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Comparing the Material Circularity Index of the Italian and Spanish motorways: A case study over the Mediterranean basin

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Closely following the attempt of the pavement engineering industry to comply with the principles of Circular Economy (CE) while simultaneously promoting its principles, it can be detected that a significant effort is being made towards the minimization of the energy and raw materials usually utilized. In this regard, Reclaimed Asphalt (RA) is a product that exhibits a tremendous exploitation potential. Knowing that by definition CE is restorative [1], regenerative, and aims to keep products, components, and materials at their highest utility and value at all times [2], i.e. it supports the "re-circulation" of materials and energy within the same or alternative product systems and thus the elimination of avoidable wastes [3], RA is the ideal candidate to be re-circulated into a closed or even open loop product system and/or approach and thus, ideal material that can re-enter the cycle of asphalt mixture production [4]–[8]. RA can be defined as existing asphalt pavement materials that have been removed during the resurfacing, rehabilitation or reconstruction operations of asphalt pavements and accordingly processed [9]. All of the motorways within the EU member-countries consist of asphalt pavements, which -as anticipated- suffer from various types of distresses [10]. Maintaining them can be environmentally, economically, and socially intensive. RA recycling and re-use are well-established practices within the road engineering industry with the aim of minimising the environmental and economic impacts asphalt mixtures and move towards more sustainable and circular recycling [10]–[15]. The available annual average quantity of RA within Europe reaches approximately 45.5 Mt; while the average annual utilized RA only 23.2 Mt [16]-[30]. The main techniques with which RA can be utilized are in hot in-plant recycling, hot in-place recycling, full depth reclamation, cold in-plant recycling and cold in-place recycling [11], [31]. The percentage of RA incorporated in road pavements is usually limited between 10% and 30%, despite the advantages that its use might imply, due to legislation limitations and technical issues such as the variability of the RA properties, the lack of complete understanding of the mechanisms taking place during the asphalt mixture production, and uncertainty of the mixture performance [15], [32]. Many studies have concluded that higher use of RA is possible when attention is paid to the mixture design and the RA's properties so that a consensus between the laboratory mix design and the full-scale realization of the asphalt pavement can be achieved [33]–[39].

In this case study, a comparative analysis between two countries of the Mediterranean basin is performed. The Material Circularity index (MCI_{MRA}) as defined by K. Mantalovas [8], of Italy and Spain in terms of their motorways' asphalt mixtures are compared for the period 2006-2019. Both countries belong to the Southern region of Europe, have similar GDP, and experience similar climatological conditions. Therefore, these countries were selected for the comparative analysis. Since the Material Circularity Index as tailored and defined by K. Mantalovas corresponds to specific and individual end products the current analysis takes place for surface, binder, and base

courses separately since these are the typical asphalt layers that constitute the asphalt pavements of the motorways. The necessary data for the completion of the quantitative aspect of the case study were collected from reputable literature sources [5], [8], [28]–[30], [40]. Utilizing the methodological framework developed by K. Mantalovas and G. di Mino, the quantification of the Material Circularity Index for surface, binder, and base courses for the Italian and Spanish motorways became possible for the period 2006-2019, and the results can be seen in Figure 1

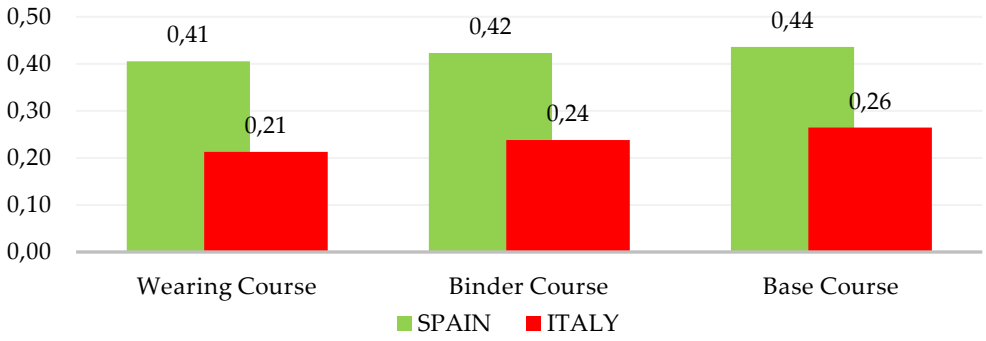

Table 1. Product Material Circularity Index per pavement layer per country

From the results obtained from this case study we can immediately identify the significant gap between the MCI_{MRA} of the two countries for all the layers. Spain's MCI_{MRA} for all the layers is on average 44% higher than the equivalent of Italy's. This could be a projection of a plethora of different circumstances. For instance, in Italy the maximum allowed RA% for surface, binder, and base courses are 20%, 25%, 30% respectively, while in the Spanish regulations asphalt mixtures with RA% up to 50% are allowed and promoted. Moreover, Italy according to data from the European Asphalt Pavement Association (EAPA), recycles 25% of the available RA while Spain reaches the threshold of 72%. Hence, the regulatory context, apparently influences the circularity and sustainability implications of the road engineering industry dictating the maximum circularity thresholds that can be achieved through the limitation of RA use. Although numerous studies by now have proven the functionality, viability, and necessity of RA use, it can still be observed that a lot of countries, regions and/or governments are still not willing to follow the scientifically established facts. For this reason, the authors believe that some key actions must be taken urgently:

- Establishment of compulsory and regulated E-o-L strategies for RA prior to its production
- Increased budget allocation to the training of stakeholders about CE, and sustainability
- Use of material flow tracking along with material passports
- Harmonised benchmarking of the mechanical/environmental performances of RA mixtures
- Target setting towards the exploitation of all the available RA
- Change utilization patters (sharing models, product as service).

Key words: circular economy; recycling; reclaimed asphalt; material circularity index; closed loop