Pavement Edge Drain-Barriers : Adduced Effects on Structural Response

H. Perrier
Ponts et Chaussées, Roven, France

J. L. Paute
Ponts et Chaussées, St Grievc, France

ABSTRACT: The present paper describes the adduced effects on the response of road structures further to the installation of PEDB systems. Laboratory research results followed by experimental construction sites have enabled highlighting of PEDB influence on the mechanical characteristics of pavements through the enhanced water balance of the structures during critical periods of the pavement service life. Deflectometric analyses of equipped and non-equipped sites have enabled quantification of the resulting structural gains. Laboratory studies supported by on-site findings have demonstrated the advantages of PEDB systems in thaw/frost periods.

1 INTRODUCTION

Water is always present in the road environment in varying quantities and at varying depths, whether in the slope of cutting or the slope of embankment, inside the road surface itself or the shoulders. The presence of this water leads to a decrease in the stability of most soils, which in turn has two major effects.

The first of these is poor conditions for the mechanical operation of the pavement (greater fatigue of structural materials), thus accelerating the degradation process. The second effect is the necessity of protecting road surfaces with weight limits during thaw/frost conditions.

In order to prevent pore water from reaching the road surface and its support, and to draw off whatever other water is present, technical drainage facilities have been developed. Amongst these solutions figures an industrial approach to cut-off drains developed at the end of the eighties, entitled Pavement Edge Drain-Barriers (PEDB).

2 EFFECT ON THE MECHANICAL BEHAVIOUR OF THE PAVEMENTT [1]

Installing a PEDB improves the hydraulic state of the pavement/subgrade assembly. From the pavement point of view, the improvement results in enhanced behaviour of the unbound mixture (UBM) forming the layers of the road foundation and its subgrade.

Two properties of the UBM condition the behaviour of flexible pavements:

a) its rigidity (Young's modulus, E)
b) its sensitivity to permanent deformation.

Figure 1 illustrates how these two parameters vary in relation to water content. Ranges in seasonal variations in the water content of materials, depending on whether the pavement is drained or not, indicate to what extent variation is possible in the Young's modulus and the permanent deformation of a unbound mixture layer. Two features should be noted in this respect:

i) The fluctuation in Young's modulus for the road base is fairly low, between 350 and 450 MPa, whereas without taking any particular precautions and with a permeable surface, in damp conditions the modulus can drop to 250 MPa. Since the service life of the pavement is linked to the modulus of elasticity of the road base, it is clear to what extent these constructional measures are important.

ii) Permanent deformation under given levels of stress is considerably lower than 1 % (2 mm for a layer 20 cm thick), and can reach 4 to 5 % in the case of a poorly drained pavement.

