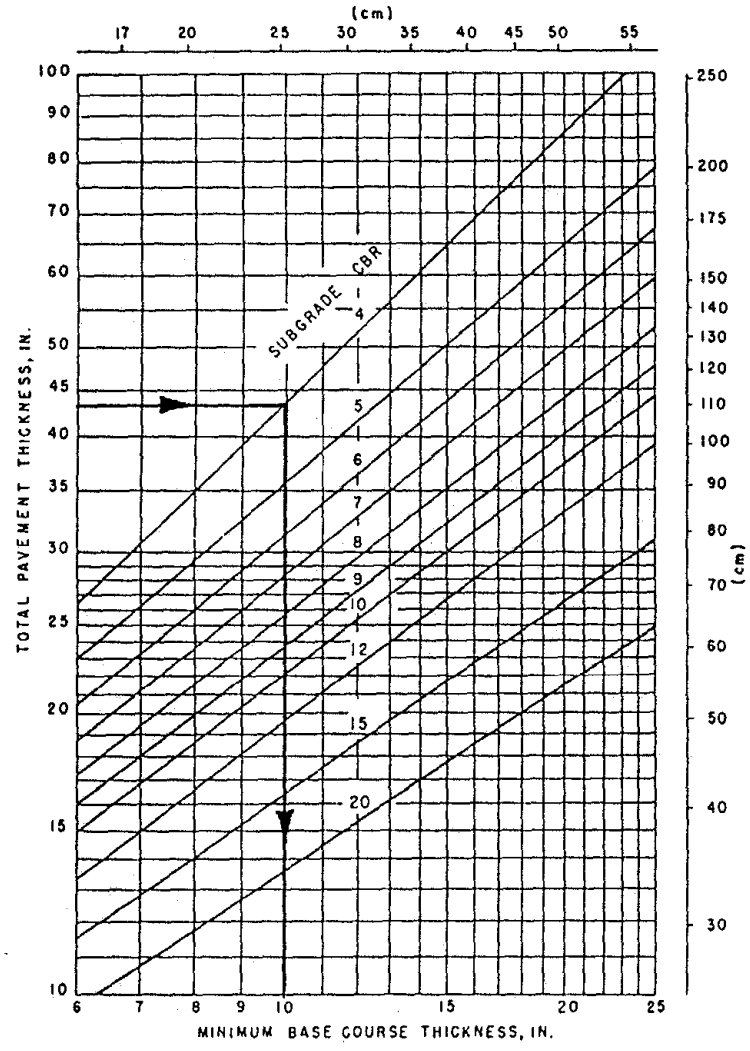

Fig. 2: FAA pavement design curves for minimum base course thickness requirements [3].

