Problematic of geotechnical performance of the Mexico City international airport runways, built on ancient Texcoco Lake

Problématique du comportement géotechnique des pistes de l'aéroport international de la Ville de Mexico, construites sur l'ancien Lac de Texcoco

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SYNOPSIS The performance of the Mexico City International Airport runways has set up peculiar problems, as a consequence of the particularly difficult conditions of the subsoil. This paper is a short review of a new structural section, which is believed that fits best to the peculiar site geotechnical conditions, and in that way it is pretended to solve in a substantial amount the problems involved in assuring stable runways built on highly compressible lacustrine deposits, and the rehabilitation of runways already constructed. The runways design is based on criteria from a runway instrumented section and with foundation material testing. The aim was to obtain a correlation between theory and reality.

INTRODUCTION

The subsoil in which the Mexico City International Airport is localized has specially difficult conditions, because it was built on the ancient Texcoco Lake bed. Serious problems have arised with the runways and apron maintenance. These problems are mainly originated as a consequence of the lacustrine deposits high compressibility down to depths close to 60 m.

Figure 1 presents the typical soil profile of the area. It shows variation with depth of properties such as: water content, shear resistance on triaxial undrained tests, and static cone tests, as well as the effective and preconsolidation pressures.

In this regard it can pointed out that shear resistance of upper layers reach typical values in the order of 1.5 ton/m2 (15 kPa). The average value of the volumetric compressibility coefficient is in the order of 0.008 and 0.025 m2/ton, (8.1,25.1 m2/kN) in recompression and virgin branches, respectively. In this respect, it is believed that notwithstanding the high compressibility of the lacustrine deposits, they have been deposited "quasi preconsolidated". If this is so, the above mentioned pecularity might be of particular interest, since it is possible to take advantage of it, in order to minimize settlements, by just taking care of not going beyond the critical or "quasi preconsolidation" pressures. In the past, because of disregarding this peculiarity, the built runways experienced quite important differential settlements, requiring periodical applications of asphalt leveling courses.

Those layers were a temporary correction of transversal grades, but the weight of the new layers triggers a consolidation process in a practically never ending way, so that at the present time the thickness of the asphalt layers already reaches about 1.5 m, the overlay frequency in the order of about 2 years, with the consequent economical and operational headaches.

