CONTINUOUS NONDESTRUCTIVE EVALUATION OF CONCRETE PAVEMENTS
SOME ASPECTS OF THE METHOD USED IN FRANCE FOR GOVERNMENT OPERATED ROADS

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Concrete slabs rarely exhibit inherent defects, their degradation being related to a deterioration in the substructures. The main purpose of continuous evaluation is to assess pavement bearing conditions and, where possible, pavement external behavior indicators are used for this purpose. For the most significant indicators (slab degradation, detachment, deflection) rapid or semi-rapid measuring instruments have been developed, some operating under traffic at speeds over 50 km/h. The GERPHO (photographic road survey unit) allows continuous photography of pavements and of the interesting part of the shoulder at a speed between 50 and 60 km/h. It reveals the structural defects of pavements: cracks, pumping wells. The APL (longitudinal profile analyzer) used with a special analysis version provides data on slab faulting based on measurements at 7.5 km/h. The DMBD (slab deflection measurement system) and the COLLOGRAPHE work at much lower rates (about a kilometer/hour). If utilization precautions are taken, particularly as concerns temperature, these devices complement very effectively the high-output investigations. They provide data on slab bearing conditions before deterioration is shown by visible defects. In addition to their use in the monitoring of pavement condition and maintenance scheduling, this equipment is used during construction with certain slab strengthening techniques for example (grouting, tying, etc.).

The analysis of the behavior of concrete pavements consisting of short slabs, undoweled joints and a treated subbase, as well as the many observations made on pavements of this type in France, show that concrete slabs rarely exhibit inherent defects, but that their deterioration is related especially to a degradation in their bearing conditions.

The continuous nondestructive evaluation of concrete pavements should, in our view, be designed essentially to allow an assessment of the condition of the subbase through the cement concrete pavement, which is particularly difficult over long distances.

One of the most reliable methods is to use boreholes to obtain information allowing an assessment of slab bearing conditions: subbase surface erosion, existence of cavities, removal or accumulation of fines, presence of water, and so on.

This method is nevertheless very limited in terms of output and cost: the boreholes cannot be set up in an arbitrary manner. The notion of sampling is thus introduced based upon the following main ideas:

1. Bearing conditions can be evaluated through certain external signs of the pavement: deterioration, slab faulting, slab deflection, etc.
2. These signs are used to attempt to locate the problem areas. At this point, no explanation can be given of the observed phenomena and it is difficult to measure the extent of the deterioration.
3. Local tests, including boreholes, are concentrated on control sections chosen either within the zones considered to be in normal condition to check that such is indeed the case, or in zones suspected of being abnormally degraded in order to determine the causes.

Concrete pavement evaluation by means of a sampling method and local tests does not differ in its principle from evaluation methods used on other types of pavement (1,2). These principles will not be described here. Only certain specific tests, for example those making it possible to estimate in the laboratory the erodability of treated subbases (3), the interpretation of conventional test results as well as the methods and equipment used for analyzing a route, are peculiar to rigid pavements. Our aim here is to describe these methods which make it possible to locate zones exhibiting a different behavior and to carry out the sampling necessary for the setup of local tests.

These methods must meet the following conditions:

1. Provide continuous or almost continuous information: the purpose is to delimit zones.
2. Involce very short operations on the pavement: to the extent possible, the operations should be integrated with the traffic.

On the other hand, these analysis methods can get by with measuring devices of average accuracy: the aim is to classify zones.

To reach these objectives, medium or high-output measurement systems have been devised for the most useful and most sensitive indicators of pavement condition: deteriorations, faulting and deflection.

Figure 1. Listing indicating the numbering and location of transverse drains under the shoulder as well as an idea of their behavior at the outlet. This examination contributed to the choice of four zones, two of apparently normal behavior and two of poor behavior.