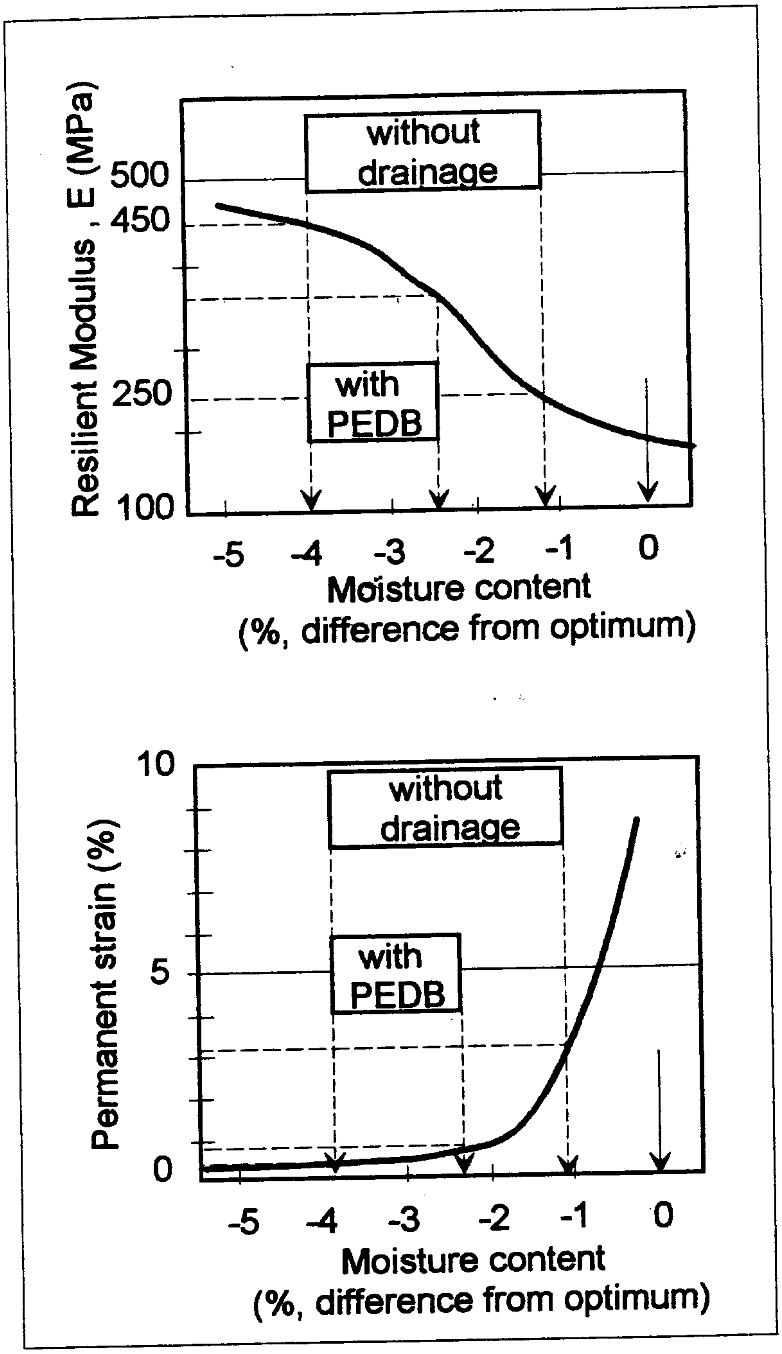

Fig. 1 : The effect of variations in natural water content, w, on the rigidity and permanent deformation of a unbound mixture used as a road base (difference from modified Proctor optimum water content).

The presence of a waterproof or poorly permeable surface in conjunction with an PEDB enables the water content of the road base to be limited in all seasons to between 2 and 3 points lower than the MPO (modified Proctor optimum) water content, and thus guarantees both the potential range of the rigidity modulus for the UBM, and low levels of permanent deformation.

In addition to the mechanical behaviour of the road surfacing structures, the service life of a flexible pavement depends on the behaviour of the subgrade. Figure 2 illustrates the effects of draining on the bearing capacity of the subgrade. The modulus of elasticity, *E*, of a subgrade can be modelled based on the following relation:

$E = A \cdot (po - u) + B \cdot pr^{C}$ where:

- po is the average stress due to the self weight of the road structure and the soil,
- u is the pore water pressure in the area of soil taken into account,
- pr is the average stress due to the moving wheel,
- A, B and C are soil characteristics.

