2020-12-03

Bio-Binder—Innovative Asphalt Technology

Amir Tabakovic
Technological University Dublin, amir.tabakovic@tudublin.ie

Recommended Citation

Tabakovic, A. (2020). Bio-Binder—Innovative Asphalt Technology. *Applied Sciences*, Applied Sciences, vol. 10, no. 23, pg. 8655. doi:10.3390/app10238655 *applied sciences*

MDPI

Editorial

Bio-Binder—Innovative Asphalt Technology

Amir Tabaković [1,2,3]

1 Centre for Research in Engineering Surface Technology (CREST), FOCAS Research Institute, Technological University Dublin, 13 Camden Row, Kevin Street, D08 CKP1 Dublin, Ireland; amir.tabakovic@tudublin.ie
2 School of Civil Engineering, University College Dublin, D04 K3H4 Dublin, Ireland
3 Civil Engineering and Geosciences, Delft University of Technology, 2628CN Delft, The Netherlands

Received: 10 November 2020; Accepted: 30 November 2020; Published: 3 December 2020

check for updates

The global road network spans 16.3 million km [1], of which 5 million km is in the EU. These road networks fulfil major economic and social goals by facilitating the movement of goods and people throughout the EU, and are therefore of the utmost importance to the economic and social life of the EU [2]. National governments invest heavily in their road networks, e.g., in 2014, EUR 53.33 billion was invested in the development and maintenance of the EU road network [3]. Each year, the world produces 1.6 trillion tonnes of asphalt [4], of which 218 million tonnes is produced in the EU [5]. The average cost of asphalt in the EU is EUR 200 per tonne. These figures show that the construction and maintenance of road networks are a significant cost to the tax payer. These costs are set to rise further as the sources of bitumen (a product of crude oil) diminish [6,7]. Improved road design and enhanced road materials offer the road industry the potential for improved efficiency and financial savings. The challenge is to develop road materials and construction methods which will improve the environmental cost and reduce the economic cost of road construction. Unlike other construction materials, road materials have developed minimally over the past 100 years [8], but since the 1970s, the focus has been on more sustainable road construction materials, e.g., recycled asphalt pavements [9]. Recycling asphalt involves removing old asphalt, and mixing it with new (fresh) aggregates, binder and/or rejuvenator [9,10]. The primary purpose of the recycling process is to restore the original molecular structure of the aged bitumen in order to extend the lifespan of the asphalt pavement (road). The road lifespan is extended by adjusting the properties of the asphalt mix, i.e., reducing its stiffness [11]. Some commercially available rejuvenating agents include Modeseal R20, Reclamite, Paxole 1009, Cyclepave and ACF Iterlene 1000. Two recent studies by Garcia et al. [12] and Su et al. [13] demonstrated that food by-products (i.e., vegetable oil) can also be used as rejuvenators and offer an alternative to crude oil. Other recent road material innovations, i.e., warm asphalt mixtures, have had unanticipated environmental impacts, e.g., contaminating soil and groundwater [14]. There is growing pressure on the road industry to reduce its environmental impact. Self-healing asphalt has potential in this regard, but it has not yet delivered in terms of improved sustainability [15], or demonstrated its reduced cost and environmental impact [16].

Bitumen, which has traditionally been used as a binder within asphalt mix, is a product of crude oil. The production of crude oil is in decline [7], and the environmental and financial costs of extraction are on the increase [6,7]. There is a need to identify alternatives to bitumen—preferably cheaper and more sustainable alternatives. Researchers have considered replacing bitumen with a plant-based alternative [17], but diverting plants from food resources to asphalt would be unacceptable given the increased pressure on food resources globally. Researchers [18,19] have studied the utilization of waste cooking oil as a binder rejuvenator in the asphalt recycling process. Lignin, a by-product of wood processing, was identified by Van Vliet et al. as a suitable source of biomass [20] for the production of bitumen [21], but the uncertain future of wood processing plants makes this potentially an unreliable/unsustainable material source.

Microalgae have been considered as an alternative source of bio fuel [22], but also have potential as an alternative bitumen or asphalt binder [23]. Audo et al. [23] demonstrated that microalgae can be converted into crude oil, which is an ideal material for the production of bio-binder. The bio-oil produced has an equivalent energy value to fossil fuels [24], making it suitable for bio-fuel but also possibly as an asphalt binder source [23]. Maximum biocrude yields in the range of 40–50% have been reported [23], though they are in an initial stage of development. The BioRePavation project [25] demonstrated that microalgae oil can be used as an asphalt binder in the construction of new asphalt mixtures and in the asphalt recycling process.

