PERFORMANCE OF 26 AND 20 YEARS OLD PRESTRESSED CONCRETE PAVEMENTS AT ALGIERS HOUARI BOUMEDIENE AIRPORT

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Prestress concrete runways and taxiway were built in Algiers Airport in 1954 and 1960. They were prestressed longitudinally by hydraulic flat jacks and transversally by tendons ; sliding abutments exist at each end. The first year's measurement findings are described as follows:a joint and end displacements, climatic conditions, friction coefficient, and stresses in the slab.
After 26 years, the primary runway with often more than 50,000 movements per year (equivalent to a total traffic of 12,000 B 747), had some transverse cracks and three very localized failures due to poor concrete batches ; during 20 years of life the secondary runway presented a settlement due to peat deposits, and an upheaval of joints. Detailed non destructive pavement testing results, theoretical study of the residual life (by American and French methods), and the existence of tested rehabilitation procedures, lead to the following life expectancies under the forecast of very heavy traffic :
- A few months for the secondary runway because of its low transverse prestress design value (therefore a thick overlay is foreseen) ;
- Roughly ten years for the primary runway (only a thin overlay is foreseen in 1985).
Based on this experience, general and particular conclusions are proposed on prestress concrete airport pavements.

Analyzing the behaviour of a particular pavement a long time after its construction is often interesting from a scientific and technical point of view : the designers' assumptions can be verified and the findings drawn from this study are a source of knowledge.

Prestressed concrete pavements caused enthusiasm among the pioneers of this technique in the 50s and 60s, then were almost completely disregarded for a long time in many countries. A renewed interest for this type of construction was recently demonstrated by the appearance of several prestressed concrete pavement sections of highway in the United States and the conclusions of the Brazilian paper dealing with prestressed concrete airport pavements at the Purdue Conference in 1977. The prestressed concrete pavement of the Houari Boumediene Airport in Algiers, formerly known as "Maison Blanche", are of a special interest which this paper intends to show :

1. Firstly, design and construction characteristics are given for the 26 year old primary runway and its parallel taxiway, and for the 20 year old secondary runway.
2. Secondly, the principal results of a detailed study made by Mr. Block during the first years of service of the primary runway are presented.
3. Next, the background being known, an overall appraisal of the service life of these pavements is made, considering the traffic supported and their present condition.
4. In order to take advantage of learning from this experience for the future, analyses of the observed local conditions of distress are gathered and linked to the design assumptions and constructions records.
5. Lastly residual pavement life evaluation enables the suitability of the initial procedures to be judged.

I - Pavements and Materials Description

A - Pavements

Prestressed concrete pavements have been used in the Algiers Houari Boumediene Airport since 1955 and 1961 (2,3,8,9)

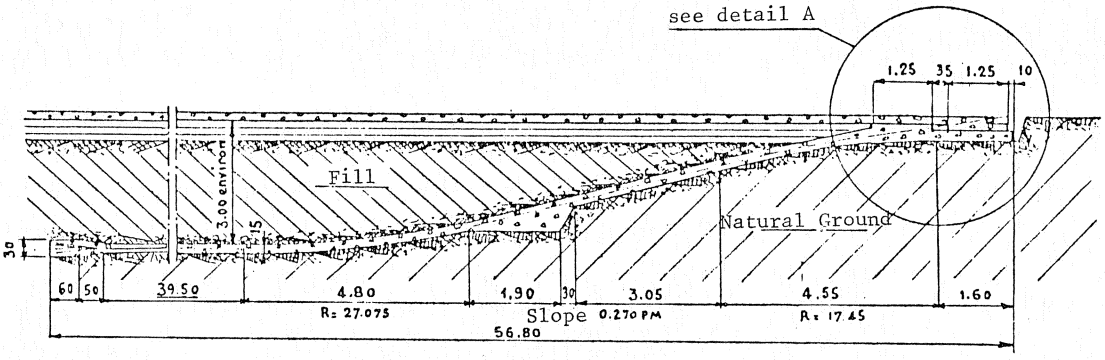
1. The prestressed concrete pavement section of the primary runway was built in 1954. Designed for 135 metric tons (298 kips) gross aircraft load, it is 2,430 m (7,972 ft) long and 60 m (197 ft) wide. The pavement consists of a 180 mm (7 ins) thick concrete slab, prestressed both longitudinally by hydraulic flat jacks and transversally by tendons. A design minimum prestress of 1.8 N/mm2 (261 psi) in both directions permits a load of 100 metric tons (220 kips) to be applied on the pavement by a 750 mm (30 ins) diameter plate. A layer of kraft paper and a 30 mm (1 1/4 ins) thick friction - reducing sand layer are placed between the slab and a 300 mm (12 ins) thick untreated granular base (figure 7) and Freysinnet's designed sliding abutments consisting

of 57 m (187 ft) long concrete sheets, are buried down to 3 m (10 ft) under the runway ;in these sheets cables can freely glide in their sheaths (figure 1). Four systems of hydraulic flat jacks, installed in each transverse joint (every 300 m in the centre part, every 150 m near the ends), permitted periodical readjustment of the amount of longitudinal prestress until 1971, thus compensating the loss due to concrete creep (figure 2).

2. A taxiway, parallel to the main runway, was also built in 1954 with the same prestressing characteristics. It is 2,050 m (6,726 ft) long and 25 m (82 ft) wide.

3. A secondary runway, 2,350 m (7,710 ft) long and 45 m (148 ft) wide, was built in 1960-1961 using similar techniques. However, the concrete slab thickness was reduced to 160 mm (6 1/4 ins) and the design minimum amount of transverse prestress to 1N/mm2 (145 psi). A special device of flat jacks in the transverse joints permits readjustment of the amount of longitudinal prestress any number of times (figure 3).

