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FROM BIOWASTE TO PAVEMENT (PART I): VALORISATION OF BIOMASSES FOR PAVEMENT APPLICATION

Kussai Alrini, Cesare Sangiorgi*
Department of Civil, Chemical, Environmental, and Materials Engineering, University of Bologna, Via Umberto Terracini, 2840131 Bologna BO, Italy
* Corresponding author: cesare.sangiorgi4@unibo.it

The transition towards low-carbon and circular road infrastructure has stimulated increasing interest in renewable and waste-derived alternatives to petroleum bitumen. Biomass and biowastes, including agricultural residues, lignin, waste oils, algae and organic industrial by-products, can be converted into functional materials for asphalt applications through thermochemical processes such as pyrolysis and hydrothermal liquefaction [1,2]. However, most biomass-derived oils have been investigated as modifiers, rejuvenators or partial bitumen replacements, while their use as standalone paving binders remains comparatively underexplored [2,3]. Within this context, organic sludge is an attractive yet challenging feedstock, combining waste-management benefits with the potential to recover carbon-rich fractions suitable for engineering applications. This study investigates the valorisation of agricultural sludge generated by the wine industry to produce a 100% bio-based paving binder. The dried sludge was pyrolysed at 450 °C, producing approximately 26 %wt. bio-oil. Following phase separation, the water-insoluble fraction was recovered and vacuum-distilled to obtain a heavy, carbon-rich material suitable for binder production. Its engineering feasibility was assessed through rotational plate viscosity, Dynamic Shear Rheometer temperature and frequency sweeps, Multiple Stress Creep Recovery (MSCR), Linear Amplitude Sweep (LAS), and Fourier Transform Infrared (FTIR) spectroscopy, with conventional petroleum binder used as a benchmark. The sludge-derived binder exhibited favourable initial workability, with an estimated mixing temperature of 121–125 °C, approximately 30 °C below that of the conventional binder. Rheological testing nevertheless revealed a distinctive thermo-rheological response, characterised by relatively high stiffness at lower temperatures and increasing temperature susceptibility at elevated temperatures. Short-term ageing substantially modified this behaviour. Following RTFOT ageing, the non-recoverable creep compliance was approximately 54% and 48% lower than that of the conventional binder at 64 and 70 °C, respectively, indicating enhanced resistance to permanent deformation. Ageing emerged as a critical factor controlling performance. Short-term ageing reduced Jnr at 64 °C from 16.14 to 1.07 kPa^{-1} while improving rutting- and fatigue-related responses. Conversely, prolonged laboratory ageing caused severe hardening, accompanied by substantial changes in oxygen-containing functional groups.
Keywords: *bio-based binder; agricultural sludge; pyrolysis; bio-oil; waste valorisation*

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