

# Evaluation and Development of Road Networks

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**Summary.** After the war, the national road network was no longer suited to heavy goods vehicle traffic conditions. As a result, the Roads Directorate defined a 33,000 km national network in 1973, on which the State would make the necessary improvements. During the same period, the Central Laboratory of Bridges and Roads (LCPC) worked on the creation of more resistant, more durable, and economical bitumen road structures. This last point proved all the more crucial during the 1974 oil crisis. The creation of 17 Regional Laboratories (LRPC) made it possible to experiment, control, and disseminate new techniques. Thus, in about fifteen years, 22,000 km of national roads were rehabilitated. At the same time, the State was preparing to build more than 10,000 km of highways. In the 1980s, the technologies developed by the Laboratory network were widely disseminated throughout the world. For around twenty years, on all continents, many states, often assisted by the World Bank, have relied on studies by SERI (International Studies and Research Service of the LCPC) to prepare and sometimes carry out the restoration of their networks.

The modernization of the national road network in the 1960s requires the creation of major connecting routes and a new design of roadway structures. The task was all the more difficult because it involves creating completely innovative roads capable of withstanding, in the long term, traffic that is expected to become increasingly heavy and significant.

## 1 Dimensioning of roadways

Road structures are built or redeveloped to accommodate cumulative traffic of varying intensity over a predetermined period, depending on their location, geographical area, and the importance of road routes. The nature of these structures and the traffic they will support are two essential parameters to determine. Additional tests will be able to refine these initial results.

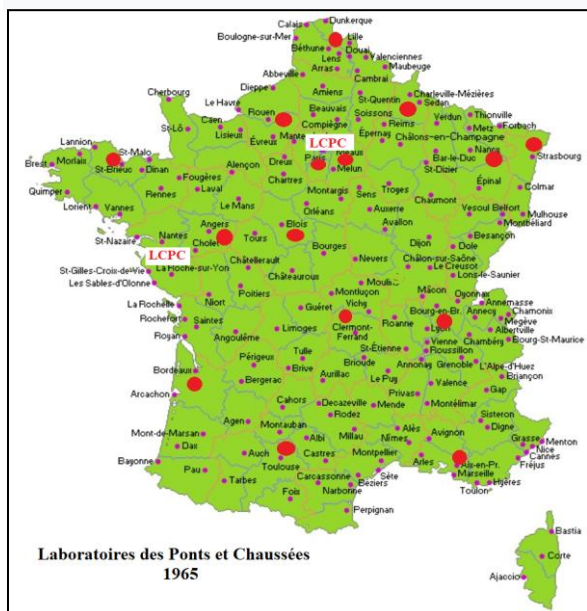


Fig 1. The laboratory network

## 1.1 Structural Assessment

In cases of rehabilitation or reinforcement, the assessment of the physical characteristics of a pavement is primarily based on its established as a priority by reference to its level of apparent degradation (visual condition) and to the load-bearing qualities (deflection) of the entire structure. [1,2]

### 1.1.1 Visual condition. [3]

Detailed visual surveys of road surface conditions were originally carried out manually, on foot. The "Désy 2000" system allows data to be entered into a computer installed in a vehicle, pre-equipped with keyboards adapted to the roads tested in a given region.

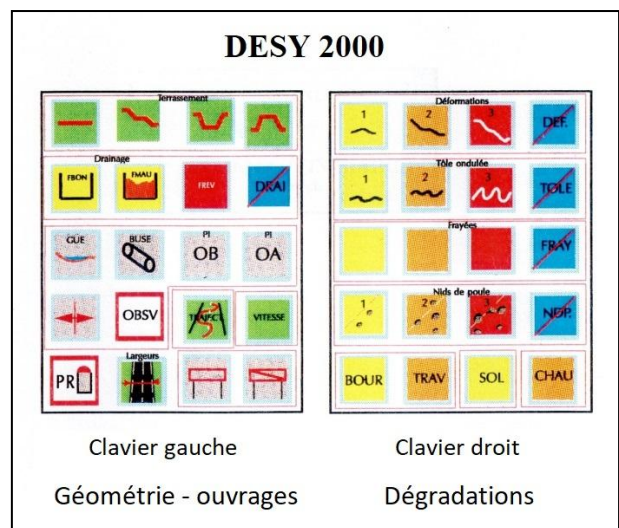


Fig 2. Example of a Désy 2000 keyboard

This survey is intended to measure the surface degradation index,  $I_s$ , which depends on the extent of cracking and deformation. The degradation index varies from 1 for pavements in very good apparent condition, to 7 for the worst pavements.