Figure 1. Longitudinal section of the abutments.



Detail A.

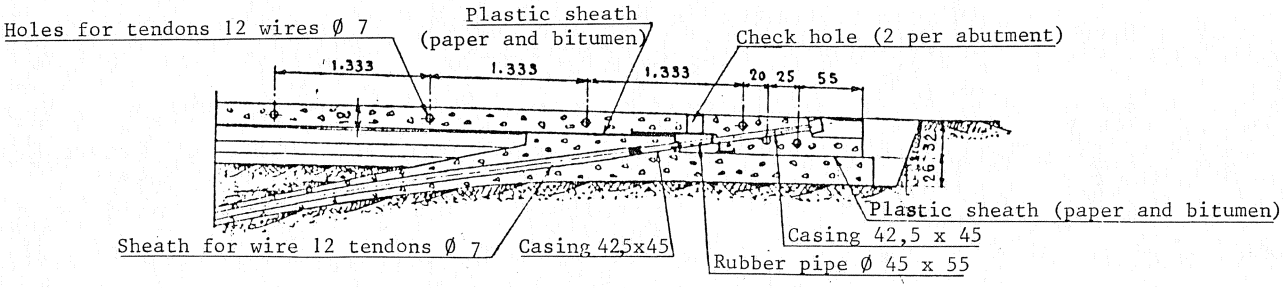
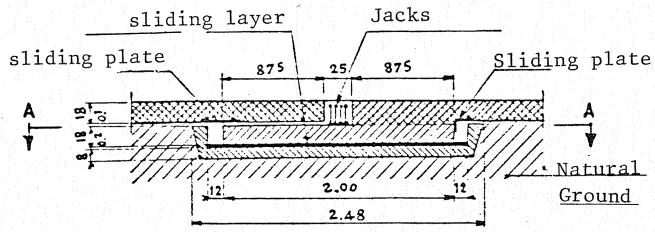


Figure 2. Primary runway active joints
Notice that in order to prevent rotations and differential vertical displacements, reinforced joint sleepers 8" thick bounded to the pavement alternately on each side of the joint, have been built to form two "fitting-in-each-other combs"

Longitudinal section



Section AA

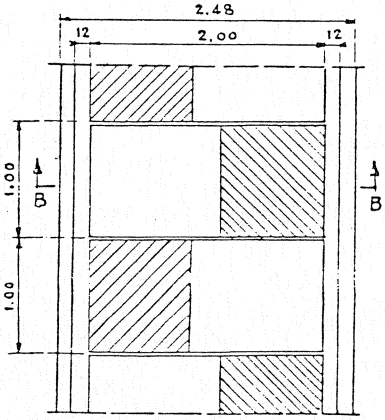
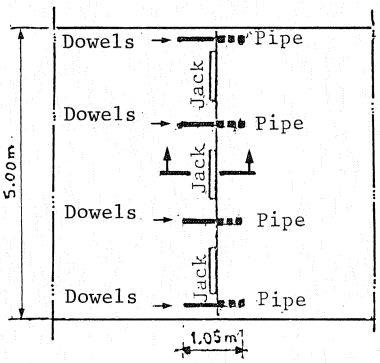
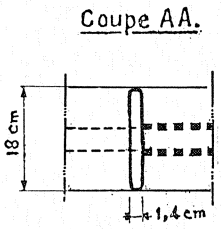
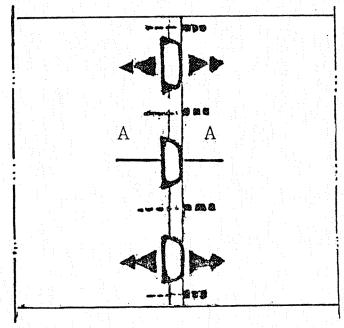


Figure 3 - Secondary runway active joints for periodic re-prestressing

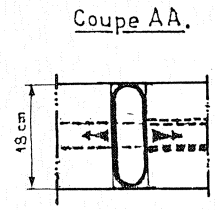




Before Stressing

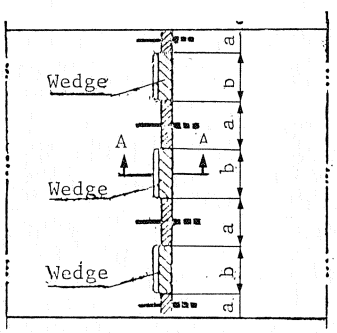


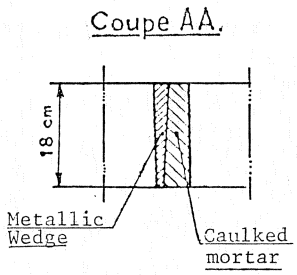
Phase II - Jacks stressing



After first stressing

Phase I - Joints equipments and construction.





Phase III - Locking of the joint

B - Materials

a) Soils. The subgrade consists of alluvial clay (CH in the Unified Soils Classification System). A design CBR value of 7 and a foundation modulus (k value) of 4.5 kg/cm3 (163 pci) were initially selected.

The soil swelling pressure was evaluated to several hundred grams per sq.cm. (about 10 psi) ; water table was not deep and varies.

b) Prestress concrete.

1. The ratio between the quantities of water and cement (0.40), the use of calcareous aggregates (0/40 mm in 3 fractions), a good mix design and a thorough vibration enabled the following values to be obtained :

	at 28 days	After 20 years
Compressive strength N/mm2 (psi)	42 (6000 psi)	56 (8000 psi)
Flexural strength N/mm2 (psi)	7(1000 psi)	8(1160 psi)

2. The high percentage of calcareous aggregates (1800 kg/m3) induced an average dilatation coefficient for the concrete equal to

$$5.3 \times 10^{-6}\ °C^{-1}\ (2.9 \times 10^{-6}\ /°F) \qquad (1)$$

which is a great advantage for prestressed concrete, and in particular in the case of a longitudinal external prestress. This limited the hygrothermic effects and the longitudinal compressive stress (maximum design value at mid-slab) was 8.8 N/mm2 (1,280 psi) at 50°C (122°F).

