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Laboratory study of the long-term climatic deterioration of asphalt mixtures

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HIGHLIGHTS

- The effect of long-term climatic deterioration on asphalt pavement is studied.
- The influence of void content under long-term climatic deterioration is analyzed.
- Moisture action is a reversible process but has little effect to heal the damage.
- Long-term moisture action presents higher influence on dense mixture performance.
- Thermal process leads to a slight material stiffening due to bitumen aging.

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ABSTRACT

Climatic actions such as rain, sun or ice are one of the major contributors in asphalt pavement degradation. The effect of these climatic agents can be a long-term process of asphalt mixture deterioration when long rainy or sunny periods are expected as well as a series of freeze–thaw cycles due to wide range of temperature. However, laboratory studies are mainly focused on short-term effect from climatic actions. Thus, the present paper aims to analyze the evolution of the strength and bearing capacity of asphalt mixtures exposed to long-term moisture, several freeze–thaw cycles and diverse days of thermal aging. In addition, the recovery of the material mechanical properties was evaluated when a rest period was applied after climate processes. This study was developed for two different asphalt mixtures (dense and open), finding that air void content has significant influence on the trend of the long-term evolution of mixture properties under moisture action, which is a reversible process unlike the other two climate agents studied. On the other hand, freeze–thaw cycles whose effect is higher on dense mixtures was found to be a short-term process regardless the air void content while thermal aging presented the lowest variations in the properties measured for both types of asphalt mixtures.

1. Introduction

During their service life, asphalt pavements are exposed to loads as a result of the combination of traffic and environmental actions that lead to the deterioration of the pavements in diverse forms such as rutting, raveling or cracking. Among the different climatic agent, the presence of moisture in the asphalt mixtures is defined as one of the major contributors in the degradation of the pavements [11,26] as well as the effect of freeze–thaw cycles and prolonged warm periods also induce the acceleration of their deterioration.

Moisture damage in asphalt mixtures is associated with the loss of adhesion and/or cohesion of the material, which causes the reduction of their strength, stiffness and durability [18,9,27]. Due to a diffusion process, in which air void distribution plays a fundamental role [10,17], water molecules can occupy positions within binder molecules and weaken the bond within the binder itself (mechanism known as softening that causes the loss of cohesion) [1]. In addition, when the moisture infiltration reaches the interface binder-aggregate, the bond between both materials is weakened, resulting in adhesive failure and taking place the known phenomenon of raveling [21].

On the other hand, the presence of moisture can lead to the mixture damage by the expansion of water in cold regions (due to water freezing), which could induce the displacement and

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cracking of the asphalt film, causing even the brittle failure of the material [14]. The effect of freeze/thaw cycles also causes the loss of aggregate-binder adhesion [13]. Moreover, the prolonged exposure of asphalt mixtures to heat leads to the aging of the binder, making them more stiffness and susceptible to cracking.

Due to the importance of these climatic agents, numerous authors and administrations have developed a series of test procedures to evaluate in laboratory the influence of moisture, freeze–thaw cycles and thermal aging in the failure forms of asphalt mixtures (AASHTO T-165; AASHTO T-182; [3,4,7,20,16,25]. However, these test methods are usually only used to assess the short-term influence of each climatic agent while bituminous pavements are commonly exposed to long rainy or sunny periods as well as to a wide seasonal temperature range including a number of freeze–thaw cycles, especially in cold regions. In addition, each climatic agent is generally studied separately, without taking into account the predominant environmental action that can lead to mixture failure, which is a fundamental factor when designing asphalt mixture depending on the region where they are used.

In this context, the present paper aims to analyze the long-term effect of the main environmental agents (long-term moisture; freeze–thaw cycles; and thermal aging) on the mechanical performance of two types of asphalt mixtures with different void contents, identifying the predominant climatic action that induces material failure depending on the type of mixture (dense or open graded). Besides, the possible recovery of their mechanical performance was evaluated after a period of time since the end of climate processes, trying to carry out a more realistic study in reference with field experiences [23,26]. For this laboratory study, the parameters recorded were the evolution of the indirect tensile strength and the stiffness, which indicate the integrity and bearing capacity of the asphalt mixtures.

2. Methodology

2.1. Materials

Two different asphalt mixtures were used during this study: a dense mixture type AC 16 S (UNE-EN 13108-1) with air void content equal to 6.4%; and an open graded asphalt mixture type BBTM 11 B (UNE-EN 13108-2) whose air void content was 20.2%. Thus, it is possible to evaluate the effect of climatic deterioration on two asphalt mixtures commonly used as surface layer in road pavements at the same time that the influence of the air void content is studied.

