NASA
Concrete Paving Stone Evaluation

Summary of Tests at
NASA - Aircraft Landing Dynamics Facility ALDF
Langley, Virginia

UNI - INTERNATIONAL®

NASA Test Overview

Section Parameters	Friction Results	Pavement Stability and Integrity Results
Installed Hexagonal Paver (10 cm), Nov. 1991	***satisfactory****	Hexagonal Section ***Failed***
Installed UNI-ANCHORLOCK® (8 cm) Tests Section, May 1992	***satisfactory****	UNI-ANCHORLOCK® Section ***Succeeded***
Replaced Hexagonal Paver with 10 cm Multiweave Paver (copy of old UNI-STONE®), August 1993	***satisfactory****	Multiweave Paver Section ***Failed***
Refurbished UNI-ANCHORLOCK®. Replaced Multiweave Paver with Rectangular Paver (8 cm) in DFW Airport Herringbone Pattern, March 1994	***satisfactory****	Rectangular Paver Section ***Failed*** UNI-ANCHORLOCK® Section ***Succeeded***
Renewed Rectangular Paver in DFW Airport Herringbone Pattern with 90 ⁰ Herringbone Pattern, April 1994	***satisfactory****	Rectangular Paver Section ***Failed*** UNI-ANCHORLOCK® Section ***Succeeded*** (same section as above!)
Restored Rectangular Paver (90 ⁰ Herringbone Pattern). Existing UNI-ANCHORLOCK® and Rectangular sealed with Addiment Sealer, June 1994	***satisfactory*** *all pavers ca.50-70% better than smooth concrete, 20% less than grooved concrete)	Rectangular Paver Section ***Failed*** UNI-ANCHORLOCK® Section ***Succeeded*** (same section as above!)

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Friction Evaluation of Concrete Paver Blocks for Airport Pavement Applications

Thomas J. Yager
NASA Langley Research Center

ABSTRACT

The development and use of concrete paver blocks is reviewed and some general specifications for application of this type of pavement surface at airport facilities are given. Two different shapes of interlocking concrete paver blocks installed in the track surface at NASA Langley's Aircraft Landing Dynamics Facility (ALDF) are described. Preliminary cornering performance results from testing of 40 x 14 radial-belted and bias-ply aircraft tires are reviewed. These tire tests are part of a larger, ongoing joint NASA/FAA/Industry Surface Traction and Radial Tire (START) Program involving several different tire sizes. Both dry and wet surface conditions were evaluated on the two concrete paver block test surfaces and a conventional, nongrooved Portland cement concrete surface. Future test plans involving evaluation of other concrete paver block designs at the ALDF are indicated.

THE HISTORY OF segmented paving or small-element surface treatments primarily involves urban street applications. In order of descending cost, these four different types of pavers have been used: 1) stone sets or cobblestones; 2) wooden blocks; 3) bricks; and 4) concrete blocks. Much of the development of the least costly segmented paving, concrete paver blocks, took place in the Netherlands and Germany in the late nineteenth century as indicated in reference 1. In the beginning, concrete paver blocks were manufactured in the same rectangular size as brick pavers and at similar cost. With increasing mechanization and lower energy consumption in the concrete block manufacturing industry, concrete paver blocks can now be produced at approximately 40 percent the cost of brick pavers and in a variety of shapes and colors. The first widespread acceptance of concrete pavers for roads occurred in the early fifties in the Netherlands and then in Germany. It was in Germany that significant advances in developing different interlocking shapes were achieved and successfully installed. From the 1950's onward, there was a steady evolution in concrete block shapes and installation patterns aimed at improving strength and durability. By the late 1970's, over 200 different concrete paver block treatments were being marketed nearly worldwide.

