RECONSTRUCTION OF THE PLATFORM OF THE SIMÓN BOLÍVAR AIR TERMINAL, WITH A CONCRETE BLOCK PAVEMENT, IN SANTA FE DE BOGOTÁ, COLOMBIA

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ABSTRACT

The use of a concrete block pavement for the reconstruction of the platform of the TASBSA (Simón Bolivar Air Terminal) in Santa Fe de Bogotá, Colombia, has proven to be technically and economically feasible, and exhibit singular characteristics for developing economies. This project is also an example of how competitive concrete paving blocks are, due to their low cost and the possibility to accommodate the construction process to the occupancy needs, not to mention the reparability, the stability in the presence of fuels, oil and other related products, and the superb appealing this type of pavement has. Those facts were used by the owners of the Terminal to decide for this type of pavement for the reconstruction.

Although the concrete block paving technology is the same everywhere, this project had some adjustments like: It had to be built in a heavy rainy year (something easier to do with concrete pavers than with any other material); and the possibility to hand-lay the pavers instead of machine-laying due to the small areas to be built at a time, and the low-cost of local labor.

The first rebuilt areas have been in use for more than six moths, and they are performing to the full satisfaction, not only of the owner but or the airlines (the users of the Terminal). As a consequence, new projects of different sizes are being considered to be built in the next years.

1. INTRODUCTION

The Terminal Aéreo Simón Bolívar S.A. - TASBSA (Simón Bolívar Air Terminal), is a private terminal located south of the eastern end of the first landing path of the Eldorado International Airport in Santa Fe de Bogotá, Colombia, with direct access through the northwestern corner of its platform (Photo 1).

The terminal consist of a 105 m x 240 m platform, with a longitudinal cantilever roof along the eastern side, where the repair services are located. Two hangars were built in 1999 in front of this roof, to house, in a better way, the maintenance installations for the second and third Colombian airlines (Aces and Aerorepública), flying form Eldorado Airport.

The platform was built in the early 1980s, and was paved with a asphalt pavement. The pavement deteriorated till 1998 when it exhibited a generalized distress due to:

(1) Fatigue of the asphalt concrete surface (even the loss of the asphalt layer in some places) and damages due to the spillage of fuel and other oil related products from the planes.

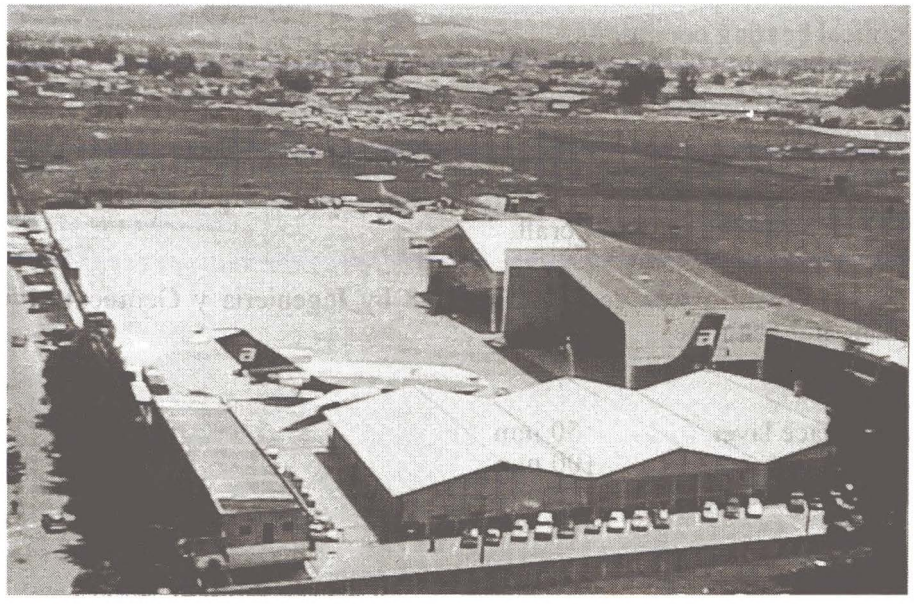

Photo 1. Panoramic view of the TASBSA, recently paved with concrete paving blocks.

