COMPOSITE PAVEMENTS: AN EXAMPLE OF A "SHARED TECHNIQUE" FOR BETTER PUBLIC SPACES AND ROAD INFRASTRUCTURES

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Abstract

Rather than continue the traditional opposition between flexible and rigid pavement materials, there are many reasons today for seeking a closer association of these materials. This "marriage of convenience" is taking place not only in connection with roadway surfaces shared for operational or aesthetic reasons but only in so-called composite structures consisting of a sort of glued strip combining cement concrete and asphalt. The paper describes the technical and economic potential, as well as the usage properties of these new designs. Precautions are of course called for to ensure good bonding of layers in the construction phase and throughout the pavement's service life. Research and trials in new construction projects and observations on old pavements have led the French highway administration to describe an official option when considering this type of structure for highway projects. Composite pavements are thus a promising area for a resurgence of concrete pavements on heavy-traffic roads, embodying very effectively the "shared technique" concept.

Introduction

The construction, requalification and maintenance of roads as well as streets benefit from an increasingly broad range of surfacing materials and structures associated with increasingly diversified and creative designs. Long regarded as a vehicle of engineering progress or economic competitiveness, the opposition and even the rivalry existing between the principal families of flexible or rigid road structures has been heightened to varying degrees depending on whether urban roadways, rural roads or airport runways are involved. This trend has hampered the emergence of new designs seeking on the contrary to combine the different materials and structures available so as to make the best use of what each has to offer.

Today, a new approach, which we shall call the "shared technique", is developing rapidly. The shared road-building technique consists in combining several types of materials whose operating mode is different (rigid and flexible). This option is to the benefit of a more functional and/or more economic structure which is generally more cost-effective in terms of the service that it can render throughout its life. The association of materials of different rheology is possible in the architecture of the structure itself, as in the case of composite pavements combining cement concrete and bituminous materials, as well as in the architecture of the surface aimed at achieving a visual and textural effect in road facilities. In this last case, reasons related to harmonious operation, safety and also the aesthetics of roads within our towns or at strategic exchange points are researched.

DEVELOPMENTS FAVORING STREETS AND ROADS USING THE SHARED TECHNIQUE

1. The general extension of approaches of the functional analysis type or, more simply, the adoption of quality assurance procedures, have been such that today the utilization functions of structures take precedence over technical functions. The latter are increasingly considered as prerequisites to be met by all competent and responsible professionals. Meeting the basic needs of users, and the ability of the different techniques, alone or more often together to meet these needs is a priority.
2. The user requirements have grown significantly and are of an overall nature (things must be done right in every area). They are expressed in terms of traffic fluidity, disturbance reduction, environmental compliance and preservation, sustainable development, safety and comfort. Against this background – offering the best in every area – it is found that the association of what each technique has most to offer ranks high among the solutions regarded as pertinent today in many industrialized countries and in France in particular.
3. In one decade, highway engineering players have had to consider the new requirements induced by legislation concerning water, noise and air, to which must also be added the law on waste disposal. These formidable challenges have called many things into question, dispelling preconceived notions, while generating much creativity, innovation and new practices. All rigid, flexible or modular pavement materials and structures have something to offer technologically in these different areas, again with the great potentialities of mixing for optimized designs.
4. Urban transportation plans call for new design and management of public spaces as well as for major urban and peri-urban radial routes, characterized by the juxtaposition of services, equipment, surfacings and structures. For the shared use of space, current designs are

characterized by the use of a very broad range of surfacing materials, structures and construction techniques on the same site, allowing the control of subsoil occupation by utility networks, runoff water channels, greenery plantings, etc. Also found, according to the creativity of urban designers, architects, landscapers and other turnkey players in the setup of quality public spaces (i.e. those operating harmoniously and providing an environment contributing to public well-being), are pavements which may be flexible or rigid, modular or continuous, compacted, poured and internally vibrated, colored, printed, textured or in their natural condition, and so on. The combination of these products that differ in their mechanical and rheological behavior, in their thickness, their surface properties and the role they play with regard to water flow, raises problems relative to interfacing and the treatment of discontinuities.

