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Adherence in a pavement rehabilitated with a polymeric grid used as interlayer

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HIGHLIGHTS

- Thermal properties of grid base material are modified by asphalt emulsion.
- Base material of geotextile must melt during application in hot of asphalt mix.
- The geosynthetic between concrete and asphalt mix improved the adherence.
- Deformations at maximum load were higher when a grid was used between layers.
- Energy absorbed increased when polymeric grid allowed the contact between layers.

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ABSTRACT

A polymeric grid was placed between layers of a pavement with the aim of preventing the reflection of cracks from the base material to the upper layer. Results explain why the usual faults that occur in rehabilitated pavements: (i) chemical modifications of geosynthetic polypropylene determined by FTIR lead to changes in its melting point; (ii) the discontinuity or continuity of the interface observed by SEM depends on the application temperature of the asphalt mix and (iii) the adherence obtained in laboratory tests correlates perfectly with the quoted chemical modifications of geosynthetic polypropylene and the structure of interface in multilayer pavements.

1. Introduction

In multilayer systems as pavements, the relative movement between the component layers constitutes an important source of cracks. A pavement works properly when it transmits the stress generated by traffic and weather conditions to all its thickness: its functioning is essential that it be as monolithic structure [1].

Polymeric grids are used in many fields of engineering [2–14]; in rehabilitation of pavements, these are inserted between the layers in order to retard the crack propagation pre-existing to a new tread layer [15–17].

When a grid is placed between asphalt layers, it is less likely to be present bond failures at the interface because they are related materials. On the other hand, pavements formed by layers of materials of different nature can have low adherence, which results in a poor or no stress distribution in the total thickness of pavement and consequently, in the appearance of premature cracks in the bearing binder [18].

Failures by adherence are longitudinal displacements, which are located in areas of the road surface [19]. Lack of adequate adherence between layers leads to structures that work as two separate systems; in these circumstances, the upper layer must provide high rigidity to be able to absorb the loads by itself because otherwise there will be failures. An adequate adherence between the pre-existing and new bearing layer can be achieved through irrigation of a binder as an asphalt emulsion [20].

The aim of this investigation was to study the adherence of multilayer pavements, on laboratory scale, formed by a standard concrete, two modified asphalt emulsions with different melting points, a grid based on polyester fibers attached to a non-woven polypropylene geotextile and finally, conventional asphalt applied at different temperatures.

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2. Materials and methods

The determination of adherence was performed on multilayer pavements formed by:

2.1. Standard concrete

The design was carried out on laboratory scale; the composition is displayed in Table 1.

2.2. Modified asphalt emulsions

Two commercial products were used (Emulsion A and Emulsion B), differing primarily in the melting point; the main characteristics established in laboratory are included in Table 2. It is noteworthy that the quoted cationic emulsions were used since they showed in previous laboratory studies a high "affinity" at environment temperature with granitic aggregates selected for the design of the systems studied (similar values of surface tension of solid and liquid) and besides because in general the anionic emulsions evaporate the water more slowly, which could lead to problems if the geotextile is placed before the end of the coalescence of the emulsion ("melting" in cold of polymeric particles by plastic deformation).

2.3. Geosynthetic

A commercial polymeric grid was selected; it is coated by a bituminous layer based on polyester fiber bonded by points to a non-woven geotextile (needling) of polypropylene with a mesh size of 40 × 40 mm; these characteristics make it easy to install in construction, Fig. 1.

To characterize the materials, the softening points by ring and ball [21] and melting points [22] were determined on samples of non-woven polypropylene geotextile: (i) free of bituminous coating as supplied by the manufacturer (extraction solvent toluene), (ii) commercial and (iii) impregnated to saturation with both modified asphalt emulsions; complementally, ignition points [23] and of flame [21] of the above-mentioned materials were also determined due to its importance for safety reasons in construction. The softening points and of melting were determined in order to define three application temperatures of asphalt mix [22].

In parallel, Fourier Transform Infrared Spectroscopy (FTIR) was performed on the commercial base material and the material impregnated with the Emulsion A in order to determine possible changes in its composition after exposure to temperatures of application of the asphalt mix.

For adherence tests, circular samples of 100 mm of diameter were randomly taken from a roll of 4 m wide by 150 m long.

2.4. Asphalt mix

The asphalt mix was designed in laboratory, Table 3. It corresponds to standard concrete based on a hot asphalt mix (dense, CAC D20 type); the CPA (Standing Committee of the Asphalt, Argentina, 2006 edition) defines as hot asphalt mix to the combination of a conventional or modified asphalt binder, aggregate (including filler) and additives such as adherence improvers, fibers, etc., manufactured in plants and placed in construction at temperatures above of ambient.