(2) The infiltration of rain water due to ponding caused by the irregularities in the surface and the loss of the original slopes due to structural failure of the pavement.
(3) Localized degradation of the base material due to the water ingress and the presence of materials with a high fines content and plasticity.
(4) Possible over-stress of the pavement structure due to the actual applied loads (Boeing B727-100, B727-200, Airbus A320), much higher than the general aviation loads for which the platform was originally designed.



Photo 2. The asphalt concrete pavement in complete distress as it was in 1998.

All those distresses were causing trouble to the airlines and a high risk of aircraft deterioration, despite the efforts and investments made by the Terminal's administration to patch the asphalt concrete with asphalt concrete, cement concrete and, even, placing metal plates to bridge

points with critical bearing conditions.

Contrasting with this generalized situation, the strip of concrete slabs under the cantilever roof was in perfect condition, although it must be acknowledged that they are under a roof, with partial exposure to sun and water (something that is supposed not to affect the concrete pavements), and they are used only by the front wheels of the airplanes, carrying approximately only 5 % of the total weight of the aircraft.

A new pavement structure was designed in 1998 by Ingeniería y Geotecnia Ltda, with two options: asphalt and concrete.

Asphalt pavement:

Asphalt surface layer	50 mm	
Asphalt base	100 mm	
Asphalt open base	90 mm	

Concrete pavement:

Concrete slab	330 mm	(4,5 MPa Flexural Strength)
Sand-modified base (on site)	300 mm	(3% sand)

Those thicknesses show an unbalance in the thickness design of both pavements, since the asphalt pavement would be 240 mm thick and the concrete pavement, just the slab, 300 mm, plus the modification of the existing base. In both cases, the actual pavement structure has to be removed to reach the right foundation level in order, once the pavement is finished, to get to the level of the existing concrete pavement at the eastern side of the platform.

The new asphalt pavement was considered a non-durable solution, due to the fuel and lubricants spillage in a repairs area, and the concrete option was found very expensive (see numeral 5 of this paper).

ICPC proposed the alternative option of a concrete block pavement (with the kind advise of John Emery). It was presented to the General Manager of the Terminal, who proceeded to ask for a complete design to evaluate the concrete paver alternative.

2. EVALUATION AND DESIGN

The concrete block pavement was designed by Ingeocim Ltda. [1] in October 1998, based on the geotechnical survey made for the original designs, and the evaluation of the existing pavement structures. Additional plate load tests (ASTM D 1195 [2]) were performed to obtain the value of the Elasticity Module for the structures, and to correlate such values with the CBR values of the original designs. A 250 mm x 400 mm steel plate was used and a Boeing B727-200 was the reaction structure. The Modules were obtained by back-calculation using the Kenlayer software developed by Professor Yan H. Huang from the University of Kentucky [3], based on finite elements.

2.1 Existing pavement

The first survey by Ingeniería y Geotecnia showed the irregularities in the thickness of the different layers of the existing asphalt pavement, with a surface of 80 mm to 120 mm of asphalt concrete; an advanced degradation due to extensive cracking and the presence of potholes. This surface layer, as told before, had a sort of remedial repairs in different materials (asphalt concrete, hydraulic concrete, soil-cement) (Photo 2).

The base showed even a high plasticity in some places, with high content of fines. The total pavement structure (comprising the surface layer, the granular base and the granular subbase),

had a total thickness from 1 m to 1,8 m. The subgrade was a high-plasticity, soft-to-medium consistency, beige clay, with the water table just 1,2 m below the surface of the platform.

The degradation of original surface was enough to get an adequate perspective of the geotechnical conditions of the existing pavement structure and the subgrade. Perforations were made (nine diggings), six drill perforations and six Yoder's Dinamic Cone Tests (to determine the CBR value). The laboratory tests comprised soil classification, natural humidity, unitary weight, grading, non-drained shear strength with manual probe and laboratory "veleta", compacting and CBR. Table 1 shows the physical characteristics of the existing pavement and the structural characteristics defined after the plate load tests.