5. In the economic area, decision makers lack factual data to support their choice in terms of whole-life cost, i.e. the cost that takes into account not only the initial capital outlay and maintenance costs over the service life of the facility, but also the environmental costs, social costs, and reconstruction costs. Even if significant advances have been achieved in integrating the overall investment cost plus maintenance based on a codified method in France, applications in the field are exceptional. The initial capital outlay is most often the decisive criterion. Acute socio-economic issues, diminishing resources, the diversity of alternatives for investments and procedures relative to contract awards are such that in the actions taken and the decisions made, it is most often the short-term considerations that prevail. In fact, even where long-term and global cost criteria are clearly called for. To minimize disturbance to users, there is a tendency today to extend the predicted service life of pavements up to 30, 50 and even 100 years in certain countries for strategic routes. A present-day prerequisite for the successful adoption and extension of a given technique is that it offer technical performance, but also that it be economically advantageous in terms of the initial investment.

CEMENT CONCRETE IN STREETS AND ROADS USING THE SHARED TECHNIQUE

From the operational viewpoint, the context described above leads to two types of shared-structure pavements depending on whether the sharing is in the structure alone or also includes the surface. The photos in Figure 1 show examples of the surface of such shared structures. Effective side-by-side use of a range of diversified techniques, although required in order to achieve the design and operational objectives for the roadways involved, is not always sufficiently mastered. Research is under way because there is an urgent need for the collection of data, observations and recommendations to prevent a certain number of disappointments and allow the specification of the best techniques.

Examples of careful design of pavements and other public spaces

Figure 1

Between the pedestrian area, the cycle path, the bus lane or the public transportation right of way, the tramway trackbed, heavy and light traffic roads, delivery areas, and so on, the entire range of architectures and thicknesses found in typical structural design guides may be represented. Pavement bases may be rigid, semi-rigid, mixed, flexible, composite. Materials used for backfills, bedding courses, trench filling, paving blocks or cobbles used to restore the history of the town and its buildings are all situations calling for more orderly, efficient and optimized approaches. This required juxtaposition of pavements and structures generates interface and bonding problems in relation with different thermal, mechanical and hydric properties. This explains why many pathologies have been found in aesthetically or qualitatively designed (paving blocks, other modular elements) pavements sometimes handling heavy traffic (buses, for example). This problem must be dealt with through better designs and better technical management of projects. Based on its experience in dealing with discontinuities, because concrete is basically and originally discontinuous (joints of all kinds, transition zones, etc.), the concrete industry must and can contribute significantly to this search for better practices. This requires methodical observation, which is not easy because it is necessary to relate what has been designed, what has been built and what is loading or stressing the interfaces mechanically, thermally or hydraulically. However, the stakes are high because realistic and well-suited solutions must be found between not dealing with the problem based on present errors and drastic solutions evoked in the technical literature but not easily applicable to real site conditions. In a more current example, the experience acquired in the widening of motorway pavements and the juxtaposition of flexible pavements and rigid pavements constitutes a good starting point. Of course, it has to be adapted to the forms, structures, construction and management methods, and of course to the loading of other types of roadways. In this area, it is also seen that the problem of the flow of water at interfaces is a key point and that cement concrete has made it possible to deal effectively with this problem. Some early conceptions of the nature of cement concrete and its impermeability have long been revised, and new possibilities have been found for it, along with other porous materials, in the most promising application areas.

While developments have been taking place rapidly relative to pavements using the shared technique on the surface, and the understanding of the functioning of the interfaces has only begun, the same is not true as concerns pavements using the shared technique in the structure. In this last case there has been much progress and consistency between conceptual aspects, research, experimentation, design guides, development schemes and technical literature. The case of composite pavements on which the present paper focuses is particularly significant in this regard.

