

Table 1. Effect of extra width on pavement performance in the presence of water (results obtained by extrapolation for a speed of 20 km/h (12.5 mi/h)).

Distance between wheel and shoulder area (m)	Deflection (10^{-2} mm)		Pressure (m of water)		Maximum water ejection rate (m/s)	
	Up-stream	Down-stream	Up-stream	Down-stream	Downstream-Upstream	Downstream-Shoulder
0.40	89	76	0.77	1.10	2.54	4.69
1.45 ^a	28	55	0.46	0.55	1.30	3.20

Note: 10^{-2} mm = $4 \cdot 10^{-4}$ in. 1 m = 3 ft. 4 in. 1 m/s = 3.3 ft/s.

^aThe extra width corresponding to this case is thus about 1 m (3.3 ft.).

Extra Slab Width.

Principle. The concrete slab is made wider so that it extends beyond the shoulder marking line.

The principle of this extra width was tested as early as 1972. Its aim is to provide:

1. A reduction in the deflection on the edge and corners of slabs and hence a reduction in "pumping" phenomena; thus, an extra width of 75 cm (2 ft.6in.) reduces slab deflection by 50 percent.
2. A limitation of traffic, particularly of commercial vehicles, on the longitudinal joint between the slab and the shoulder by moving this joint away from the traffic lane.

The French 1977 catalog of standard pavement structures (1) calls for extra widths on truck lane slabs extending beyond the shoulder line by 25 cm (10 in.) for traffic levels not exceeding 150 trucks/day/lane (ADTT/lane); or 50 cm (1 ft.8 in.) for traffic levels between 150 and 300 ADTT/lane; or 75 cm (2 ft.6 in.) for higher traffic levels.

Application and Implications (4). The implementation of this principle does not involve any technological problems, except in the case where bridge piers are very close to traffic lanes (closer than 1.5 m (5 ft.)).

There are, by contrast, significant economic implications especially in the case of a two-way road since an extra slab width is then provided on each side of the road. An extra width of 75 cm (2 ft. 6 in.) entails an additional 4 percent in the total cost of the pavement in the case of a one-way facility and twice that in the case of a two-way facility.

About 400 km (250 mi.) of pavements have been completed with an extra width, 75 cm (2 ft.6 in.) in almost every case, the traffic varying from 500 to 5,000 ADTT/lane.

Performance. Increasing the slab width to 4.25 m (14 ft.) by adding 75 cm (2 ft.6 in.), for a thickness of 25 cm (10 in.), does not raise any problems.

The effectiveness of extra slab widths with respect to the reduction of traffic on the shoulder and hence the limitation of damage to the longitudinal joint is unquestionable.

The structural benefits as concerns pumping is more difficult to quantify because these extra widths are often used in combination with porous shoulders and lean concrete (see below). There is an effective reduction in deflection whatever the environment.

On the other hand, from the hydraulic viewpoint, extra slab widths do not solve the problem of

pumping as such. They only limit its effect, as shown in Table 1.

Porous Shoulder. Based upon the principle that it is not possible to perfectly waterproof a concrete pavement, lateral drainage for the present case of pavements with a treated subbase (3) allowing the fast drainage of infiltrated water has been provided on all concrete pavements in France on which traffic exceeds 150 ADTT/lane since 1975. The traffic levels on pavements thus designed vary from 500 to 5,000 ADTT/lane.

Various Systems Used. In almost every case, drainage is obtained by means of porous concrete with 150 kg (333 lb.) of cement per cubic meter, offering a porosity of from 15 to 20 percent and a compressive strength from 6 to 10 MPa (850 to 1400 psi). Initially, for about 100 km (62 mi.) of shoulder, the entire shoulder was made of porous concrete covered with 4 cm (1 2/3 in.) of bituminous mix. Then for economic reasons, the amount of porous concrete was limited strictly to what is required along the slab edge (Figure 2). Nevertheless, as much as 2 percent is still added to the cost of the pavement. The latter arrangement has been applied on about 100 km (62 mi.)