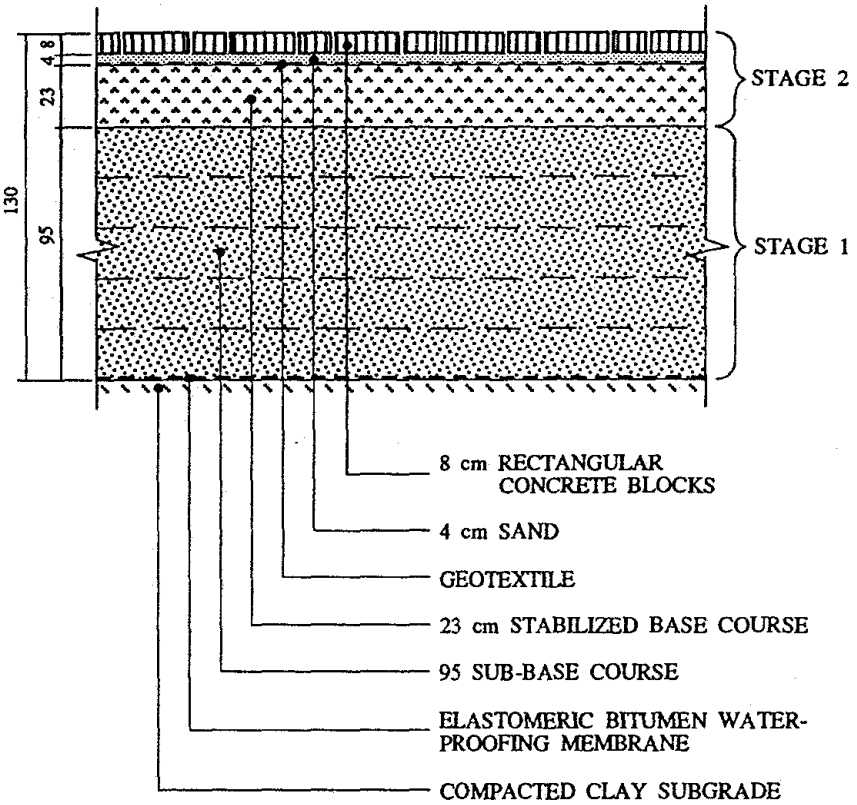

Fig. 3: Cross-section of CBP aprons in Hangars 10 and 11.

Table 1: Comparison of Estimated Costs of Rigid and CBP Pavement Alternatives

Item	Unit	Unit Price $	Rigid Pavement		CBP Pavement	
			Quant. per m^2	Price $/m^2$	Quant. per m^2	Price $/m^2$
Reinforced concrete	m^3	205	0.35	72		
Stabilized base course	m^3	80	0.25	20	0.28	22
Subbase course	m^3	16	0.20	3	0.95	15
8 cm. concrete blocks	m^2	19	-	-	1.0	19
Geotextile fabric	m^2	2		-	1.0	2
Asphaltic membrane	m^2	7	-	-	1.0	7
Total Price ($ per m^2)				95		65

the structural pavement design presented above. Table 1 summarizes the cost estimate comparison. Unit prices are based on average paving market prices and on local foreign exchange rates as of May 1989.

It can be seen that under identical subgrade and loading conditions, the CBP pavement alternative is cheaper by about $ 30.- per m^2 as compared to the conventional rigid pavement structure. This expresses a saving of about 32 percent. The above cost estimate was verified under actual bidding and construction conditions. The total project savings were about $ 190,000.- for Hangar 10 and $ 210,000 for Hangar 11.

Additional cost saving was achieved during the construction of the two hangar aprons. First, a substantial time-saving was accomplished with the block laying as compared to tedious and time-consuming operations for framework, alternate slab casting, curing and joint installation involved in the rigid pavement construction.

Second, the dismantling of the 2,300 m^2 of Hangar 10's apron, due to design relocation of Hangar 11, was quite rapid and simple. The paving blocks were stored and re-used in the second apron. Had a concrete pavement been installed, it would have been dismantled by shattering, using air compressors. This operation requires substantial cost and time.

MATERIALS AND CONSTRUCTION

The following materials were used for the construction of the two apron pavements:

Concrete Blocks - 8 cm. thick rectangular 10x20 cm. precast concrete blocks were used. The blocks had crushing strength typically in excess of 50 MPa.

Bedding Sand - Naturally occurring coarse silica sand having a 4 mm. maximum particle size and a minimum of 5% passing the # 200 sieve.

Joint Filling Sand - Fine natural dune sand having a 1.5 mm. maximum particle size.

Geotextile - Polypropelen non-woven needled-punched fabric having a weight density of 250 gr/m^2.

Stabilized Base Course - Crushed graded aggregates which comply with the following gradations:

SIEVE	2"	1.5"	3/4"	1/2"	3/8"	#4	#10	#40	#200
% by weight pass.	100	70-100	39-71	30-60	27-58	20-50	15-40	5-25	5-10

The crushed graded aggregates were stabilized with 3% portland cement. The aggregates complied with the following requirements: Sand equivalent - minimum 50%; Los-Angeles Abrasion - maximum 32%; Elongation - maximum 45%; Flakiness - maximum 30%.