DEFINITION, TYPOLOGY AND OPERATING MODE OF COMPOSITE PAVEMENTS

A composite pavement is the result of the combination within a structure of hydrocarbon layers or modular elements with internally vibrated cement concrete. This typology may be extended to varying degrees (for example, roller-compacted concrete, etc.) but, initially, four families of composite pavements have been considered here more specifically.

Type 1 composite pavement:	cement concrete (1) + asphalt surfacing (2)
Type 2 composite pavement:	cement concrete (3) + surfacing in modular elements (4)
Type 3 composite pavement:	base or treated subgrade + bituminous materials (5) + cement concrete (1)
Type 4 composite pavement:	combination of composite pavements 1 and 3: bituminous materials (5) + cement concrete (6) + asphalt surfacing (2)

(1) dense concrete slab or continuously reinforced concrete
(2) bituminous concrete or porous asphalt
(3) slabs of dense ordinary concrete or lean concrete
(4) paving blocks or slabs
(5) dense asphalt or asphalt-treated material
(6) continuously reinforced concrete

If, on the national and international levels, we are beginning to better understand composite pavements types 1 and 2 (cf. reports and publications of PIARC Committee C7 on rigid pavements in this regard), real progress has been achieved in recent years with type 3 composite pavements and hence with general type 4 composite pavements, corresponding to an innovative technological contribution for engineering as well as for the economy today.

Understanding the bonding of cement concrete layers and bituminous materials was the basic starting point for progress. It was necessary to progress from a situation in which the official structural design of concrete pavements did not include the structural contribution of bituminous materials not considered to be bonded to the concrete, to a situation in which under certain conditions this bond may exist durably and should be taken into account in a pavement's structural design calculations. This was done more specifically in the case of continuously reinforced concrete (CRC), as the international assessment of composite pavements using other more conventional concrete techniques were more limited and called for greater care.

In fact, in light of findings of the national FABAC (continuously reinforced concrete fatigue) project, and an experimental site involving fusible sections with a very short service life in order to correlate the structural design models, as well as tests based on core samples tests conducted on motorways from 15 to 30 years old in France and Belgium, it was possible to acknowledge the proper bonding between CRC and underlying bituminous materials for 15 years. Beyond this "service half-life," it was considered that the pavement operated under "unbonded" conditions because of some random results observed admittedly on sections in which no particular construction arrangements were made for bonding.