LOCATION	OUTLETS, ZONES IN CUTS	OUTLETS, ZONES IN FILLS	ESTIMATION OF WATER FLOW	
Mid-distance between kilometer mark 18.8 and exit point (curve) just before entry point 21 bis (≃ kilometer point 18.550)		C R A	Buried outlet	Zone I
About 50 m after the joint of entry point 21 bis		C R B	Low flowrate	
		C R C	Outlet in water	
	CD 1		Average	
	CD 2		Low	
	CD 3		Low	
	CD 4		Low	
	CD 5		Low	
	CD 6		Average	
	CD 7		Low	
	CD 8		Low (depositing of fines)	
	CD 9		Average	
	CD 10		Average	
	CD 11		Low	
PK 17,2		C R 12	Low (fines)	
PI 21		C R 13	Nil	
		C R 14	Low	Zone II
		C R 15	Average/low	
		C R 16	Average	
		C R 17	Average	
Roissy entry		C R 18	Average	
		C R 19	-	
		C R 20	-	
		C R 21	Average	
		C R 22	Average	
		C R 23	Average/low	
Entry point 20 (kilometer mark 16)		C R 24	Average	
		C R 25	-	
		C R 26	Low	
		C R 27	Average	
		C R 28	Average	
		C R 29	Average	
		C R 30	Average	
	CD 31		Average	
	CD 32		Nil	
	CD 33		Average	
	CD 34		Average	
Lamp-post D 52	CD 35		Average flowrate	
	CD 36		Nil	
	CD 37		Low	
	CD 38		Average	
Paris N Paris C	CD 39		Nil	
Near panel (before exit point 19)	CD 40		No outlet	
	CD 41		Average	
PS 19	CD 42		No outlet	
Kilometer mark 13.300	CD 43		Average	
Lamp-post D 20 (PK 13,160)	CD 44		Average	
Kilometer mark 13.040	CD 45		Average	Zone III
Lamp-post D 13	CD 46		Average	
	CD 47		Average	
PS B 3	CD 48		Low	
Entry coming from B3 (closed off - kilometer mark 12.600, lam-post D 6)				
Kilometer mark 12.520	CD 49		Low (the drain crosses the entry road along 3 m)	
PS 16	CD 50		Low	
Mid-distance between exit point 16 and exit point 15	CD 51		Nil (trace of old flows)	
Kilometer mark 12.150	CD 52		medium/low	
PS 15 (Kilometer mark 12.100)				
Kilometer mark 11.920	CD 53		Low	
Lamp-post D 95	CD 54		Low	
	CD 55		Low	
Kilometer mark 11.600	CD 56		medium/low	
Beginning of entry from B3 (end of surface dressing and beginning of bituminous concrete)	CD 57		Average	
Kilometer mark 11.150 (end of entry from B3)		C R 58	Outlet embedded in a fill (discharge)	
Kilometer mark 11.100		C R 59	Low	
Lamp-post C 64		C R 60	Average	Zone IV
		C R 61	Nil	
		C R 62	Nil	
Drains close together (every 20 m approximately)		C R 63	Buried	
		C R 64	Nil	
		C R 65	Nil	

We shall look into how these tools are integrated within the investigation methodology in order to provide all or part of the information required for assessing pavement quality, followed by a description of their utilization and an illustration of the different aspects of tangible data obtained through special concrete pavement evaluation studies.

Pavement Condition Survey

Visual observations to be carried out on a con-

crete pavement are of three types:

1. Surveys of concrete pavement degradations.
2. Surveys of degradations in the immediate vicinity of the concrete slabs on the shoulder.
3. Observations covering the surroundings of the pavement.

Degradation surveys should yield classified and quantified data. These operations can be automated. On the other hand, observations covering the surroundings, while just as important, are difficult to codify. Automated methods must be supplemented by inspections on the spot. Figure 1 illustrates this point with a listing relative to visual observations carried out on the outlets of the drains of a concrete pavement during a period of continuous rainfall (4). Using a necessarily manual method, it was possible to associate in this investigation the notion of drainage effectiveness in the choice of four control zones also chosen as a function of other testing and observation conditions.

As regards the automation of degradation surveys on the pavement and the shoulder edge, satisfactory results were obtained as soon as the objectives and limits were properly defined:

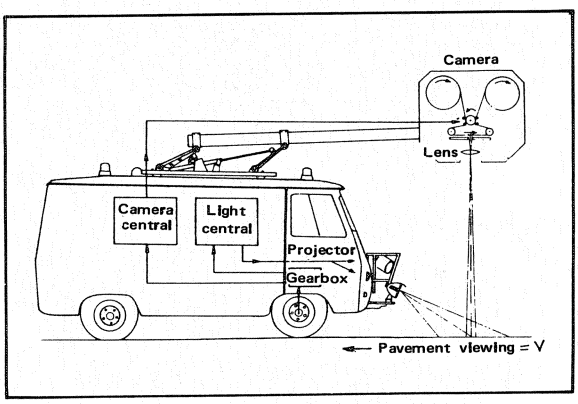
1. In the classification of degradations adopted for concrete pavements (Table 1), we confine ourselves to the category of structural degradations.
2. For this category, it is essential to be precise in the acquisition and processing of data. It is necessary to point out and often to act as soon as a small number of new structural defects appear (cracking of limited extent, for example).
3. One of the major causes of the occurrence of these defects is the quality of the connection between the slab and the shoulder. Besides the observation of deteriorations on the pavement concrete, it is also important to check whether the conditions which bring about its degradation are present (cracking, settlement and pumping pools on the slab edge). The observation of the shoulder edge over a width of about 0.5 meter is indispensable, with the same attention to detail as for the observation of the concrete slabs.
4. In France, there is a device called the GERPHO (Group for the Examination of Roads by Photography) whose selectivity is particularly well suited to the objectives mentioned.