Table 1 Structure of the existing pavement, mm.

	Vehicular access, fuels zone	Central platform zone	Northeastern platform zone	Hangars zone	Design value (MPa)
Asphalt Concrete Excessive surface cracking	80 to 120	80 to 120	80 to 120	200	480
Granular base	300 to 450	450 to 800	500	1 600 (poor quality)	378
Granular subbase	150 to 450	700 to 1 000	400		206
Total thickness	1 000	1 500 to 1 800	1 000 to 1 200	1 800	
Subgrade	Cracked silt (500)	Medium-dark beige clay, medium to firm consistency, high plasticity	Cracked hard silt, high plasticity (500)		58
	Dark beige clay, medium consistency		Dark beige clay, medium consistency		

The calculated modulus showed the high degree of deterioration of the existing asphalt concrete, and the acceptable quality of the base and subbase layers to be taken into account for the new structure.

2.2 Design of the new pavement

The new pavement was designed with the Federal Aviation Administration design method, modified by Knapton and Emery [4], and verified with the Kenlayer software [3]. The design plane was found to be the Boeing B727-200, with the characteristics listed in Table 2.

Table 2 Characteristics of the design plane (B727-200)

TOTAL WEIGHT	78 471 kg
REAR AXLE LOAD	92,4 %
TIRES IN THE REAR AXLE	4 (two pairs)
TIRE LOAD IN THE REAR AXLE	18 126 kg
TIRE PRESSURE	1,5 MPa
CONTACT AREA PER TIRE	154 900 mm^2
DIAMETER OF THE CONTACT AREA	444 mm
TIRE SEPARATION	860 mm

For a year traffic of 1 200 planes, the thickness of the new pavement was found to be 1 m:

Concrete paving blocs	80 mm
Sand layer	30 mm
Base (Soil-cement (CBM3))	280 mm
Subbase (Granular (Type 2))	610 mm

The base material Type CBM3 (Cement Bonded Material Type 3) corresponds to a granular material stabilized with cement (soil-cement), with an average 7 days compressive strength of 10 N/mm^2. The subbase material, Granular Type 2, is a granular material with a minimum CBR value of 20 %, similar to the existing base and subbase material in the platform. Both are denominations by the Department of Transport of the United Kingdom [5]). The existing material was assumed as the subbase, and the soil-cement of the base was designed in the laboratory, with an 11 % cement content, and a thickness of 280 mm, using this same material.

The drainage was a critical topic since the platform is very shallow (only 0,7 % slope down to the west), and there were restrictions imposed by the existing slabs (east side) and the drainage channels (west side). The lower confining curbs were provided with draining holes for the sand layer. A grid of vertical drains were built through the soil-cement base, with a 5 m separation in both directions, and a diameter of 25 mm. They were made nailing a steel pipe in the base course and pulling-it-out after cutting the whole thickness. Then it was filled with the same sand of the sand layer, with no protection on top since the sand had no way to escape to the very closed under-layers.

3. CONSTRUCTION

It was found competitive to produce the soil-cement on site. With a Caterpilar RR-250 road reclaimer soil stabilizer, the 100 mm of the existing asphalt layer was removed and ground, together with enough base material to complete the 280 mm of compacted soil-cement base. The cement was added on site, in 50 kg bags (Photo 3). The bags were opened and emptied, immediately before the first pass of the soil stabilizer equipment. Once the soil was mixed with the cement, an earth leveler was used to get a more even surface before starting the compacting using a roller compactor. An asphalt slurry was used to seal the soil-cement for curing.

The construction was made in one-year's time (Jan. 1999-Jan. 2000). It was relatively simple since there was no need to remove any material from the job site, and no new material was required in order to replace the base or subbase structures. The concrete block surface was built following the standard methods described in ICPC's publications [6,7]. A total of 18.562 m^2 of rectangular, 200 mm x 100 mm x 80 mm pavers were laid by hand, with a labor output of 30 m^2/day-men, due to the need to build a series of strips to maintain the full operation.



Photo 3. Cement bags distributed on the removed and mixed surface and base material.



Photo 4. Concrete pavers being hand-laid in herringbone pattern.