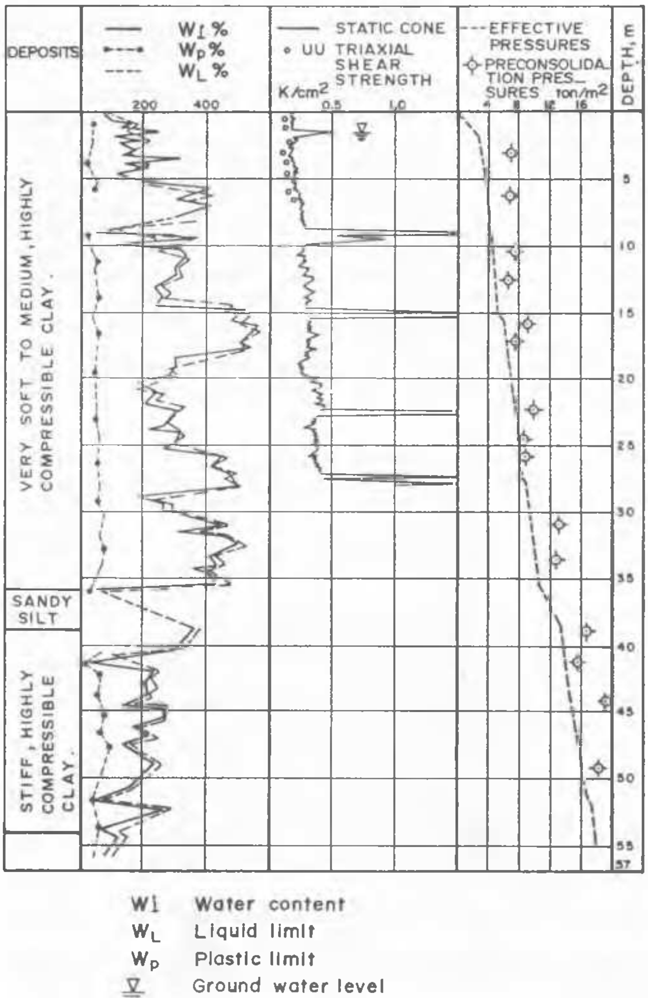

Fig. 1 Profile and Some Properties of the Subsoil.

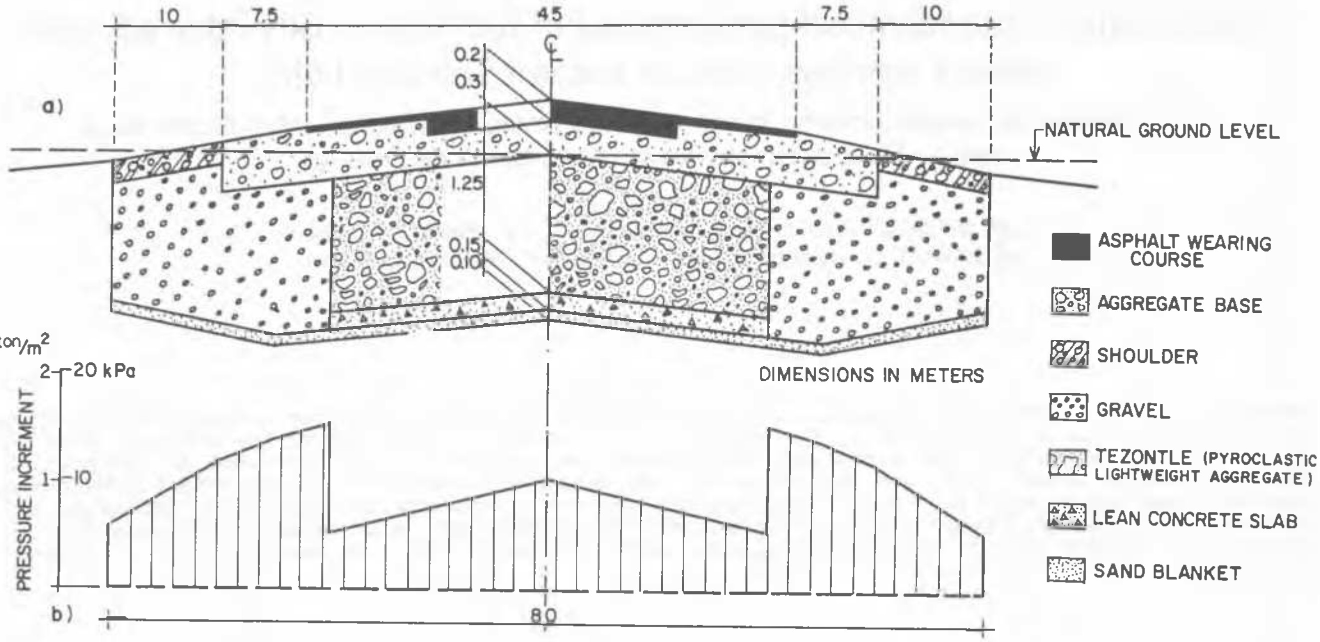

Fig.2 Structural Pavement Section
a) Typical section
b) Distribution of pressure increment

In order to solve the above mentioned problem, - in 1959 a new structural section for the pavement was designed for a 300 m runway extension (Aguirre et al. 1967), based on the principle of substitution of masses, in an effort to reduce as much as possible foundation soil pressure increments induced by the pavement weight. The design embodies lightweight rock materials, to be lay down in a trench. In view of the satisfactory performance observed, it was decided in 1980, to take advantage of the improved runway section design just mentioned, when a new airport in the same area was planned. The design was somewhat improved with geometric and structural features, as shown in fig.2.