### 1.1.2 The lift

The bearing capacity value is established by measuring the deformation of the pavement body when a load of 6.5 tonnes is applied, which corresponds to the standard 13 tonne axle load for French roads. This deformation is related to the structural characteristics of the pavement and the stresses it withstands. A distinction is made between flexible pavements, constructed of unbound gravel materials, and rigid pavements constructed of bound materials such as cement gravel, slag gravel, bitumen gravel, or asphalt concrete. The former are subject to punching shear under load, the latter to slab bending, which distributes the forces over the pavement substrate (natural ground, embankment, or subgrade). Permissible Values.

Flexible pavements transmit loads vertically to the subgrades. The elongation on the substrate  $\epsilon_z$  must be less than the permissible elongation  $\epsilon_{ad}$ . Rigid pavements are subjected to tensile stresses  $\sigma_t$  at the base of their layers, which must be less than the permissible stress  $\sigma_{tadm}$ .

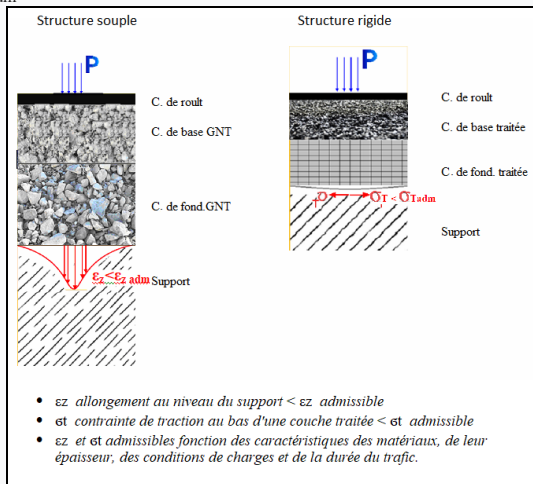


Fig 3 – Elongations and constraints

The road deformation, the deflection, is continuously recorded by the Lacroix deflectograph [4,5].



Fig 4 – The defectograph

The deflection is measured between each pairing of the vehicle's rear axle by feeler arms equipped with sensors and articulated on a reference beam. Once the measurement is made, the system lifts the sled, moves it 3 to 5 m towards the front of the truck and repositions it for a new test. The distance between two measurement steps is 3 to 5 m depending on the type

For flexible pavements, the permissible deflection value depends on the geographical area of the country concerned: in Sahelian zones it is lower than in temperate countries such as France. It is effectively linked to the quality of the supporting soils and their level of imbibition.

For example, for low to medium traffic (§ 1.2), the values below of characteristic deflection  $d_c = m + 2\sigma$  are retained for France (for a given road section  $d_c$  encompasses 95% of the values –  $m$  being the average,  $\sigma$  the standard deviation on the section considered) with two thresholds,  $d_1$  and  $d_2$ , values which distinguish good load-bearing structures from poor load-bearing structures