Table 1. Brief classification of concrete pavement defects

Construction defects	- Cf. history of pavement (cracks, spalling, scaling)
Nonstructural defects	- Spalling - Corner cracks - Scaling - Surface wear
Structural defects	- Slab cracking - Longitudinal cracking - Transverse and oblique cracking - Slab faulting - Pumping pools

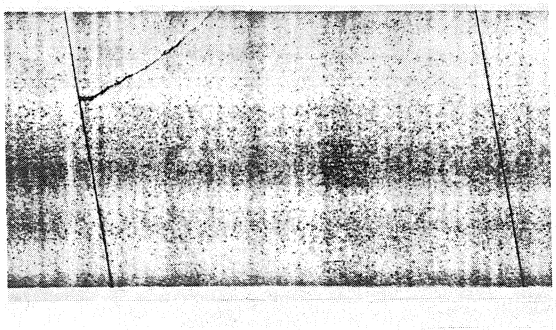
The GERPHO (Figure 2) makes it possible to photograph continuously the lanes of the pavements, as well as the area of interest in the shoulder, at a speed of from 50 to 60 km/hour.

Figure 2. Diagram of GERPHO (Group for the Examination of Roads by Photography).



The device produces a film which is a top view of the pavement to 1/200 scale. The film extract presented in Figure 3, quite similar to what is observed on the viewing table, shows clearly the selectivity of the device for the observation of the defects which concern us, namely slab corner cracking, cracking and crazing along the shoulder, pumping pools in the slab corners filled with bituminous material, and the removal of fines. On the other hand, pavement wear is poorly distinguished.

Figure 3. Example of observation on reading table: slab cracked in corner; crazing of shoulder and pumping pools.



The principle of the analysis of GERPHO recordings on concrete pavements is based upon an analysis of degradations carried out slab by slab, the individual slabs being numbered. Each element is identified through a reference marked on the pavement prior to the surveying operations.

The identified degradations are recorded on punched cards using an acquisition code. The most important points of this code are indicated in Table 2. The results are presented in the form of a list giving, opposite each numbered slab, the type(s) of defects observed. They can be supplemented by an automated output of the route diagram.

Considering the amount of information they contain, these documents are still rather cumbersome to use, and it is necessary in most cases to supplement them with more general documents giving an overall view of the studied route and bringing out the sensitive zones.

An example of such a synthesis consists in considering the problem on the scale of the kilometer and introducing a degradation coefficient. The

Table 2. Concrete pavement - Coding of defects and repairs.

1. DEFECTS ON CEMENT CONCRETE SLAB	
CRACKED LONGITUDINAL JOINT (CLJ): longitudinal crack at the limit of the lane (insufficient or no sawing of longitudinal joint)	CRACK LONG. JOINT
LONGITUDINAL CRACKS (LC): cracking between or in the direction of the two transverse joints	LONG. CRACK
TRANSVERSE CRACKS (TC): cracking between or in the direction of the two longitudinal joints	TRANS. CRACK
OBLIQUE CRACKS (OC): cracking > 0.5 m between or in the direction of two adjacent joints	OBLI. CRACK
BROKEN CORNER (BC): cracking < 0.5 m between or in the direction of two adjacent joints	BROK. CORN.
2. SLAB REPAIRS	
PARTIAL (REC PAR): reconstruction of a small part of the slab, for example reconstructed slab corner	PART
ACROSS SLAB (REC PAS): partial reconstruction across the entire width or the entire length of the slab	A.S.
TOTAL (REC TOT): reconstruction of entire slab	TOTAL
These three codes are followed by a code indicating the nature of the reconstruction.	
- Reconstruction in bituminous mix	BITUMEN
- Reconstruction in cement concrete	CONCRETE

Principle of this coefficient is the summing of the number of degradations encountered on the slabs within the chosen scale, together with the weighting of each type of degradation as a function of its seriousness. A degradation of a high order is assigned an increasing coefficient in relation to a lower-order degradation.

As an example, the following equation is used as an indicator of the evolution of defects in concrete pavements in the case of the freeways handling heavy traffic around the Paris area.

$$C = 3x + 2(y + z) + u + v$$

where C = degradation coefficient, x = % of fractured slabs (two cracks or more), y = % of transversely cracked slabs, z = % of longitudinally cracked slabs, u = % of obliquely cracked slabs, and v = % of slabs with small breaks in corners.

Although essentially intended to be a classification of the different sections of a route and an objective quantification of the pavement evolution parameter, this coefficient permits certain quality judgements:

- $C < 10$: pavement in good condition
- $10 < C \leq 30$: pavement in average condition, requiring supervision
- $30 < C \leq 50$: pavement in alarming condition, requiring service
- $50 < C \leq 80$: pavement requiring strengthening or reconstruction
- $C > 80$: pavement requiring urgent work.

Figure 4 shows the evolution of the degradation coefficient on a route about 40 km long. This shows the urgent need for strengthening on clearly delimited sectors almost 20 years old.

Further, this document allows the working out of a forecast study with regard to strengthening requirements in the years to come, considering the defect development rates represented by the relative differences in threshold heights between the different surveys.

Survey of Permanent Deformations of Slabs and Their Supports - Slab Faulting

The behavior of short-slab, undoweled concrete pavements over a treated subbase (referred to in France as pavements of the "Californian" type) makes it possible to explain the slab faulting phenomenon by the erosion of the subbase and the transfer of fines from the leave slab toward the approach slab.

Knowledge of the vertical displacement (faulting) between slabs thus constitutes a valuable and particularly sensitive indicator of the performance of the pavement and on its situation within the general evolution process.