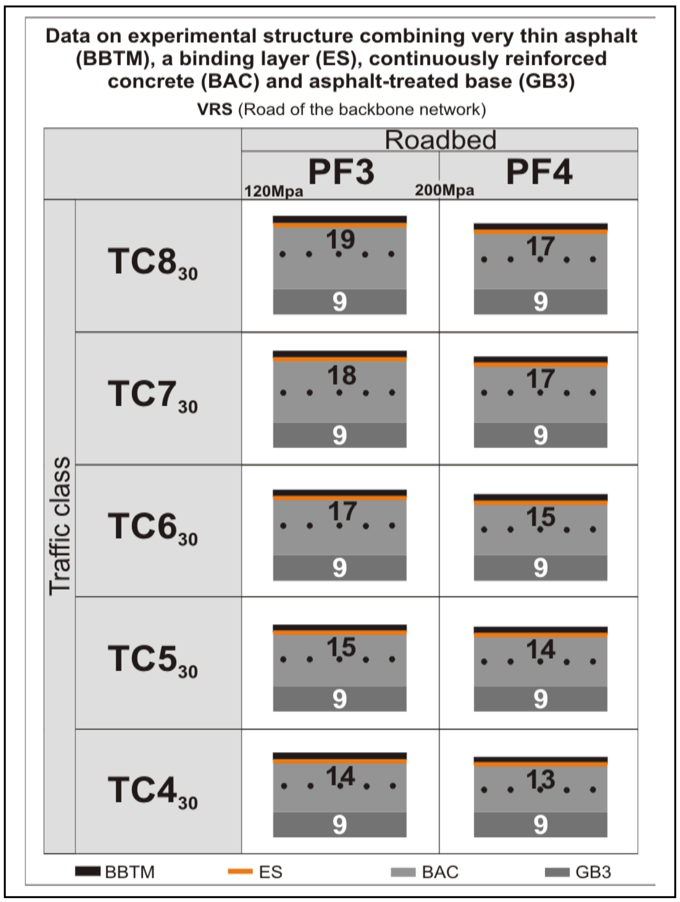

Figure 2

With the backing of the SETRA (French highway and motorway research office), the Road Directorate of the French Public Works Ministry officialized these significant findings by publishing a structural data sheet for an experimental pavement (Figure 2) made up of:

- very thin bituminous concrete (designated BBTM in France) surfacing
- continuously reinforced concrete (CRC) in the pavement body
- class 3 asphalt-treated base (French designation GB3) under concrete.

The structural design assumptions that led to the preparation of this data sheet are:

. service life: 30 years for roads of the "structuring" network (designated VRS in France), 20 years for roads of the "non-structuring" network (VNRS)
. risk rate: in accordance with the 1998 structural design guide
. functioning of pavement at the interface between the continuously reinforced concrete and the asphalt-treated base (ATB): bonded for 15 years, unbonded until the end of the pavement's theoretical service life.

In order to improve the bonding at the CRC/ATB interface, shotblasting or hydroregeneration (water blasting) has to be carried out on the asphalt-treated base before placing the concrete.
An increase in the present discontinuity coefficient (kd) of the CRC, which had been taken equal initially to that of doweled slabs, while it may be considered that the functioning of these structures at these discontinuities is quite different.
This coefficient kd applicable to concrete structures in fact makes it possible to take into account:

. slab edge stresses ("edge effect")
. stresses induced by the camber of the concrete due to the temperature gradient.

To ensure good waterproofing of the CRC with regard to runoff water infiltration, a single-layer surface dressing will be applied 2 to 3 months after concrete placement. This surface dressing has to be preceded by shotblasting or water blasting (hydroregeneration) of the CRC surface followed by the application of an 0/10 or 0/6 mm very thin bituminous concrete.
It is logical that the administration calls for great care, rigor, quality and transparency in the use of these structures. Consequently, these data sheets come with the following comments and specifications:

"This experimental structural data sheet may in no case be substituted for those contained in the 1998 design guide (catalogue of structures) (Figures 3a and b). The guide is today the only reference document to be applied obligatorily for pavement structures on the non-concessionary national highway network.
It comprises structures tested by experience. The data sheet has been drawn up to enable contractors interested in the use of continuously reinforced concrete on pavements to use this type of structure in a project of their choice and to evaluate the economic as well as the technical impact.
It goes without saying that, as it is an experimental structure, it calls for rigorous execution conditions with particular monitoring by the highway department, which will assist the contractor in every phase of project design and execution and will ensure that the expected performance levels have indeed been obtained. The risk of failure in this pavement structure before it reaches the end of its theoretical service life is greater than that appearing in the 1998 design guide, since certain hypotheses, and in particular the duration of bonding, have not yet been validated by experience.