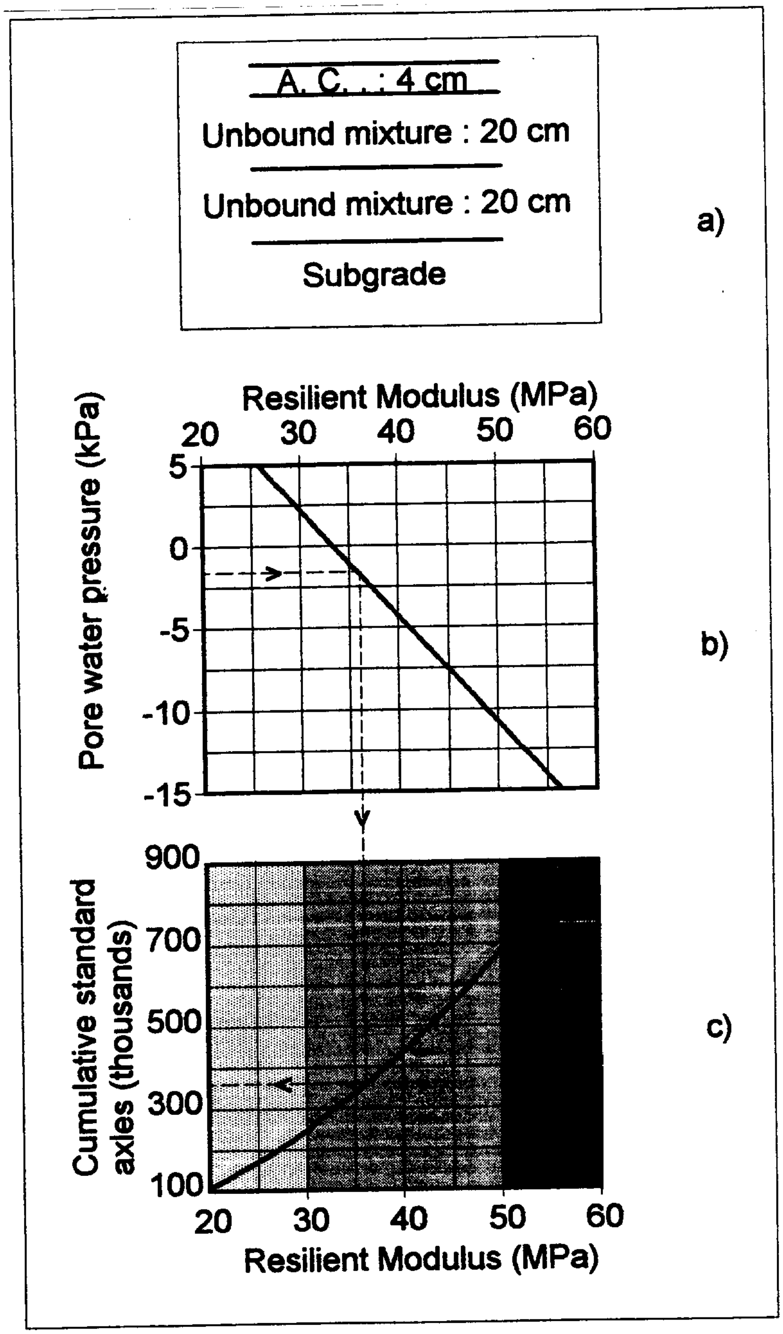

Fig. 2 Effect of pore water pressure on the subgrade resilient modulus and admissible cumulative standard axles of 65 kN.

When the humidity of fine soil increases, i.e. for an pore water pressure range of -15 kPa to +5 kPa, (fine soils in temperate regions), figure 2b, which has been established for a silty soil, shows that the soil modulus is reduced by one half when the pore water pressure rises from -15 to +5 kPa. The impact on the service life of the structure, determined as a function of the admissible strain at the top of the subgrade, EZ, is considerable, since for a variation in pore water pressure from 0 to -12 kPa, the cumulated traffic of 130 kN axles increases from 300,000 to 700,000 axles. This example should be considered as a study in trends. It indicates the impact of the pore water pressure of the subgrade on the service life of a flexible pavement and the potential value of improving the drainage systems and maintaining them in good working order.

Installing a PEDB reduces the fluctuations in pore water pressure due to rainfall and to infiltration by surface water into the road foundation, and maintaining them at a lower level as is indicated for example in figure 3. It has frequently been observed that a PEDB penetrating 0.30 m into a fine subgrade leads to an average reduction of 5 kPa in pore water pressure, resulting in an increase of the order of 30 % in the modulus of elasticity of the subgrade.

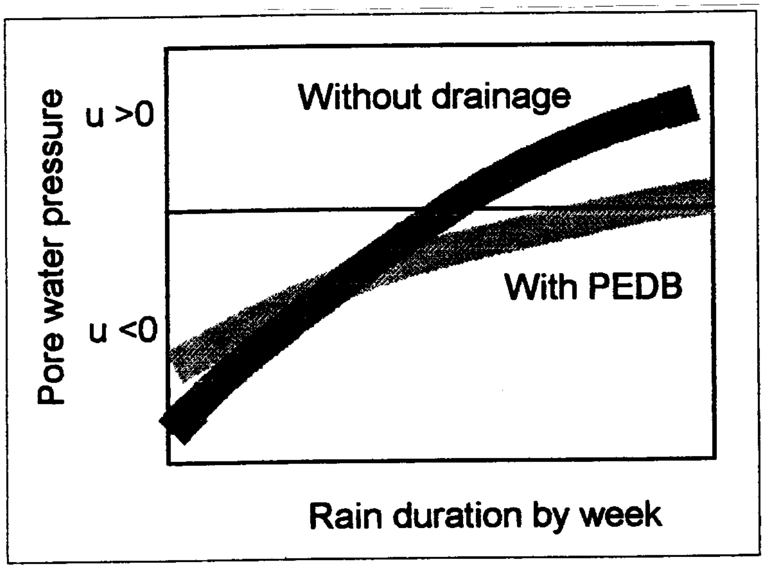

Fig. 3: The effect of installing a PEDB on the pore water pressure of the subgrade.