In regards to use of concrete paver blocks at airports, one of the first reported installations was on the apron service roads at Schiphol International Airport, Amsterdam in the late 1970's. Starting in 1981, concrete paver blocks were installed at Luton Airport, England, in aprons and end of runway turning areas. These concrete paver block surfaces at Luton Airport have successfully withstood over a million aircraft movements and studies reported in references 2 and 3 have shown excellent durability, low maintenance requirements, and resistance to jet blasts, abrasion, snow plow operations, freeze-thaw cycles, and chemical spills involving fuel, hydraulic fluids, anti-icing and de-icing chemicals, and other fluids. Reference 4 summarizes an extensive study of concrete block pavements for airfields by the U.S. Army Corps of Engineers which indicates these pavers are particularly applicable for use in low-speed airport traffic areas including runway ends, cross taxiways, aprons, pads, and handstands. In late 1980's, an apron area and three cross-taxiways at Dallas/Fort Worth International Airport, Texas, were constructed using concrete paver blocks in a herringbone pattern. Reference 5 discusses this concrete paver block installation at Dallas/Fort Worth and figure 1 shows a portion of the apron area constructed with the pavers. In terms of strength and durability, the concrete paver block surfaces installed at various airports have performed well, but the industry needs more information relative to aircraft tire friction performance on these concrete blocks. Hence, two paver block test surfaces have been installed at NASA Langley's ALDF and preliminary results from cornering tests at aircraft tire rated loads and inflation pressures will be discussed in the following sections.

TEST FACILITY AND EQUIPMENT

An aerial view of the ALDF is shown in figure 2. The test track is 853 m (2800 ft) in length including approximately 122 m (400 ft) for the test carriage to catapult up to speed, a 549 m (1800 ft) section to perform tests, and 183 m (600 ft) for the test carriage to stop. A pressurized water jet propulsion system, capable of delivering over 9000 kN (2,000,000 lb) of

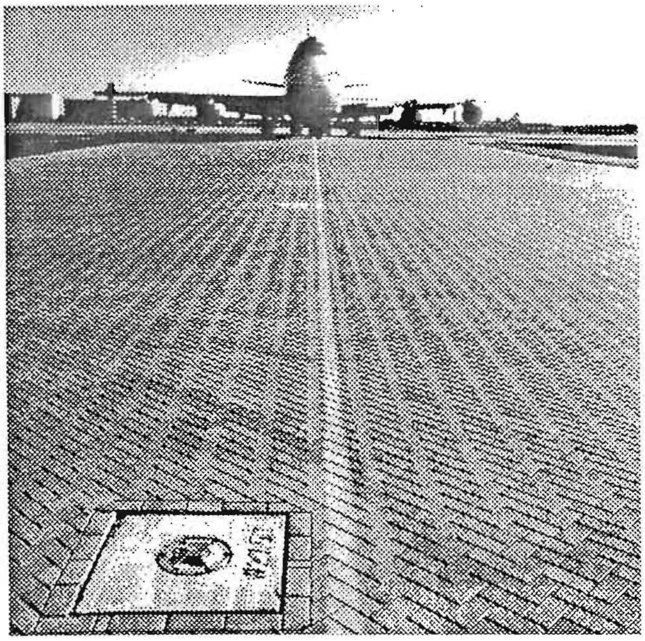


Figure 1. Airport apron paver block installation.

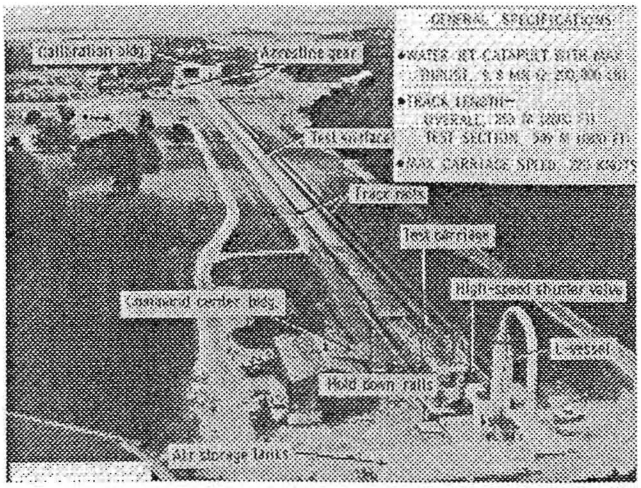


Figure 2. Aircraft Landing Dynamics Facility.