Sub-base Courses - Crushed quarry material which complied with the following gradation:

SIEVE	3"	3/4"	#4	# 200
% by weight passing	100%	60-100%	25-65%	0-15%

The aggregate complied with: sand equivalent - minimum 25%; liquid limit - maximum 25%; plasticity index - maximum 6%; laboratory CBR - minimum 60%.

Asphaltic Membrane - A 3 mm. thick prefabricated asphaltic felt comprising polymer modified bitumen and reinforced with a 250 gr/m^2 non-woven polyester geotextile fabric [13].

The construction of the apron pavements was customarily performed using conventional flexible and concrete block paving methods. The following distinctive points should be stressed:

In order to preserve the optimal compaction moisture of the clay subgrade, it was quickly covered with the asphaltic membrane. The membrane strips, having a 1 meter width, were specially torch-welded in order to achieve maximum sealing.

The pavements were constructed in two stages (see Fig. 3). During the first stage, only the sub-base courses were laid. This was carried out in order to provide a working surface for the construction of the hangar structure, and also to avoid damaging the CBP pavement by the heavy and destructive construction equipment. Only parallel to the completion of the hangar roof, were the stabilized base-course and the top block layer paved.

After completion of the stabilized base course, it was covered by the geotextile and paved with blocks in a continuous operation (see photograph in Fig. 4). Shortly after unrolling the geotextile, the bedding sand was screeded to the proper height. The blocks were then manually laid in a "herringbone" pattern. The blocks were vibrated with a plate vibrator in order to force the bedding sand part way up the joints. Finally, the fine dune sand was brushed and vibrated into the remaining space in the joints.

Finally, after completion of all construction operations, and before opening the hangar to service, the top surface was treated with a sealing compound. An 'ACM PAVSEEL' was used [14]. This is an elastomeric prepolymer for in-situ bonding and sealing