3. To avoid transverse cracks due to shrinkage during construction, each slab was submitted to a temporary prestress every 100 m (328 ft), using flat jacks inflated during cold hours and deflated during hot hours. This system also improved the flexural strength of the concrete.

4. Steel for transverse prestress (8): This steel had an elastic nominal resistance of 1,180 N/mm2 (171000 psi). In order to ensure the minimum transverse prestress of 1.8 N/mm2 regardless of the hygrothermic conditions, an initial maximum tension of 1.180 N/mm2 was applied to the tendons (12Ø7 mm (0.28 in) for the primary runway, 12Ø5.3 mm (0.21 in) for the secondary runway). The tendons were placed every 1.33 m (4.36 ft) ; it can be noted that this spacing is large compared to the usual spacing of 3 to 6 times the slab thickness.

5. To account for the total effect of delayed strains and hygrothermic variations, the following value was retained :

$$\lambda \cdot Eb = +\ 4.91\ N/mm2\ (712\ psi) \qquad (2)$$

C - General Indications

Generally speaking, the engineers who supervised the project consider that the primary runway was built under excellent conditions, considering the safety factors in the design and the careful construction procedures.

II - First year's measurement findings (1)

A - Experimented devices

Between 1954 and 1957, 46 extensometers and 19 temperature records were used and the displacements of each side of the 4 abutments were measured. From 1957 on, the total longitudinal stress (using the hydraulic flat jacks in the taxiway), the temperature (atmosphere, slab surface and at depths of 4.4 cm (1.76 in), 9.4 cm (3.76 ins.) and 16.4 cm (6.56 ins.) and the displacement of one end of the pavement to the abutment were recorded. In 1958, an important report (unpublished) compiled the results and provided mathematical interpretations. Only a few synthetic results are presented hereafter.

B - Displacements measurements results

a) Measurements of longitudinal strain near the abutments indicated the following points :

1. The longitudinal stress remained around 6.38 N/mm^2 (925 psi), the "elastic" nature of the abutment being taken into consideration (see figure 1).

2. Creep of the concrete was important (the "modulus" varied from 44,000 N/mm2 (6,400,000 psi) during the first prestressing operation, to 12,000 N/mm2 (1,778,000 psi), 26 months later).

3. The displacement of the pavement ends is small (about 0.2 mm/°C).

b) Measurements of longitudinal strain near the center of the runway indicated the following :

1. More than 150 m (492 ft) from the abutments and roughly one month after the prestressing operations, the concrete shows no significant strain.

2. During a prestressing operation, keeping a pressure in the flat jacks during several days (e.g. 3.92 N/mm2 (550 psi)) until a given displacement is reached (e.g. 11.8 mm (0.46 in) for a distance of 300 m (984 ft) between 2 consecutive systems of jacks) facilitates obtaining a longitudinal stress (e.g. 3.92 N/mm2 (550 psi)) in a more reliable way than applying a high pressure (5.90 N/mm2 (813 psi) for example) during a short time.

3. Uneven stresses may occur : A difference of 1.47 N/mm2 (213 psi) was noticed during several months between 2 jacks distant apart 150 m (492 ft).

4. The abutments do not compensate for concrete creep at the middle of the runway.

5. Mathematical developments and several experimental results enabled the determination of the stress conditions and the distance, from the free end, where the friction coefficient can be considered as constant for delayed phenomena (the value of this coefficient is close to 1 for the conditions prevailing in Algiers).

C - Results of temperature measurements

The data given below are due to the climate in Algiers and the concrete characteristics. They are of great importance in the good behaviour of the prestressed concrete facilities in the airport.

a) Measured temperatures

Table 1. Measured temperatures

	Winter	Spring	Summer
Mean air temperature	10°C	15°C	25°C
Mean slab temperature	5°C	20°C	30°C
Maximum frequent difference between top and bottom of slab	7°C	10°C	15°C

Records of extreme temperature indicated the following :

1. In Summer at the slab surface : 55°C at 2 p.m. and 20°C at midnight, with an average slab temperature up to 35°C and a difference of temperature up to 35°C and a difference of temperature between the top and the bottom of the slab of 20°C.

2. In Winter, the slab temperature drops down to 0°C and the slab temperature sometimes remained constant and homogeneous for 24 hours ; generally speaking, variations of temperature are minimal in Winter (this is not the case in a continental climate).

b) Heat transfer within the slab

From the following equation :

$$\text{Surface temperature} = t_0 \sin 2\pi \frac{\tau}{T} \qquad (3)$$

(24 hours cycle)

Temperature (at depth z) =

$$t_0\, e^{-\alpha (h-z)} \sin\left[2\frac{\tau}{T} - \alpha (h-z)\right] \qquad (4)$$

(origin at mid-slab ; slab thickness = 2 h), it was possible to explain the measurements, and the following values were derived :

α (absorbtion coefficient) = 5.75

Hence :

$$\frac{C}{K} = \frac{\text{Specific heat}}{\text{Thermal conductivity}} = 100$$

(units : Calory, metric ton, meter, hour).

A low specific heat and a high thermal conductivity therefore produced, the other parameters being otherwise constant, a delay and a reduction of temperature transmission and consequently temperature gradients smaller than those usually cited in the litterature.