thrust from a 46 cm (18 in.) nozzle, accelerates the nearly 54,500 kg (60 ton) test carriage up to the desired test speed. At the end of the test section, a five-cable carriage arrestment system engages the nose block mounted on the front of the carriage and brings the carriage to a stop. The test tires are mounted on an instrumented dynamometer which is attached to the drop fixture in the middle of the carriage. This drop fixture is hydraulically controlled to move vertically and apply the desired load to the test tire. Test tire drag, vertical and side loads are measured with strain gages and wheel speed, brake torque, and wheel accelerations are also monitored during each test run. Test carriage forward speed and track position are measured and if a tire braking test is performed, brake pressure and antiskid command signal are measured. All instrumentation signals are telemetered during the test run to analog recorders and a computer located at the command center building at the propulsion end of the track. Reference 6 contains a more detailed description of the unique capabilities of the ALDF.

The nongrooved Portland cement concrete test surface installed at the ALDF is shown in figure 3. The surface was installed as level as possible to permit achieving uniform water depth for wet surface tests. A water sprinkler system installed alongside the entire 549 m (1800 ft) test section maintains the desired surface wetness conditions. The concrete test surface has a relatively smooth macrotexture as measured using the NASA grease sample technique described in reference 7. The average texture depth of the test surface is 0.30 mm (0.012 in.).

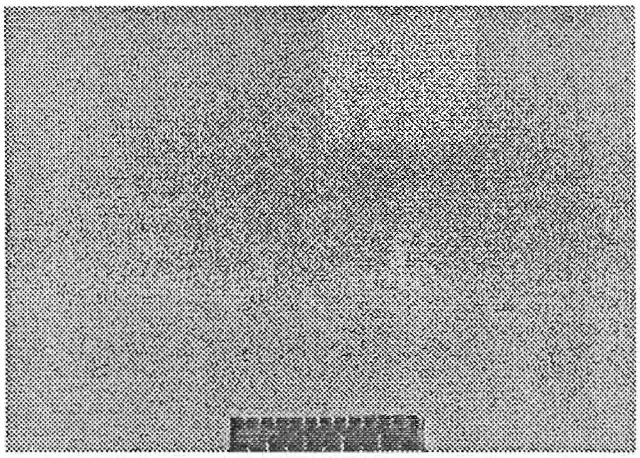


Figure 3. Nongrooved concrete test surface.

Two different shapes of concrete paver blocks have been installed in the last 61 m (200 ft) of the ALDF test section as shown in figure 4 using a fine sand base and a combination concrete/wood constraining edge

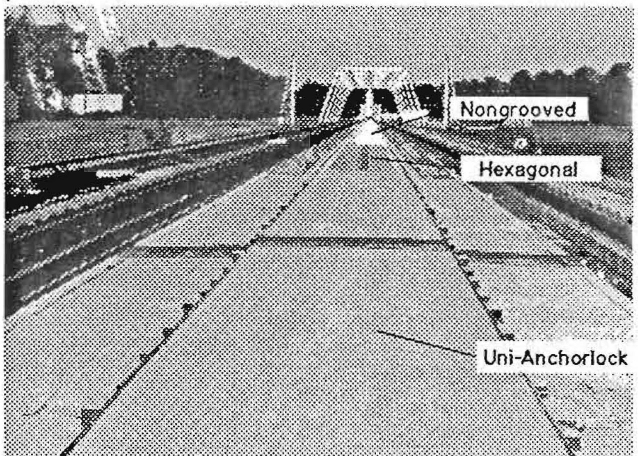


Figure 4. Concrete paver block test section.

The first 30 m (100 ft) contains a new, uniquely designed, hexagonal concrete paver block test surface as shown in figure 5. Dimensions of an individual hexagonal-shaped, concrete paver block are given in figure 6. The hexagonal shape was chosen to enhance interlocking capability and the radial, six-groove, surface configuration represents an initial effort to optimize wet friction performance. The average texture depth measured on this concrete paver block test surface was 0.40 mm (0.016 in.), 33 percent higher than the nongrooved concrete. Other surface configurations and designs to improve wet friction performance may be evaluated later with this hexagonal concrete paver block.