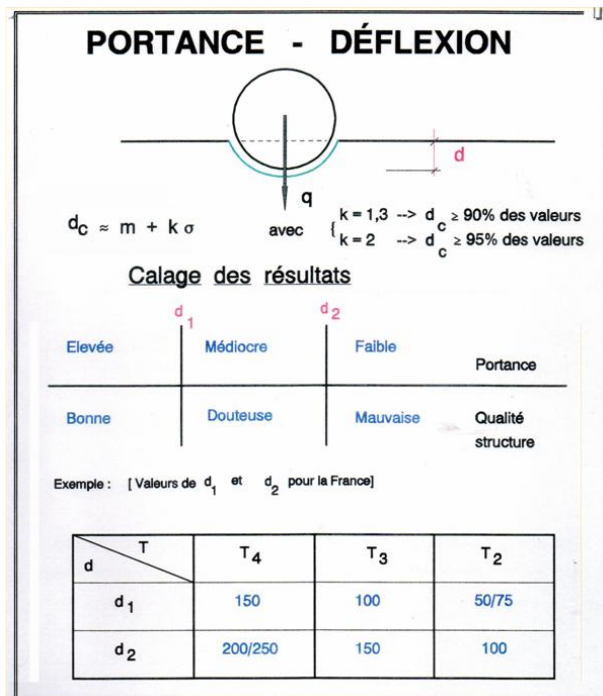


Fig 5 – Deflections for low to medium traffic

### 1.1.3 Additional tests

The most common complementary tests are borings or coring and longitudinal evenness measurement.

Borings measure the thickness of pavement layers, characterize the quality of the constituent materials, and determine their imbibition levels, particularly if they are sensitive to water. These tests provide information on visible pavement defects and bearing capacity values.

Longitudinal evenness is continuously measured using the longitudinal profile analyzer (APL) [6]. The APL

trailer is attached to a towing vehicle. Its measuring wheel moves up or down depending on the road surface condition. This movement causes a change in the angle that the wheel-carrying arm forms with an inert pendulum that converts the profile variations into electrical signals. Every 5 cm, the angle between the arm and the pendulum is recorded to obtain the level of the coating. The pendulum is independent of the towing vehicle so that vertical movements of the vehicle do not alter the measurements.

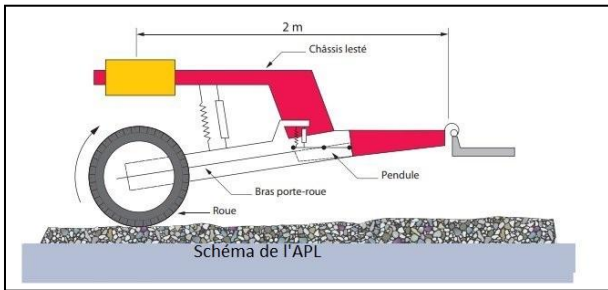


Fig 6 – APL principle diagram

### 1.1.4 The route diagram

The route plan brings together all of this data. It also describes the history of the road's construction, its maintenance, its geometry, and the engineering structures that run along it.

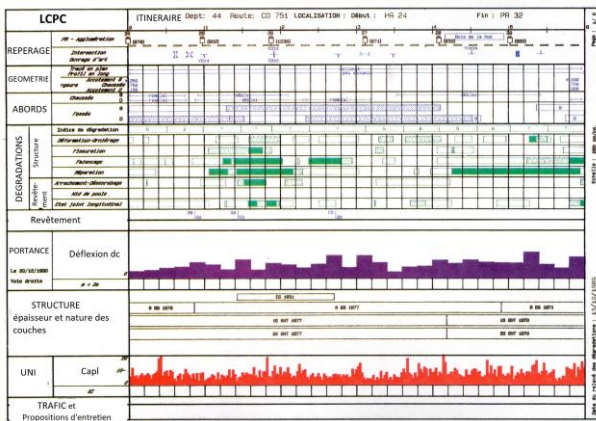


Fig 7 – Route diagram

### 1.2 Traffic evaluation

Roadways are built or redeveloped based on the traffic they will have to carry for a lifespan predetermined by their manager (state, region, department, municipality), i.e., for a period during which, a priori, no major repairs will be required.

It is necessary to assess as accurately as possible the traffic the roadway will receive over its estimated lifespan. Five traffic classes, from T<sub>4</sub> to T<sub>0</sub>, from lightest to heaviest, have been defined based on the average daily heavy goods vehicle traffic:

Traffic PL/j ≥ 5t	25-50	50-150	150-300	300-750	750-2000
Classe	T4	T3	T2	T1	T0
A Coef d'agressivité	≤ 0,5	≤ 0,8	0,8	0,8	≥ 0,8

Vehicles with a total weight greater than 5 tonnes are counted. The coefficient of aggression A depends on the different loads of the vehicles traveling the route. At the national level, it is estimated to be less than 0.8 for lightly trafficked roads and greater than 0.8 for roads with the highest loads, particularly major roads and motorways.