2.5. Specimen preparation

The specimens were prepared starting from a concrete cylinder with 100 mm diameter and 50 mm height. The modified asphalt emulsion was applied by irrigation (0.9 liter of solids per m^2) on the top face (smooth, free of dust and lubricant, and in moisture equilibrium condition achieved under laboratory condition); then, before coalescence is completed, it were placed the geosynthetic and finally, the standard asphalt mix by compaction at three temperatures as mentioned (50 mm thick), Fig. 2.

Table 1
Composition and characterization of the standard concrete.

Components	Volume, cm^3	Density, g cm^{-3}
Water	163	1.00
Composite Portland cement 40	119	3.06
Coarse aggregate, 6:12	320	2.67
Fine aggregate	38	2.65
Air	15	–
Superfluidifier	4	1.15
Flexural strength, MPa		4.5
Compressive strength, MPa		36.0

Table 2
Main characteristics of modified asphalt emulsions.

Test	ASTM standard	Emulsion A	Emulsion B
1. On liquid emulsion			
Saybolt Furol viscosity a 25 °C, s	D88	33.7	31.5
Asphalt residue by distillation, g/100 g	D-244, 11/15 sections	65.3	62.5
Distillable hydrocarbons, ml/100 ml	D1461	0.5	0.6
Water content, g/100 g	D95	37.5	39.6
Settlement after 5 days, g/100 g	D244, 29/32 sections	1.7	2.1
Residue on sieve # 850 mm, g/100 g	D244, 38/41 sections	0.06	0.05
Particle charge	D244	Positive	Positive
2. On distillation residue			
Penetration in residue, 0.1 mm	D5	90	88
Ductility, cm	D113	>100	>100
Oliensis	D1370	Negative	Negative
3. On coalesced solid			
Melting point, °C	D87	140–147	164–175

Reference was formed by the standard concrete, the Emulsion A and the asphalt mix placed by compaction at a temperature set depending on the melting point of the geotextile; the specimen was prepared in triplicate in the same way that when included geosynthetics.

2.6. Adherence tests

It were used the methods by shear stress (LCB, Laboratorio de Caminos de Barcelona, España) and by direct tensile (LEMaC, Centro de Investigaciones Viales de la Universidad Tecnológica Nacional Facultad Regional La Plata, Argentina), respectively.

Both tests were conducted with the corresponding software and continuous recording of measurement; the conditions for these tests were as follows: test speed, 1.27 mm/min; temperature, 20 ± 2 °C and boundary conditions, according to device to adherence measurement by shear stress or direct tensile. It is performed Scanning Electron Spectroscopy (SEM) on several interfaces of composites.

2.6.1. Adherence by shear stress

This test consisted of subjecting the specimens made in laboratory to a shear stress in the plane of discontinuity, by applying a bending load. The test allowed determining:

2.6.1.1. Adherence Tension τ y Adherence Coefficient CAd. The tension is calculated from the experimental results using the equation $\tau = 0.0980665\ P/2\ A_T$, where τ is the adherence tension (MPa), P is the maximum load applied by the load cell and equivalent to twice of the reaction in the support acting on the plane of weakness (kg) and, finally A_T is the cross-sectional area of the specimen (cm^2).

With respect to the Adherence Coefficient, it was determined by relating the adherence of the specimen that included the asphalt emulsion/geogrilla (τAd1, kg cm^{-2}) as interlayer with the maximum adherence obtained in the specimen that displayed an intimate contact at the interface of concrete/asphalt mix (τAd_{max}, kg cm^{-2}), that is by using the equation $Cad = \tau Ad1/\tau Ad_{max}$.

2.6.1.2. Deformation L by slipping corresponding to the maximum load. The continuous recording allowed determining the Deformation L corresponding to the maximum load, in mm.

2.6.1.3. Energy T absorbed by the specimen. The work resisted by the test specimen, expressed in kg mm, was calculated by using the values obtained through continuous recording by the equation $T = \sum \Delta D \cdot \Delta Cav$, where ΔD is the differential deformation by slipping between two successive records and ΔCav is the average value of load really applied at the interface (i.e. $P/2$) for an interval equal to the corresponding ΔD deformation.

2.6.2. Adherence by direct tensile

This test consisted of subjecting the samples made in laboratory to a tensile stress; as well as for adherence by shear stress, it was determined the adherence, the Adherence Coefficient, the deformation by slipping and the energy absorbed by the specimen.