Figure 2. Lateral drainage on the edge of the pavement with a porous concrete trapezoid. This inexpensive arrangement (2 percent of the cost of the pavement), together with a nonerrodable subbase, is a basic element of the performance of concrete structures. Care must however be exercised in its application (porosity, outlets).



Performance. Nondestructive inspection of porous concrete materials is difficult. Several optical or physical systems are used.

It is presently possible to rule out any risk of short- or medium-term clogging: inspections carried out show that porosity is maintained satisfactorily with time.

A good indication of the effectiveness of the system is the absence of water in the longitudinal joint between the slab and the shoulder. In the rare cases in which water has been detected it has been attributable to poor construction construction practice (nonporous concrete, absence of outlets).

On a site in which the shoulder is made up entirely of porous concrete, in-situ water discharge measurements have revealed permeability values with orders of magnitude on either side of the laboratory measurements (measured by introducing a given amount of water into a hole of 16 cm (6 1/2 in.) diameter).

1. Discharge measured in laboratory: 400 cm³/s (24 1/2 cu.in./s).
2. Maximum in-situ discharge: 1,200 cm³/s (73 cu.in./s).
3. Average in-situ discharge: 30 to 80 cm³/s (1 3/4 to 5 cu.in./s).

These values demonstrate a high permeability guaranteeing fast water removal. Consequently, the time during which water is present in the pavement is reduced to that of the rainfall, and even further if the sealing of the joints is done regularly, since the response times are short. On the other hand, the drying time can be several hours.

Lean Concrete.

Principle. Lean concrete (6) is used as a substitute for treated granular materials to guarantee high erosion resistance.

Lean concrete (with about 160 kg (355 lb.) of cement per cubic meter, placed by the slipform machine) has been used in almost all road projects with a treated subbase, particularly in the case of heavy traffic levels (always higher than 500 ADTT/lane).

The required bending-tensile strength is 3.5 MPa (500 psi). Lean concrete has enabled the reuse of crushed cement-treated materials or concrete coming from pavement demolition in the case of reconstruction work on slow-traffic lanes.

For lower traffic levels, a granular material properly treated with a hydraulic binder can very well be used.

Table 2 below gives some results of mechanical tests.

In all, 180 km (112 mi.) of lean concrete subbase were completed. Compared with a cement-treated material, the additional costs is a few percent.

Application. Manufacture and placement of the lean concrete, carried out with the same equipment used for the slab concrete, does not pose any particular problem.

On the other hand, there is a greater risk of crack propagation from the lean concrete into the surface concrete than in the case of cement-treated materials. To overcome this drawback, the solution currently used is to double the proportion of the curing product (rubber dissolved in a petroleum phase), i.e. about 250 g/m² (7 oz/cu.yd.). This process however does not offer an absolute guarantee. A polyanne sheet is used only in extreme cases because the folds which inevitably form in this plastic material can be the cause of significant thin spots in the slab concrete, leading to cracking or to increased slab deflection. A curing test with a paraffin-based product is to be carried out.

Assessment of Behavior. The assessment of these new structures is very favorable. The three constructional arrangements described above afford a real improvement in structural performance.

The first projects were completed only 9 years ago and a total of about 200 km (125 mi.) of pavements have been constructed. High traffic levels are however involved so that, in certain projects, the theoretical service life has already been reached, as on the northern motorway at the exit of Paris (cumulative traffic in 1976: about 20 million commercial vehicles). In this specific case, the

Table 2. Bending strength of lean concretes for subbases (MPa).

	Reconstruction of Motorway (°)		A 36	Selestat detour	RN 165 Brest-Quimper	Reconstruction of A 6 Motorway
	1976	1977				
D e s i g n	2 days	1.9 (1.96)	2.15 ^a	-	1.9	-
	7 days	2.5 (2.8)	2.5	2.2	2.8	2.2
T e s t	2 days	1.9 (1.2)	1.7 ^a	-	-	-
	7 days	2.7 (2.0)	2.4	2.9	2.5-3.1	2.4
	28 days	3.6 (2.8)	2.9	3.68	4.2	3.9

Note: 1 MPa = 142 psi

(°) Lean concrete using crushed-concrete aggregate. ^a At 4 days.

structural condition of the pavement is excellent and the cracking rate is very low (about 1 to 2 cracks taken together, excluding construction cracks).