D - Results of direct stress measurements

Two graphs can summarize the results (figures 4&5).

The following remarks can be made about these measurements :

1. The value of $\frac{\lambda Eb}{1-\mu}$ varies between 0.084 $N/mm^2/°C$ for seasonal variations to 0.35 $N/mm^2/°C$ for daily variations in summer.

2. With the climate of Algiers, low amounts of longitudinal prestress are as likely (or more likely) to occur during a cold night of a hot summer period than during a continuously cold winter.

3. The stress at the top of the slab varies between 0 and 11.8 N/mm2 (1,707 psi) and the difference of strain between top and bottom can reach 6.9 N/mm2 (996 psi) in summer.

4. The average stresses vary between a low of 1.77 N/mm2 (256 psi) in winter almost constant throughout the year, and a high of 7.85N/mm2 (1,138 psi) in summer.

III - Appraisal of the pavement's behaviour during 26 years

A - Distresses

a) Linear cracks. Since the construction, almost no longitudinal cracks have appeared. On the other hand, transverse cracks appeared as years passed, about which several remarks can be made :

1. They are usually narrow.

2. It has not been proved yet that they go through the entire slab thickness.

3. Some of them run across the total runway width, whereas some affect only 1,2, or 3 longitudinal lanes of construction.

4. Very few transverse cracks can be found near the abutments (100 to 200 m (300 to 600 ft) from them),

Figure 4. Stress/temperature diagram in the slab (1)

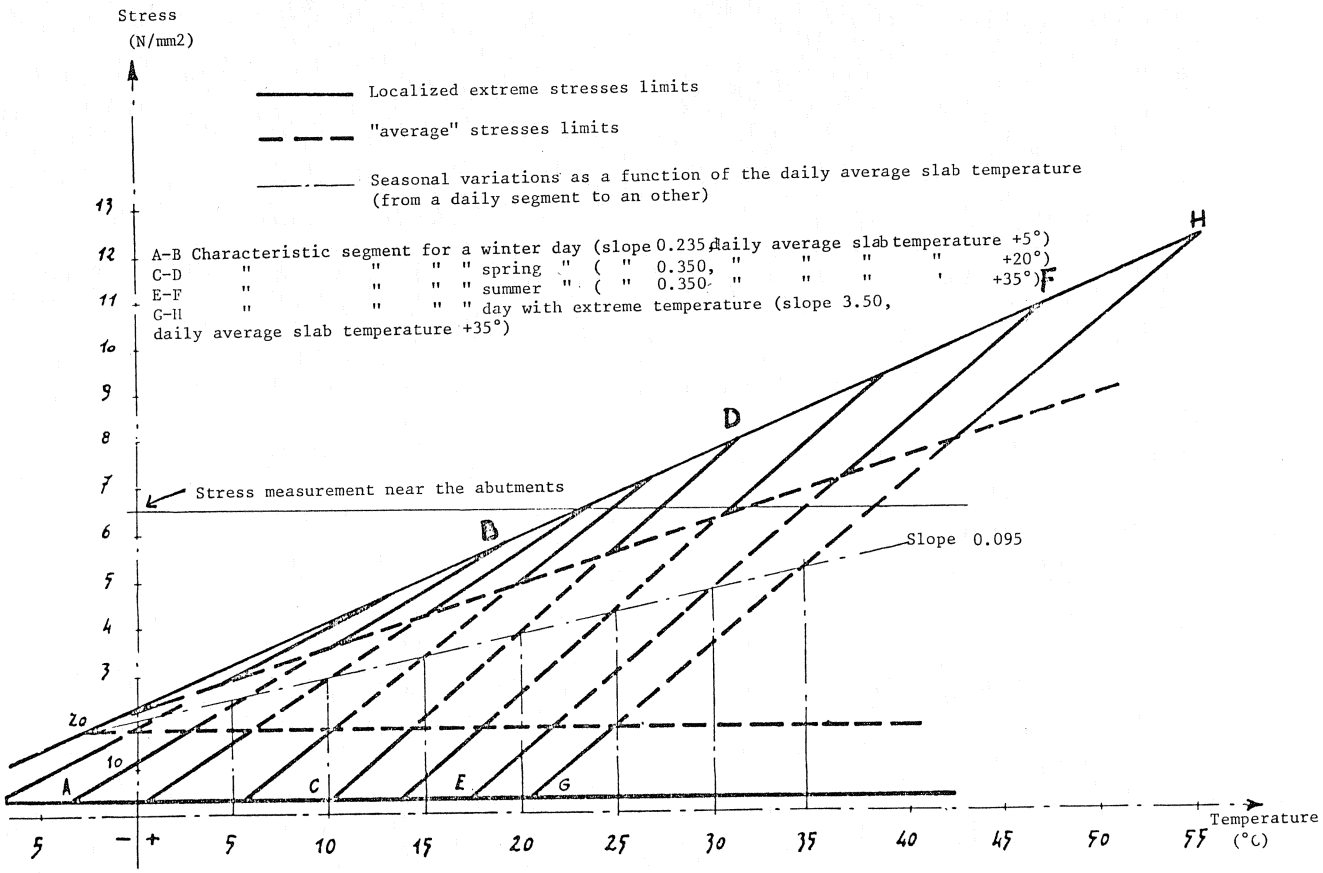
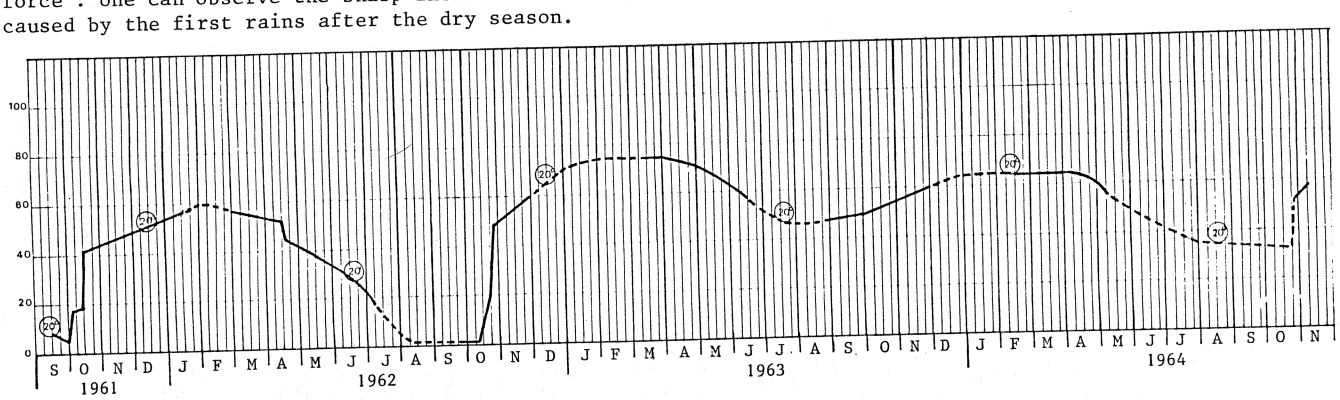