Two types of aggregates were used to manufacture both asphalt mixtures: ophite for the coarse fraction of the mineral skeleton (6/12 mm and 12/18 mm for the AC 16 S, and 6/12 mm for the BBTM 11B) whereas limestone aggregates were utilized for the fine fraction (0/6 mm for the dense mixture, and 0/3 for the open mixture). These aggregates were selected since they are commonly used in roads construction in Spain. Table 1 shows that the aggregates used present physical and mechanical properties in consonance with the Spanish Standard. Regarding the filler used, it was Portland cement type CEM II/B-L 32.5 N (UNE-EN 197-1), of which the 95% had a particle size smaller than 0.063 mm. The apparent density (UNE-EN 1097-3) of the filler was 0.7 Mg/m^3.

Both asphalt mixtures (dense and open mixture) were manufactured with the same conventional bitumen type B 50/70, whose main properties were: penetration value (UNE-EN 1426) equal to 54 d mm (25 °C; 0,1 mm); softening point (UNE-EN 1427) of 50.4 °C; and fragility temperature (UNE-EN 12593) similar to −8 °C. In addition, both mixtures were manufactured with similar bitumen dosage (4.5% over the total weight of the mixture) with the aim of analyzing only the influence of air void content. For this porpoise keeping the same percentage of bitumen and varying the aggregates grading, two asphalt mixtures were studied (Fig. 1 shows the gradation for the dense and open mixtures). Other researchers have studied other variables such as the influence of energy compaction modification [2].

Table 2 shows the main physical and mechanical characteristics of both asphalt mixtures used in this study. To characterize the response of the dense mixture was used the Marshall method

Table 1
Aggregate properties.

Tests		12/18 Ophite	6/12 Ophite	0/6 Limestone	Specification
Particle grain size (UNE-EN 933-1)	Sieves (mm)	% passing	% passing	% passing	
	22.4	100	100	100	–
	16	52	100	100	–
	11.2	6	90	100	–
	8	2	44	100	–
	4	2	3	92	–
	2	2	2	65	–
	0.5	2	2	31	–
	0.25	2	2	26	–
	0.063	1.5	1.5	15.3	–
Shape of coarse aggregate. Flakiness index (UNE-EN 933-3:12) (%)		8	12	–	⩽20
Resistance to fragmentation (Los Ángeles test, UNE-EN 1097-2:10) (%)		8	8	–	⩽20
Cleaning of coarse aggregate (organic impurity content) (Anexo C, UNE-EN 146130:00) (%)		0.01	0.01	–	<0.5
Sand equivalent (UNE-EN 933-8:12) (%)		–	–	63	>50
Relative density and absorption (UNE-EN 1097-6:01)	Apparent density (g/cm^3)	2.90	2.89	2.94	–
	SSD* (g/cm^3)	2.76	2.79	2.89	–
	Density after drying (g/cm^3)	2.81	2.82	2.87	–
	Water absorption after immersion (%)	1.67	1.25	0.81	–

* Relative density on Saturated Surface-Dry Basis.

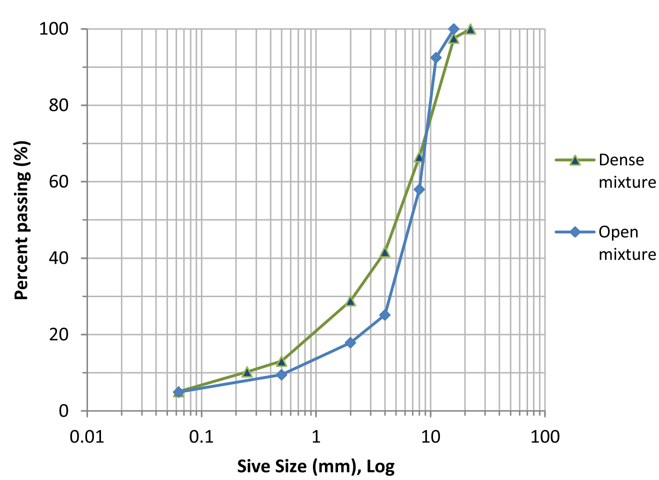

Fig. 1. Aggregate grading used for dense and open mixtures.