In the case of current studies in which only a few months or at best a few years are available for evaluating the quality of pavements and proposing solutions, it is not often possible to make use of local measurements, even when they are precise, intended to be used for characterizing the rate of evolution of the faulting. In addition, contrary to appearance, what is involved is a delicate measurement because, on the one hand, it is sensitive to a defect in the smoothness of the slab edge and, secondly, the representativeness of a local measurement on a transverse joint is not very satisfactory as a faulting indicator for the entire joint.

On the other hand, for our purpose which is primarily to establish a preliminary route, to delimit and to classify different sections, it is possible to be less demanding as concerns precision.

Slab faulting is manifested as a very particular type of defect in smoothness which, owing to the periodicity of the joints, is cyclic. We thus endeavored to determine what its contribution was to the deterioration of the overall evenness of the pavement (5).

It was thus possible to work out a method for the continuous measurement of slab faulting using the Longitudinal Profile Analyzer (Analyseur de profil in long) which, in its usual version, is designed to provide information on the evenness characteristics of pavements within the limits most perceptible to the user (quality of evenness in three wavelength ranges: 0.3 - 3 m, 3 - 13 m, 13 - 40 m) (Figure 5).

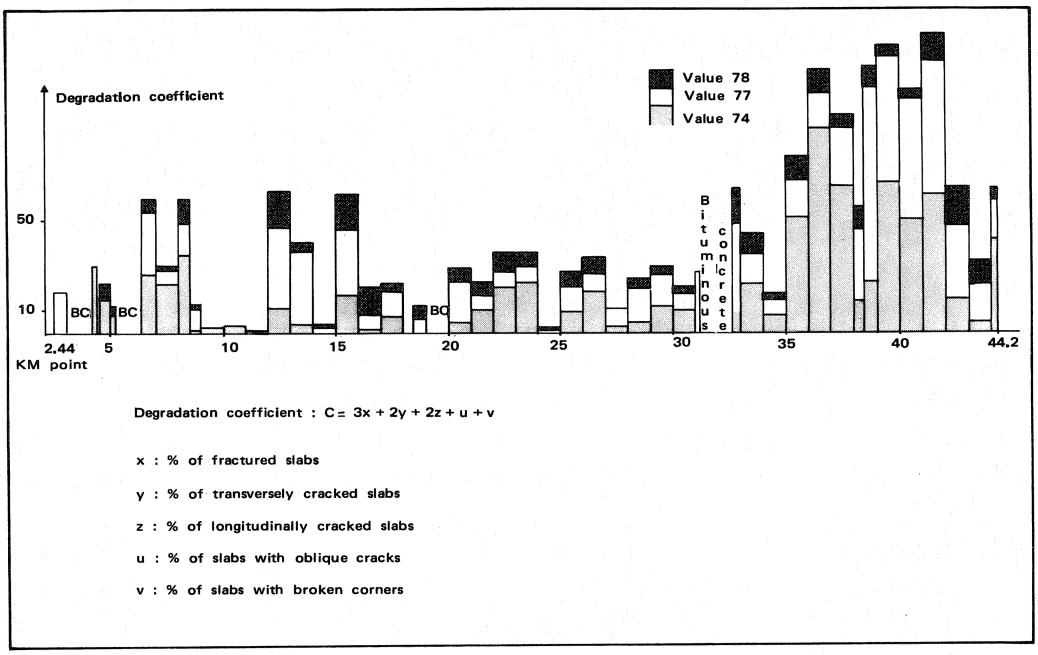
The current measurement rate of this device is 72 km/hour.

A comparative study between different static and dynamic devices allowing the measurement of slab faulting demonstrated that local measurement accuracy is medium: ± 2 mm 85 to 92 percent of the cases depending on the device. The confidence interval is even high compared with the usual faulting values (5).

However, the random nature of this scattering allows a good estimation of the average value of the faulting. The results were thus presented in the form of average faulting over a distance of 100 meters (hectometer) measured in a longitudinal profile. The error in relation to the real average was brought to ± 1 mm in 95 percent of the cases.

These considerations induced us, firstly, to continue collecting a large number of data made

Figure 4. Evolution of degradation coefficient in 3 years plus an additional year on a concrete pavement determined by GERPHO. This diagram makes it possible to delimit the section requiring the most urgent repairs (kilometer mark 35 to 42) for which the degradation coefficients are higher than 50 and where coefficients of 100 are reached. An idea of the degradation process can be formed by comparing the white parts of the histograms representing 3 years of evolution and the black parts (1 year of evolution).



possible by the use of a high-output device and, secondly, to group the results by introducing a faulting coefficient based upon the same principle as the degradation coefficient mentioned earlier.

Figure 5. Photograph of APL (Longitudinal Profile Analyzer). Measurement speed under normal conditions: 72 km/h (operates in traffic in rural areas).