Figure 5. Seasonal variations of the longitudinal prestressing force : one can observe the sharp increase in stress because of the concrete expansion caused by the first rains after the dry season.



5. The highest frequency of cracks are localized either on the outer slabs (see explanation in chapter IV) or in certain cross sections,

6. The cracks usually follow the prestressing tendons.

b) Localized defects (5)

1. In 1970, a circular defect appeared on the primary runway, 10 cm (4 ins) in diameter, near the wheel path on one central lane of construction. This defect became more significant under the influence of the traffic, and a repair was attempted when it covered 1 m2 (11 sq.ft.). However, this did not prevent the defect from spreading and in 1980, its oval shape was 5 m (16 ft) long in the transverse direction and 3.5 m (11 ft) wide in the longitudinal direction.

2. In a similar manner, a second localized defect developed from a transverse crack in the center part of the primary runway. In 1980 it was 3m x 2.5 m (9.8 ft x 8 ft) in extent, and showed a 3 cm (1.2 ins) settlement (repaired with epoxy resin).

3. On an outer lane of construction of the primary runway, a third localized defect developed recently, showing a slight upheaval and a few star-shaped small cracks (about 1 m2 (11 sq.ft.)) giving the idea of buckling, but with no apparent tendency to extension.

c) Upheaval of joints on the secondary runway

The problem caused by an upheaval of the joints containing the hydraulic flat jacks on the secondary runway appeared during the first prestressing operation in 1961. The description and evolution of this phenomenon were dealt with in subsequent reports. Briefly summarized, the following occurred :

1. Upheaval of the joints in April 1961 during the prestressing operations (4 to 5 mm average and up to 12 mm). By lowering the jacks by 1 cm, the joints came back to their proper place.

2. The pilots complained about a bad rideability and subsequent measurements showed a new upheaval, particularly at these joints. During a period of three months in the fall of 1963, this upheaval seems to have doubled and reached 28 mm at these joints. A first smoothing operation was made in 1963 by grinding off up to 10 mm.

3. After new complaints by the pilots, a second grinding operation was made in 1967. Up to 20 mm were taken off ; this was possible because at the joints the slab was built 20 mm thicker.

Several explanations were proposed :
-Combined result of strains due to hygrothermic effects,
- Uneven pressures by the subgrade.

d) Settlement due to the crossing of an old river bed

The secondary runway crosses an old river bed 150 m (492 ft) wide containing peat and muck deposits. In 1960, a solution was adopted consisting of rising the longitudinal profile of the runway (up to 25 cm (10 ins.) at the highest point) within aircraft operation tolerances. Since then, a settlement more important than foreseen occured and it was necessary to apply a levelling overlay to a localized area. This was done by a bonded concrete overlay. This overlay now shows cracks, but the underlying prestressed slab seems to remain in fair condition. However, risks of buckling are too important now for a new longitudinal prestressing operation without repair of this area.

B - Analysis of the total past traffic (6)

a) Design loads at the time of construction. The primary runway and its parallel taxiway were designed in April 1953, based upon full-scale tests made at Orly. From these tests, it was concluded that a concrete slab, prestressed in both directions could carry, without cracking, loads up to 140 tons, applied through a 1 m diameter plate (i.e. a pressure of 1.8 N/mm2), the compressive strength of the concrete being 45 N/mm2 at 90 days, the amount of prestress in both directions being 2.0 N/mm2. The "k" modulus of the subgrade where these tests were made was 4.5 kg/cm3, and after a few repetitions of the load, the resilient deformation was considered stable and satisfactory (less than 10 mm). In Algiers, the characteristics were considered equivalent, with a similar subgrade : concrete slab thickness 18 cm, amount of prestress in both directions 1.8 N/mm2. The runway was considered suitable for 135 to145 tons gross aircraft, with a safety factor of 2.5 for the design load of 56 tons applied with a 1.8 N/mm2 (256 psi) tire pressure.

The secondary runway was designed in January 1960, for single wheel loads of 37.5 tons with a tire pressure of 1.4 N/mm2 (199 psi). The concrete slab is 16 cm (3.6 ins) thick, with a longitudinal amount of prestress of 1.8 N/mm2 (256 psi) and a lateral amount of prestress of 1.0 N/mm2 (142 psi) minimum values. The test made in Orly were once more the basis of the design, this time backed up by a theoretical evaluation. The safety factor was estimated to be 2.55 for the above design load.

b) Since the pavements were designed and built, both traffic and aircraft gross weight increased dramatically.