The equivalent axle weight, based on the legal French axle of 13 tonnes, is calculated as shown in the table below:

Poids essieu (t)	1,5	4,5	9,5	13,0	15,5	19,5
Equivalent 13 t	0,00018	0,0144	0,285	1	2,02	5,06

A 1.5 T axle penalizes the structure 10,000 times less than a 13 T axle, while a 19.5 T axle penalizes it 5 times more.

For a given route, the cumulative traffic N is calculated by reference to the lifespan of the roadway, the aggression factor A of the vehicles using it, and the annual daily traffic, all vehicles combined, according to the formula:

$$N = TxCxAx365$$

- T: average annual daily traffic

- A: aggression factor

- C: accumulation factor, function of

the expected length of service, n, and the traffic growth rate, i.

$$C = (1+i)^n/n+i$$

For example: C = 10,9 (n = 20 years and i = 4%) -

C = 9,1 (n = 15 years and i = 7%).

Equivalent traffic: the equivalent traffic N<sub>e</sub> retained for the dimensioning of roadway structures is defined by reference to the 13 T axle. It is therefore lower than the total actual traffic. It can vary depending on the routes. In the general case in France we consider

$$N_e = 0,65N$$

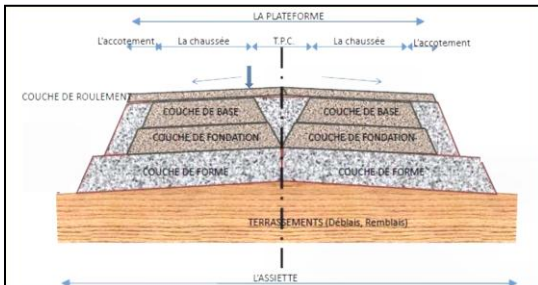
## 2 Roadway structures – The national network

The design of a roadway to be built or reinforced depends on two physical parameters: the quality of the structures and the volume of traffic. SETRA (Technical studies department for roads and highways) and the LCPC (French National Road and Highway Council) have published several technical guides for the assessment and design of roadways, including:

- The Flexible Pavement Inspection Guide in 1977,
- Preventive Maintenance of the National Road Network in 1979,
- "VIZIR": a computerized version for capturing road information in 1991, translated into several languages: English, Spanish, Portuguese, and even Chinese,
- "ALIZE", method for calculating roadway design [7].
- The 1977 catalog of new roadway structures, updated in 1998,
- Road Maintenance Management (LPC LB) in 1994,
- Routine Road Maintenance – Practical Guide – 1996

Flexible pavements, made of unbound materials, are reserved for light traffic, T4, T3, and possibly T2. Their wearing courses consist of surface dressings, sometimes bituminous mixes for T2 traffic. For heavy traffic, rigid structures are used on the subgrade or natural ground, sometimes treated with lime, as base layers and very often as subgrades.

These structures are made of gravelly materials treated with bitumen or hydraulic binders (cement, blast furnace slag, etc.). The wearing courses are exclusively bituminous mixes.



**Fig 8** – Theoretical structure of a roadway

The road construction and maintenance strategy has evolved significantly over the past 50 years. Technical studies, increased traffic, the definition of priority routes, and economic data have all driven the transformation of the national road network, managed by the state. As early as 1973, the state had downgraded 50,000 km of roads, entrusted to departments, to devote itself to a network of 33,000 km. It then reinforced 22,000 km of major routes and began construction of the motorway network. In 1993, the network comprised 22,000 km of national roads and 10,000 km of motorways. Today, the state manages 9,000 km of "structural" national roads, most of which are concessions.



**Fig 9** – The national road network

### 3 Exported techniques

Thanks to its researchers, primarily the LCPC teams, the LPC network, their experience, and laboratory and on-site inspections, French road construction technology experienced tremendous growth during the 1980s. Innovations in material manufacturing, pavement structure construction, and implementation are recognized in many countries on several continents. French technology is at the forefront. Teams are called upon to evaluate routes and road networks, and to inspect projects carried out by our companies. Until the 2000s, French roads were considered among the best in the world.

We will travel through some fifteen countries in Africa (red dots on the map below), sometimes returning several times to the same country: studies of networks, routes, and airfield runways (Nouadhibou, Nouakchott, Accra, Mohéli). We will also explore the dirt roads and runways in Chad, Gabon, and Niger.