Since it may be asked whether the arrangements which solve the problem of pumping do not bring about a modification in the slab failure mode by increasing the stresses in the slabs under high temperature gradients, some of the considered measures are:

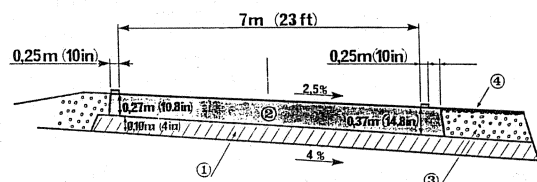
1. Reduction in performance requirements of lean concrete (from 3.5 to 2.5 MPa (500 to 344 psi)); mechanical strength and erosion resistance requirements were set too high.
2. Reduction of extra width to 50 cm (1 ft.8 in.) for medium-traffic levels.
3. Reduction of slab length (presently 4.5 m to 6 m (15 to 20 ft.) with an average of 5 m (16 ft.8 in.)).
4. Optimization of shoulder area near longitudinal joint, as cracking of the bituminous material occurs on certain sites.

Structure with Thick Slab over Porous Subbase in Untreated Granular Material

Review of Principle of this Structure.

Figure 3. Typical cross section of a structure consisting of thick slabs over a porous foundation in untreated granular material (motorways handling 300 to 750 ADTT/lane). This structure is characterized by: (1) an untreated porous subbase, (2) a thick slab under the commercial vehicle lane. At the present time, 200 km (125 mi.) of this type of pavement have been completed. The application does not pose any problems. The assessment of the behavior of this type of structure requires special investigations.

1 - Untreated porous subbase; 2 - Slab; 3 - Untreated granular material; 4 - Asphalt concrete.



This structure is based upon the principle of very fast drainage of water capable of infiltrating into the pavement, using a porous subbase in untreated granular material.

The pumping phenomenon is also expected to be eliminated.

The modulus of elasticity of the porous layer, lower than that of a treated material, requires a substantial increase in the concrete slab thickness, at least under the commercial vehicle lane, in order to ensure adequate strength and fatigue performance.

The slabs are short (5 m (16 ft.8 in.) on the average) with undowelled joints.

This results in:

1. Better load transfer owing to the increase in slab thickness.
2. A reduction in the curling caused by temperature and humidity conditions, and hence a reduction

in stresses.

3. The possibility of using larger aggregates and hence lowering the proportion of cement used.

4. A single passage with the slipform machine.

Completed Structures - Construction Arrangements. Almost all the pavements completed were on motorways. With the exception of some special cases of very limited importance, the characteristics of the pavement constructed, relatively uniform, are the following (Figure 3):

1. Traffic: 500 to 600 ADTT/lane.
2. Subgrade of comparable quality to that of a structure with a treated subbase. The materials can be crushed 0/31.5 mm (0/ 1 1/4 in.) limestone, shales, silt treated with lime-cement or sand treated with cement. The deflection of these improved subgrades varies from 0.5 mm (1/50 in.) (treated materials) to 2 mm (1/10 in.)
3. Subbase in crushed limestone of 4/60 mm (1/8 / 2 1/2 in.) then 5/40 (1/6 / 1 5/8) and finally 6/20 (1/4 / 7/8) with a constant thickness of 15 cm (16 in.) for the first structure (1977), reduced to 10 mm (4 in.) and then 8 mm (3 1/4 in.) at the present time.
4. Concrete slab 8 meters (9 ft.) wide (two lanes of 3.5 meters (4 ft.) and extra width of 75 cm (2 ft.6 in.) owing to traffic) with a variable thickness in the cross section, a possibility permitted by one-way traffic.

In the first project the thicknesses were:

1. 40 cm (1 ft.4 in.) under the commercial vehicle lane, a thickness corresponding approximately to the sum of the thicknesses of the treated subbase and of the slab in the conventional design.
2. 25 cm (10 in.) under the high-speed lane, the observations made on old pavements showing that the high-speed lane was always in good condition whatever the quality of the subbase.