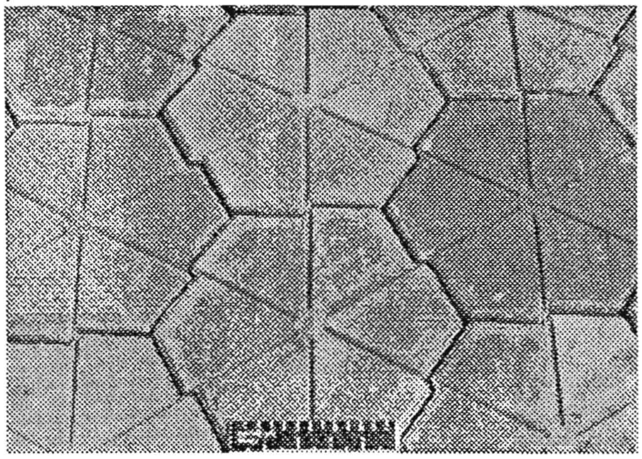


Figure 5. Hexagonal concrete paver block surface.

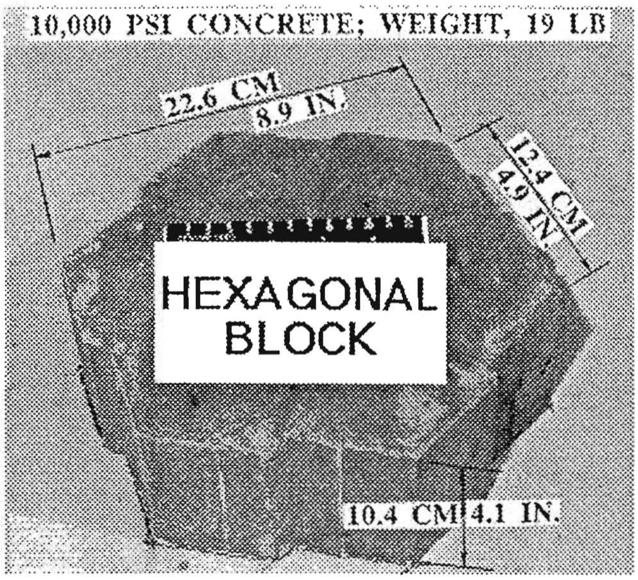


Figure 6. Hexagonal paver block dimensions.

The second concrete paver block, 30 m (100 ft) long, test surface is composed of Uni-Anchorlock paving blocks as shown in figure 7. The "L" shaped configuration of Uni-Anchorlock paver blocks, as shown in figure 8, acts as an anchor, preventing twisting, tipping, or lateral movement when stressed. The average texture depth measured on this concrete paver block test surface was 0.36 mm (0.014 in.). The mix design used in both types of concrete paver blocks installed at the ALDF meets normal paver design requirements as given in references 2 and 4.

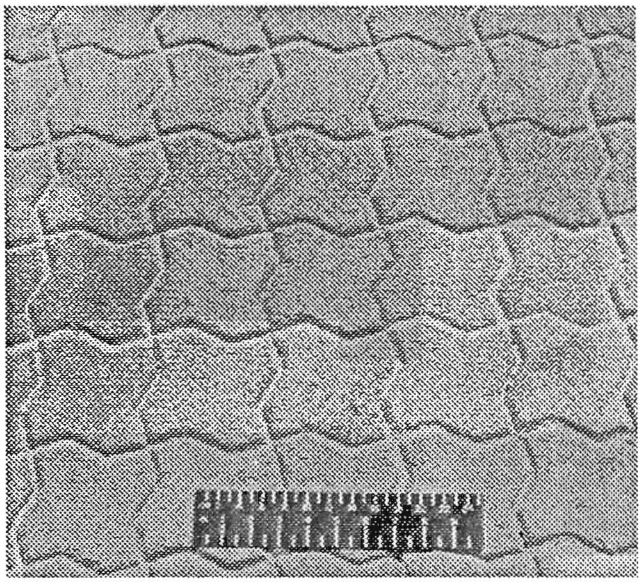


Figure 7. Uni-Anchorlock paver block surface.