**Fig 10** – Map of studies in Africa

The LCPC's International Studies and Research Department (SERI), with Paul Autret as its director, was created in the 1980s to develop techniques for analyzing and rehabilitating earth roads, often made of laterite. Several publications have been published by the LCPC, including:

- 1989, Roads in Developing Countries [8],
- 1994, Development of Road Maintenance Management Support Systems Abroad [9],
- 1997, "VIZIRET", Studies of Unpaved Roads [10],
- 2002, Influence of Road Condition on Vehicle Travel Time in Sub-Saharan Africa or "VIZIRVIT" [11].

The department is also known in Asia as:

- Armenia and Georgia, on three occasions, to study the Yerevan-Batumi route, a Georgian port on the Black Sea,
- Nepal to analyze the paved road network,

- South Korea, on four occasions, to train Korean engineers, to work in the field, to evaluate the paved network [12],
- China, in Canton where Paul Autret organized a conference to present LCPC techniques and on three occasions in Beijing, to train engineers in our techniques and to present the methods and equipment for road monitoring (deflectograph, APL, core drill...)



Fig 11 – Map of studies in Asia

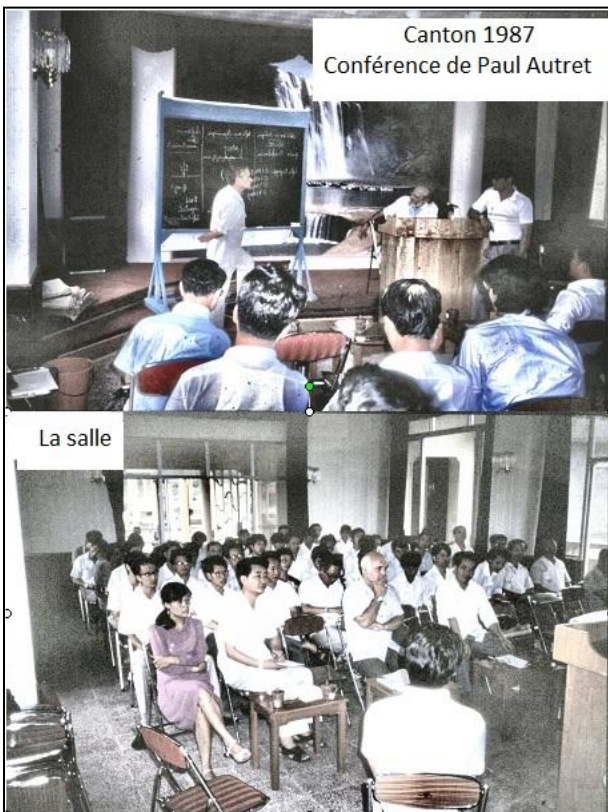


Fig 12 – Conférence by Paul Autret, director of SERI, in Canton before a panel of Chinese technicians and engineers

#### 4 The results in a few words

For over 30 years, from the late 1960s to the 2000s, France acquired exceptional technical resources. SETRA, created in December 1967, organized the planned construction of new-generation roads and motorways. This service was supplemented in 1968 by eight CETEs (Technical Equipment Study Centers), decentralized organizations evenly distributed across the

country. The CETEs provided engineering services in various fields:

- the general design of transportation infrastructure, engineering structures, and roadways,
- network operation and road safety,
- the environment: water, noise, air quality,
- natural environments, energy, waste, natural and technological risks,
- the development of IT related to these engineering services.

The regional laboratories were integrated into the CETEs (the Toulouse and Bordeaux labs were part of the Bordeaux CETE). With 2,500 technicians and engineers, the LPCs constituted almost half of their workforce.

The State, through its technical services, built a national network of major road and motorway routes, capable of handling constantly increasing heavy traffic. New manufacturing and material processing equipment, and innovative structures that were both durable and economical in aggregates and binders, particularly bitumen, made these major achievements possible. Our innovative techniques have been exported to several continents by expanding the scope of our studies to include earth and laterite roads. Thanks to the efforts made by the state, thanks to the quality of its services, at the dawn of the 21st century, France still had the best road network in the world and our road construction techniques were recognized and appreciated on all continents.

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