Optimization of reclaimed asphalt pavement and recycled concrete aggregates in Cold Emulsified Porous asphalt mixture

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Introduction

With the always increasing paving of road all around the world, each year a huge quantity of natural aggregates and bitumen is consumed. The road pavement industry has a high impact on the environment, and in the last decade there has been an increasing interest in designing road materials with low embodied environmental impact and energy demand (Yang et al., 2020). To meet these needs the main recycled materials applied for new road or for rehabilitating old one are recycled concrete aggregates (RCA) and reclaimed asphalt pavement aggregates (RAP). The first one comes from the demolishing of concrete that is crushed and recycled, and the second one, the RAP, is produced from the milling and recycling of old pavement (Xu et al., 2022). Furthermore, the traditional hot mix asphalt (HMA) materials demand a high energy consumption and produce a high air pollution, creating an unsafe and unhealth work place for the construction workers. Therefore, the cold mix asphalt (CMA) represents a low carbon production approach for the manufacturing of present and future flexible pavements (Wang et al., 2018). This technology allows the development of asphalt mixture at ambient temperature without the need of heating up the aggregates and using a bitumen emulsion instead of the traditional neat bitumen. Different studies already proved that this specific technique decrease the emission of CO_2 connected with the manufacturing of the asphalt mixtures and save energy and money (Shanbara et al., 2021). Moreover, when looking at the urban environment, the proper choice of road materials to reduce the Urban Heat Island phenomenon is the use of cooling and permeable pavement, and most precisely porous asphalt concrete, also called open-graded courses (Nwakaire et al., 2020). Thus, the present research study focused on the characterization of RCAs and RAP materials as aggregates replacement in porous asphalt concrete produced with a cold mix technology.

Methodology

The objective of the study was to characterized the two different recycled aggregates and assessed their feasibility to be used in cold porous asphalt mixture through laboratory tests. The laboratory investigation was divided into two different steps. The first part of the investigation involved the characterization of the two recycled materials in terms of physical and geometrical properties of the aggregates based on the European standards for the aggregates used in asphalt concretes. This first part involved the following tests:

- Grading distribution of the aggregates following the European standard EN 933-1;
- Flakiness index and shape index following the European standard EN 933-4 and 933-3 respectively;
- Particle density and water absorption following the EN 12697-5 and EN 1097-6;
- Fragmentation test following the RILEM Protocol for the RAP aggregates and the EN 1097-2 for the RCAs;
- Classification of the constituent of the RCAs following the European standard EN 933-11;
- Cohesion test for the RAP aggregates following the RILEM Protocol.

After the characterization of the recycled aggregates, the second step was to develop a grading curve of the porous asphalt mixture that needed to by in compliance with the Italian specification. In order to do that, the two recycled aggregates were combined together and a specific percentage of each one was chosen to obtain the final size distribution of the mixture. Then, the optimal dosage of bitumen emulsion, water, cement and filler were investigated to complete and design the final mixture to be mechanically and physically tested. Two main properties, precisely the air voids content (EN 12697-8) and the indirect tensile strength at 25°C (EN 12697-12), were investigated, compared and combined together to find the proper dosage of each constituent of the mixtures. Moreover, to further ensure the right choice of the constituent percentage, the study of the vertical permeability (EN 12697-19) was developed since it represents one of the main properties of porous asphalt concretes.

Results and discussion

By following the European standards EN 933 and EN 12697, the recycled materials are investigated for assessing their utilization in asphalt concrete. In Table 1 are reported some of the properties tested in lab in terms of physical and geometrical characteristic of the recycled aggregate and the corresponding European standard.

Table 1. Geometrical and physical properties of RCA and RAP.

Properties	RAP	RCA
Flakiness index [%] (EN 933-4)	3	5
Particle density [g/cm^3] (EN 12697-5)	2.530	2.592
Shape Index [%] (EN 933-3)	0.5	8.3

After assessing the properties of the aggregates and detect the compliance with the European standard, the grading curve of the open-graded mixture was studied. The studied curve was compared with a grading distribution previously sanalysed of a mixture produced with virgin aggregates, as Figure 1 shows.

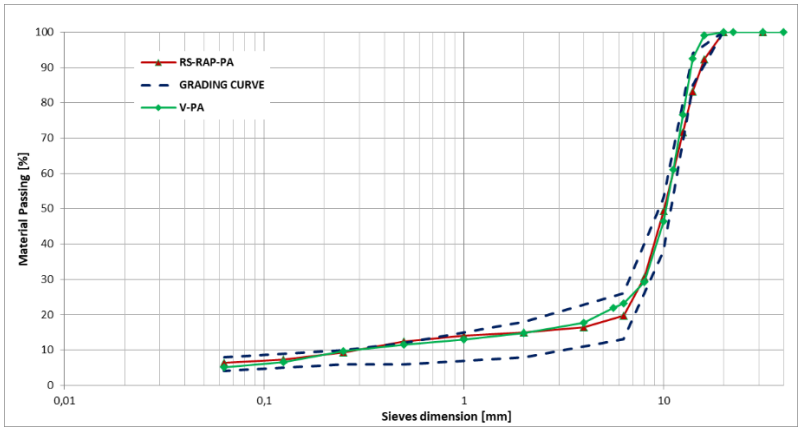

Figure 1. Size distribution of the investigated open-graded mixture.

The next step in the analysis consist in the investigation of the optimal dosage of each constituent of the mixture, starting with fixing a specific amount of initial emulsion content (IEC), calculated through a mathematical approach, and changing three different ratios of cement and filler.

Conclusions

Based on the knowledge found in this study it can be assessed that the recycled concrete aggregates and the RAP aggregates are perfectly in line with the European standard for aggregates of asphalt concrete and represent the clear choice as replacement for virgin materials in road pavement. Furthermore, from the optimization of the mixture is clear that the recycled aggregates work quite well in cold porous asphalt concrete, especially in terms of air voids content and vertical permeability. However, a deeper investigation is need to definitely assess the feasibility of these materials in cold porous asphalt mix using a bitumen emulsion. Future analysis will involve the mechanical, functional and durability investigation of the proposed eco-friendly mixture.

References

Nwakaire, C.M., Onn, C.C., Yap, S.P., Yuen, C.W., Onodagu, P.D., 2020. Urban Heat Island Studies with emphasis on urban pavements: A review. Sustain Cities Soc 63, 102476. https://doi.org/10.1016/J.SCS.2020.102476

Shanbara, H.K., Dulaimi, A., Al-Mansoori, T., Al-Busaltan, S., Herez, M., Sadique, M., Abdel-Wahed, T., 2021. The future of eco-friendly cold mix asphalt. Renewable and Sustainable Energy Reviews. https://doi.org/10.1016/j.rser.2021.111318

Wang, Y., Leng, Z., Li, X., Hu, C., 2018. Cold recycling of reclaimed asphalt pavement towards improved engineering performance. J Clean Prod 171, 1031–1038. https://doi.org/10.1016/j.jclepro.2017.10.132

Xu, X., Luo, Y., Sreeram, A., Wu, Q., Chen, G., Cheng, S., Chen, Z., Chen, X., 2022. Potential use of recycled concrete aggregate (RCA) for sustainable asphalt pavements of the future: A state-of-the-art review. J Clean Prod 344. https://doi.org/10.1016/j.jclepro.2022.130893

Yang, G., Wang, C., Wen, P., Yin, W., 2020. Performance Characteristics of Cold-Mixed Porous Friction Course with Composite-Modified Emulsified Asphalt. Journal of Materials in Civil Engineering 32. https://doi.org/10.1061/(asce)mt.1943-5533.0003047