THICKNESS, 3.13 IN. (80 MM);
WEIGHT, 15 LB (6.8 KG)

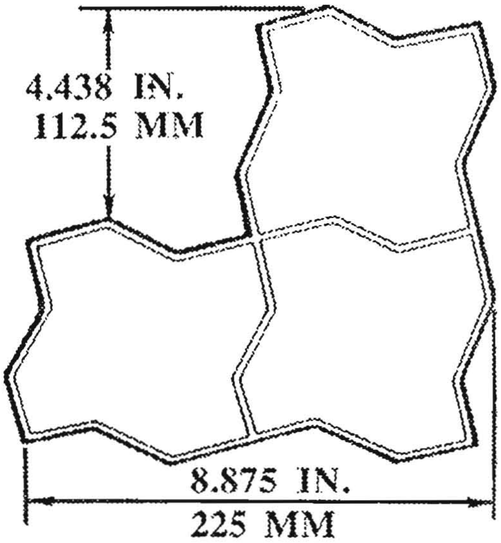


Figure 8. Uni-Anchorlock paver block dimensions.

The tread features of the radial-belted and bias-ply 40 x 14 size test tires used in evaluating these two concrete paver block test surfaces are shown in figure 9. Both tires have similar four-groove tread patterns with the radial-belted tire having a slightly wider middle rib. These tires were both tested at an inflation pressure of 1.17 MPa (170 psi) and a rated load of 123 kN (27,700 lb). This size tire is found on DC-9 and B-737 jet transport aircraft main landing gears. Rolling resistance test runs at zero degree yaw were performed only under dry surface conditions. Cornering friction performance tests were conducted up to 20 degrees tire yaw angle on both dry and wet surface test conditions and up to 160 kts carriage speed.

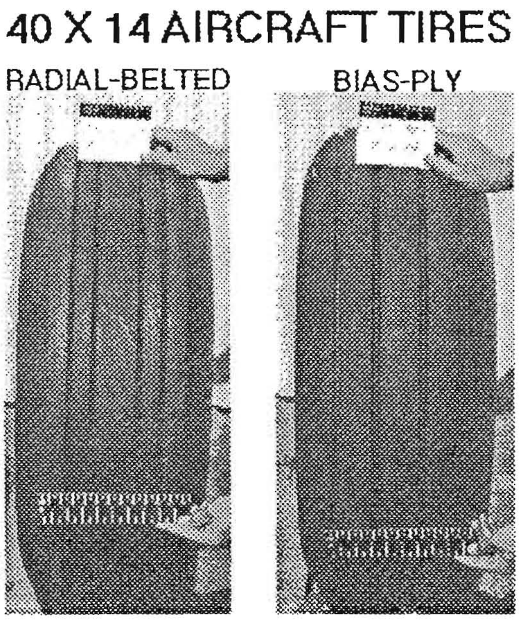


Figure 9. Test tire tread features.

PRELIMINARY TEST RESULTS

From limited, low speed (5 kts) test runs with both the radial-belted and bias-ply tires, rolling resistance measurements were similar on the dry, nongrooved concrete, the hexagonal-shaped and Uni-Anchorlock pavers. The radial-belted rolling resistance was lower by approximately 5 percent than the bias-ply tire. Additional rolling resistance test runs up to 160 kts are planned with both tires to confirm these preliminary results.

The initial design, hexagonal-shaped, radial six-grooved, concrete paver block produced some promising wet friction performance results when compared to the nongrooved concrete surface. Figure 10 shows comparative dry and wet steering friction performance variation with speed on the hexagonal-shaped paver block and the nongrooved concrete surfaces obtained with the bias-ply 40 x 14 tire constrained to a 9 degree yaw angle.

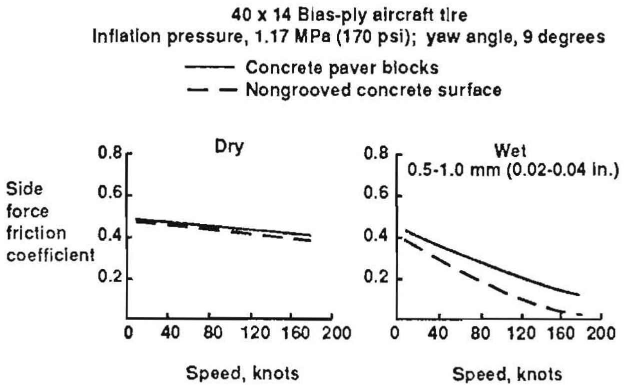


Figure 10. Tire cornering performance with yaw angle.