The pavers were laid in herringbone pattern, aligned with the main axis of the platform (Photo 4). They were specified and provided with 2 mm spacers and a chamfer of, approximately 6 mm in both vertical and horizontal projections. All the adjustments were disc-sawed and the finished surface was plate compacted. Once the pavement was completed with the sand into the joints, it was proof-rolled to get a more even surface. After each zone was completed, it was inspected for local depressions and cracked pavers (approximately 1/1000) and the required repairs were made. Some sand was left on top of the joints, between the chamfers, to allow it to continue migrating into the joint. Since 1999 was a rainy year, the application of a sealer was postponed till the end of the project and when the pavement could drain. There has been no problem with dust blowing that could damage the parked planes.

The quality control of the project followed a tight schedule of tests, both for the materials and construction procedures. Concrete paving blocks were produced and tested according to the Colombian Standard, NTC 2017 Concrete Pavers, requiring a flexural strength of 5 MPa average strength for a sample of 5 units out of lots of 10.000 units, and very tight dimensional tolerances (there is no freeze-and-thaw condition in Colombia). Compression and deformation tests were made on the soil-cement base material, from samples during construction and from cores taken from the hardened and cured base, plus the regular density and humidity tests.

One thing that was observed during construction was that since the rectangular platform was built in a kind of spiral or circle (to allow permanent use of it), when the construction front came back to the starting point, the pavers were larger than the original ones, due to the fact that the producer had one mold and it wore-off during the process. Although the last units had dimensions according to the standard tolerances (as in any other standard), the contractor preferred to have a straight cut in the boundary of the previous zone and the new one, instead to try to accommodate to the adjoin herringbone pattern with wider joints (Photo 5).

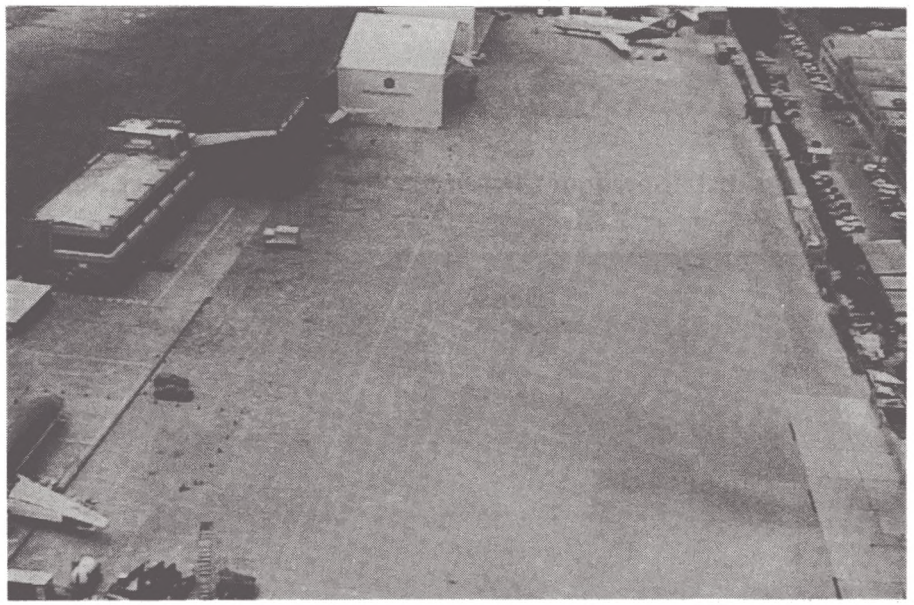

Photo 5. General view of the platform with slight indications of the construction phases.

4. INSTRUMENTATION

In order to evaluate the behavior of the first zone to be built (providing access from the landing path to the platform), two pressure cells and four strain gauges (vibratory string) were set just beneath the soil-cement base layer. Two stations have one pressure cell and one strain-gauge at the same level. The other two stations have one strain-gauge. The pressure cells were installed in a sand bed and the strain-gauges directly in contact with the soil-cement. For the transmission of the loads a Boeing 727-200 was used, with a tire pressure of 1,5 MPa.