3 EFFECTS IN RELATION TO FROST AND THAW CONDITIONS [2]

Frost has a major impact on the perennation of road structures. PEDB's are seen as a means of reducing the stresses connected with installing weight limits during thaw conditions (duration, frequency, tonnage) since the frost/thaw problem in pavements is linked to excess water.

i) During short periods of frost, the improvement in the hydric state of the structure reduces the supply of water enabling the formation of ice lenses. The short duration of the frost does not enable the supply of water to be re-established by cryosuction. The support material freezes in bulk without absorbing water, and therefore poses no risk when the thaw sets in.

ii) During long periods of frost, the duration of the frost enables the supply of water to be re-established as soon as ice lenses begin to form.

In a frost/thaw cycle, there is a distinction to be made between two phases: the onset of frost and the onset of thawing. The role of the PEDB in these two phases is different.

At the onset of the frost, the structure of the PEDB (with its high porosity and lack of water to freeze), rapidly leads the cold into the depths of the pavement, and the PEDB becomes a cryogenic source which draws off water. The phenomenon leads to local drying out of the pavement materials, which, when the frost front penetrates the pavement, slows down and limits the formation of ice lenses. The area of influence of the phenomenon is limited.

At the onset of thawing, the PEDB rapidly leads the heat into the depths of the pavement and thus itself becomes a source of heat. The PEDB ensures a discontinuity in the frost table which is created at the onset of the thaw by heat input through the pavement (figure 4b).

When a PEDB is not present, the difference in water content between the shoulder and the road foundation leads to faster thawing of the latter in relation to the former, and it is this thaw differential which is at the origin of the water loading under the pavement (fig. 4a). The phenomenon increases the saturation of the subgrade. Defrost water is thus trapped under the pavement until the frost table has completely defrosted. The presence of a PEBD prevents water from being loaded under the pavement and enables the evacuation of thaw water.

The forces generated by cryosuction concentrate the water (ice lenses) and reorganizes the structure of the materials forming the subgrade. This reorganization and the evacuation of concentrated water are the basis for subgrade consolidation noted in frost/thaw cycles, a densification of the material which results in its later sensitivity to frost [3].