Because of the airport importance, which requires runways as much as possible free of abnormal performance, the decision was made to built a 200 m long experimental section in the area, using the same design and materials, as shown in fig. 2(a).

This paper intends to describe the criteria used in designing the runway cross section, shown in fig 2. plus the performance and observations made during almost four years of instrumentation and soil mechanics testing. It comments also the application of the same design criteria in the rehabilitation of old runways under use, in order to solve successfully, as it is believed by the authors, the problem of endless differential settlements and maintenance jobs, as occur in such unfavorable soils as those found in the old Texcoco Lake bed, already mentioned early in this paper.

DESIGN

There are two basic conditions to be met in the design:

1.- The structure should be able to support the imposed loads for the design aircraft (Boeing 747), and to distribute the stresses to the subsoil in an adequate way, keeping in mind the very low shear resistance of it.

2.- The total and differential settlements induced by the pavement weight, shall be kept below certain limiting values, to secure satisfactory pavement's performance and a reduced frequency and cost of maintenance, as has been happening so far in this project.

The first basic condition was taken care off as follows:

a) By measurements of pressures in the test section at the pavement-soil interface, induced by the design aircraft load.

b) Determination of the stress distribution at various depths, by means of the elasticity theory.

c) Estimate of subsoil shear strength at various depths, based on UU triaxial tests on undisturbed samples.

d) Comparison of design load shear values with subsoil shear strength values, at the various depths.

The second condition compliance is the real design problem, due to the high deformability of Mexico City clay, as depicted by fig. 1 data. One adopted measure was the inclusion of a natural light-weight volcanic gravel (tezontle) in the pavement, as shown in fig. 2(a) although was not enough. It is necessary to do something else.

During the design of another foundation problem in Mexico City clay, the authors used with reasonable success an expedient procedure consisting in applying a surcharge dead load adjacent to the structure.

Therefore, the same idea was incorporated in the runway pavement design. The intended purpose is not to avoid pavement settlements, but prevent differential settlements. The mechanics of interaction between pavement, lateral adjacent surcharges and subsoil, are simple and not mentioned here.

Using a trial procedure the width of the lateral surcharges was determined, in order to get differential settlements between pavement's center and edges, less that a limit value of 0.1 m. Natural gravel, 7.5 cm maximun size, of conventional weight, was used for those lateral surcharges. The above limit value of 0.1 m, is necessary to prevent larger settlements at the pavement center than in the edges.

For this condition the total calculated settlement for the section middle point was 0.52 m. This value was obtained from the standard consolidation test, keeping each pressure increment under laboratory conditions, with the usual 24 hr. intervals.

PERFORMANCE

In general the performance of the structure agrees with was expected in the design. The observed settlements tend to be uniform, as shown in fig. 3. The detailed analysis of the differential settlements between center and edges of the pavement, on 18 half sections observed, point out that in 13 of them, differential settlements are below the maximun value established of 10 cm, and in the remaining five cases the differential settlements exceeded that value as much as 50%. It has to be mentioned that only in two of those last five cases, settlements in the edges were less than at the center; in the other three the opposite happened. In the authors' jugdment this is explained in terms of the heterogeneity of materials and variation of construction procedures.

Figure 4 shows the evolution of vertical movements in a typical observation point, located at the middle of one central strip. It can be observed that the measurement of elastic heave at the time of digging yields 5.5 cm. This figure is a little less than the theoretical value of 7 cm. In the same figure it can be also observed that the subsequent heave has slow evolution, and its effect practically ends with the first load increment.