1. The archives of the airport enabled to trace back the past traffic evolution in terms of total number of movements, commercial movements and, to some extent, aircraft type. The total number of movements of B747 equivament to the past traffic was evaluated, at first approximation at 12,000.

2. The annual total number of movements was often higher than 50,000 movements.

C - Provisory conclusion

The comparison between the total past traffic and the design traffic shows that even with a considerable increase in the past traffic level, the overall pavement condition is satisfactory.

This conclusion is more suitable for the primary runway and its parallel taxiway, the two pavement sections which are older and which carried most of the traffic.

IV - Causes of distresses and conclusions for the future

The distress types described above were analysed in order to determine their principal causes.

A - Determination of the causes

Figure 6. Number of cracks totally crossing one construction lane of the main runway or the taxiway (10)

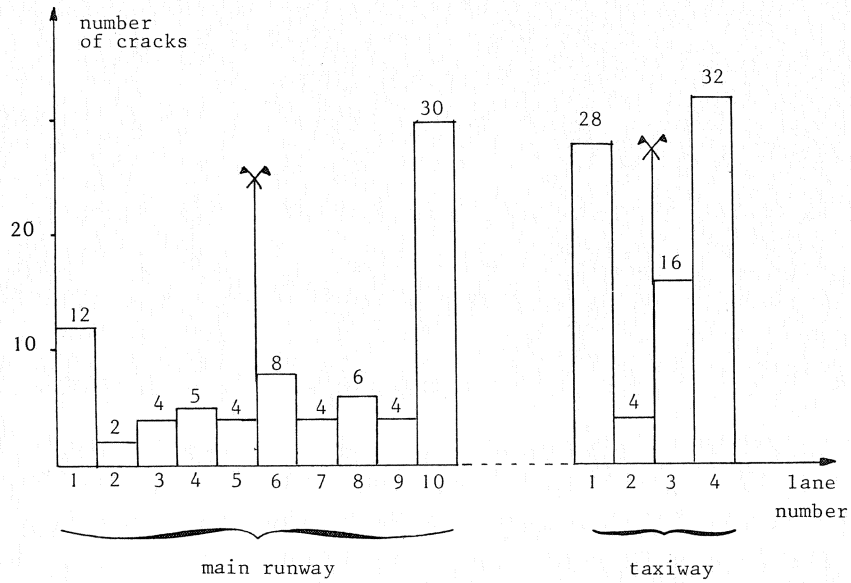


Figure 7. View of the pavement layers at the site of a major defect.

very sound concrete on the top .....

sheath of the transversal prestressing

too dry concrete insufficiently ..... compacted

siliceous sea sand .....

layers always found very sound in the borings:

- water bound macadam layer .....
- draining layer .....
- formation hardening layer .....

a) Transverse cracks. The transverse cracks affecting both runways and the taxiway are without doubt to be associated with a certain loss of longitudinal prestress. Unfortunately, it was not possible to ascertain the date of the appearance of these cracks in order to determine whether this loss occured in winter before a prestressing operation or during cold summer nights (see paragraph II.D). The higher number of transverse cracks across the outer lanes of construction (see figure 6) tends to show that a differential heave of the clay subgrade, due to seasonal variation of moisture content, is probably more important than a possible influence of the traffic.

b) Localized failures. The following conclusion have been reached after breaking the concrete and repairing these failures.

The main cause of the failures is most probably an important but very localized deficiency of the quality of the concrete at the bottom of the slab ; this is shown on figure 7.

c) Miscellaneous. Four borings performed near the tendons in the sound parts of the taxiway showed that the cement used for injection was lacking. However the tendons were not corroded, even though some water was present.

B - Learnings for the future

Even though the transverse cracks had no bad immediate results, this should be avoided, especially because of seeping water. From the example given by the areas near the abutments, where a sufficient amount of longitudinal prestress seems to remain, and where few cracks appeared, it can be concluded that a periodic prestressing operation can avoid the cracks regardless of the subgrade and traffic influence.

Regarding the localized failures :

1. It must be noted that even with sound concrete thicknesses reduced to 10 cm(4ins) in areas covering several square meters, the slab did not fail during 16 to 20 years even in the wheel paths.

2. In a similar manner, a slab with only 2 cm (0.8 ins) to 6 cm (2.4 ins) of sound concrete on the top in an area covering 1 to 2 sq. meters presented no buckling until 25 years after the construction, while the stress at the surface can reach 12 N/mm2 (1707 psi).

3. On the other hand, this shows that a prestressed concrete pavement must be realized with utmost care in order to avoid localized failures : the three areas which gave some concern correspond to three very bad concrete batches out of more than 10,000.

The description of a few localized distresses and the analysis of their causes should not leave the impression that the pavements are in a bad condition : for the pilots and the engineers, their overall condition is good to very good, after 20 and 26 years of service.

V - Evaluation of the remaining life under the forecast traffic

Forecasting is an art, and a difficult one. In order to evaluate the probable remaining life of the prestressed concrete pavements, 3 types of approach were used : a thorough pavement testing, a theoretical approach and a study of the repair procedures.