On the following projects a slight rebalancing was provided (37 cm (1 ft.3 in.) on slow lane side, 27 cm (11 in.) on fast lane side).

Since the drainage of the pavement takes place through the subbase, the shoulder was made of a solid material of a highly variable nature, often comparable to that of the material of the subgrade, sometimes laying a nonwoven separating material.

Placement, Output and Cost (7). The only technological difficulty may come from the draining layer. This layer must:

1. Allow the movement of trucks supplying the slipform machine.
2. Maintain a correct and regular thickness in spite of construction traffic.
3. Allow the passage of the spreader and correct placement.
4. Permit the use of crushed, relatively hard materials (Los Angeles coefficient of about 30).

The limitation of construction traffic to a strict minimum, i.e. about 100 meters (110 yd.) before the spreader, and final shaping just ahead of the spreader, for example by means of a small vibrating machine, made it possible to solve the problem even at sites involving extreme conditions (draining layer cross slope of 8 percent).

The output achieved in laying the untreated draining granular material depends on the equipment used (800 m/day (900 yd/day) with a conventional grader, 1200 m/day (1350 yd/day) with an Autograde).

Concrete placement output depends directly on the manufacturing capacity but also on the efficiency of the hauling system and the placement capacity. On a project in which the rated manufacturing capacity was 800 m³/h (1050 cu.yd/h), the average output was 3,200 m³/day (4200 cu.yd/day) and the maximum output 4,200 m³/day (5500 cu.yd/day).

The cost of the thick-slab structure is generally a few percent less than that of a conventional structure.

Performance (5). Between 1977 and 1984 about 200 km (125 mi.) of thick-slab structures were completed.

The traffic handled is from 500 to 600 ADTT/ lane.

The oldest pavement handled 1.3 million trucks or about one-fourth of the traffic for which it was designed.

The operating characteristics and long-term performance of this new structure are difficult to assess. There are in fact few suitable investigation facilities. The main question has to do with the performance of the draining layer and its interface with the subgrade. In fact, it is this layer which must provide proper support of the slabs. The investigation procedures currently used are aimed at determining the period after which suitable supporting conditions are no longer provided owing to the attrition of aggregates in this layer near the edges, to a certain contamination of this layer from the outside or from the subgrade, or to the deformation of the grain skeleton.

Following are the results of investigations conducted to date.

Slab Deflections. Slab deflections are at least of the same order as those measured on a conventional structure (0.15 to 0.2 mm (0.006 to 0.008 in.) on the average, and up to 0.5 mm (0.02 in.)). If it is assumed that deflection corresponds to pure bending, the stresses in the concrete would be higher than those in a conventional slab. However, if the movements of the slab ends are examined during the passage of a truck, a slab tipping component also appears to be involved.

Slab Faulting. The measured faulting is not significant.

Measurements with Strain Gauges Embedded in the Concrete during Placement. The measured values are small (of the order of 10⁻⁷). However, as appears to be logical, it is observed that in view of the cross section with considerable thickness variations and the absence of tie bars on the central longitudinal joint, the slab of the truck lane is stressed most along this joint and not on the shoulder side.

Cracking. Seven slabs were cracked transversely on the first project. These slabs all had a length of 6 m (20 ft.). This confirms, as a first approximation, the need to limit the slab length. The slabs currently have a length of 4.5 m (15 ft.).

Drainage, Condition of Interface between Subgrade and Draining Subbase. The subbase materials are highly porous (permeability of 2 to 7.10⁻² m/s (3/4 to 2 3/4 in/s)).

It can be easily seen, and in-situ tests have confirmed, that these characteristics are excessive. Investigations conducted under the slab of the first pavement in which the subgrade consisted of limestone materials show the following:

1. The 4/60 mm (1/8 / 2 1/2 in.) material is always very porous.
2. The separation between the bottom of the draining layer and the limestone platelets of the subgrade is very clear.
3. It may be concluded that these limestone platelets contribute to vertical drainage: the materials were normally moist, fairly regularly throughout their thickness. This moisture appears higher than under pavements with a continuous structure.

