CEMENT CONCRETE OVERLAYS ON FLEXIBLE PAVEMENTS IN FRANCE

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1. INTRODUCTION

Up to 1973, pavement overlays were made for heavy traffic with 15 cm of bituminous base course or 25 cm of hydraulic gravel and 8 cm of asphalt concrete. Between 1973 and 1976, experimental sites were carried out in cement concrete laid by vibration [1]. This deliberate government action [2] was aimed at :

- maintaining a variety of techniques guaranteeing a minimum of competition on one hand, and the survival of a technicality on the other ;

- developing a low energy (table 1) and low aggregate (table 2) consumption technique ;

- restricting the use of imported materials (bitumen) while using a well known industrial material (Portland cement) ;

- having suitable solutions for different site conditions.

2. DESCRIPTION OF THE EXPERIMENTAL SITES AND PAVEMENT BEHAVIOUR

Five sites were carried out in all [3]. They covered over 50 km in two traffic lanes (table 3).

The concrete was produced by a discontinuous mixing plant (fig. 1), with production rates varying between 160 and 240 m^3/h according to the sites.

The laying was carried out by a slip form paver (fig. 2 and 3), across the full width on the straight lines and by half widths on bends. The profiles are either straight with a 2 % slope, or rooflike with a 2.5 % slope. Widths vary between 6 and 8 meters depending on traffic. For the wider ones, aggregate treated shoulders were made under the slab on both sides of the old road. In one instance, a lean concrete reshaping was carried out to put a straight profile on the old pavement. The Californian technique (short, non-dowelled slabs) was selected ; the longitudinal and transversal joints are sawn.

Table 1. Energy content of different types of pavements

	TYPE OF PAVEMENT	CEMENT CONCRETE PAVEMENT		ASPHALT CONCRETE PAVEMENT	
	TRAFFIC LEVELS (TRUCKS/LANE /DAY)	TO 750<2,000	T3 50<T<150	TO 750<T <2,000	T3 50<T<150
ENERGY CONTENT (THERMAL UNIT/	CONSTRUCTION MAINTENANCE	1,380 1,435	960 1,270	2,430 2,175	1,140 1,165
LINEAR METER OF PAVEMENT)	TOTAL......	2,815	2,230	4,605	2,305

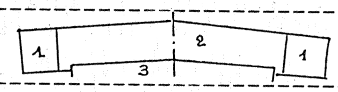
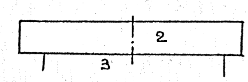
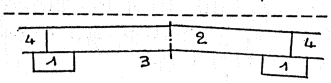
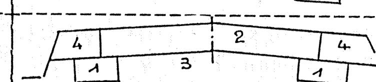
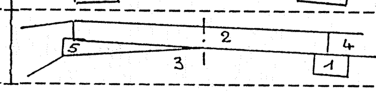
The works took place perfectly right and results were deemed very satisfactory.

After more than ten years of use, a series of condition tests was carried out to evaluate the state of the pavements

Table 2. Dry aggregate consumption of different types of pavements per meter of pavement for a medium traffic

TYPE OF PAVEMENT	PAVEMENT TYPES: SEMI-RIGID BASE AND SUBBASE CEMENT WATED MATERIALS	MIXED (BASE : ASPHALT SUBBASE : CEMENT)	CEMENT CONCRETE (CEMENT TREATED BASE)	CEMENT CONCRETE (BASE LEAN CONCRETE
BI-DIRECTIONAL	9.7	8.4	8.2	7.4
UNI-DIRECTIONAL	9.2	8	7.1	6.3

Table 3. Experimental sites of cement concrete overlays on flexible pavements

	LENGTH (KM)	WIDTH (M)	AVERAGE THICKNESS (CM)	MINIMUM THICKNESS (CM)	TRAFFIC (TRUCKS/DAY /LANE)	CROSS-SECTION
1. MAY 1973	12.4	6.5	21	17	600 (1982)	
2. NOV 1973 JAN 1974	3	7	20	17	20 (1973)	
3. MAY 1974	8	7.5	22	17	600 (1981)	
4. SEP 1975	22	7.5	25	20	1,000 (1960)	
5. MAY 1976	4.6	8	23	20	1,000 (1980)	