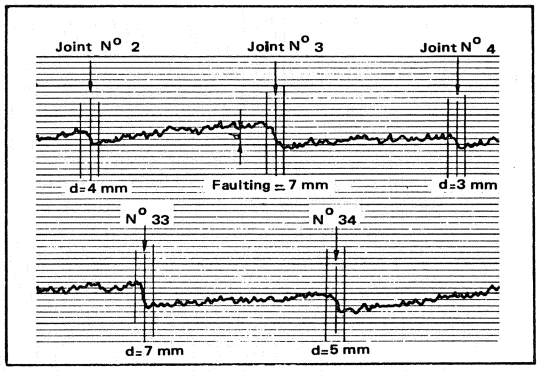


These studies led to the following:

1. A high-efficiency measurement system, the Longitudinal Profile Analyzer (APL in French) used currently on French roads together with electronic corrections for the transfer function of this equipment, and a device allowing the display of the faulting values on graphic outputs (Figure 6) (5).

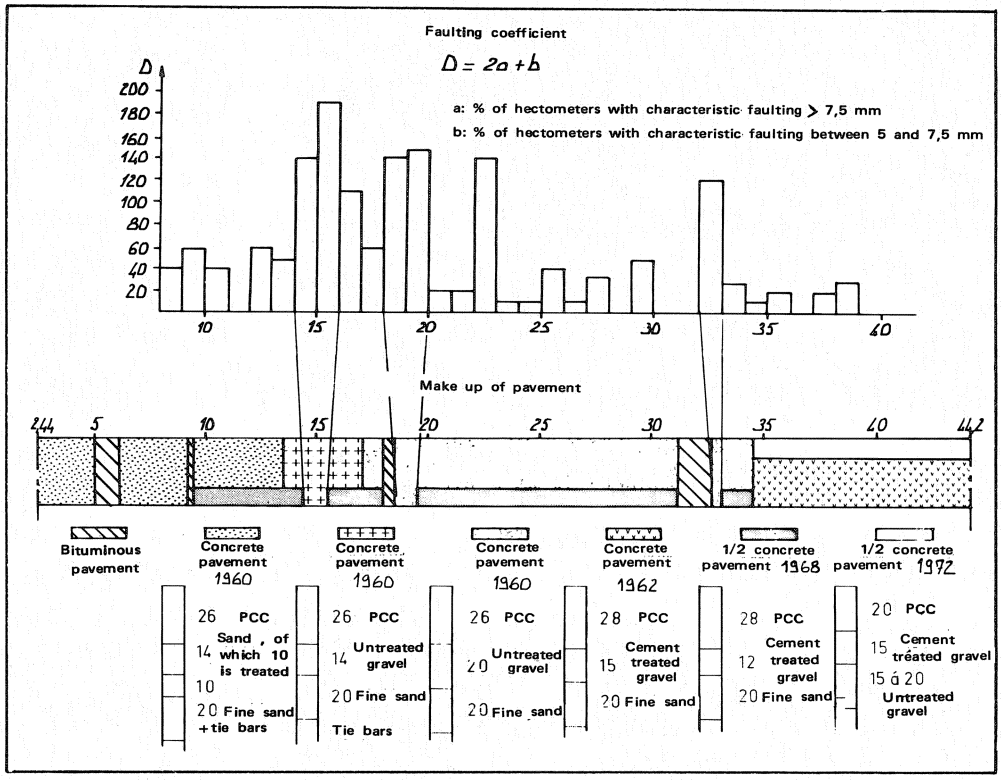
2. A temporary method for the manual processing of these recordings: each joint is analyzed in two phases: location of joint (the most difficult operation) and determination of the faulting between two vertical lines drawn on each side of the presumed joint at a distance fixed once and for all.

Figure 6. Example of recording obtained with the APL at 72 km/h. In the present case, manual analysis consists in positioning the joints as shown by the recording and the slab lengths at a distance corresponding to e = 0.24 m on the pavement and then plotting two vertical lines on each side of the joint position and measuring the difference between the intersections of these vertical lines with the recording curve of the APL signal.



3. The development of an automated method for calculating slab faulting from APL measurements (5). This method is based upon slope comparisons applied to the digitized values of the APL signal. It leads in practice to pairs of "distance-faulting" values for the joints or cracks exhibiting detectable faulting. As an example, Figure 7 shows a data sheet of one of the first applications of the method using

Figure 7. Evaluation of faulting coefficient obtained on 30 km of concrete pavement. The faulting peaks correspond to old pavements which made up the truck lanes in the ramps before general widening to dual three-lane capacity.



the APL 25 (simplified version of the APL 72) processed manually (6). A degradation coefficient in the form D = 2a + b is introduced where: a = % of hectometer with characteristic faulting greater than 7.5 mm, and b = % of hectometer with characteristic faulting between 5 and 7.5 mm; characteristic faulting = faulting of a lower order than the maximum faulting encountered along a hectometer.

It is premature to assign an appreciation scale to this coefficient (its purpose being to classify the zones in relation to each other), but it may be noted that the values from 150 to 200 reached on the old truck ramps correspond to a highly deteriorated pavement based on this criterion. Under 40 to 50, the defects are not clearly perceptible to the user under the circumstances in France.