These curves were derived from other data plots of side force friction variation with yaw angle at different speed increments. For dry conditions, the steering performance was similar for both test surfaces evaluated, but under wet conditions, the hexagonal-shaped paver block surface produced higher steering friction throughout the speed range tested.

Figure 11 shows some comparative low speed (5 kt) dry and wet cornering friction performance variation with yaw angle for the radial-belted and bias-ply 40 x 14 tires operating on the nongrooved concrete, the hexagonal-shaped pavers, and the Uni-Anchorlock paver test surfaces. This bias-ply tire has not been tested yet on the Uni-Anchorlock paver blocks.

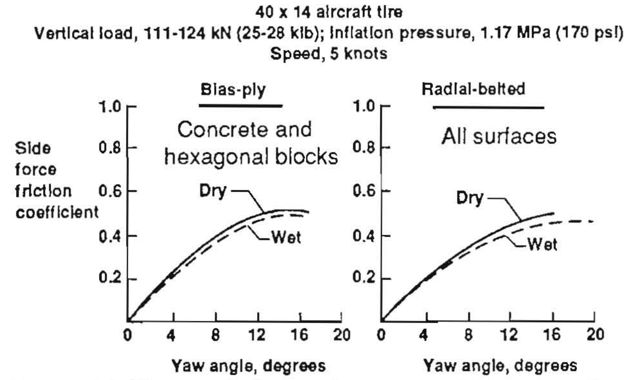


Figure 11. Tire cornering performance with yaw angle.

At this low speed, type of tire, test surface configuration, and wetness condition did not significantly affect the tire cornering friction performance. The radial-belted tire data indicate that peak cornering at this low speed is reached at a higher yaw angle than the bias-ply tire. Additional test runs at the ALDF are planned to confirm these data trends and references 8 and 9 contain other tire friction performance data collected in the START program.

Although these limited tire friction results on the two concrete paver block surfaces evaluated at the ALDF are encouraging, several other factors such as stability, durability, cost, and ease of maintenance must also be considered for concrete paver block installations at airport facilities. Evaluation of other paver block designs is planned for future tests at the ALDF in the START program.

CONCLUDING REMARKS

An overview has been given of the development of concrete paver blocks for initial use on urban streets and subsequent applications at airfield facilities. The selection and installation of two different concrete paver block test surfaces at the Aircraft Landing Dynamics Facility (ALDF) for aircraft tire friction evaluation is discussed and some preliminary test results are reviewed. This effort is identified as part of the Joint NASA/FAA Surface Traction and Radial Tire (START) Program currently scheduled over a three-year period. Future testing in the START program will include different tire sizes and pavement test surfaces to substantiate the preliminary data trends established from completed tests.

Fax from Tom Yager, NASA Oct. 11/94

ALDF TEST RUN MATRIX FOR PAVER BLOCK EVALUATION

40 X 14 ~~Bias-Ply~~ Tire; Infl. Pres., 170 PSI; Vertical Load, 27000 lb
Radial & Test fixture drop position at STA 12 + 60

RUN SEQ.	SPEED, KNOTS	YAW, DEG.	SURFACE CONDITION	ACTUAL RUN NO.	REMARKS
1	160	0	Wet		Radial tire only; Rect. block herringbone & Uni-anchorlock
2		1			" " "
3		2			" " "
4		3			" " "
5		4			" " "
6		6			" " "
7		8			Both tires; bias tire only on 90° rectangular blocks
8		10			Radial tire only; Rect. herringbone & Uni-anchorlock
9		12			" " "
10		14			None
11		16			Radial tire only; Rectangular herringbone & Uni-Anchorlock
12	130	0			" " "
13		1			" " "
14		2			" " "
15		4			" " "
16		8			Both tires; bias tire only on 90° rectangular blocks
17		12			Radial tire only; Rect. herringbone & Uni-anchorlock
18		16			" " "
19	100	0			" " "
20		1			" " "
21		2			" " "
22		4			" " "
23		8			Both tires; bias tire only on 90° rectangular blocks
24		12			Radial tire only; ~~Rect.~~ herringbone & Uni-anchorlock
25		16			" " "

PAVER BLOCK TEST RUN MATRIX - Continued.