1 - Cement treated material 2 - Cement concrete 3 - Old pavement
4 - Non treated material 5 - Leveling course

Fig. 1 Production plant

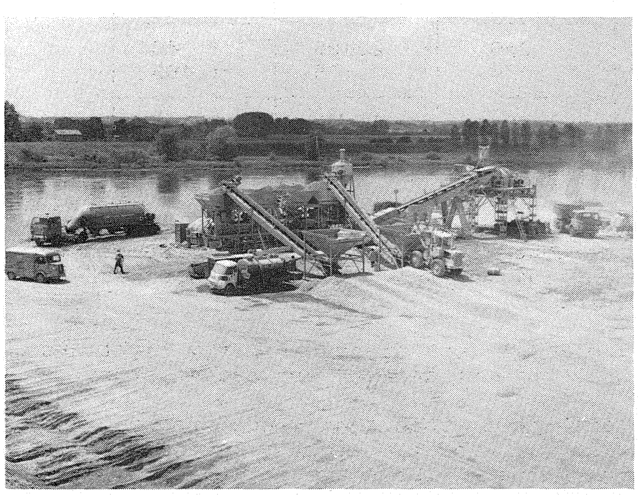


Fig. 2 Slip form on the County Road (C.D.) 940 jobsite (1974)

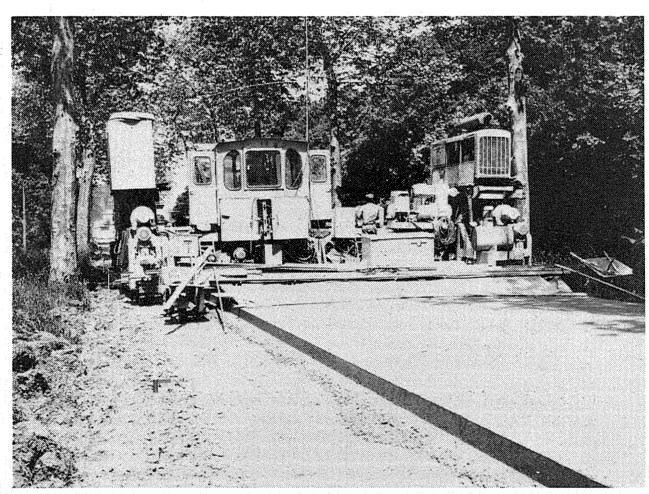


Fig. 3 Slip form on the County Road (C.D.) 940 jobsite (1974)

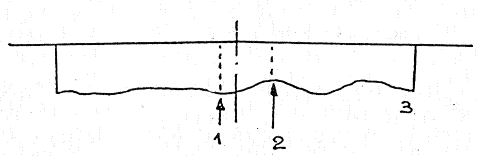
and to sum up the maintenance works during this period. The structural condition of the pavements is excellent and has not been altered despite very heavy traffic in some cases. On the most used (1,000 heavy trucks per day and per direction), slab deflections average $20/100^{ths}$ and there is no stepping of the slabs. This very good condition is due to the absence of loose fines under the slabs, the old pavement being non-erodible. Moreover, despite the presence of fine elements on the verges, there was no migration under the slab.

Three kinds of maintenance work were carried out. The first is bound to cracks which occurred during the hardening. These were mainly caused by a major unevenness of the support (fig. 4).

Fig. 4 Longitudinal crack

The crack occurred where the slab thickness was minimum, not always at the centerline of the pavement.

1 - EXTRA THICKNESS OF CONCRETE UNDER THE LONGITUDINAL JOINT
2 - MINIMUM THICKNESS
3 - RUTTED PROFILE OF OLD PAVEMENT



The second was as a result of an exceptionally hot and dry summer (1976) which has caused a major subsidence of the supporting soil on very short sections (600 m over 22 km) that involved repair work amounting to less than 0.5 % of the initial cost. The third involved standard maintenance, such as joint resealing and restoration of surface roughness. Table 4 summarises these operations.