This is a promising development in terms of the improvement of the sustainability of microalgal cultivation [26]. The high uptake capacity of microalgae for nitrate and phosphate, coupled with its sustained photosynthetic activity, is the basis of its recognized potential in treating wastewater [27]. Pal et al. [28] have shown that this approach is especially relevant in arid areas, where food and water resources are scarce and microalgae can play an indispensable role in nutrient and carbon recovery from waste resources, as well as in the treatment/use of waste or other marginal water resources. The microalgae obtains nutrition from the dissolved nitrogen and phosphorus found in the wastewater (which would otherwise be a pollution threat) [29]. This process will convert the nutrients found in wastewater into an environmentally friendly fertilizer. Microalgae that proliferate in wastewater facilities are not suitable for human consumption [29], but are ideal for the production of products to be implemented in road construction, such as asphalt binder and bitumen rejuvenators [23]. This presents a unique opportunity to create a circular economy, whereby microalgae can be cultivated within the wastewater treatment process and later processed to extract the oil from the algae. The oil can be further used in the production of the asphalt bio-binder, and other co-products of the process can be used as animal feed or land fertilizer. The utilization of bio-oils in bitumen and asphalt production presents a timely opportunity for the asphalt industry to simultaneously improve its sustainability record and reduce its negative impact on the environment.

Funding: This research received no external funding.

Acknowledgments: This Special Issue would not be possible without the contributions of all authors and reviewers. Special thanks to Jim Wang for his continuous support with organising this Special Issue.

Conflicts of Interest: Author declares no conflict of interest.

References

1. OECD. *Road Traffic, Vehicles and Networks. 2013 in Environment at a Glance 2013: OECD Indicators*; OECD Publishing: Paris, France, 2013.
2. Vita, L.; Marolda, M.C. *Road Infrastructure—the Backbone of Transport System*; EU Directorate General for Research and Sustainable Surface Transport: Brussels, Belgium, 2008.
3. Federation, E.U.R. *Roads Statistics: Year Book 2017*; European Union Road Federation Place Stéphanie 6/B B-1050: Brussels, Belgium, 2017.
4. EAPA. *The Asphalt Paving Industry, A Global Perspective*; EAPA: Brussels, Belgium, 2011.
5. EAPA. *Key Figures of the European Asphalt Industry in 2014, in Asphalt in Figures*; EAPA: Brussels, Belgium, 2016.
6. Leggett, J. Big Oil's Looming Bubble. In *New Internationalist*; McGowen House: Northampton, UK, 2014; pp. 20–21.
7. Worth, J. Ending the oil age. In *New Internationalist*; McGowen House: Northampton, UK, 2014; pp. 12–16.
8. Tabaković, A.; Braak, D.; Gerwen, M.; Copuroglu, O.; Post, W.; Garcia, S.J.; Schlangen, E. The compartmented alginate fibres optimisation for bitumen rejuvenator encapsulation. *J. Traffic Transp. Eng.* **2017**, *4*, 347–359. [CrossRef]
9. Tabaković, A. Recycled Asphalt (RA) for Pavements. In *Handbook of Recycled Concrete and Demolition Waste*; Pacheco-Torgal, F., Tam, V.W.Y., Labrincha, J.A., Ding, Y., de Brito, J., Eds.; Woodhead Publishing: Sarston, UK, 2013; pp. 394–423.
10. Tabakovic, A.; Gibney, A.; McNally, C.; Gilchrist, M.D. The Influence of Recycled Asphalt Pavement on the Fatigue Performance of Asphalt Concrete Base Courses. *ASCE J. Mater. Civ. Eng.* **2010**, *22*, 8. [CrossRef]