RUN SEQ.	SPEED, KNOTS	YAW, DEG.	SURFACE CONDITION	ACTUAL RUN NO.	REMARKS
26	5	0	Wet		Both tires; all three paver block patterns
27		1			Only radial; Rectangular block herringbone and Uni-anchorlock
28		2			Both tires; all three paver block patterns
29		4			" " "
30		8			" " "
31		12			" " "
32		~~12~~ 16			Only radial; Rectangular block herringbone pattern & Uni-anchorlock
33	160	8	Dry		Both tires; bias tire only on 90° rectangular blocks
34	130				" " "
35	100				" " "
36	5				" " "
37	TBD				
38	TBD				
39	TBD				
40	TBD				

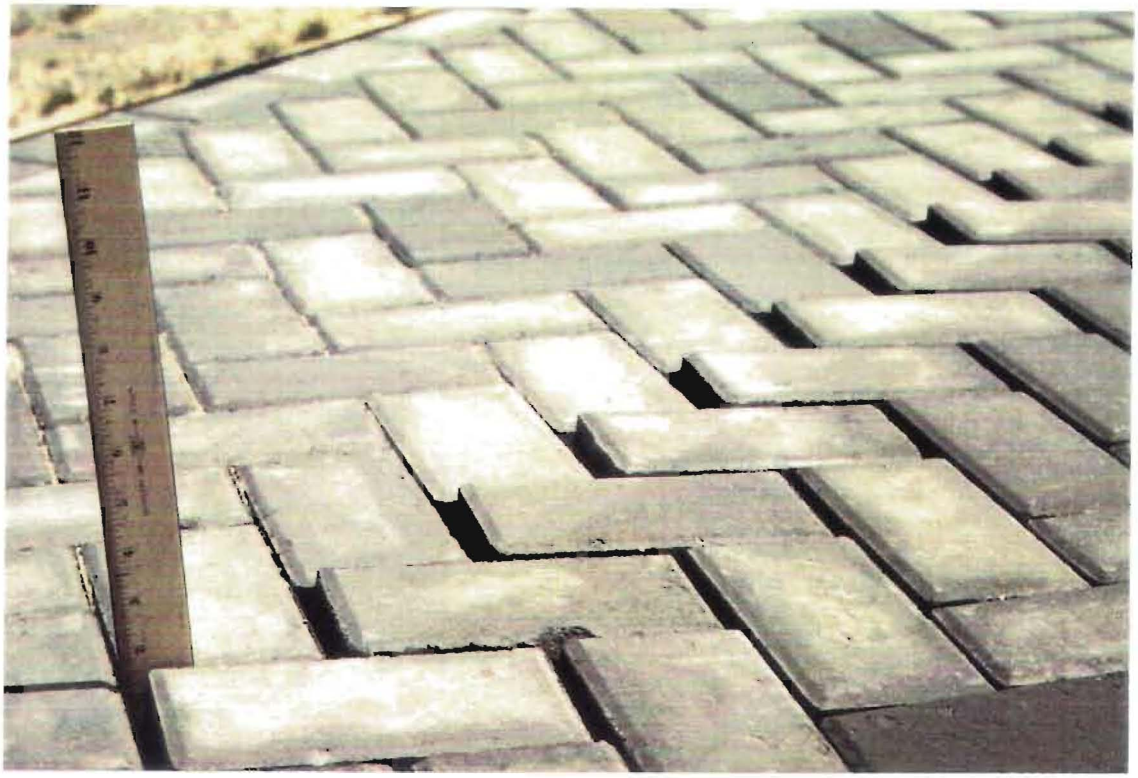
GENERAL NOTES:
- Rectangular blocks in herringbone pattern installed in early March 1994 and placed just ahead of Uni-anchorlock block test section (each 100 ft in length)
- 37 test runs performed with radial tire between March 17 and April 15, 1994
- Significant movement found in rectangular block section with herringbone pattern
- Rectangular block section removed, base sand and sidewall supports refurbished, and blocks re-installed at 90° angles to each other.
- 24 test runs conducted with both radial and bias-ply aircraft tires between July 1-22, 1994
- Movement in rectangular block section due to tire loading is still evident but not as severe as found with herringbone pattern