Survey of Instantaneous Deformations of Slabs and of Their Supports: Slab Deflection

As in the case of deflection on flexible or semi-rigid pavements, the instantaneous deformation (deflection) of a concrete slab edge under the effect of a standardized load constitutes a performance indicator for a rigid pavement.

In practice, slab deflection measurements have been used especially up to the present time as a means of selecting zones in which slab bearing conditions are defective, and are completed in the subsequent phases by more refined studies using boreholes in order to determine the cause of the defective performance: are there small horizontal cavities under the corners or edges of the slabs resulting from the erosion of the subbase; is there abnormal deformability in the subbase due to inadequate thickness or quality; or does the subgrade have a particularly low bearing capacity? In most cases encountered in France on Portland cement concrete pavements with a treated subbase, the first of the above-mentioned causes is predominant and slab deflection measurements are interpreted in terms of the extent of the cavities under the slab ends.

More so perhaps than for most rigid pavement measurements (deformations, stresses), it is indispensable to associate the slab deflection test with as precise a knowledge as possible of the thermal conditions in the concrete slabs when the test is carried out. On the one hand, it is necessary to avoid hot periods during which the joints are blocked and there are no deflections, and hence to work during medium-temperature periods, i.e. low compared with the temperatures at the time of the initial construction of the pavement. On the other hand, this test should not be carried out when the temperature gradient in the slab is high, as this curls the slab and increases or decreases artificially the extent of the deflections; the test should thus be carried out when the temperature gradient is as low as possible.

The extent of the influence of thermal conditions on the result of deflection measurements, which we shall show below, makes it particularly difficult to evaluate the condition of the pavement: a large deflection is the indication of deterioration only if the temperature gradient is low or positive whatever the average temperature of the slab; a small deflection indicates good performance only if the temperature gradient is low or negative and the average temperature low.

The comparison of several series of measurements can be done only if the thermal conditions during the measurements are known precisely and are not very different: ± 2°C for the average temperatures, ± 0.2°C/cm for the gradients. In all the other

cases, the comparisons are uncertain and can be but qualitative.

In practice, the rigor and the strictness of the procedure used is in proportion to the complexity of the work involved.

In the case of the assessment of a route and a classification of zones according to the quality of slab bearing conditions, measurements are carried out in cool temperature and in cloudy weather, even at night during certain periods of the year, while recording the average ambient temperature during each measurement sequence.

In the case where the follow-up of pavements is to be organized or where the evolution of slab bearing conditions is to be evaluated, it is necessary to have "reference lots" allowing good knowledge of the response of the pavement for various thermal conditions (gradient and average temperature).

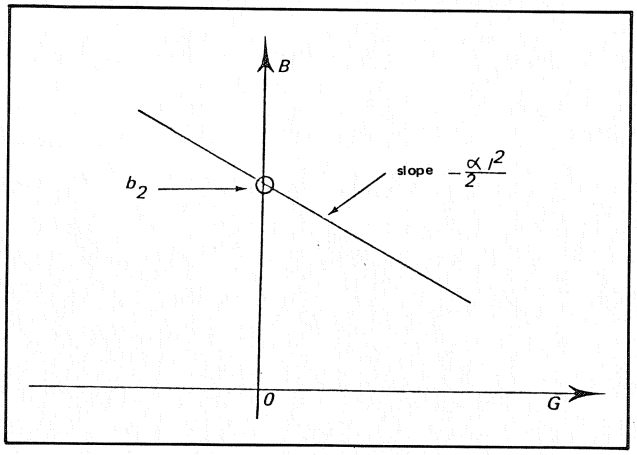
A reference lot consists of at least 20 or so slabs, on one of which are placed temperature probes at at least three levels in the concrete thickness. Several series of deflection and temperature measurements are carried out during continuous periods so as to cover a sufficiently wide range of thermal conditions.

A study (7) based upon a simplified theoretical slab performance diagram showed that the deflection measured at the end of a free slab subjected to a temperature gradient is of the following form (Figure 8):

$$B = b_2 - \frac{G \alpha l^2}{2}$$

where b_2 is the real height of the cavity, G the constant gradient equivalent to any temperature distribution, l the separation length, and α the expansion coefficient.

Figure 8. Expression of the measured slab deflection B as a function of the real depth of the cavity under the slab b_2 and the equivalent constant gradient G.

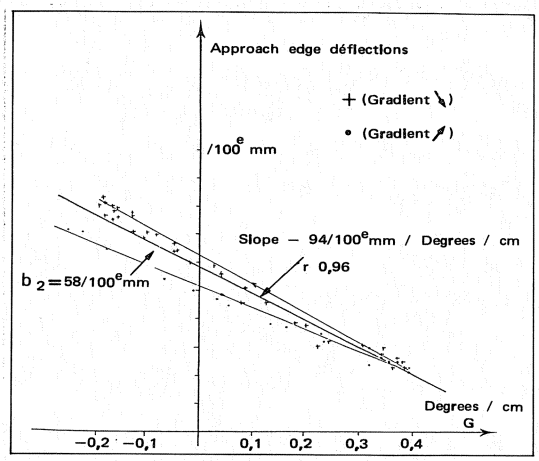


The different measurements to be carried out on the reference lot enable the experimental determination of this line. As an example, Figure 9 gives the results obtained on a reference lot including 40 concrete slabs 28 cm thick submitted to continuous measurements for 24 hours.