Other measurements and studies are under way, in particular measurements of the pressure at the interface between the subgrade and the subbase by means of sensors, and measurements of vertical displacement by means of sensors whose supports are implanted.

Provisional Conclusion. The structure with a thick slab placed over an untreated porous subbase is a new structure. Conventional investigations are moreover not suited to this type of structure. New ones are being developed. The result is that, while this structure is operational in terms of its application (200 km (125 mi.) of pavements completed), the limited performance perspective (6 years) and the traffic level (1.3 million trucks) are such that its behavior has not yet been determined precisely and it consequently maintains an experimental nature. It may nevertheless be considered at the present time that this structure is performing at the level initially expected.

Other Structures

On the occasion of various projects, other structures were completed, of limited extent and of an experimental nature.

Among these may be mentioned a structure completed in 1977 using short slabs with undowelled joints placed over a subbase 15 cm (6 in.) thick in porous concrete similar to the one used in the shoulder. The commercial vehicle traffic on these structures is very small. Observations have demonstrated the good mechanical and hydraulic performance of the porous concrete (no erosion, no clogging). Higher slab deflection values may be noted compared with the structure using a lean concrete subbase. Also completed was a section with thick slabs in which a nonwoven material 8 mm (1/3 in.) thick was substituted for the porous untreated granular material.

Technology - Materials

In addition to the lean concrete described in the previous pages, two new techniques have been developed in France in recent years: gritting of fresh concrete, and compacted concrete.

Gritting of Fresh Concrete

Principle. The use of local aggregates is often an important factor for the competitiveness of the use of concrete. France's geology is such

Table 3.

SITE	YEAR	SURFACE (sq.m) ^a	CONCRETE	EVENNESS: Measured with the APL 25 longitudinal profile analyzer: % of values lower than or equal to threshold of ^b :				
				4	6	8	10	13
A 35	1980	240,000	Siliceous		63 %	98 %		99.5 %
A 26	1981	420,000	Limestone	20 %	57 %	82 %		98.5 %
A 26	1982	460,000	Limestone	42 %	82 %	95 %		100 %
A 26	1983	200,000	Limestone	60 %	91 %	98 %		100 %
A 26	1984	280,000	Limestone	79 %		95 %	100 %	

^a 1 sq.m = 1.2 sq.yd. ^b For a given threshold (4, 6, 8, 10 and 13), the higher the percentage, the better the evenness.

that local materials often have a insufficient polishing resistance for heavy traffic (accelerated polishing coefficient of at least 0.45).

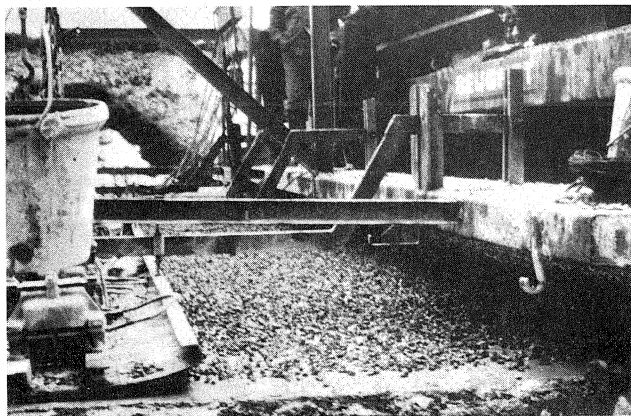
To overcome this, a widely used technique consists in placing a surface dressing, sometimes after the construction of the pavement (cost of \$1.80/m² (\$1.60/sq.yd.)). Another consists in driving aggregates with a high polishing strength (APC ≥ 0.50) into the fresh concrete behind the extrusion plate (Figs. 4-5) of the slipform machine.

For this purpose, the spreader is equipped:

1. With an aggregate storage hopper.
2. Under this hopper, an aggregate feed roll.
3. Behind this assembly, a vibrating beam driving in the aggregate placed on the surface of the concrete.

The concrete slab then receives a protective curing (no grooving being carried out, of course).