A - Pavement testing

Pavement testing was made using a Pavement Profiler, a non-destructive vibratory device (11) measuring deflections under dynamic loads. Routine tests at fixed loads (between 3,000 and 6,000 lbs) and frequency (between 10 and 60 Hz) were made througout the pavements at regular intervals. From these tests, plans showing contour lines of areas with equal maximum deflections were prepared. Special tests were also made with varying load intensities and frequencies. Several models can be used to interprete the results. With the usual elastic models, it is possible to determine the parameters used in the evaluation of the remaining life of the pavements. Other methods are under study, especially adapted to prestressed concrete pavements. These parameters are primarily the radius of relative stiffness and the design flexural strength of the concrete derived from the measurements of slab rigidities. A preliminary analysis indicates substantial variations of these parameters even within a same infrastructure. Design ranges of values are estimated as :

- flexural strength between 4.1 and 5.3 N/mm2 (580 to 750 psi).
- radius of relative stiffness between 44 and 66 cm (17 to 26 in.).

Average deflections of the prestressed concrete pavements are, not surprisingly, 50% or more higher than on conventionnal rigid pavements submitted to the same load. The deflection survey indicates in particular higher deflections near the border of construction lanes and points out a significantly better behaviour of the older pavements (18 cm thick main R/W and T/W) as compared to the more recent pavement (16 cm thick secondary R/W).

B - Results of a theoretical evaluation of the remaining life under the forecast traffic

The behaviour of prestressed concrete slabs under loads and a mathematical approach to determine the stresses and the bearing capacity were studied by Cot & Becker in 1956 and by Sale, Hutchinson & Carlton between 1961 and 1974. Based upon these results, a design procedure was published in 1974 by E. Odom & P. Carlton, sponsored by the FAA. Their work was used for the pavements evaluation in Algiers.

Under some assumptions, the first one being that the longitudinal amount of prestress is reestablished, it was possible to determine the allowable number of load repetitions for a given load. Taking the example of a Boeing 747, and taking the longitudinal prestress amount as a decisive factor, this number was estimated at 27,000 and the same number was evaluated to be 18,000 when the transversal amount of prestress, less 10%, is considered. A similar evaluation being made for various aircraft types, an equivalency between the movements of various aircrafts can be established. By cumulating the effects presently using the runways, and under certain estimates of traffic growth, an estimate of the residual life was reached (see table 2.).

The past cumulated traffic, as previously seen results in a reduction of the useful remaining life of 3 to 5 years. This would result, for the primary runway, if it is considered that during the works on the secondary runway, it will carry the total traffic in the estimation that it will be able to carry the traffic, from 1985 to 1989. On the other hand, it appears that the secondary runway requires a prompt rehabilitation in order to carry the forecast traffic.

A theoretical approach was made, based upon the works by MMs. Cot & Becker, as presented in 1956 in

a paper entitled "Design of prestressed concrete pavements". The details are not given here, but it can be noted that with the same initial assumptions similar results were obtained.

Table 2. Pavement residual life

Facility	Primary runway		Secondary R/W	
Traffic growth hypothesis	5%	10%	5%	10%
Longitudinal prestress critical 1.8 N/mm2 (256 psi)	16 years	13 years	2 years	2 years
Transversal prestress critical 1.6 N/mm2 (228 psi) Primary R/W 9 kg/cm2 (128 psi) Secondary R/W	12 years	10 years	5 months	5 months

C - Rehabilitation procedures

The potential appearance of new localized failures made the design of a careful repair procedure for the existing failures mandatory. If the repair had not been successful, it would have been necessary to decide on a prompt overlay.

Even though it is not possible now to judge the period of time during which the repairs will last (these repairs were made in May 1980), their excellent present behaviour is encouraging, especially considering the difficult conditions of the design (existing prestress in both directions) and the realisation (very short time allowed during which the runway could be closed). The repair was made as indicated on figure 8.

Among the points to which a particular attention was paid, one can note :

1. The repair was made during a cold period, as far as possible (even though the month of May is already late).
2. The same materials as in the initial construction were used, in order to avoid a difference in the coefficient of the thermal expansion.
3. Thermal and hydraulic shrinkages of the concrete were minimized.
4. A light reinforcement of the slab was provided to prevent the concrete from breaking if cracks appear.
5. Horizontal displacement of the slab was allowed by a sand layer.
6. Strict control of the works was enforced, particularly to decide the extent of the concrete to be replaced.

D - Final evaluation of the lasting ability of the pavements.

The above considerations permit to conclude, with all the due precautions, and provided the last verifications confirm the results, that :

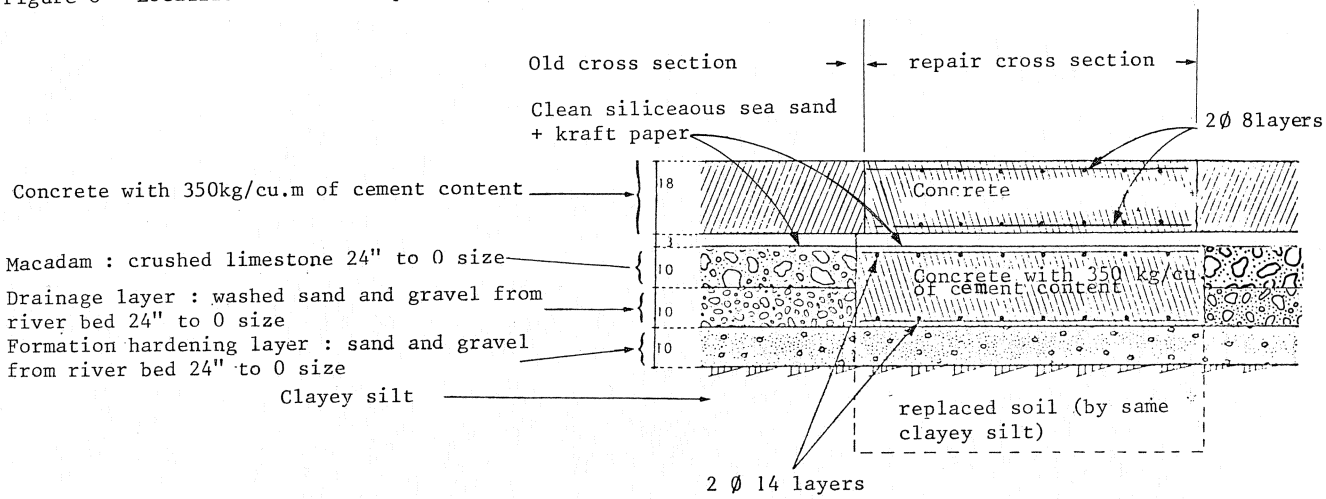
1. The primary runway without reinforcement would most probably have a total service life of over 35 years, under a heavy international traffic,
2. The secondary runway will need rehabilitation prior to being submitted to a regular use by wide body aircraft.