Table 4. Summary of maintenance carried out to date

1. (1973)	. SEALING OF 25 M OF LONGITUDINAL JOINT (1976) . RESEALING OF JOINTS (1980) . REPAIR OF 10 BROKEN SLABS (1981) . SURFACE DRESSING (1981)
2. (1973-1974)	NO MAINTENANCE
3. (1974)	. SEALING OF 25 M OF LONGITUDINAL JOINT (1976) . TIGHTNESS OF JOINTS (1980) . REPAIR OF 10 BROKEN SLABS (1981) . SUPERFICIAL COATING (1981)
4. (1975)	. TREATMENT OF 500 M OF LONGITUDINAL JOINT (1977) . REPAIR OF 20 SLABS (1980) . RESEALING OF JOINTS (1978-80) . SURFACE DRESSING (1982-84)
5. (1976)	. SURFACE DRESSING (1981)

These experimental sections enabled to define with precision design and carrying out of these overlays.

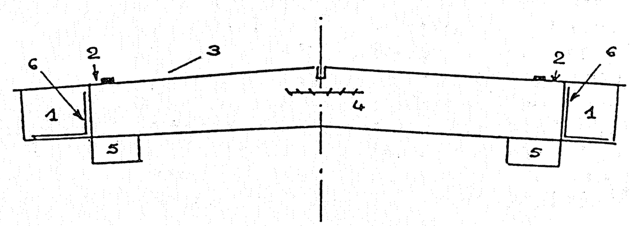
3. DESIGN OF OVERLAYS

The good behaviour of these pavements enabled this technique to be deemed operational, and to define design rules [4] [5].

The slabs are short (4.5 m), non-reinforced, and the joints are non-dowelled. The concrete is placed directly onto the old pavement (fig. 5) or, in some cases, onto a leveling course of lean concrete.

Fig. 5 Cross section

1 - STABILIZED SHOULDER
2 - EXTRAWIDTH ACCORDING TO TRAFFIC
3 - TRANSVERSAL JOINT
4 - TIE BAR
5 - HARD SHOULDER
6 - GEOMEMBRANE



The cross section shows a 2 % slope for single cant, and 2.5 % for slopes meeting at the centerline of the road. 50 cm extra width are provided where traffic is over 300 heavy trucks per day and per direction, and 25 cm where traffic is between 50 and 30 heavy trucks per day and per lane. Longitudinal joints are placed between every traffic lane. They are sawn or moulded. The longitudinal construction joints are made up of double joints (keyway and key) and jointing tie-bars (Ø : 14 cm, length : 60 cm) placed every 75 cm along the mid-plane. This jointing is also used for longitudinal joints in the case of rooflike profiles.

The thickness of the slab is calculated according to the principles of the Technical Guide for the design of overlays on flexible pavements [6]. This calculation is based on traffic (classified by the class of structure, deflection and thickness of asphalt concrete of the old pavement) and its frost behaviour index. It takes into account a 7 % annual increase of heavy truck traffic as well as local weather conditions (selection of reference winter). The good frost-thaw behaviour (stress distribution) of rigid pavements is also taken into account by increasing the frost behaviour index of the old pavement (2.5 points). The minimum thicknesses are specified in table 5.

4. <u>PREPARATION OF THE JOBSITE</u>

Before starting work, the site must be examined in order to define practical means of traffic diversion and to plan the work progress.

For the survey of the diversion network, through traffic should be taken into account as well as that of roadside residents. This is just as much to enable roadside residents to circulate freely as to guarantee the continuity of public and security services. These necessities often affect the choice of dates as well as the phasing of work. This survey pays particular attention to the layout of cross-roads, to the different ramps to be constructed, to the bends and to the conditions of the support. An account of the cross-section profiles and surface defects of the old pavement (pothholes, bumps, ruts...) must be drawn up in order to define possible reshaping or grinding requirements. Awareness of this state enables a better surveying of the quantity of materials to be used.

Work progress can also be influenced by the existence of particularities such as upperbridges or subways, the presence of trees near the pavement, level crossings with a railway line, layout modifications, etc...

Table 5. Thickness of concrete overlays (short plain slab without dowel/and with dowel) according to the traffic and the condition of the old pavement

DEFLECTION RANGE	TRAFFIC RANGE OF TRUCKS/LANE/DAY			
	T0 >750	T1 300-750	T2 150-300	T3 50-150
C2 (50 TO 75/100 MM)	22/20	21/19	19	-
C3-C4 (75 TO 150/100 MM)	24/21	23/20	21/19	19/18
C5-C6 (150 TO 300/100 MM)	25/23	24/22	23/20	21/19

The shoulders are made of stabilized materials over a sufficient width to ensure an edge strip of good bearing capacity over one meter (including concrete widenings). If this verge is likely to loosen fines, it is preferable to place a geomembrane to prevent their migration under the slab. Finally, if the pavement to be laid is wider than the old one, hard-shoulders made of hydraulic course of about 30 cm in thickness should be built up to the level of the old pavement.