Figure 4. Gritting of fresh concrete. After spreading from 6 to 7 kg/m² (11 to 12.5 lb/sq.yd) of chippings on the surface of the fresh concrete, these chippings are driven into the concrete by means of a vibrating beam (seen on the left in the photo). All these operations are carried out by a machine mounted behind the slipform paver.



Projects completed - Developments (7). Table 3 provides the data concerning various completed projects.

The spreading machine has always been an Auto-grade CMI. The structure of A 35 was a conventional structure (see first page) and that of the A 26

Figure 5. Gritting and baring of fresh concrete. Surface finish: to guarantee high antiskid properties from the outset, the surface of the gritted concrete slab is bared by means of a rotary mechanical brush.



projects a thick-slab structure (see fourth page). The size of the gritting aggregate was 17/20 mm (3/4 / 5/6 in.) and the proportioning about 6 kg/m² (11 lb/sq.yd).

The first two projects were carried out with a grit driving beam designed to vibrate and also to tamp, an adaptation of the Belgian system for concrete placement between fixed forms.

The tamping movement, designed to drive in the aggregate without sinking it excessively into the concrete, had the drawback of substantially degrading the smoothness of the concrete leaving the slipforms (the poorer results of the second project compared with the first being due to the presence of slopes in which the concrete, under the tamping action, has a tendency to fall horizontally).

To deal with this problem related to the use of a slipform machine, the tamping effect was eliminated and the aggregate was placed by the action of a vibrating screed.

A substantial improvement in smoothness during the last two projects can be noted.

This evolution had the negative effect of excessive sinking of aggregate into the surface, lowering the initial skid resistance of the pavement. It may be considered that, under the effect of traffic, with the wear of the mortar, this skid resistance will rise again to the level of the first project.

However, to deal with this defect (perhaps merely an initial one) following the completion of

experimental road sections, in 1984 the baring of gritted concrete was carried out 24 to 48 hours after its placement thanks to the use of a curing product having a retarding effect. This gritting and baring technique also makes it possible to use aggregates of 10/14 mm (2/5 / 5/8 in.) size (easier supply) which will be proportioned at 6-7 kg/m² (11-12.5 sq.yd). The cost estimate for this technique today is \$1.20/m² (\$1/sq.yd). As shown by Table 3, the results of smoothness tests were satisfactory.

Compacted Concrete

For road bases (base and subbase), and for both new construction as well as reconstruction under traffic, considerable use is made in France of granular materials treated with hydraulic binders (cement, granulated slag, flyash) and contractors have mastered the use of these techniques.

Consequently, many contractors are equipped with manufacturing and spreading equipment designed for these materials.

Moreover, France does not have much equipment for the vibration of concrete and, when it exists, this equipment is often heavy and poorly suited to current jobsites. The use of vibrating concrete for the strengthening of pavements raises sometimes complex operational problems.

This has led to the idea of a compacted concrete, i.e. a material whose performance is comparable to that of a vibrated concrete but manufactured and placed with equipment for materials treated with hydraulic binders, allowing immediate traffic movements (Fig. 6).

Figure 6. Placement of compacted concrete. This material is similar in design to granular materials treated with a hydraulic binder (manufacture, placement, immediate trafficability) but with a higher binder content giving laboratory performance results comparable to those of a vibrated concrete. The absence of a bituminous wearing course calls for excellent placement to obtain suitable smoothness. Only medium- and long-term monitoring will make it possible to evaluate the structural properties of this material.



To be economically valid, the compacted concrete pavement structure should not include a thick wearing course in bituminous concrete, but at most a surface dressing. The very first studies and applications took place in 1977. However, the real application of this technique began in 1980.

Experience acquired during these three years (about 100 road projects, maximum traffic 500 ADTT/lane, 2 million square meters (2.5 million sq.yd)) has made it possible to develop the material and its technology, but the experimental perspective is not yet sufficient to allow a precise evaluation of its structural performance.

