

Special Issue on Nano-Modified Asphalt Binders and Mixtures to Enhance Pavement Performance

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1. Introduction

This Special Issue is dedicated to the use of nanomaterials for the modification of asphalt binders to support the analysis of the relevant properties and to determine if the modification indicated a more efficient use of asphalt mixtures' fabrication or their modification in the context of asphalt mixtures' fabrication and the improvement (or lack thereof) of these last ones to constitute effective asphalt pavement layers. All these approaches aimed to enhance performance for flexible pavements.

A total of 10 contributions were published. Four of the contributions are classified in the abovementioned first group, "Binder's modification", and five in the other group, "Asphalt mixtures' modification". The remaining contribution was a review of the effects of the modifications with nanomaterials, particularly nanosilica, nanoclays, and nanoiron, on the performance of asphalt mixtures. It could be classified in the second-mentioned group were it not for its "review" characteristics.

2. Use of Nanomaterials in the Asphalt Industry

The review published [1] described the effect of using nanosilica, nanoclays, and nanoiron to achieve better, more efficient asphalt mixtures, mechanically and in durability terms, fostering high-performance and long-lasting asphalt pavements.

Reference to several studies was already done, mostly focusing on the asphalt binder properties and its rheology, and the description of their positive findings had been the driver to the study of modified asphalt mixtures, the main focus of the review.

It could be seen that, for asphalt mixtures:

1. The modifications with nanosilica present better mechanical resistance and higher resistance to moisture damage than the other nanomaterials. The modification effect increases according to the increase in the percentage of nanomaterial used, but this could be not economically feasible.
2. The modifications with nanoclays were dependent on the type of nanoclay (raw or organic, and this last one costing the double). The use of this type of modification should be carefully defined to get excellent performance with the lowest percentage of use possible.
3. The modifications with nanoiron delivered essential improvements in the mechanical performance of the modified asphalt mixture. With a low percentage of use, if effective, this modification can be competitive.
4. The nanomaterials' modification also gave reasonable indications regarding the durability (better properties when aged) of asphalt mixtures.

These features highlight the need for a life cycle cost evaluation when addressing the use of this type of modification to establish the right balance between the construction costs, sustainability, and long-term performance of nano-modified asphalt mixtures.

3. Binders' Modification

In this group of papers, two ([2] and [3]) addressed the use of nano hydrophobic silane silica (NHSS) modification for asphalt cement and studied its behavior under freeze–thaw (F–T) aging conditions. The findings indicated that NHSS could, in certain situations, inhibit the F–T aging process of asphalt cement, but, NHSS being an inorganic material, its connection with asphalt cement is more likely to be destroyed under the F–T aging process. However [3], NHSS could increase the aggregate–bitumen interface shear strength under any working conditions, including spring thaw season. Moreover, paper [3] offers two models to evaluate the moisture damage degree and moisture damage rate of aggregate–bitumen interface shear strength.

A new material Graphene Nano-Platelets (GNPs), has been used to enhance pavements' structural and functional performances [4]. The results showed that GNPs improved not only the rutting resistance of the pavement but also its durability. The high surface area of GNPs increases the pavement's bonding strength and makes the asphalt binder stiffer. GNPs also provide nano-texture to the pavement, which enhances its skid resistance.

Finally, paper [5] evaluates the impact of modifiers' chemistry on modified binders' long-term cracking potential, meaning the recycling of reclaimed asphalt pavement material within the application of new asphalt layers. Chemical analysis indicated that the best performing modified binders had significant amounts of nitrogen in the form of amines. On the other hand, poor-performing modified binders had traces of sulfur. Additionally, modifiers with lower average molecular weights appeared to have a positive impact on the performance of aged binders. The inferences for this field of studies underlined that nanomaterials, improving aging behavior, could be a very effective asphalt cement modification, as appointed in the previous section.

4. Asphalt Mixtures' Modification

A study [6] on the moisture susceptibility of a nanoclay-modified asphalt concrete (AC) mixture containing plastic film (in flakes) collected as urban waste, evaluated with specimens subjected to an accelerated aging procedure, indicated that the combination of a nanomaterial with a by-product could be a viable solution for the recycling of plastic film, being an eco-friendly alternative to disposal in landfills.

The combination, in another study [7], of nanoclay with an SBS polymer (an elastomeric product), for the modification of asphalt mixtures, evidenced the notion that this type of mixture improved permanent deformation and leveled fatigue behavior when compared to conventional asphalt mixtures, unmodified and modified just with SBS polymer. These results could help to introduce an effective alternative for flexible pavements, where higher resistance to rutting is required.

Another exciting application was brought by the paper [8] with the study of the effect of adding Electric Arc Furnace (EAF) slag and Graphene Nanoplatelets (GNPs) on the microwave heating and healing efficiency of asphalt mixtures. The results obtained indicate that the additions of graphene and EAF slag can allow significant savings, up to 50%, on the energy required to perform a proper healing process by microwave technology, which in any case is a technology still in development.

The contribution of a type of nanomaterial, the nano-titanium dioxide nano-TiO₂, to the attenuation pollutants coming from the use of fossil fuel, an essential issue for confined environments as tunnels or underground parking places, was brought by the paper [9], investigating four influencing factors on the photocatalytic effect of the nano-TiO₂ particle sizes. The main results were that smaller particles (5 nm against 10–15 nm) and a higher dosage of nano-TiO₂ improved the elimination of hydrocarbons and nitrogen oxide significantly. The effect on the elimination of carbon oxide and carbon dioxide was not as expressive as for the other type of pollutants.

Finally, paper [10] showed the application of LCA to nano-silica-modified asphalt mixtures. It has the potential to guide decision makers on the selection of pavement modification additives to realize the benefits of using nanomaterials in pavements while avoiding potential environmental risks.

5. Final Considerations

The Guest Editors believe that this group of papers, published in this Special Issue, fosters awareness about the use of nanomaterials to modify asphalt mixtures to obtain more performant and durable flexible road pavements.

There are also other studies and applications going on, namely because there is still a route to the practical validation of the use, but this base is a robust one, especially for the researchers and practitioners interested in developing and applying these kinds of solutions.

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