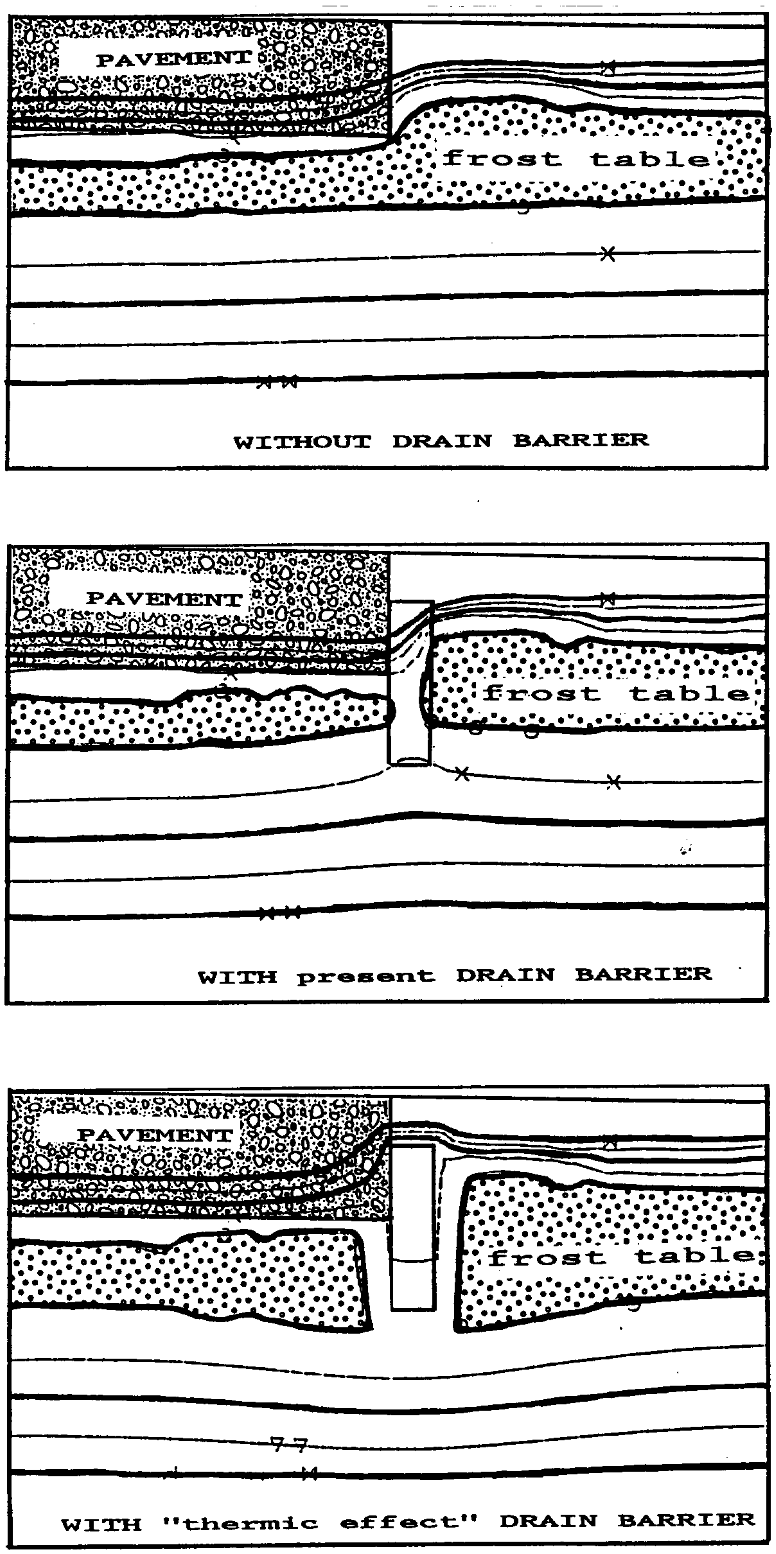

Figure 4: Modeling: state of the road structure during thaw :

a) without the PEDB
b) with an usual PEDB .
c) with a "thermic effect" PEDB

The design of the PEDB in relation to frost is mainly based on the dimensional characteristics and on the surface properties of the filter geotextile which sheathes the PEDB (wettability).

When the frost table melt, the hydraulic load of the thaw water is very low. In order for the water to penetrate the PEDB it is therefore necessary for the latter's resistance to water penetration to be very low (less than 5 mm according to NF standard G 38020).

The effective height of the drain thaw protection must be greater than the depth of frost, in order to guarantee discontinuity in the frost table . When the depth of frost is deeper than 1 m, the height of the drain is limited to 1 m.

The presence of water, trapped in the drain cores at the onset of frost, is the cause of the appearance of ice flakes, which then block the drain and limit its efficiency (absence of real discontinuity in the frost table). In order to prevent the fin drains from becoming blocked it is preferable to use PEDB's of relatively large thicknesses (e ≥ 20 mm).

CONCLUSION

Pavement Edge Drain-Barriers are a good approach to minimize the effet of variations in natural water content on the rigidity of road materials and thus, a good way to increase the service life of the road. During frost/thaw periods, the PEDB are a alternative solution to temporary traffic limitation (duration, frequency, tonnage).

REFERENCES

[1] PAUTE, J.L. and RAIMBAULT, G. (1989) Road surface fin drains - Revue générale des routes et aérodromes, n°669 - RGRA publication.

[2] PERRIER, H. and all, (1990) Effect of vertical barriers on road behaviour in freeze/thaw periods. 4th Int. Conf. on Geotextiles, The Hague.

[3] DYSLI, M. (1991) Frost and its effect on soils and foundations, Ecole Polytechnique de Lausanne.