This curve makes it possible, by extrapolation, to determine the corrections necessary during an operational measurement, it being understood that this measurement must satisfy in every case the primary conditions mentioned above: cool temperature, no sun. With each reference lot is associated a certain route length. It is desirable to have one reference per type of structure, without however extrapolating from the same lot for sections longer than 20 km.

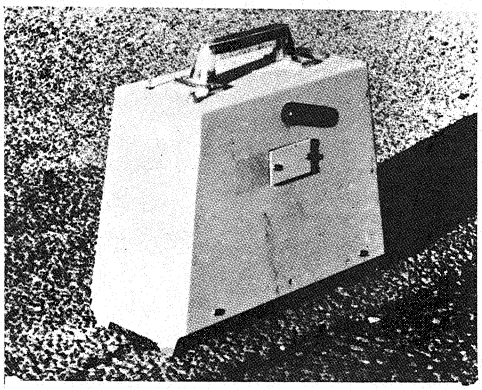
Aside from the local measurements carried out by means of single- or dual-transducer beams for the fine analysis of the reference lots or sections of small length, slab deflection measurements are carried out with a device specially designed for this purpose, called the Slab Deflection Measurement Device (Dispositif de Mesures de Battement de Dalles, DMBD).

Figure 9. Variation of leave edge deflections as a function of the equivalent constant temperature gradient.



The Slab Deflection Measurement Device (DMBD) is designed in the form of a series of self-contained measurement units (Figure 10) allowing deflection measurements on concrete pavements in successive sequences of 40 joints or cracks.

Figure 10. DMBD (slab deflection measurement device). View of a measurement unit which is placed on the pavement over a joint or a crack on the slab edge. Dimensions: height 32 cm, length 35 cm, width 15 cm, weight 2.4 kg.



Each of the 40 units, similar in volume and weight to a small traffic-control cone, has at its base two transducers without a fixed reference of the geophone type which are placed on each side of the joint to be tested. Under the effect of a reference load consisting of a single-axle truck loaded

to 13 tons and moving under well defined conditions (1 meter from the edge and at a speed of 40 km/hour), each unit placed at the slab corner records and stores an approach end deflection and a leave end deflection (Figure 11).

Figure 11. DMBD - View of a measurement sequence on a freeway immediately after the passage of the loading truck (loaded to 13 t on rear axle). 40 slab edges are tested per sequence.



The information contained in each unit is transferred onto a printer tape on which appears, unit by unit or joint by joint, the deflection class of the approach edge and of the leave edge.

By convention, slab deflections have been placed in seven categories:

1. Class 0, 0 to 0.1 mm.
2. Class 1, 0.1 to 0.2 mm.
3. Class 2, 0.2 to 0.3 mm.
4. Class 3, 0.3 to 0.5 mm.
5. Class 4, 0.5 to 0.75 mm.
6. Class 5, 0.75 to 1 mm.
7. Class 6, > 1 mm.

The analysis of the measurements consists in determining the characteristic deflection by sections of 100 to 200 meters of lane. By analogy with the characteristic faulting mentioned earlier, the characteristic deflection is defined as the center of the class of immediately lower order than the maximum deflection. An example of such an analysis is given in Figure 12 where three rows of concrete slabs on an airport runway 2400 meters long were evaluated in a single night. This representation of the characteristic deflection by basic sections of 100 meters shows very heterogeneous slab bearing conditions (the entire range of deflection classes is represented) and makes it possible to note a high to very high deflection concentration, notably greater on the first half of the runway (hectometer marks 1 to 13) and on the upper half-runway.

Finally, it may be pointed out that slab deflection measurement data is becoming sufficiently complete, for roads as well as for airport runways, and will make it possible to draw up the first sheets for evaluating the results of these measurements.

A distinction is made between concrete pavements with a treated subbase (Table 3) and pavements with an untreated subbase (Table 4). We interpret the results obtained on airport runways at average loads as indicated in Table 4.

Deflection measurements can be carried out by means of the Lacroix LPC 04 Deflectograph, placing the measurement cart manually during several passes. This usage is however limited to short sections.

Figure 12. Example of DMBD measurement results on an airport runway 2400 meters long (slab of 30 cm in concrete over 10 cm of sand - cement).

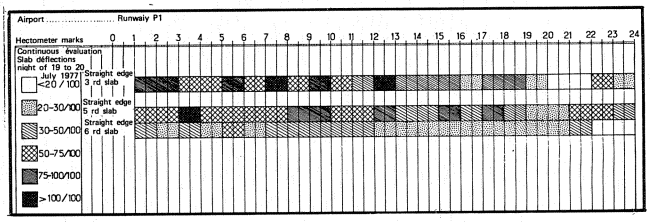


Table 3. Order of magnitude of characteristic deflections obtained, and meaning as concerns concrete pavements with a slag- or cement-treated subbase.