Figure 5 shows the evolution of settlements on central and edge points produced by the pavement weight on a typical section, during a lapse from June 1980 to December 1983. It can be seen that settlement in the central point reached 48 cm, very close to the long range total estimated value of 52 cm. In order to predict future settlements, use was made of a theory proposed by Juárez-Badillo (Juárez, 1985) from which the following equation is obtained to be applied in the present case.

$$\frac{70}{s} = 1 + \frac{900}{t} \qquad (1)$$

in which:

t = elapsed time, in days

s = resulting average settlement in the section, in cm

As it can be seen in fig. 5 the above mentioned calculated total settlement of 0.52 m, would occur after 2000 days, approximately, according to eq. 1, and if 10,000 days are considered the settlement may reach a value of 0.65 m, exceeding in 30% the originally calculated value. This difference might be due to the quite large secondary consolidation effect, characteristic of Mexico City clay, underlying the Airport project.

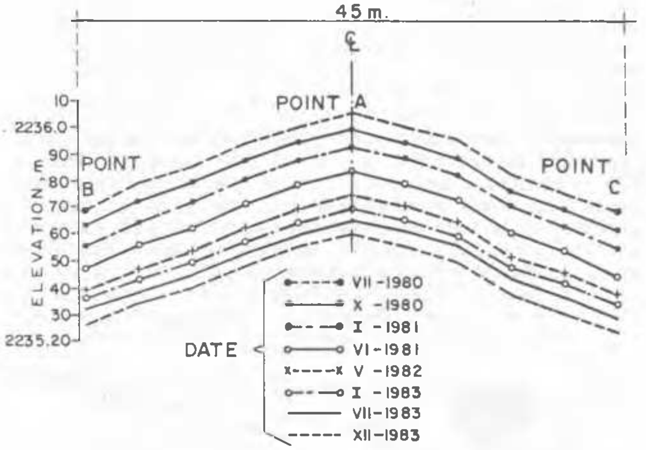

Fig. 3 Settlement Observations in Typical Cross Section

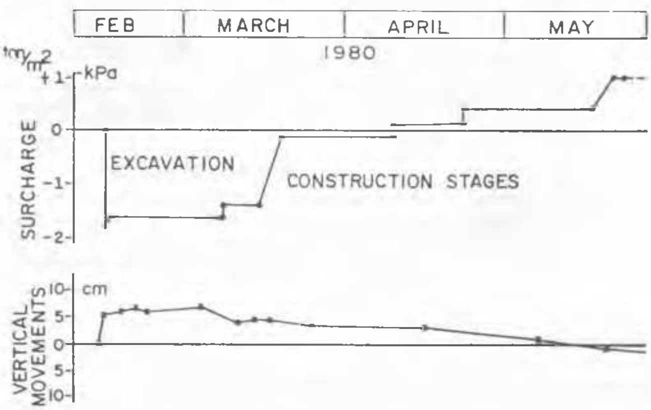

Fig. 4 Vertical Movements during Construction Stages

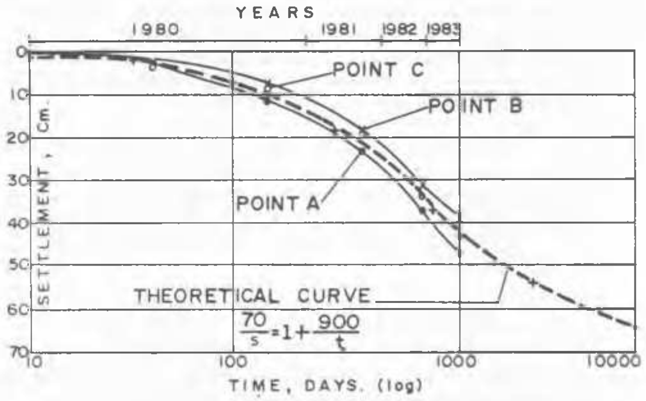

Fig. 5 Settlement Evolution and Theoretical Prediction

In regard to the distribution of stresses due to the charges imposed by the design aircraft and because of the complexity of the stratified materials system, that is involved in the pavement structure, it was decided to calculate that distribution with two limit cases. The first was considering a Boussinesq distribution, without establishing elastic differences within the pavement and the subsoil. The second one was a two-layer system (Burmister criterion) with pavement deformation modulus 100 times larger than the subsoil one. On the other hand, vertical stresses transmitted by the design aircraft landing gear were measured. It should be noted that pressure cells, four in total, were installed and observed, between the various pavement layers and at the pavement foundation interface; they showed the stress distribution resulting of both methods. The stresses measured in the concrete slab-soil interface were insignificant, as a consequence of the efficient materials distribution effect of the pavement layered system, particulary the slab concrete at the bottom (See Fig. 6).

