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Editorial

Special Issue: Functionalized and Smart Asphalt Mixtures via the Modification/Application of Nano/Micromaterials

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Asphalt pavements are designed to resist weathering and road traffic while guaranteeing safe and comfortable driving conditions at low cost and with minimal environmental impact [1]. When a material reacts to an external stimulus and presents additional abilities, it is considered smart and multifunctional [1,2]. Functionalization consists of developing a new material capability. Several capabilities have been applied to asphalt mixtures, such as photocatalytic [3,4], superhydrophobic [5–7], self-healing [8–10], de-icing/anti-icing [11,12], self-cleaning [13–15], thermochromic [16–18], and latent heat thermal energy storage [19–21]. These abilities are developed mainly by employing nano/microparticles, phase change materials (PCMs), fibers, and dyes [1]. Additionally, there is interest in converting ambient energy into other useful forms of energy [22], which will offer new functionalities. In addition to the new capabilities, the functionalization of asphalt mixtures may improve the mechanical properties or aging resistance.

Photocatalytic capability has been one of the most investigated topics with regard to the functionalization of asphalt pavements, as it is related to benefits regarding road safety (by the photodegradation of organic compounds, such as oils and greases, adsorbed on the surface), in addition to the environment and social benefits through the degradation of air pollutants [13,23]. Among several pollutants, photocatalytic surfaces degrade NO_x, SO_2, and volatile organic compounds [3,24,25]. During the functionalization process of asphalt mixtures, the main application processes of the nano/micromaterials are spraying or spreading the nanomaterials onto the surface as a coating, and their incorporation into the whole layer via bulk incorporation during the asphalt mixing or inserting the particles into the asphalt binder (asphalt binder modification) [26].

In winter, snow and ice formation on roads increase the number of accidents due to the reduced friction between tires and pavement [5,27]. To mitigate this problem, it is recommended to use deicing agents and conductive materials in the asphalt mixtures [27–29]. In the first case, the ice and snow can melt due to a chemical process [30,31], while the second requires a microwave machine [11]. Another way to mitigate the problem is by repelling the water from the surface; thus, the ice/snow formation is avoided. Superhydrophobic asphalt mixtures have this capability. This technique provides safer roads during rainy periods and has an additional self-cleaning effect as the dirt particles over the surface are removed [5,7,32,33].

The self-cleaning capability is achieved together with three surface capabilities: (i) superhydrophobic: based on the effect of the lotus flower, water presents a form of a sphere, rolling on the surface and carrying the deposited dust. (ii) superhydrophilic: water spreads on the surface, which is washed in rainy periods, (iii) photocatalytic: related to the self-cleaning effect, photocatalytic materials degrade organic compounds over their surface [1]. In all cases, removing particles and degrading adsorbed compounds increases road safety by increasing friction.

Another type of asphalt capability that promotes safer roads and materials strength, reduces aging, and mitigates the Urban Heat Island (UHI) is the thermochromic capability [16–18,34]. The changing color of the surface can warn the drivers if there is ice, one of the worst road situations due to the low temperature. It can increase light reflection and conversely reduce sunlight absorption, as the black color of asphalt materials increases the surface temperature. With the reduction in the temperature, it is possible to improve the mechanical performance and avoid the UHI.

With the development of latent thermal energy storage capability, it is also possible to mitigate the UHI. Reducing the magnitude of temperature fluctuations also benefits the mechanical properties of the asphalt mixtures, preventing rutting and avoiding thermal cracks. For this purpose, Phase Change Materials (PCM) have been applied to asphalt mixtures through bulk incorporation (a dry process) or asphalt binder modification (a wet process) [19–21].

The cracks in the asphalt mixtures are among its most critical degradations. Using some materials from a different point of view makes it possible to develop the self-healing capability to close microcracks. This capability is achieved by incorporating conductive materials, microcapsules with high content of maltenes, nanoparticles, or even ionomers [1,9,35–37]. This can provide a longer lifetime for the pavements, causing less emission of CO_2, consumption for paving, and road traffic disruption.

When energy harvesting knowledge is applied to asphalt mixtures, road pavements can convert significant amounts of ambient energy into other useful forms of energy. Pavements are continuously submitted to solar radiation and vehicle loads, from which it is possible to convert energy into electrical energy. The solar radiation and the mechanical energy can be harvested by photovoltaic cells and piezoelectric devices, respectively [22,38,39].

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