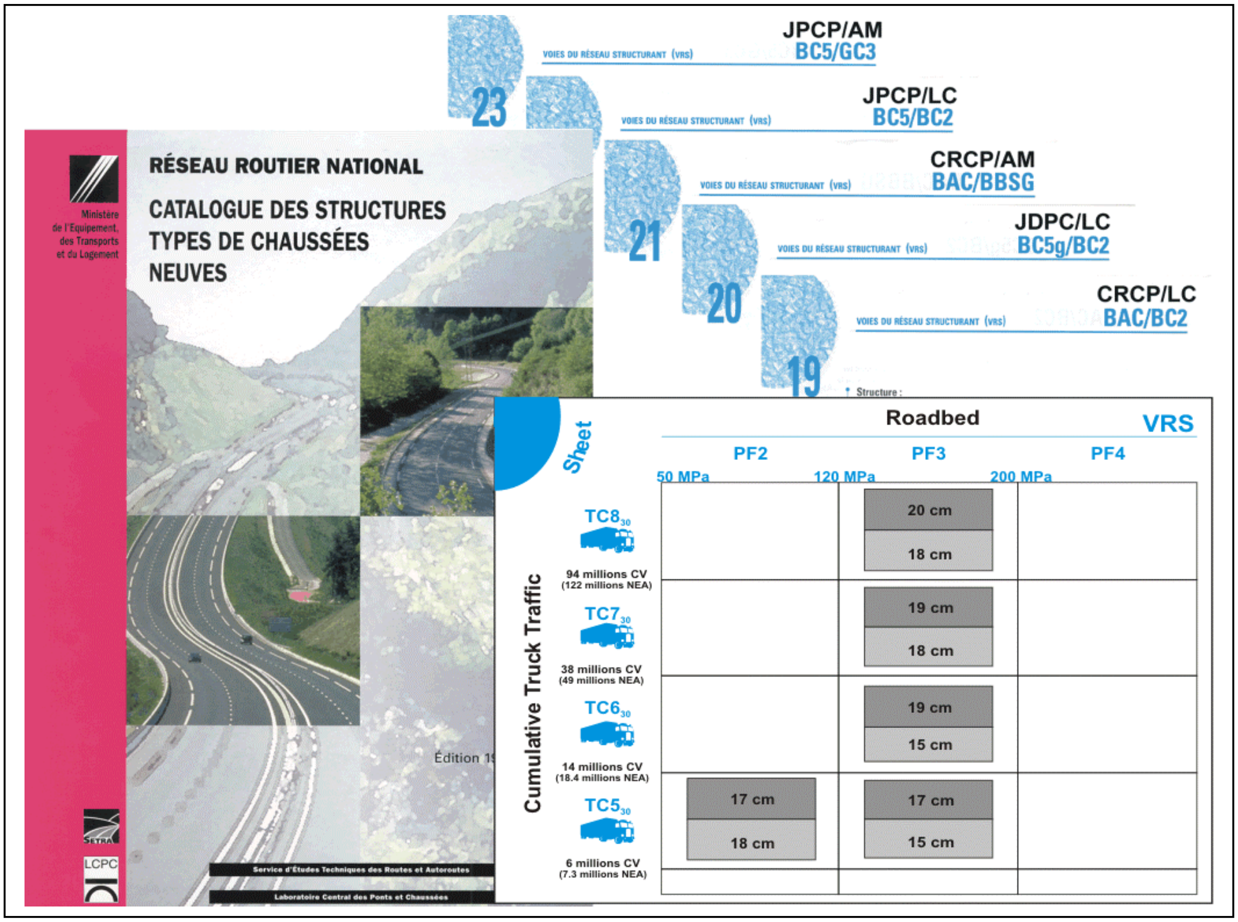
JPCP/AM
BC5/GC3
JPCP/LC
BC5/BC2
CRCP/AM
BAC/BBSG
JDPC/LC
BC5g/BC2
CRCP/LC
BAC/BC2
RÉSEAU ROUTIER NATIONAL
CATALOGUE DES STRUCTURES
TYPES DE CHAUSSÉES
NEUVES
Sheet
Roadbed
VRS
PF2
PF3
PF4
50 MPa
120 MPa
200 MPa
Cumulative Truck Traffic
TC8
94 millions CV
(122 millions NEA)
TC7
38 millions CV
(49 millions NEA)
TC6
14 millions CV
(18.4 millions NEA)
TC5
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Figure 3a