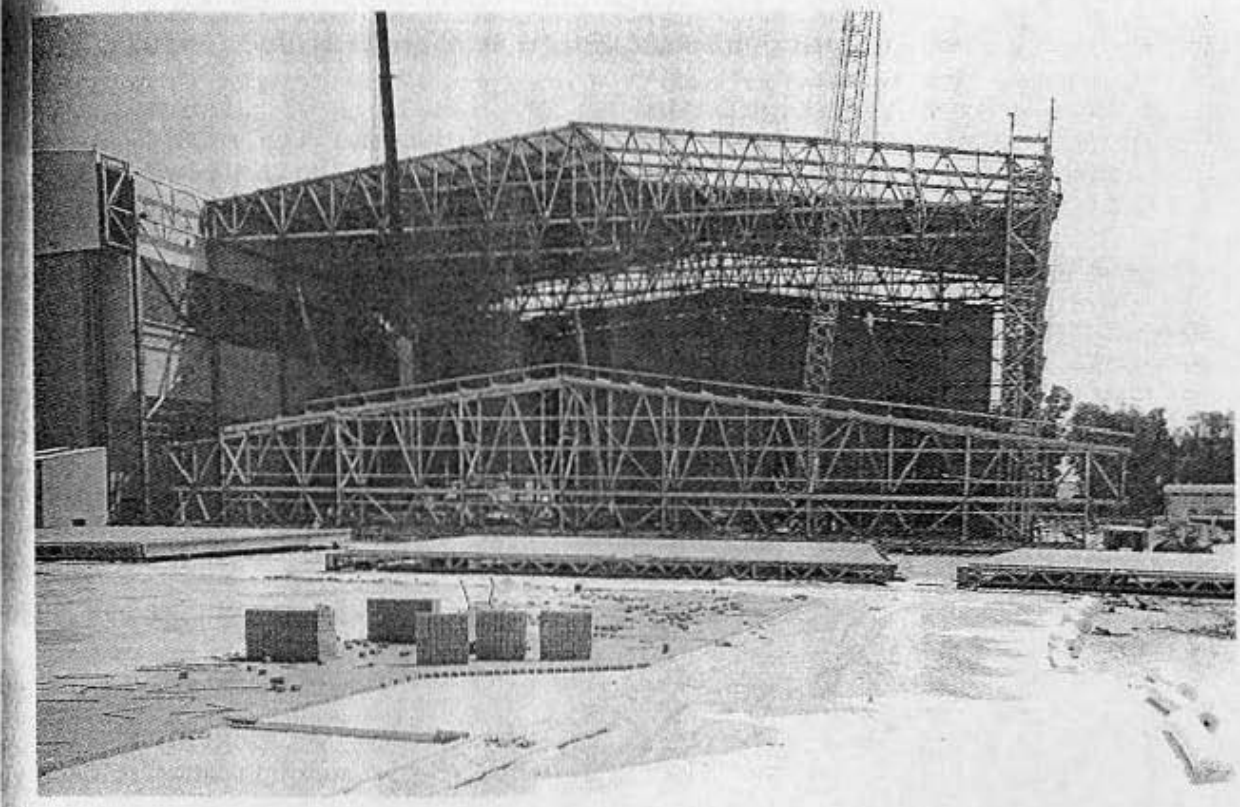

Fig. 4: Unrolling the geotextile and laying of the concrete blocks on top of the stabilized base course in a continuous operation.

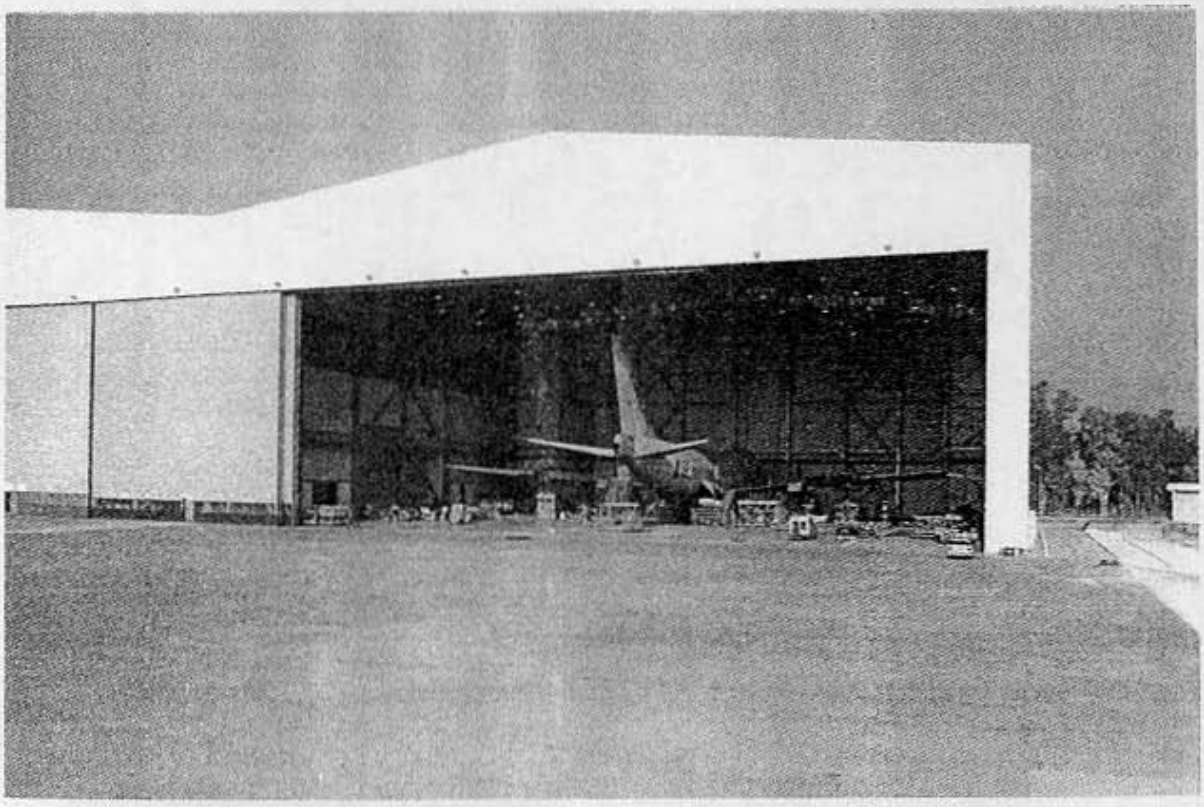

Fig. 5: Hangar 10 and its CBP apron in early days of service.

of joints in block paving. This compound stabilizes and seals the jointing sand, yet is sufficiently flexible to permit the CBP to behave flexibly.