VI - Conclusions

A - Overall opinion on prestressed concrete techniques for airport pavements and necessary conditions.

1. An excellent long lasting smoothness of a prestressed concrete pavement is an important quality

Figure 8 - Localized failures repair design



rightly appreciated by the pilots. This is possible to obtain, as the primary runway in Algiers shows. The example of the secondary runway points out two conditions : a good prediction of the soil deformations, and the design and construction of very rigid joints (see IA figure 2 for example).

2. Prestressed concrete techniques require very careful realization. The few localized failures on the primary runway shows that :
- a very strict control of the concrete must be enforced,
- a satisfactory safety factor can be obtained with an overall quality of design and construction.

3. In the design of prestressed concrete pavements, safety factors must be adapted to the uncertainty in which the parameters describing the future loads are known. Between the primary runway and the secondary runway, the reduction of the slab thickness from 18 cm (7 ins) to 16 cm (6.3 ins) and the reduction of the amount of transverse prestress from 1.8 N/mm2 (256 psi) to 1.0 N/mm2 (142 psi) are among the principal reasons which make a difference between the residual life of the two runways. The designers of the main runway in 1954 have probably rightly appreciated the safety factors considering uncertainty in the behaviour of the runways and the traffic evolution. However, this evaluation depends on the standard life taken into consideration.

B - Opinion about the technical solutions used in Algiers Airport

1. The longitudinal external prestress seems, after 26 years of experience, to be a good choice for the pavements in Algiers : the use of calcareous materials with a very low coefficient of thermal expansion, the climate in Algiers (few rapid variations of temperature in winter, dry climate in summer and rains in winter), and an overall good quality of construction, permitted, up to now, to avoid the dangerous buckling observed on other pavements, despite an underestimate of the long term concrete creep which will perhaps require an unforeseen represtressing operation.

2. The system of transverse prestress by tendons, before actual testing is done, also seems to be a good choice, considering the good condition of the pavements.

3. The abutments have fulfilled their functions in a very good way up to now. The system consisting of buried abutments supporting traction efforts has a good behaviour ; it would only be a problem in case of necessary testing or repair. The elastic type of these abutments was efficient ; question remains as to know whether fixed abutments would not have been sufficient as they are cheaper to build.

4. Providing some joints in which the prestress force can be measured is very useful. This should be a systematic device for prestressed concrete airport pavements.

C - Further studies needed

Several fields of interest for further studies can be defined in view of the experiments in Algiers :

1. Research on maintenance procedure for structural localized repair of prestressed pavements seems necessary today.

2. Testing of prestressed concrete runways requires :
- adapting the usual methods,
- developing a simple method to measure the prestress amount and principal directions in a given point,
- developing non-destrutive means of testing the state of corrosion of the tendons.

3. The ultimate need to rehabilitate prestressed concrete pavements requires :
- to develop design procedures allowing for the best use of the remaining prestress characteristics of the existing pavements,
- a study of the hot bituminous overlay is necessary to avoid a localized abnormal rise of temperature which could cause a buckling of the prestressed concrete structure.

4. Generally speaking, the good results of the use of external prestress in Algiers suggests that :
- a maximum value of the coefficient of thermal expansion of the aggregate should be defined which would avoid the risks of buckling.
- a quantitative description of the climates suitable for the use of external prestress should be done.

D - Description of the work schedule

With the above consideration dealing with prestressed concrete infrastructures, the following works are contemplated to make their life longer.

a) Waterproofing the shoulders. Waterproofing the shoulders with a bituminous coat, in order to reduce even stop the differential movements under the edges of pavements.

b) Prestressed structures. For the prestressed structures themselves, and due to the exploitation contingencies, the following schedule is foreseen :

1. An operation permitting to readjust the amount of longitudinal prestress on the primary runway, so that it can carry the total traffic while the works are made on the secondary runway.

2. Under very heavy aircrafts, the estimated remaining life of the secondary runway is short, according to the theoretical approach, and this even with a reestablished longitudinal prestress. Moreover, the important settlement due to the old river bed leads to retain the solution of an important bituminous overlay the design of which will take into account the residual prestress.

c) Remaining life of the primary runway. The probable remaining life of the primary runway under very heavy aircrafts estimated on the basis of two methods (US Corps of Engineers or MMs. Cot & Becker) is roughly ten years. However, for safety reasons, a light overlay of about 12 cm of bituminous concrete is programmed for the year 1985. This decision was based on the following points :

1. Existing transversal lateral cracks were not taken into account in the calculations.

2. Risk of accelerated corrosion under tension of the tendons with the presence of water in the sheaths of the transversal tendons.

3. High sensitivity of the bearing capacity of the soil with a localized increase of its water content.

4. Clear will to preserve the integrity of the prestressed structure which gave proof of excellent qualities in the past and can last longer if it is perfectly waterproofed.

5. Accessory useful purpose for placing a center-line lighting system.

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