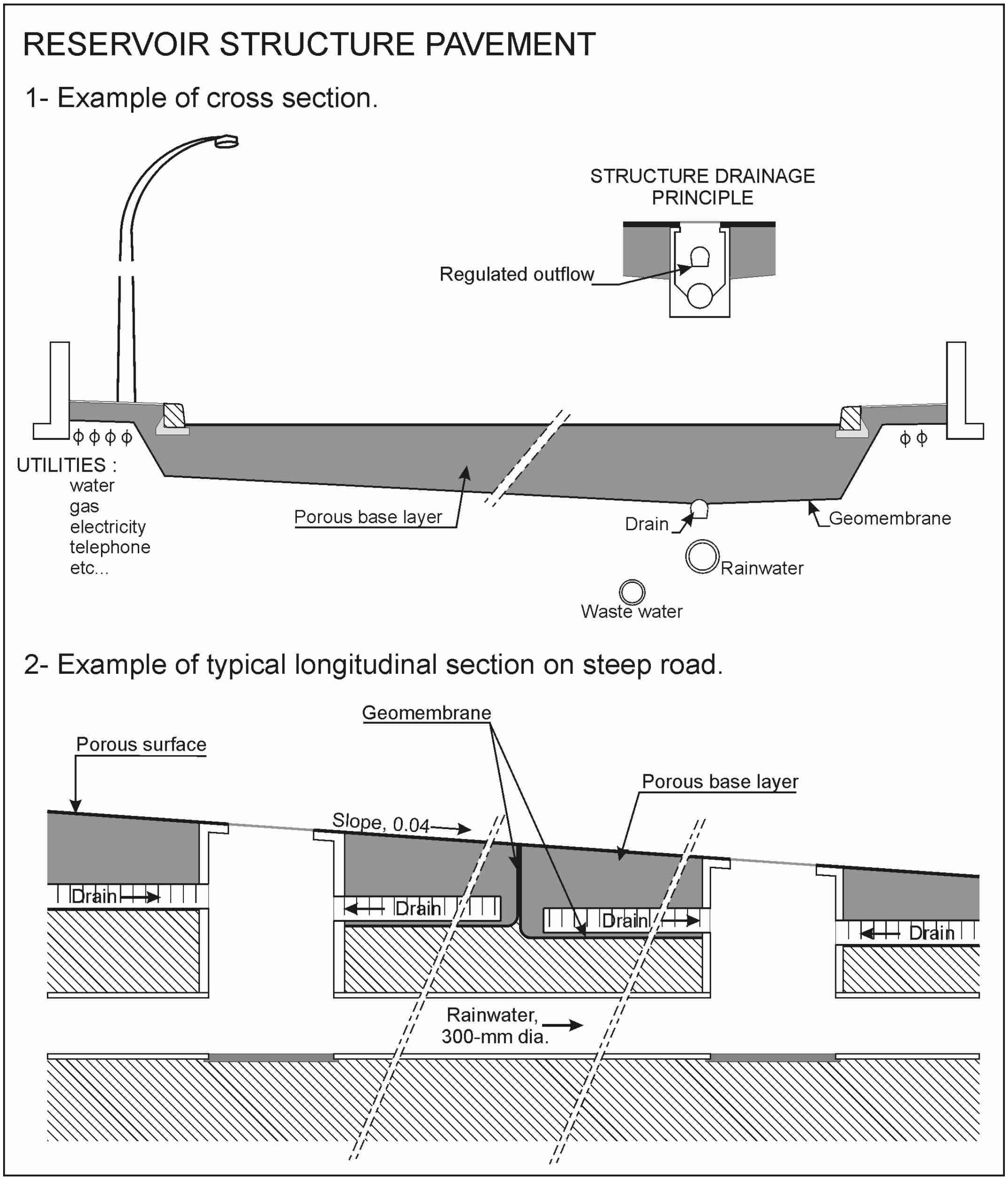


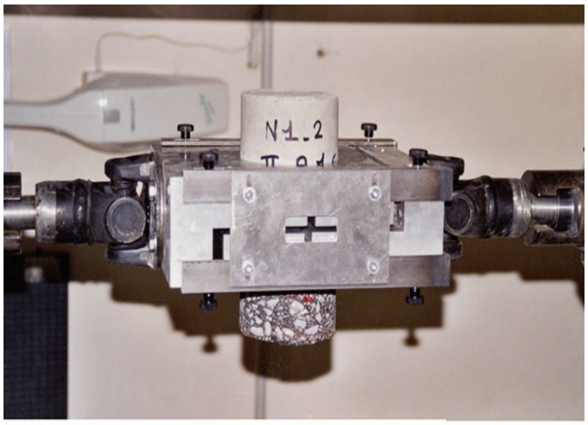
Figure 3b

For this reason, it is mandatory to obtain the written approval of the head of the pavement construction techniques directorate of the SETRA (French highway and motorway research office) before making a final decision on the choice of this structure."