11. Brownridge, J. The role of an asphalt rejuvenator in pavement preservation: Use and need for asphalt rejuvenation. In Proceedings of the International Conference on Pavement Preservation, Newport Beach, CA, USA, 13–15 April 2010.
12. Garcia, A.; Jelfs, J.; Austin, C.J. Internal asphalt mixture rejuvenation using capsules. *Constr. Build. Mater.* **2015**, *101*, 309–316. [CrossRef]
13. Su, J.F.; Qiu, J.; Schlangen, E.; Wang, Y.Y. Investigation the possibility of a new approach of using microcapsules containing waste cooking oil; in-situ rejuvenation. *Constr. Build. Mater.* **2015**, *74*, 83–92. [CrossRef]
14. Trombulack, S.C.; Frissell, C.A. Revbiew of ecological effects of roads on terestrial and aquatic communities. *Conserv. Biol.* **2000**, *14*, 13.
15. Tabaković, A.; Post, W.; Cantero, D.; Copuroglu, O.; Garcia, S.J.; Schlangen, E. The reinforcement and healing of asphalt mastic mixtures by rejuvenator encapsulation in alginate compartmented fibres. *Smart Mater. Struct.* **2016**, *25*, 084003. [CrossRef]
16. Anderson, F.A. Final Report on the Safety Assessment of Melamine/Formaldehyde Resin. *J. Am. Coll. Toxicol.* **1995**, *14*, 373–385.
17. Garcia, A.; Austin, C.J.; Jelfs, J. Mechanical properties of asphalt mixture containing sunflower oil capsules. *J. Clean. Prod.* **2016**, *118*, 9. [CrossRef]
18. Saha, R.; Melaku, R.S.; Karki, B.; Berg, A. Effect of Bio-Oils on Binder and Mix Properties with High RAP Binder Content. *J. Mater. Civ. Eng.* **2020**, *32*, 04020007. [CrossRef]
19. Rodrigues, C.; Capitão, S.; Picado-Santos, L.; Almeida, A. Full Recycling of Asphalt Concrete with Waste Cooking Oil as Rejuvenator and LDPE from Urban Waste as Binder Modifier. *Sustainability* **2020**, *12*, 8222. [CrossRef]
20. Gellerstedt, G.; Henriksson, G. Chapter 9—Lignins: Major Sources, Structure and Properties. In *Monomers, Polymers and Composites from Renewable Resources*; Belgacem, M.N., Gandini, A., Eds.; Elsevier: Amsterdam, The Netherlands, 2008; pp. 201–224.
21. Vliet, D.; Slaghek, T.; Giezen, C.; Haaksman, I. Lignin as green alternative for bitumen. In Proceedings of the 6th Euroasphalt and Eurobitumen Congress, E&E Congress 2016, Prague, Czech Republic, 1–3 June 2016.
22. Murphy, F.; Devlin, G.; Deverell, R.; McDonnell, K. Biofuel Production in Ireland—An Approach to 2020 Targets with a Focus on Algal Biomass. *Energies* **2013**, *6*, 6391–6412. [CrossRef]
23. Audo, M.; Paraschiv, M.; Queffélec, C.; Louvet, I.; Hémez, J.; Fayon, F.; Lépine, O.; Legrand, J.; Tazerout, M.; Chailleux, E.; et al. Subcritical Hydrothermal Liquefaction of Microalgae Residues as a Green Route to Alternative Road Binders. *ACS Sustain. Chem. Eng.* **2015**, *3*, 8. [CrossRef]
24. Umakanta, J.; Das, K.C. Comparative Evaluation of Thermochemical Liquefaction and Pyrolysis for Bio-Oil Production from Microalgae. *Energy Fuels* **2011**, *25*, 5472–5482.
25. French Institute of Science and Technology devoted to Transport, P.a.N.I. BioRePavation. 2020. Available online: http://biorepavation.ifsttar.fr/ (accessed on 20 October 2020).
26. Kesaano, M.; Sims, R.C. Algal biofilm based technology for wastewater treatment. *Algal Res.* **2014**, *5*, 231–240. [CrossRef]
27. Craggs, R.; Sutherland, D.; Campbell, H. Hectare-scale demonstration of high rate algal ponds for enhanced wastewater treatment and biofuel production. *J. Appl. Phycol.* **2012**, *24*, 329–337. [CrossRef]
28. Pal, D.; Khozin-Goldberg, I.; Cohen, Z.; Boussiba, S. The effect of light, salinity, and nitrogen availability on lipid production by Nannochloropsis sp. *Appl. Microbiol. Biotechnol.* **2011**, *90*, 1429–1441. [CrossRef] [PubMed]
29. Wiley, P.; Elliott, C.; Thomas, H. Microalgae Cultivation Using Offshore Membrane Enclosures for Growing Algae (OMEGA). *J. Sustain. Bioenergy Syst.* **2013**, *3*, 18. [CrossRef]