Characteristic Deflection Measured under Average Temperature (< 20°C) and with Small Gradient (< 0.2°C/cm)	Meaning for Slab Bearing Conditions
0 - 0.2 mm	Normal deflection value
0.2 - 0.3 mm	Significant risk of problems relative to bearing conditions
0.3 - 0.5 mm	Poor bearing conditions
> 0.5 mm	Critical zone - Maintenance urgently needed

Table 4. Order of magnitude of characteristic deflections obtained, and meaning as concerns concrete pavements with untreated subbase.

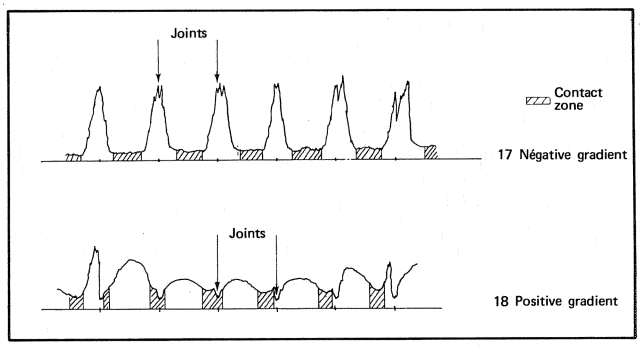
Characteristic Deflection Measured under Average Temperature of 20°C and with Small Gradient (< 0.2°C/cm)	Assessment of Deflection Value
0 - 0.2 mm	Small deflection
0.2 - 0.5 mm	Average deflection
0.5 - 0.75 mm	Large deflection
> 0.75 mm	Very large deflection

On the other hand, the French Highway Department (LCPC) is presently investigating a device allowing the measurement of the response of the structure to maintained vibrations. The Collograph (Figure 13) can be regarded as a "Dynaflect" working continuously (9). These studies have led to positive results in the search for discontinuities in concrete slabs and at the level of their bearing conditions. Figure 14 shows a "collogram" on which the cavities generated by slab curling appear clearly.

Figure 13. The Collograph. A vibrating load is applied to the pavement by a small vibrating compactor. The signal is picked up by a moving transducer system (seismic transducers, geophones HS_1) located behind the broom. After filtering, the signal is displayed on a graphic recorder. One thus obtains the "collogram" of the pavement. The measurement speed of the prototype depends on the roughness of the pavement: from 1 to 4 km/h. It is expected that about 10 km/h will be reached with the subsequent versions of the system.



Figure 14. Examples of collograms observed on a concrete pavement in the case of positive and negative temperature gradients.



Conclusions

The different points selected in this article, based upon a complete method for the evaluation of rigid pavements, the principles of which are mentioned in the special issue on "Concrete Pavements" (September 1978) of the Bulletin de Liaison des Laboratoires des Ponts et Chaussées (10), summarize the progress achieved in the past 2 or 3 years relative to the three basic criteria for evaluating the condition of a concrete pavement.

It is important to note, firstly, that all the presented documents resulting from the application of these evaluation methods are drawn up from information obtained on a slab-by-slab basis. The basic slab-by-slab information can be used for detail examinations of as many sections as desired. It can be stored on different media to allow better characterization of pavement evolution.

The survey of the condition of concrete pavements by means of the GERPHO renders the services expected. The many measurements carried out during this period on heavily-trafficked freeways, in particular, have made it possible to confirm the method and to limit the visual surveys to what is strictly necessary. Automatic analysis methods, followed by the grouping of results with the use of a degradation coefficient, are receiving widespread application and permit good evaluation of the degradation rate.

Slab faulting recordings are obtained in a satisfactory manner for a rough study with a special use of the Longitudinal Profile Analyzer (APL). Route diagrams presenting faulting coefficients from measurements carried out at 25 or 72 km/h have been produced. The automation of analysis is being completed.

The DMBD and, exceptionally, the Deflectograph 04, allow slab deflection measurements which are used more rigorously by better knowledge of their meaning and their limits. A method has been established which makes it possible, in the case of rather fine measurements for following the evolution of pavements, for example, to take into account the thermal conditions during the measurements. Care must however be exercised as concerns the basic precautions to be taken during measurements (temperature lower than blocking temperature, and low gradient). The measurement rate is moderate (1 km per effective work hour) but nevertheless makes it possible to cover long distances. Evaluation criteria have been established for the deflection measurements for each rigid pavement category.

However, as in the case of semi-rigid pavements, the measurement of deformations under load (deflection) appears to be insufficiently sensitive for assessing the condition of concrete pavements and predicting their evolution. Present research is thus oriented toward dynamic evaluation devices, of which the Collograph represents the first generation.

The progress achieved in these different areas has made it possible, because of the high output possibilities and the wealth of information provided by continuous data in highway surveys, to considerably improve the reliability of concrete pavement evaluation surveys. For this type of pavement, they allow the use of an analytical procedure common to all the other pavement categories: preliminary diagnosis of homogeneous sections before undertaking more refined local tests necessary for evaluating the quality of the pavements investigated and determining maintenance or reconstruction requirements.

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