It is interesting to observe that this solution entails a reduction in the thickness of the CRC base by 22% compared with current conventional designs, giving this structure higher performance and making it economically competitive. It should induce prime contractors and designers of the "structuring" network as well as the "non-structuring" network to take it into consideration in project designs and proposals. If the economic context of high bitumen cost continues, this innovative structure should have a good future in store, in particular for more rational use of granular material resources and with a view to finding alternative solutions for hydrocarbon binder-based techniques or products. It is essential that works implementing this new type of "shared technique" structure be scheduled in the short term so as to verify that overall know-how in this area is mastered and so that the adopted design hypotheses may be regarded as credible. After its long preparation, and benefiting from the positive view of the international technical community, this innovation of importance in terms of its concept and in terms of the players involved with their new professional logic, is thus a living, monitored and evolving reality.

Given the very important issues raised by this composite "shared" structure and design, it is important to mobilize the full potential of research and investigations to better understand and control the bonding of layers at the interfaces. This subject is covered in different ways in connection with the research theme undertaken by the French transport research laboratory (LCPC) for public and private laboratories acting on behalf of administrations as professional organizations. An operational part of these studies concerns improved technical methods allowing better bonding of asphalt on concrete, including early-age concrete, as well as better methods for the bonding of fresh concrete over an asphalt-treated base. We shall confine ourselves here to an overview of applied research conducted jointly by an industry project group and a government laboratory.

To better understand the arrangements made on the site for optimum bonding, a shearing test of the Casagrande box type used in the USA and Belgium (Figure 4) was used.



Shearing support on traction press

Shearing test on a concrete specimen on asphalt-treated granular material

Figures 4 a and b

The asphalt-treated base had to resemble as closely as possible the structural, physical, surface or textural reality of the worksites. It was hence decided to set up bitumen-treated base sections 10 cm thick and of diversified composition and surface treatment, and to take some 150 core samples intended to be covered with cement concrete in the laboratory by the use of cylindrical casing. After the appropriate setting time, shearing tests were carried out using the traction press adapted for the stirrup designed specially for this purpose.

The parameters tested in connection with any potential influence on the bonding between concrete and bituminous material were the following:

. two types of asphalt-treated base material of 0/14 gradation, one with a normal texture (GB3 according to French standard NF T 98-138) and the other with an open texture. The "curing time" parameter for the ATB had to be taken into account (48 to 72 hours and 7 to 12 days).

. three types of pavement concrete:

- 0/20 concrete using 330 kg of CPJ-CEM II/B 32.5 cement
- 0/10 concrete using 370 kg of CPJ-CEM II/B 32.5 cement
- 0/10 concrete using 370 kg of CPA-CEM I 52.5 R cement.

The parameters were gradation, type and proportioning of concrete, setting time (48 to 72 hours and 28 days).

. surface condition with type of treatment:

- clean and dry substrate
- clean and wet substrate
- clean and dry substrate after milling
- clean and dry substrate after shotblasting
- clean substrate having received a prior bitumen emulsion film.

Note that the project group wished to remain under conditions as close as possible to those of the worksite, so it was decided to set up the ATB sections in full scale and carry out surface mechanical treatment with industrial machines (except for the tack coat in bitumen emulsion in which subsequent core sampling would have greatly degraded the surface bitumen film).

. shearing test temperature (tests conducted at 0°C and 20°C).