5. <u>CARRYING OUT OF WORK</u>

Among the particular points needing a verification, the following can be noted :

- is it possible to organize traffic deviation in such a way as to avoid disrupting local economic life ?

- Does the network of ready-mix plants comply with the requirements for the production of pavement concrete ?

- Does the laying half a width at a time solve the diversion problem ?

- Is it possible to consider the laying of bends in one pass (the case of variable profiles) ?

- Is it possible to combine minimal thickness, minimal consumption and satisfactory evenness ?

- Is it possible to reduce the time required to reopen the pavement ?

So many questions to which the three sites described here (table 6) have provided a partial or complete answer.

Table 6. Description of the County Road (C.D.) 928, National Highway (R.N.) 6 and National Highway 85 sites

SITE	LENGTH (KM)	WIDTH (M)	TRAFFIC (VEHICLES/ DAY/BOTH DIRECTION)	OUTPUT (M/DAY)	PLACING METHOD
C.D. 928 (1983)	5.3	6	4,500	500	FULL WIDTH
R.N. 6 (1985)	11	8	15,000	800	2 HALF WIDTHS
R.N. 85 (1986)	25	8	18,000	600	FULL WIDTH

The overlay on the County Road 928 was carried out in 1983 [7]. This section of road has a daily traffic of 4500 vehicles, with 10 % of trucks. The site was 5.6 km long in two sections. The roadway was completely deviated, the placing being done on the full width. The concrete was produced by two ready mix concrete plants capable of producing 50 m^3/h each. Delivery was handled by concrete truck mixers.

The concrete was laid by a slip form machine with an articulated table. It is necessary when laying the full width of a pavement to change from a rooflike profile to a plane profile. This device enabled slopes to be changed automatically (bends) by continuous registering of the geographical position of the machine (fig. 6). The pavement was reopened within 8 days.

The following conclusions can be drawn from this job :

- the use of ready mix concrete and concrete truck mixers is only suitable for concrete laying at a slow output. The plant requires an adaptation (weigh-batching additive unit, mixing quality control...). Moreover, it is necessary to achieve a high standard of regularity for concrete consistency and in delivery times for supplies.

- The articulated table concept is very well suited to bends. A preliminary analysis of the bend is necessary.

- The ground under the spreader's caterpillar tracks must have a good bearing capacity.

The National Highway 6 and National Highway 85 sites were carried out with the same kind of equipment (fig. 7 and 8)

Fig. 6 Principle of the articulated table

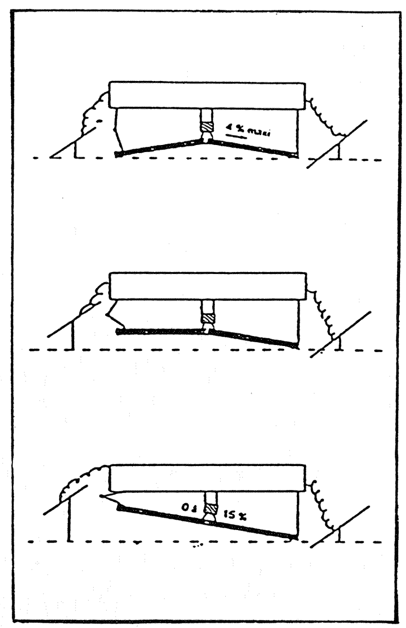


Fig. 7 Continuous production plant

This plant is totally automatically controlled. Its average output is 240 m^3/h.