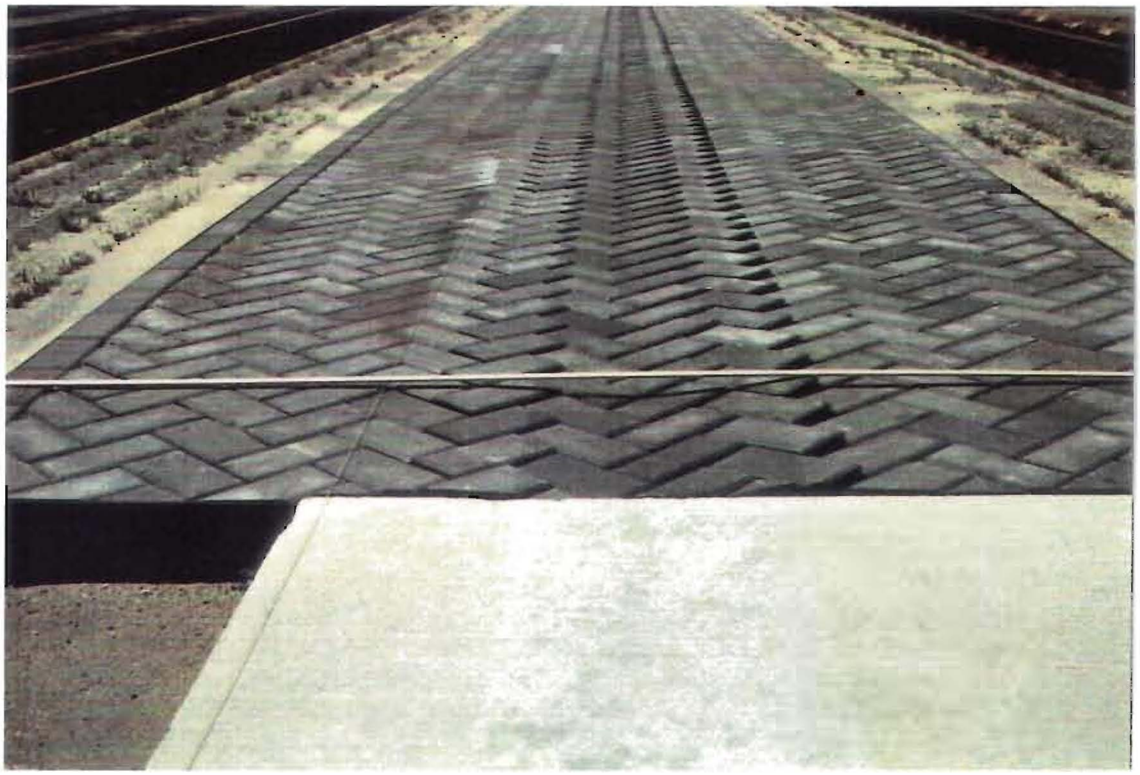
CONCRETE PAVER BLOCK TEST SECTION

NASA Pavement Test Apparatus,
Langley Virginia

Failing Hexagonal Paver

UNI-ANCHORLOCK®
paving stone section,
showing no deformation after
NASA test trial runs,
Spring 94





Rectangular paving stone section,
showing severe deformation after NASA test trial runs,
Spring 94

Renewed Rectangular Paving Stone Section (90⁰ Herringbone Pattern), again showing severe deformation, Summer 94

Please note that the UNI-ANCHORLOCK® Section is the same as in the earlier test!

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94-03146

Langley Research Center
Hampton, Virginia 23665-5225