The maximum vertical stress measured was 0,06 MPa, and the maximum strain was $0{,}7 \times 10^{-6}$. The Kenlayer finite element method was used for the analysis of the obtained measurements. By means of a back-analysis, using those stress and strains results, an Elasticity Module was stated for the soil-cement material. In this calculation, the assumed modules were 3 100 MPa for the concrete block layer, 207 MPa for the base and 59 MPa for the subbase. The values for the base and subbase were obtained by correlating the values of the measured CBRs and

plate bearing tests obtained during the evaluation of the existing pavement.

Figure 1 shows the horizontal tensile strain at the base of the soil-cement base (fibers of maximum tensile stress) vs. the elasticity module of the soil-cement course. It can be observed that as the module increases, the horizontal strain diminishes (what is obvious) but what is more important it that the measured strains agree with the highest modules, almost the values of hydraulic concrete of higher strength.

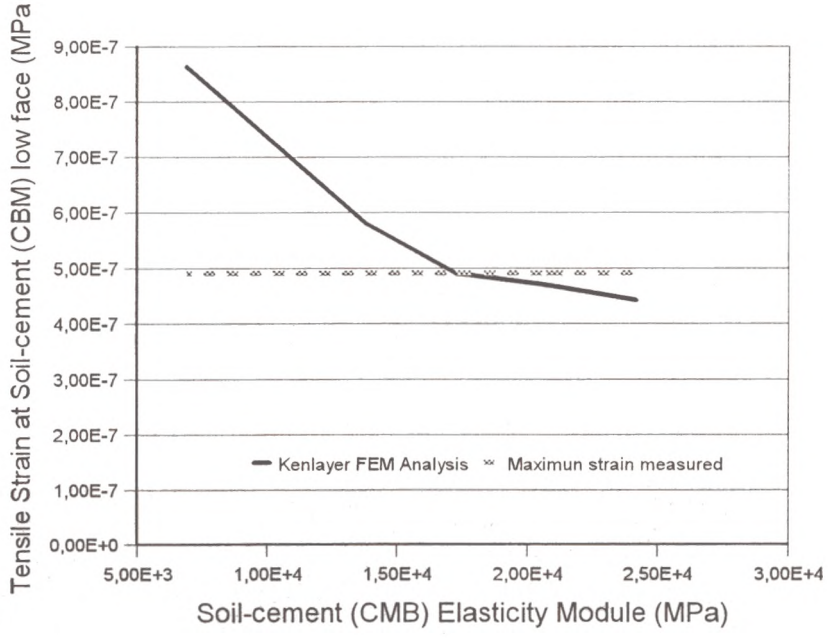

Figure 1. Soil-cement Elasticity Module vs. Tensile Strain at the low face of the base.

On the other hand, Figure 2 shows the vertical stress at the interface between the soil-cement layer and the subbase layer. The vertical stress measured with the cell agrees with the analysis made with Kenlayer for a module of elasticity of 13 812 MPa for the soil-cement layer. This module is in the range obtained with laboratory cylinder specimens tested under compression. The module assumed for the design was 6 906 MPa, so the pavement had an adequate an successful behavior

5. COSTS

Cost is, most of the times, the final factor for the decision on the type of pavement to be used in one project. The final construction cost of the pavement was US$ 46,3/m^2. It did not included the costs of the first and final designs, the geotechnical exploration and the administrative costs (directly assumed by the administration of the Terminal), but includes the costs of supervision. It does not include the sealer, a job that is postponed for later 2000 or whenever the finances of the Terminal recover from the recession the country has been for several years. There is no costs for base or subbase, since they were already on site, just for the stabilization with cement (66 kg/m^2). Cement cost is US$ 144/t; concrete pavers cost US$ 6,4/m^2, and labor (minimum wage) is US$ 1/h.