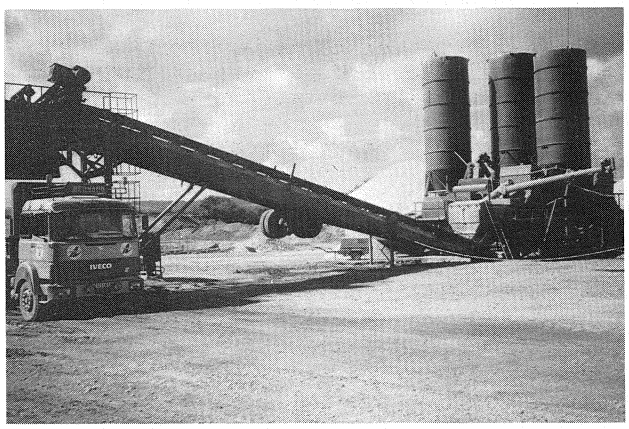


Fig. 8 R.N. 6 overlay (1985) : Slip form machine

This equipment allows to lay concrete with a slope variation of the "roof" cross section.

Production was carried out by a continuous mixing plant and the laying was done by a very compact slip form machine. The first site was worked in half width and the second in one pass. By working in half width it was possible to maintain the different services for the roadside residents. This has also facilitated the jobsite traffic, which is more difficult to organise when laying a full width. The latter requires water to be stocked at different places for sawing and stripping.

The pavements were reopened in 72 hours thanks to the use of a high-early-strength cement (CPA 55). Working over the full width enables an economic gain of approximately 12 % and a time saving up to 50 %. It is the most suitable method when there are no roadside residents to be taken into account.

It is absolutely necessary that the height guiding of the machine be done by two wires once the width is more than 4 meters. The layout of the guidance wire ensures by "smoothing", the necessary compromise between overconsumption and evenness without jeopardising the minimum thickness. It was therefore possible to guarantee the thickness within a variation of 0.5 cm, which is an important advantage for the concrete technique.

6. CONCLUSION

Preparation for an overlaying jobsite requires a specific attention, particularly taking into account the conditions of the jobsite before the works and its local environment. Once this particular operation accomplished, all the informations and appropriate means are available for this type of jobsite to be carried out. The conditions concerning the preparation of the contract and the carrying out of works have been perfectly classified and are completely mastered by the French contractors.

To improve the cost-efficiency of the concrete overlay technique, the traffic management difficulties should be reduced. For this purpose, two main researches are in progress :

1) Reduction of the delay to reopen the road (table 7):

Table 7. Delay before reopening to traffic

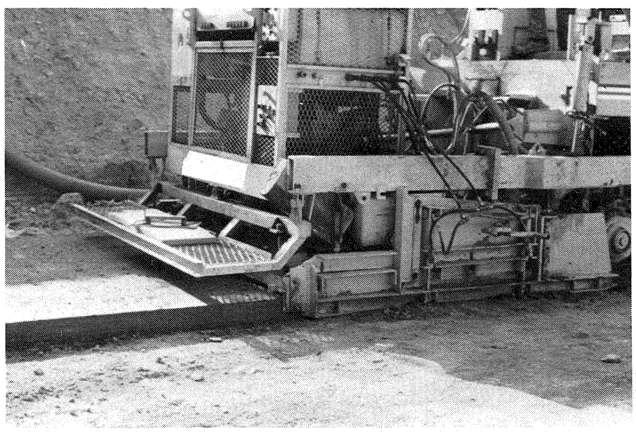
SITE	DATE OF CONSTRUCTION	DELAY
1 TO 5	1973 TO 1976	1 TO 2 WEEKS
C.D. 928	1983	8 DAYS
R.N. 6 AND 85	1985-1986	72 HOURS

Currently, the delay to reopen the road to the traffic is 24 hours for the cars and 72 hours for the trucks. But this term could be shorter. Indeed, the concrete behaviour under loading at the early age is badly known. Recent fatigue tests at the early age seem to show that the Miner's law is not suitable (ratio between resistances to bending of specimens after 24 hours test fatigue after 24.48 or 72 hours and specimens without test fatigue about equal to 1). A confirmation study is in progress.

2) Zero-clearance [9] equipment :

A french road contractor with the LCPC are going to perfect an equipment allowing to use a finisher frame. This equipment, named "concrete-tool" (fig 9) works like a finisher frame and remains usable for applications of other materials (to remove the "concrete-tool" and to put the asphalt table back are just needed). The tracks are in front of the slab and lateral tracks are not necessary. The first tests have given encouraging results.

Fig. 9 Zero clearance : "concrete tool" to finisher



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