Other interesting findings regarding relevancy and methodology, the main results of this study conducted in just a few months are summarized as follows:

. The values of the shearing tests are close to 1 MPa at 20°
. "Normal" GB3 (asphalt-treated base) favorable (less scattering of results)
. ATB after curing (7 to 12 days), rather favorable
. Dry and clean substrate, slightly more favorable than dry and wet substrate
. Bitumen emulsion over ATB, unfavorable
. Light milling of ATB, favorable
. Shotblasting of ATB, favorable
. 0/20 cement concrete, favorable (in relation to 0/10 concrete)
. CPA CEM I 52.5 R cement, favorable.

Factors influencing the shearing test values:

- test temperature
- concrete setting time.

In general, the tests conducted have shown that the bonding of concrete over an asphalt-treated base was always excellent and that fracture took place more at the level of the first centimeters of the asphalt-treated base (concrete side very black and showing the bitumen mortar and mastic).

The graph in Figure 5 illustrates the comparative values and shearing resistance obtained in characterizing the bonding of a concrete for CRC over a normal asphalt-treated base after 7 to 12 days of curing for different types of conditions and treatment: dry and wet substrate, planing, shotblasting or equivalent, emulsion.

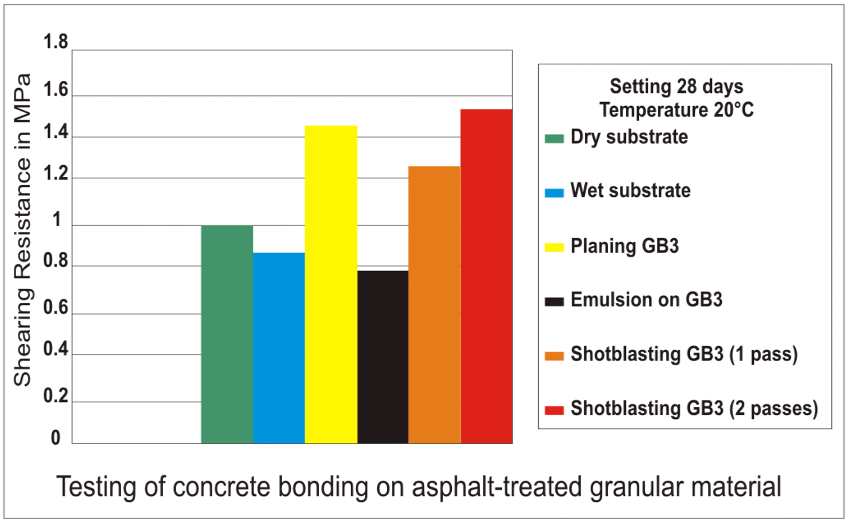


Figure 5

Conclusions

Composite pavements constitute one of the most promising forms of the development of the "structurally shared" pavement concept, even if today their development is still modest compared with the practices observed on a daily basis in the implementation of "surface shared" structures. In either case, the pace has been set for urban and peri-urban roadways. From an idea originating in urban roadways (concrete + asphalt for Paris roadways), composite pavements have in a few years witnessed the opening of applications in heavy traffic facilities. The comparison of international experiences with the backing of the PIARC and on the occasion of joint investigatory works such as the CEMBUREAU Congress, ISCP-PURDUE, etc., has been significant in this awareness of new potentials. France has acted as a stimulus in giving tangible form to these advances by research, experimentation, and progress in terms of design guides and recommendations mentioned in the present paper. The French policy of favoring partnerships between public authorities, suppliers and industrial firms, as well as the complementarity of public and private engineering firms, had contributed to these positive and encouraging results, but we have not yet acquired full knowledge in this area in which developments are far from being completed. Among other questions to be clarified in the future may be mentioned the fact that it is still too premature to qualify composite structures in terms of whole-life cost or in terms of reconstruction cost. However it may be thought in this regard that the quality materials used for the construction of such pavements, some of which may already contain low-percentage recycled products, will constitute within a few decades potential sources of highly prized highway construction materials.

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