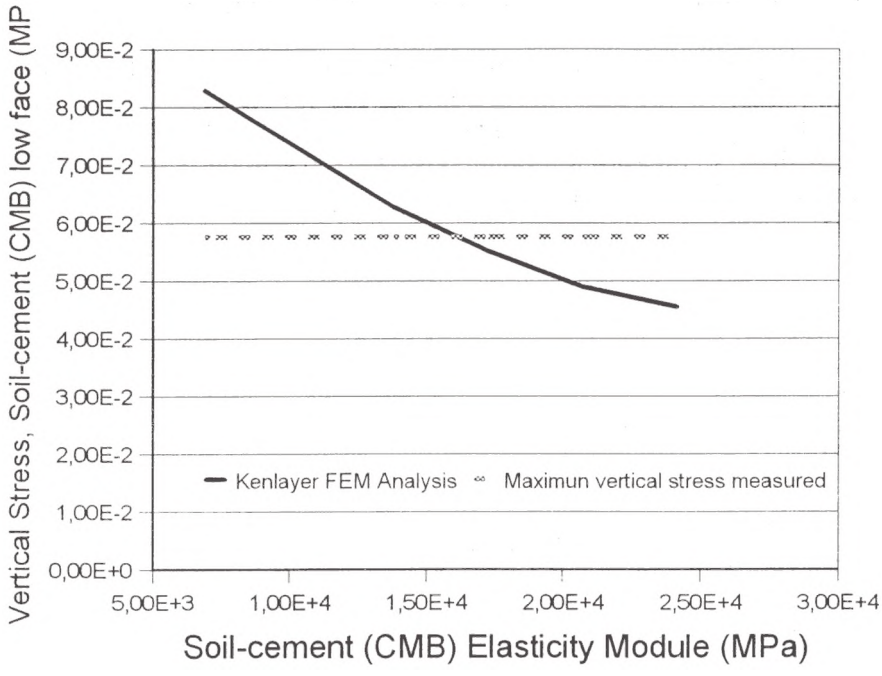

Figure 2. Soil-cement Elasticity Module vs. Vertical Stress at the low face of the base.

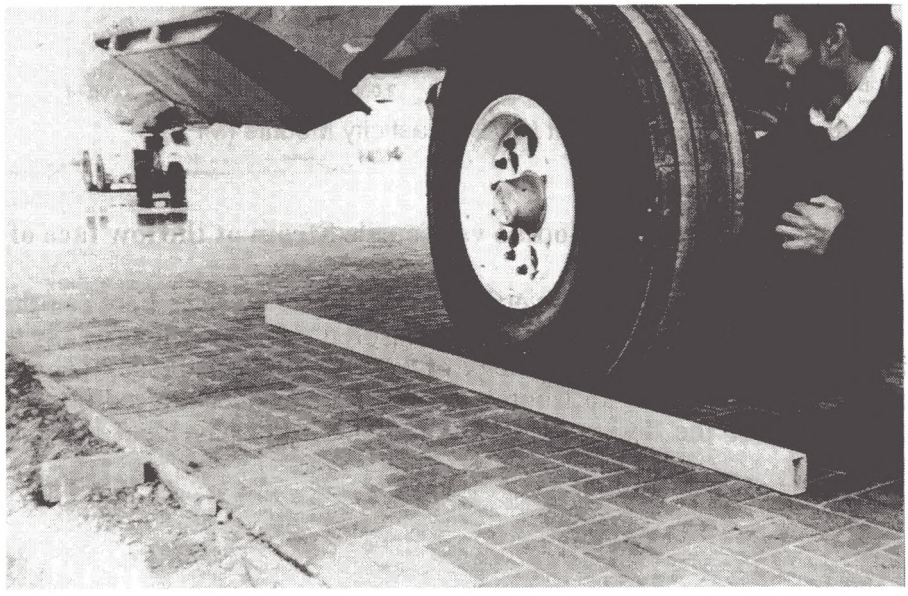

Photo 6. Surface level verification during the load tests.

A rough cost comparisons show that, considering just the main materials and equivalent activities, and based on the up-mentioned thickness designs, the concrete paver structure costs near US$ 20, the asphalt structure costs US$ 25 and the concrete structure costs US$ 50. As it was mentioned before, the concrete paver pavement final construction cost was US$ 46,3. So it can be seen how concrete pavers are not only technically feasible but economically competitive, even against very slim asphalt alternatives.