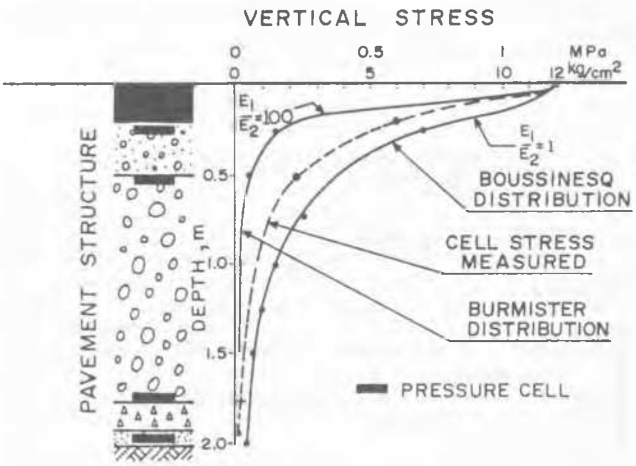

Fig. 6 Stress Distribution under B-747 Aircraft.

CONCLUSIONS

1.- The main conclusion that araises from the experimental section, is the confirmation that the investigated pavement structural section for new runways, in the Mexico City International Airport, represents an interesting way to solve the problem derived from the very difficult geotechnical conditions, when apparently another feasible alternative does not exist.

2.- As a colateral conclusion, construction procedures, as well as selection and handling of materials, deserve careful attention, in order to reduce, as much as possible, differences between real and predicted settlements.

3.- Attemps to predict settlement evolution from existing theories, did not yield successful results, due to the complexity of the problem, and the difficulty to define hydraulic boundary conditions, plus very peculiar performance of Mexico City clay, in which the secondary consolidation plays a main role; this phonomenon has not been investigated enough so far. It is hoped that the settlement evolution, measured in this project, will help in the future to verify the new theories that may araise to solve settlement problems, as the one mentioned herein

4.- Finally, it is convenient to comment that as a consequence of the lessons learned along the work described in this paper, one way to solve the rehabilitation of the pavement of the existing runways of Mexico City International Airport was obtained, and at the same time, it is hoped to solve the maintenance problem. This procedure is based on the same principle mentioned above. Fig. 7 shows the layout of it.

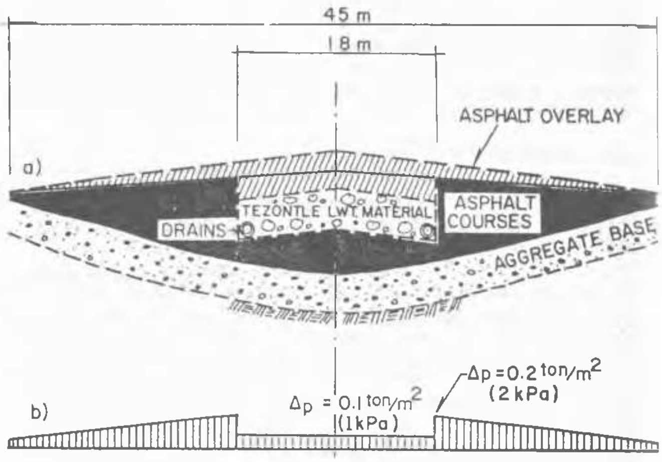

Fig.7 a) Typical section for rehabilitation of old runway by substitution of asphalt courses by lightweight materials and resurfacing
b) Surcharges diagram

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