An overall look at the completed Hangar 10 and its CBP apron in their early days of service is illustrated in the photograph of Fig. 5.;

PERFORMANCE

Today, after three years of service of the first apron, the concrete block pavements have performed excellently under heavy aircraft operations to the users' total satisfaction. The CBP solution provided an operating pavement surface which is strong, stable and durable. The surface exhibits good frictional characteristics, a good standard of rideability, and an adequate capability of rapid removal of surface water under standard slopes.

The condition of both aprons are closely monitored and surveyed for future implementation and conclusions.

ACKNOWLEDGMENT

The authors wish to acknowledge the Ackerstein Industries Company for providing important industrial and technical assistance during the block manufacturing and construction of the block pavers. Also, thanks are due to Prof.M. Livneh, Prof.J. Knapton and Engr.J.A. Emery for their valuable technical and scientific assistance.

REFERENCES

1. Private Communications with Engr. M. Hirshberg and Mr. G. Ackerstein, Ackerstein Industries Ltd., Herzlia, Israel, 1989, 1990.

2. Emery, J.A. "Concrete Pavers for Aircraft Pavement Surfaces." Journal of Transportation Engineering, ASCE, Vol. 112, No. 6, November 1986.

3. Emery, J.A. & Knapton, J. "The Design of Concrete Block Aircraft Pavements." Proc., 3rd Int. Conference on Concrete Block Paving, Rome, Italy, May 1988.

4. Emery, J.A. "An Evaluation of the Performance of Concrete Blocks on Aircraft Pavements at Luton Airport." Proc., 3rd Int. Conf. on Concrete Block Paving, Rome, Italy, May 1988.

5. Smith, D.R. "Concrete Pavers Offer Airports New Paving Alternatives." Airport Services - The Business Monthly for Aviation Airport Management, August 1989.

6. Private Communications with Prof. M. Livneh and Prof. I. Ishai, Transportation Research Institute, Technion, Haifa, Israel, 1989, 1990.

7. Private Communications with Prof. J. Knapton and Engr. J.A. Emery, England, 1989, 1990.

8. Ishai, I. & Livneh, M. "Interlocking Concrete Block Pavement for Heavy Abrasive Caterpillar Loading." Proc., 2nd Int. Conf. on Concrete Block Paving, Delft, Holland, April 1984.

9. Nesichi, S., Ishai, I., & Livneh, M. "Concrete Block Pavements in Israel -- State-of-the-Art." Proc., 1st Int. Workshop on Interlocking Concrete Pavements, Melbourne, Australia, September 1986.

10. Ishai, I. & Livneh, M. "Three-Year Performance of Concrete Block Pavements Under Heavy Abrasive Caterpillar Loading." 3rd Int. Conf. on Concrete Block Paving, Rome, Italy, May 1988.

11. Livneh, M. & Ishai, I. "Development of Pavement Design Methodology for Concrete Block Pavements in Israel." Proc., 3rd Int. Conf. on Concrete Block Paving, Rome, Italy, May 1988.

12. Livneh, M. & Ishai, I. "Israeli Experience with Runway Pavements on Expansive Clays." Proc., 6th Int. Conf. on Expansive Clays, New Delhi, India, December 1987.

13. Ishai, I., Livnat, N., & Livneh, M. "Subgrade and Pavement Improvement with Asphaltic Membranes." Geotechnical Special Publication No. 30, ASCE, Vol. 1, 1992.

14. Advanced Construction Materials Ltd: "ACM PAVSEEL," an Informational Leaflet, London, U.K., August 1989.