Following are some of the main results of this experience (8, 9):

Mix Design. What is involved is 0/20 or 0/14 mm (4/5 or 5/8 in.) granular materials (fewer segregation problems, in particular on the surface during application) in which the hydraulic binder content (cement or cement + wet flyash + lime in certain cases) can vary from 0 to 14 percent. The water content can vary between 4 and 7 percent. The material is very sensitive to the water content: excess or insufficient moisture considerably lowers its mechanical performance.

The characteristics of the aggregates are those recommended for materials treated with hydraulic binders.

Laboratory Study. The required performance is 3.3 MPa (470 psi) in the compression splitting test after 28 days (2.8 MPa (400 psi) for light traffic). It is advisable to carry out a sensitivity study because a variation of 5 percent in compactness or 1 percent in water content easily leads to a 20 or 30 percent drop in strength if accumulated.

Manufacture. Plant manufacture is necessary and, considering the sensitivity of the material, good accuracy is required. The use of wet flyash in which the water content can vary considerably calls for special precautions (storage, lump breaking).

Hauling. Care must be taken to minimize variations in water content by using a tarpaulin.

Placement. Since performance is affected by compactness, the subgrade should be capable of allowing thorough compacting and the placement thickness should not exceed 25 cm (10 in.).

As compacted concrete is not designed to receive a bituminous mix as a wearing course, particular care must be given to its placement, especially from the viewpoint of surface properties (homogeneity, strength and smoothness). For the placement operations, use may be made of either a finisher or a grader. On the other hand, planing is required before the end of the application, followed by final compacting.

Curing must be carried out immediately. It is preferable, when a surface dressing is to be provided, not to place it until a few days after completion, after the surface has become rigid and after small surface defects have been corrected.

Cracking is allowed to develop freely and no special constructional arrangements are made.

Results - Behavior.

Performance. The mechanical properties of the material in place are substantially lower than those of the laboratory studies, particularly considering the variations in compactness. A value of 0.7 times the laboratory strength can be reasonably used for

structural design purposes.

Smoothness. The smoothness obtained is never equal to that obtained on the structure consisting of a treated material covered with a bituminous mix. This makes it necessary to limit the use of this technique to traffic levels not exceeding 10,000 vehicles per day.

Behavior. Depending on the jobsites (temperature at time of construction, nature and content of binder, etc.), the behavior of compacted concrete as concerns heat shrinkage cracking is comparable to that of treated granular materials or vibrated concrete (cracking intervals varying from 5 to 30 meters (5 1/2 to 33 ft.), slab deflections capable of reaching 0.5 mm (0.02 in.)). The evolution of shrinkage cracks in the absence of joints is of course more sensitive than in sawn vibrated concrete. It is too early to quantify it, but it is probable that this is one of the reasons this technique is limited to medium-traffic pavements.

Dimensioning. The dimensioning resulting from the above observations is intermediate between that applicable to vibrated concrete and cement-treated materials.

Market. The dimensioning presently adopted, as well as the smoothness which, as we saw, limits the use of this technique to pavements handling traffic levels not exceeding 10,000 vehicles per day, are such that this technique is limited economically and is always competing with other available techniques.

On the other hand, this type of material is of greater value for storage, parking areas, etc. where the problem of smoothness is less troublesome.

Conclusion

The use of concrete pavements in France is limited and must compete with other structures and techniques which are highly competitive and familiar to contractors. To conserve part of the market, concrete pavement techniques must be improved and adapted constantly. This is what has led to the constant developments in structures and their multiplicity (another technique, continuously reinforced concrete, will be used in new pavement construction in 1986) and the need to monitor the evolution of their medium- and long-term performance.

As of now:

1. The structure consisting of undowelled short slabs placed over a nonerodable surface (of the lean concrete type) with lateral drainage is being confirmed as a valid structure, possibly requiring minor changes to limit the effects of temperature gradients.

2. The structure consisting of a thick slab over an untreated porous subbase is operational; its present performance is satisfactory; long-term monitoring will make it possible to confirm the assumptions regarding its operational validity.

3. The gritting of fresh concrete associated with partial surface baring may be regarded as operational.

4. Compacted concrete techniques have been finalized; the performance of this material on pavements also requires monitoring with respect to time.

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