ABSTRACT

The modern design of the transportation infrastructures requires the simultaneous maximization of technical, social, environmental and economic performance of all materials employed for the road construction. For these reasons, the recycling of Reclaimed Asphalt (RA) is becoming a strategic alternative, in lieu of landfill disposal and consumption of virgin resources, to construct road pavements and ensure the technical requirements and match the goals of the circular economic. While evidences available in the literature and as results of full-scale applications confirm the feasibility of the hot recycling of RA, some limitations restrain the recycling to small quantities (10 to 30 %). The main concern is related to the stiffness and brittleness of RA binder that, if introduced in larger amount in the mixture through RA particles, would lead to a general embrittlement of the asphalt mixture with a consequent reduction of fatigue life and increased at low-temperature cracking. However, the maximization of the RA recycling is nowadays possible if the RA binder is properly revitalized or rejuvenated by the so-called REjuvenating Agents (RE). The effectiveness of such additives is still debated in the pavement community.

The present study conducted during the three years PhD program belongs to such a context. In particular, it aims to investigate the effectiveness of RE through a novel methodology based on the concept of Model System (MS), followed by a subsequent analysis at mixture scale, further completed with a study in terms of energetic and environmental impacts by adopting the Life Cycle Assessment (LCA) methodology.

RE effectiveness is generally studied at binder scale, after extraction of RA binder by means of solvents that could negatively impact on the binder itself, or at mixture scale, with time- and money-consuming procedure. The MS concept is introduced to analyze the RE effectiveness from a new point of view by avoiding solvent extraction and intensive testing procedures. 5/8 RA particles from different sources, in original states or after a pretreatment with three RE, are compacted to obtained cylindrical samples with high VMA, regardless the state of binder phase. In this way, it is expected that the principal contribution on the final response is given by the binder phase with limited contribution of aggregates interlocking. The effects

of RE in terms of the compactability, volumetric properties, viscoelastic behavior before and after aging and mechanical performance (ITS and cyclic fatigue tests) are investigated on the rejuvenated MS, by comparing them with the unrejuvenated and reference MS. Results highlight the effectiveness of RE to improve RA performance, suggesting also the need of rejuvenation to produce materials with performance highly comparable to those obtained with totally virgin materials.

The analysis conducted at mixture scale involves two mixtures prepared with 50 % RA, rejuvenated or not, and mixture made with 100 % virgin components. Such mixtures are analyzed in terms of compactability, viscoelastic behavior and mechanical performance. Results show that RE improves the performance of the recycled mixture with the final outcomes very close to those determined on the mixture prepared with 100 % virgin components.

Finally, such mixtures are studied to define the energetic and environmental burdens by analyzing the impacts from the production/extraction of the raw materials up to the production of the mixtures. While the recycling of high RA quantities improves the energetic and environmental performance, the employment of RE slightly penalizes the whole sustainability but the rejuvenated mixture is still more performant than the mixture with 100 % virgin components.